Tahoe Science Center Tour Cheat Sheet

Welcome

- Welcome to the UC Davis Tahoe Science Center
- Introduction (name, tour info)
- Bathrooms needed? Visitor needs met?
- Where are you from?
- How much time do you have available?

Map *(Theme: Sense of Place)*

- Where are you staying? (point to location on the map)
- Where have you been? (find locations on the map)
- Where are we now? (point to Tahoe Science Center on the map)
- How Tahoe was formed (faults, earthquakes, volcanic activity, glaciers)
- Features – 3 faults, deepest point, landslide debris, glacially carved valleys/moraines, tributaries, Tahoe Keys, Angora fire
- Watershed outline (definition of a watershed)

Hands-On Interactive Exhibits

- iPads (DIY Lake Science, Healthy/Unhealthy Lakes, State of the Lake)
- Interactive activities (clarity, water pressure, light refraction, rocks, and erosion)

Boat *(Theme: Sense of Place/Understanding Lake Tahoe)*

- Loss of clarity
- Pollutants are fine sediment (turn lake brown) and nutrients nitrogen and phosphorus (cause algae to grow and turn lake green)
- Research UC Davis does on the Research Vessel Le Conte (Secchi Disk, Van Dorn Sampler, Plankton Net, Research Buoys)

Research Photo Wall *(Theme: Science and Research)*

- Different types of research UC Davis does on Lake Tahoe
- Answers on corkboard in Docent Room and in the docent manual on pages 61-63

Lab *(Theme: Understanding, Discovering, and What Can Be Done?)*

- Food web (non-native introductions, decline of Lahontan Cutthroat Trout and Daphnia, and human impact)
- Invasive species impacts (human impact)
- Aquariums (various ages of Lahontan Cutthroat Trout, native and nonnative species)

3D Theater

- Movies available including "Lake Tahoe in Depth" (15 minutes), "Mapping Change" (10 minutes), "Following a Drop of Water" (2 minutes), "Let's Go

Jump in the Lake" (9 minutes), 3D Earthquake Viewer (interactive and custom)
- 3D glasses required

Sandbox

- Shaping watersheds
- Making it rain (hold hand flat with outspread fingers)
- Build Lake Tahoe
- Insert 3D printed model of Lake Tahoe to fill lake (overflow, drought conditions result in different shape of lake, tsunami modeling)
- Learning how to read a topographic map (contour lines and contour intervals)
- Developed by UC Davis and now there are more than 720 Augmented Reality Sandbox exhibits around the world (visit https://arsandbox.ucdavis.edu for more information)

Other

- Kids' corner with crayons and various take-home activity books
- Touchscreen by the kids' corner (exit survey, email sign-up, clarity interactive activity)
- Donation Buoy (the Tahoe Science Center is a non-profit organization that relies on donations to keep programs running)
- Lake Tahoe in Depth Touchscreen Exhibit (2 touch-screen monitors near women's bathroom)
- Forest Health and Fire Poster
- Take Care Flip Panel
- Take Care Pledge Wall
- Green Building Exhibit next to stairs
- Brochures, stickers, flyers by the front desk

Introduction to Tahoe Science Center Exhibits

The UC Davis Tahoe Environmental Research Center (TERC) worked with exhibit design consultants and a locally-formed Education Steering Committee (ESC) to review the main themes and messages and determine ways to communicate these through interpretive exhibits. The following overarching themes and exhibit topics resulted.

Overarching Themes

1. A Sense of Place-------------------Welcome To This Place Called Lake Tahoe
2. Issues at Lake Tahoe-------------Learning and Understanding
3. Science and Research-----------Discovery
4. What Needs To Be Done-------Management and Engagement

Exhibit Topics by Theme

1. A Sense of Place = Welcome To This Place Called Lake Tahoe

- Why is Lake Tahoe special? Lake Tahoe is amazingly blue, very clear, extraordinarily deep, long residence time, and very old.
- The Lake Tahoe watershed was formed by faulting, volcanic activity, and glacial action. The area continues to be seismically active.
- What is a watershed? What is an airshed?
- Ecological history of lake.

2. Issues at Lake Tahoe = Learning and Understanding

- What are the main causes for concern at Lake Tahoe? How is Lake Tahoe changing?
- 3 main issues are clarity, climate change, and aquatic invasive species
- Lake Tahoe is losing water clarity.
- Erosion is a natural process, however, urbanization has caused the rate of erosion to speed up.
- The process of “eutrophication” (or the enrichment of a lake) is accelerating at Lake Tahoe.

3. Science and Research = Discovery

- Limnology is the study of lakes and inland waters.
- Lake systems are dynamic, driven by the sun, wind and weather patterns.

(Physical Limnology)
- Lake Tahoe's food web has been greatly altered. (Biological Limnology)
- Science and research have helped to protect Lake Tahoe. How is science helping us understand?
- Various environmental goals can sometimes come into conflict with each other.
- Global and long term climate change impacts.
- Natural hazards – earthquakes, wildfires, tsunami potential, landslides, etc.

4. What Needs To Be Done = Management and Engagement

- Humans are part of the problem... and can be part of the solution.
- What can you do to help protect Lake Tahoe and other lakes, streams, and watershed systems?

Exhibit Interpretive Outline

The 100% Final Design Report (The Sibbett Group, June 2006) provides the interpretive outline for exhibits and exhibit elements of the Tahoe Science Center funded by the Thomas J. Long Foundation. This document is available for review at your request. The main outcomes are presented in the following table:

Ref. #	Exhibit Title	Topic	Outcomes & Messages
1.00	Donor Recognition & Information	Welcome to the Tahoe Science Center	Receive an introduction and orientation to the UC Davis Tahoe Science Center. Learn about what to do and where to go in the building. Visitors will: • Be welcomed to the Tahoe Science Center. • Become oriented to the building. • View the individuals and organizations that supported the Tahoe Science Center and the Tahoe Environmental research Center (TERC).

2.00	Welcome to the Tahoe Science Center	Welcome to the Tahoe Science Center	Become familiar with the Tahoe Science Center and its relationship to TERC. Visitors will: • Understand that they are entering the Tahoe Science Center. • Realize that the Education Center provides information about past discoveries, current research and conservation efforts to protect the clarity and natural resources of Lake Tahoe. • Discover that the Lake Tahoe Basin is a watershed (Tahoe Watershed Map Graphic).
3.00	The RV John LeConte / A Sense of Place	Lake Tahoe, Its Origin and Unique Characteristics	Become familiar with Lake Tahoe's origin and its unique characteristics Visitors will: • Become immersed in the research efforts at Lake Tahoe (Immersion Environment). • Be introduced to the field of limnology and that, limnologists at Lake Tahoe study how the lake works (A/V Program). • Understand that there is cause for concern from environmental changes that impact Lake Tahoe (A/V Program). • Realize that Lake Tahoe is losing water clarity (A/V Program). • Appreciate that Lake Tahoe is amazingly blue and extraordinarily deep (Photomural). • Discover that the Lake Tahoe Basin is a watershed (Graphic).

4.00	The Laboratory / Understanding Lake Tahoe	Lake Tahoe, its Environmental Threats	Become familiar with Lake Tahoe's environmental threats and how the lake works. Visitors will: • Become immersed in the research efforts at Lake Tahoe (Immersion Environment). • Understand that there is cause for concern from environmental changes that impact Lake Tahoe (A/V Program). • Discover that erosion is a natural process, but that urbanization has caused the rate of erosion to speed up at Lake Tahoe (A/V Program). • Become familiar with the process of eutrophication and the significance of its acceleration at Lake Tahoe (A/V Program). • Realize that Lake Tahoe's food web has been greatly altered (Interactive).
5.00	Research Photo Wall	Lake Tahoe, Its Ecological Protection	Become familiar with the research efforts to protect the lake Visitors will: • Appreciate that science and research have helped to protect Lake Tahoe (Research Photo Wall). • Appreciate the number of scientific fields contributing to research at Lake Tahoe
6.00	Take Care Flip Panels Take Care Pledge Wall	Lake Tahoe, Its Protection	Become familiar with human efforts to protect Lake Tahoe Visitors will: • Realize that humans are part of the problem and can be part of the solution. • Learn about what they can do to help protect Lake Tahoe and the watershed they live in. • Declare how they will help to preserve Lake Tahoe (Interactive Pledge and Voting).

7.00	3D Visualization Lab	Lake Tahoe in Depth (3D movie)	Visitors will: • Understand that Lake Tahoe was formed by faulting and volcanic activity. • Understand that lakes are dynamic systems driven by the sun, wind and weather patterns. • Be introduced to the ecological history of Lake Tahoe. • Understand that there are many environmental issues facing Lake Tahoe.
		Let's Go Jump in the Lake (3D movie)	Visitors will: • Understand seasonal effects on Lake Tahoe and its ecosystem. • Learn about Lake Tahoe's aquatic food web. • Be introduced to how climate change is altering the lake system.
		Mapping Change in the Sierra Nevada Forests (3D movie)	Visitors will: • Be introduced to historic and current mapping of the Sierra Nevada forests. • Understand how and why the forests have changed over recent years. •Learn about how climate change has and will affect the forests surrounding Lake Tahoe.
		Follow Drop of Water (3D movie)	Visitors will: • Understand what a watershed is. • Learn about how water travels through a watershed. • Learn about human impacts on a watershed.
		3D Earthquake Viewer (Interactive, Custom)	Visitors will: • Investigate where earthquakes occur around the world. • Learn about plate tectonics and plate movement.

Welcome Tour Groups and Individuals

Hello and Welcome

- My name is…
- We are glad you came today to visit the UC Davis Tahoe Science Center.

Gathering Information from Visitors

- Ask: Where are you from and what interests brought you to TERC?
- Ask: If visiting, where are you staying while at Lake Tahoe?
- Ask: How did you find out about us?
- Ask: How much time do you have today and which tours are you interested in?

What to Expect

We offer two different tours:

- Tours of our Science Education Center.
- Green building tours of the Tahoe Center for Environmental Sciences.
- Each tour lasts between 30 and 60 minutes, but we can adjust the schedule to suit your interests.

Who are we?

- UC Davis Tahoe Science Center operated by the UC Davis Tahoe Environmental Research Center
    - Researchers in the lab on the third floor
    - Educators in the education center on the first floor
- The building itself is a collaboration with Sierra Nevada College, but the science center is designed, supported, funded, and operated by UC Davis.

Education Center Tour

- The Education Center tour lasts between 45 and 90 minutes (can also be shortened).
- Ask: How familiar are you with the Lake Tahoe area?
- Begin by introducing the lake at the watershed map. Ask: What is a watershed?
- Before moving to the boat, be sure to point out where we are located on the map as well as some other points of interest (this will help when at the 3D visualization lab).
- See Video Exhibit Talking Points and Discussion/Questions in the Docent Manual.

Green Building Tour (available upon request)

- The Green Building Center tour lasts between 45 and 60 minutes (can also be shortened).
- The building is "Green" – Ask: What does it mean to be a "green building"?
- This building received a Platinum award from the U.S. Green Building Council for "Leadership in Energy and Environmental Design" (LEED). This is the highest LEED award that a building can receive.
- Begin in front of the building by describing the site chosen for the building.
- See *Green Building Tour Talking Points* in the Docent Manual.

Before Visitors Leave

- Any questions?
- Please take the time to complete our **Visitor Exit Survey** at the monitor by the kids' station.
- Ways to be a part of the solution:
    - **Support the Tahoe Science Center through donations!** (show them the donation buoy near the boat) Checks can be made out to "UC Regents"
    - Carpool, bike, and use mass transportation
    - Leave no trace!
- For Residents, please share:
    - UC Davis TERC Newsletter
    - Top 10 Ways to Save Lake Tahoe ("Learn How You Can Help Save Lake Tahoe"
    - What You Can Do to Keep Tahoe Blue
    - Best Management Practices ("Saving Lake Tahoe in Your Backyard")
    - Defensive Space ("Get Defensive")
    - Environmental Improvement Program (EIP)
- For Visitors, please share:
    - UC Davis TERC Newsletter
    - Top 10 Ways to Save Lake Tahoe ("Learn How You Can Help Save Lake Tahoe")
    - What You Can Do to Keep Tahoe Blue
    - Tahoe Boat Inspections ("We're All In This Boat Together")
    - Trail maps
    - TART bus schedule
- All additional information materials are available next to the front desk.

Lake Tahoe Basin Watershed Map

Images from remotely sensed data can be used to investigate environmental changes. Work conducted at the UC Davis Tahoe Environmental Research Center uses this imagery to detect and differentiate vegetation, communities on land, temperature changes across the lake, and document subtle changes in the regional landscape over time.

This map is an artificially colored infrared IKONOS image. The IKONOS satellite sees objects as small as 3 feet! Taken in July 2002, we placed the image over a digital elevation model that represents the actual shape or topography of the ground. The bright green color has been artificially enhanced to highlight features of the watershed.

Talking Points

Creation of the Lake Tahoe Basin Watershed Map

- The map consists of two separate digital elevation models (or DEMs):
    - Topography of the watershed and surrounding areas from the USGS.
    - Bathymetry under the lake was obtained in 1998 using high-resolution multibeam-SONAR by the USGS.
- IKONOS satellite image draped over watershed is false color.

Water Movement in the Lake Tahoe Basin

- The colored area represents Lake Tahoe's watershed.
    - Ask if everyone understands the concept of a watershed (the area of land that drains to a common water body). This concept is very important and should be explained.
    - Any precipitation that falls within the colored area on the map will end up in Lake Tahoe, unless it evaporates or is taken up by plants first.
    - Examples of other well-defined (and much larger) watersheds include those of the Mississippi River-Missouri Drainage Basin, Great Lakes and St. Lawrence River Watershed, and California's Central Valley.
- One reason Lake Tahoe has remained so clear is the small size of its watershed in relation to the lake's size. Compare to other known watersheds.
- There are 63 different rivers and streams that flow into Lake Tahoe. Find

the one where visitors live or are staying.

- Lake Tahoe's only outlet, the Truckee River, is located in Tahoe City. From here, water flows down through Reno and to Pyramid Lake. Pyramid Lake is known as a terminal lake because there is no outlet to carry the water further. Water from Lake Tahoe does not flow to the ocean but ends its journey in a desert lake.
- The Upper Truckee River flows through South Lake Tahoe and is the most urbanized part of the basin. It is responsible for 1/3 of the inflow into Lake Tahoe.

Formation of the Tahoe Basin

- Lake Tahoe and the surrounding mountains, streams, meadows, and cliffs offer a fascinating glimpse of geologic history. Our region was morphed by plate tectonics and sculpted by volcanoes and glaciers. Research continues re-writing that story and the exact timeline is still up for debate.
- One hundred million years ago, all the materials that would become the Lake Tahoe Basin and surrounding mountains, valleys, and formations sat at the bottom of a vast inland sea in a subduction zone.
- That sediment and a series of volcanoes sat on top of a massive magma chamber that would form the Sierra Nevada Batholith. Eventually, the batholith rose up from underneath the volcanoes and sediment, exposing the granite rock for which the Sierra Nevada is now famous in places like Yosemite, Desolation Wilderness, and Donner Summit.
- The Tahoe Basin began forming about 3 to 3.5 million years ago through fault movements of Tahoe's 3 main faults – the West Tahoe Fault between modern-day Emerald Bay and Dollar Point, the Stateline Fault running south from Crystal Bay and the Incline Village Fault running south from Incline Village.
- Normal faulting lifted the Carson Range on the east and the Sierra Nevada on the west.
- Between these two ranges, other blocks also dropped down forming a valley that would eventually become the Tahoe Basin.
- Volcanic uplifting events in the basin from Mt. Pluto to Mt. Rose also occurred.
- Glaciers sculpted the modern Tahoe's shape by cutting valleys and glacier moraine lakes.

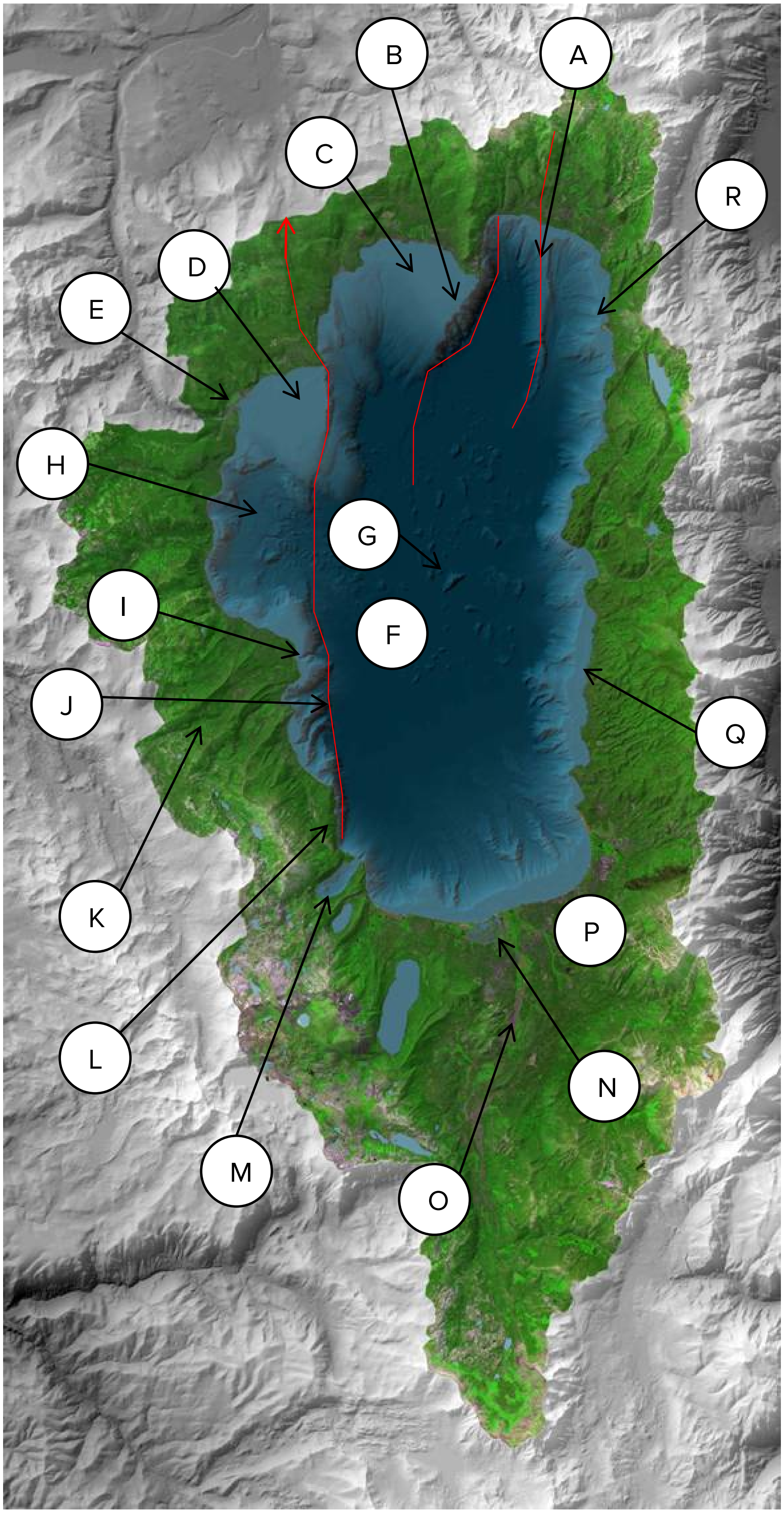
You Can Also Point Out:

- 3 normal faults run through the Tahoe Basin:
  - Incline Fault (runs through the middle of Crystal Bay)
  - Stateline Fault (runs along the west shore of Crystal Bay, with a very steep, straight 1,400-foot fault scarp (a steep bank or slope) from Stateline Point)
  - West Tahoe Fault (between Emerald Bay and Dollar Point)
- McKinney Bay Landslide/Tsunami and debris in the lake – Approximately 60,000 years ago an enormous underwater landslide started in McKinney Bay and sent tons of boulders, rocks, and soil plunging 1,500 feet to the lake bottom. The force scattered rock debris all the way across the lake floor. The energy released from this landslide resulted in a tsunami which destroyed every living thing surrounding the lake within fifteen minutes.
- Angora Burn Area - The Angora Fire was a wind driven fire that started near North Upper Truckee Road subdivision near Angora Lakes, Fallen Leaf Lake, Echo Lake, and South Lake Tahoe, California on June 24, 2007 as a result of an illegal campfire. The fire burned 3,100 acres, destroyed 242 residences and 67 commercial structures, and damaged 35 other homes.
- Tahoe Keys in South Lake Tahoe - The Tahoe Keys is a housing development on the south shore constructed in the mid-1960's within the Upper Truckee Marsh. The Upper Truckee River once flowed through the Tahoe Keys, but was diverted to prevent flooding. The developed property is over 150 acres in size and contains two separate marinas.

Questions

- Can you find the burn scar left from the July 2002 Gondola Fire near Heavenly Valley?
- The largest wetland area in the basin used to be located where the Tahoe Keys is now. How has the loss of this large wetland affected Lake Tahoe?

Key Physical Features of the Tahoe Basin



A. Incline Village Fault
B. Stateline Fault
C. Underwater Shallow shelf near Kings Beach
D. Tahoe City Shelf
E. Truckee River Outflow
F. Sediment at the Bottom of Lake Tahoe
G. Underwater Blocks
H. McKinney Bay Underwater Landslide
I. General Creek Sediment Plume
J. West Shore Fault
K. Glacially Carved Valleys
L. Steep Area of D.L. Bliss State Park
M. Emerald Bay
N. Tahoe Keys
O. Upper Truckee River
P. South Lake Tahoe
Q. Cave Rock
R. Sand Harbor

Key Physical Features of the Tahoe Basin

A. **Incline Village Fault:** *Heading south past the fault is the deepest part of the lake at 1,645 feet. You will notice giant ripple marks, some with 50 meters between them.*

B. **Stateline Fault:** *Amazing snorkeling and a ~1400 foot drop.*

C. **Kings Beach Shelf:** Underwater shallow shelf near Kings Beach

D. **Tahoe City shelf:** *Remaining shelf after landslide. May not have slid due to being composed of volcanic material instead of sediment, although could possibly be disrupted in a large (7.0 magnitude) earthquake.*

E. **Truckee River:** *Tahoe's only outlet, 63 streams and rivers flow into the lake.*

F. **Sediment at the bottom of the lake:** *The bottom is mostly flat but after years of sedimentation the layer of sediment that makes up the bottom is estimated to be almost double the depth of the water level.*

G. **Underwater blocks:** *The largest block from the landslide is 1 km across. The blocks are composed of consolidated sediment.*

H. **McKinney Bay underwater landslide:** The McKinney Bay underwater landslide *occurred somewhere between 10,000 and 60,000 years ago. A 7.0 magnitude earthquake is thought to have caused this land area to collapse. The displacement would have caused a large tsunami with waves as high as 100 to 300 feet tall. Seiche waves (where water would slosh back and forth) are estimated to have lasted for 24 hours following the initial tsunami.*

I. **General Creek sediment plume:** *Clearly shows sediment coming from stream into lake and fault scarp cutting through it. Sediment plume to the left does not have fault cutting through it indicating a younger age.*

J. **West Tahoe Fault:** *Runs the whole west side of the lake. See evidence of fault "slippage" or movement. This distinct fault through the sediment is evidence that the fault ruptured relatively recently as the fault cuts through it.*

K. **Glacially carved valleys:** *Glaciers came through here in the Tahoe (100,000 years ago) and Tioga (50,000 years ago) ice ages. The land pushed by a glacier and deposited is called a "moraine" which you can see prominently above General Creek sediment plume.*

L. **Steep area of D. L. Bliss State Park:** *great hiking spot.*

M. **Emerald Bay:** *Just south of Emerald Bay is Cascade Lake, the larger lake is Fallen Leaf Lake. The ridge on the south side of Fallen Leaf Lake is Angora Ridge, the site of the 2007 fire that burned 260 homes. Observe that these are also glacially formed, and moraines are present here as well.*

N. **Tahoe Keys:** *former wetland developed in the 1960's. Loss of filtering and warmer water creates favorable habitat for invasive species, some of which may have been dropped in lake from fish tanks.*

O. **Upper Truckee River:** *Responsible for approximately one third of the inflow to the lake.*

P. **South Lake Tahoe:** *Airport, Mackinaw/Lake Trout fishing just off shore. The fish also spawn here as they are exposed to the photic zone but are still protected by the erosional feature of the shelf. Sediment shelf here is similar to the west shore pre- landslide.*

Q. Continue along east shore. Point out **Cave Rock**: *the remnant of a volcanic plug considered to be sacred by the Washoe Tribe.*

R. Point out **Sand Harbor** and **Mount Rose** as you head back to Incline Village

For additional information, see the Geology Section of your Docent Manual (located in Additional Resources) for details about the Tahoe Timeline, Tahoe Geology, Sierra Nevada Geologic Time Scale and the Tsunami at Lake Tahoe.

Turning on the Science Center

Front Desk Computer

To use the front desk computer, press the two small power buttons on the computer and computer screen. The small computer unit is located on the floor below the desk (Fig. 1) and the power button will light up white. The monitor power button can be found on the right side of the computer screen behind the power button symbol (Fig. 2). Reach your finger around the right side to turn on.

To turn off the front desk computer: Shut down all your programs. Go to the Windows icon on the bottom left of your screen and select [Shut Down]. Press the same power button on the computer screen to turn it off (Fig. 2) as well.

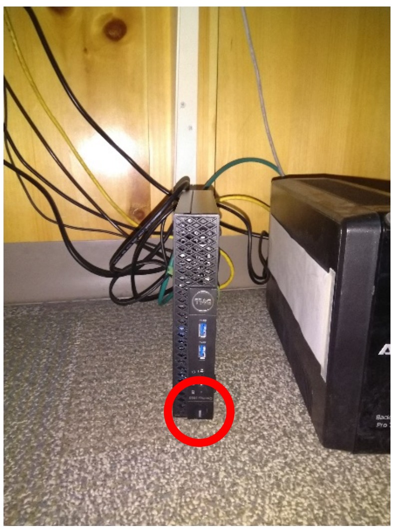
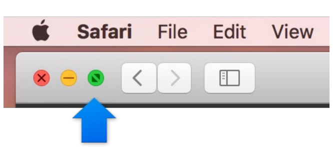


Figure 1

Figure 2

"Lake Tahoe in Depth" Touchscreen Exhibits

To turn on "Lake Tahoe in Depth" exhibits (Fig. 3), find the power button by running your hand along the bottom back underside of the touchscreen monitor. You can either feel for the slightly raised dot on the rightmost button on the underside of the TV, or look underneath the TV monitors for a printed arrow sticker pointing to the location of the power button (Fig. 4 and 5). Press this button to turn on the touchscreen (Fig. 4). The monitor takes time to boot up so please be patient. Do the same on the other touchscreen monitor. Both exhibits should have a full screen display and look like the picture in figure 3.



If the internet browser window is visible, press the green maximize button on the browser once or twice as required to return it to full screen.

Turning it off: Find the same button used to turn on the monitor and press it one time to turn it off at the end of the docent shift (Fig. 3). The screen should go black.

Figure 3

Figure 4

Figure 5

<u>Small Touchscreen Near Buoy</u>

To turn on the small touchscreen (Fig. 6), simply hit the power button in the lower right-hand corner (Fig. 7). To turn off, press the same power button.

Figure 6

Figure 7

“Shaping Watersheds” Augmented Reality (AR) Sandbox

To turn on the AR Sandbox, press the power button once on the projector above the exhibit (Fig. 8). It takes a while for the projector to warm up to full brightness, so give it time. It is working properly when there is a topographic map projected on the sand and virtual water flows onto the landscape when your hand is open above the virtual landscape (five fingers separated and held about 1 foot above the sand). Turning it off: Press the power button twice to turn it off (Fig. 8). The projector should turn off and the topographic map projection will disappear when it is off.

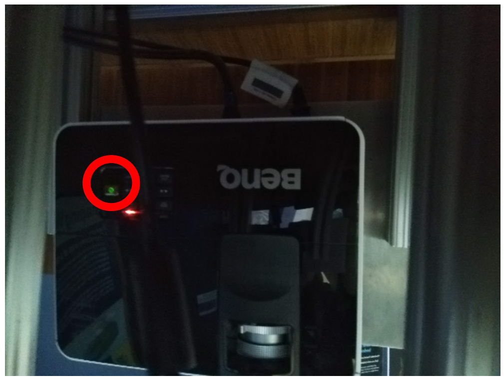


Figure 8

Aquarium Lights

To turn on the aquarium lights, hit the power switches located on the back right side of each tank light. There are four light switches total for the two aquariums against the wall) as shown in Fig. 9. The tank light on the lab counter is a sliding switch in the center (Fig. 10).

Figure 9

Figure 10

Microscope (Lab side)

First, remove the red dust cover from the microscope. Check the dial on the top left of the microscope and ensure that it is turned to the **DOC** position (Fig. 11). Place the object for magnification on the glass tray.

To turn on the TV screen above the microscope, press the power symbol (Fig. 12) on the bottom right of the screen.

To adjust the clarity of the image that is projected on screen, use the fine tuning dial located at the neck of the microscope (Fig. 13). Alternate the dial back and forth and use trial and error to find the clearest image.

Figure 11

Figure 12

Figure 13

Use the forward most dial on the right side of the base of the microscope to adjust lighting by rotating and positioning the mirrors to reflecting the optimal lighting (Fig. 14). Adjust these mirrors until you can see the figure on the TV. This is optional.

For additional lighting, you can turn on one or more lights. To turn on the microscope light, turn the dial on the back left side of the microscope toward the wall until it clicks and the light comes on (Fig. 15). The more you turn it the brighter the spotlight becomes. If even more lighting is needed, turn on the extra lights to the left side of the microscope (Fig. 16).

Turning it off: If you turned on any of the lights, please turn these off (Fig. 15 and Fig. 16). For the TV press the power button (Fig. 13). Then place the red dust cover carefully on top of the microscope.

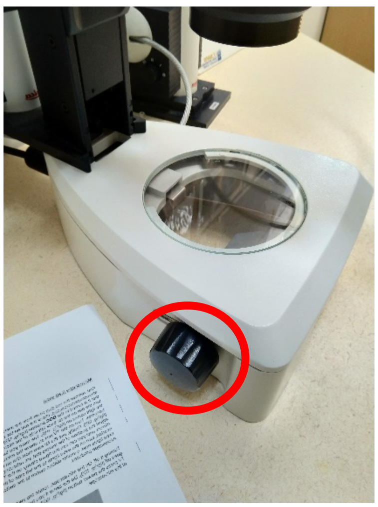


Figure 14

Figure 15

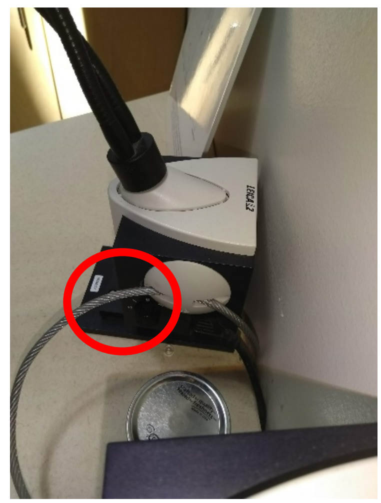


Figure 16

Large TV Monitor Next to Elevator

The large TV on the lab side located next to the elevator plays a muted continuous loop of field research video footage. The remote for this TV is located on the shelf by the wall-mounted buttons that operate the main lab exhibit videos (Fig. 17).

To turn the TV on: Use the remote shown in Fig. 17 and 18 to turn on the TV. Push the green TV button and look for two very small green lights at the bottom right of the screen to turn on. Alternatively, the TV can be turned on by pressing the “Power” button located on the right side of the TV. Give the TV time to turn on.

To start the Blu-ray Player: The screen will either give you an option to select DVD-R VIDEO (as shown in Fig. 19) to start the video or remain blank. If the screen remains blank, the Blu-ray disc player is not on. To turn it on, press the “BD” button on the remote followed by the green "POWER" button and wait for the "Starting Blu-ray disc unit" screen to appear (Fig. 20). When it appears, select the DVD_R VIDEO icon and then press the play button. Sometimes you have to press the PLAY button more than once to cycle through the different options (BD Data, Video, and finally DVD-R VIDEO). When you have selected it, make sure it starts the video (Fig. 22).

You can use the double arrows above the play button to skip to the next or previous chapter. Note that the chapters are marked on the lower left side of the screen (Fig. 22). Make sure to return the remote to its original spot (Fig. 17).

<u>Turning TV OFF:</u>

Press the green TV (Fig. 18) on the remote while pointing at the TV and then return the remote to its original spot. Alternatively, press the "Power" button on the right side of the TV.

Figure 17

Figure 18

Figure 19

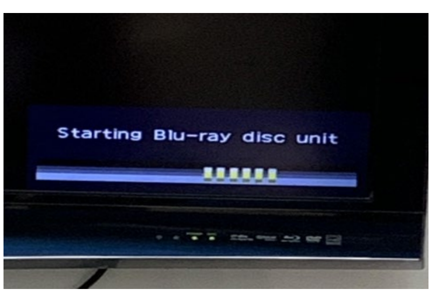


Figure 20

Figure 21

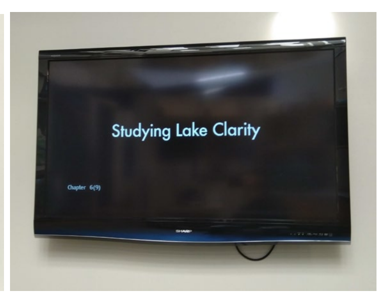
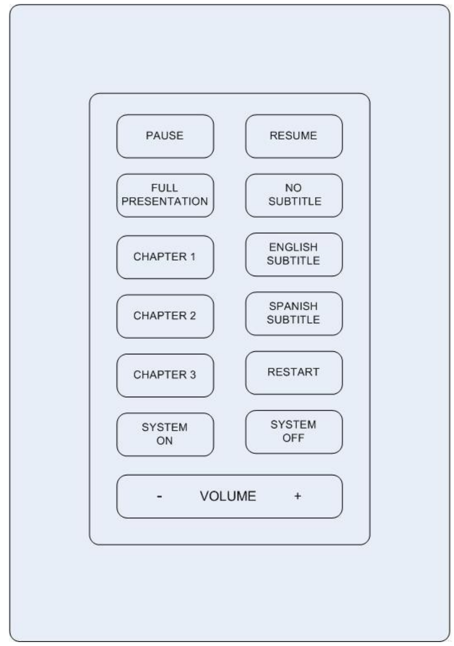


Figure 22

Operating the Video Exhibits



Control Panels for Exhibits: Please use only the "Lab" control panel to turn the system ON or OFF. The Virtual Lab control wall-panel is located on the wall behind and to right of small monitor.

Wall-Panel Buttons

- *[PAUSE] – pauses video
- [PLAY ALL] – plays all three chapters
- [CHAP 1] – play only chapter 1
- [CHAP 2] – play only chapter 2
- [CHAP 3] – play only chapter 3
- [ON] – turns system on – use Lab exhibit side only
- *[RESUME] – resumes video after pausing
- [NO SUB] – returns videos to no subtitles (must be pressed before video chapter is chosen)
- [ENGLISH] – English subtitles (must be pressed before video chapter is chosen)
- [SPANISH] – Spanish subtitles (must be pressed before video chapter is chosen)
- *[RESTART] – this button currently does nothing
- [OFF] – turns system off – use Virtual Lab exhibit side only
- *[VOLUME +/-] – controls volume level

**These buttons are currently disabled or not recommended for use.*

Turning the System On

Press the [ON] button at the Lab Exhibit. Always use the Lab side (and not the boat side) for turning the system on or off. Allow plenty of time (2 – 3 minutes) for the system to boot up completely upon starting the system. After the system has had a few minutes to warm up, **always** play one chapter on both the boat and lab to make sure all of the monitors are working properly.

LAB SIDE

BOAT SIDE

NOTE: It seems like a lengthy process at times; however, our technicians say the biggest problems can occur when we do not wait long enough between commands. Please take your time, allow the system to start up properly, and allow the system to respond before pressing the next command button.

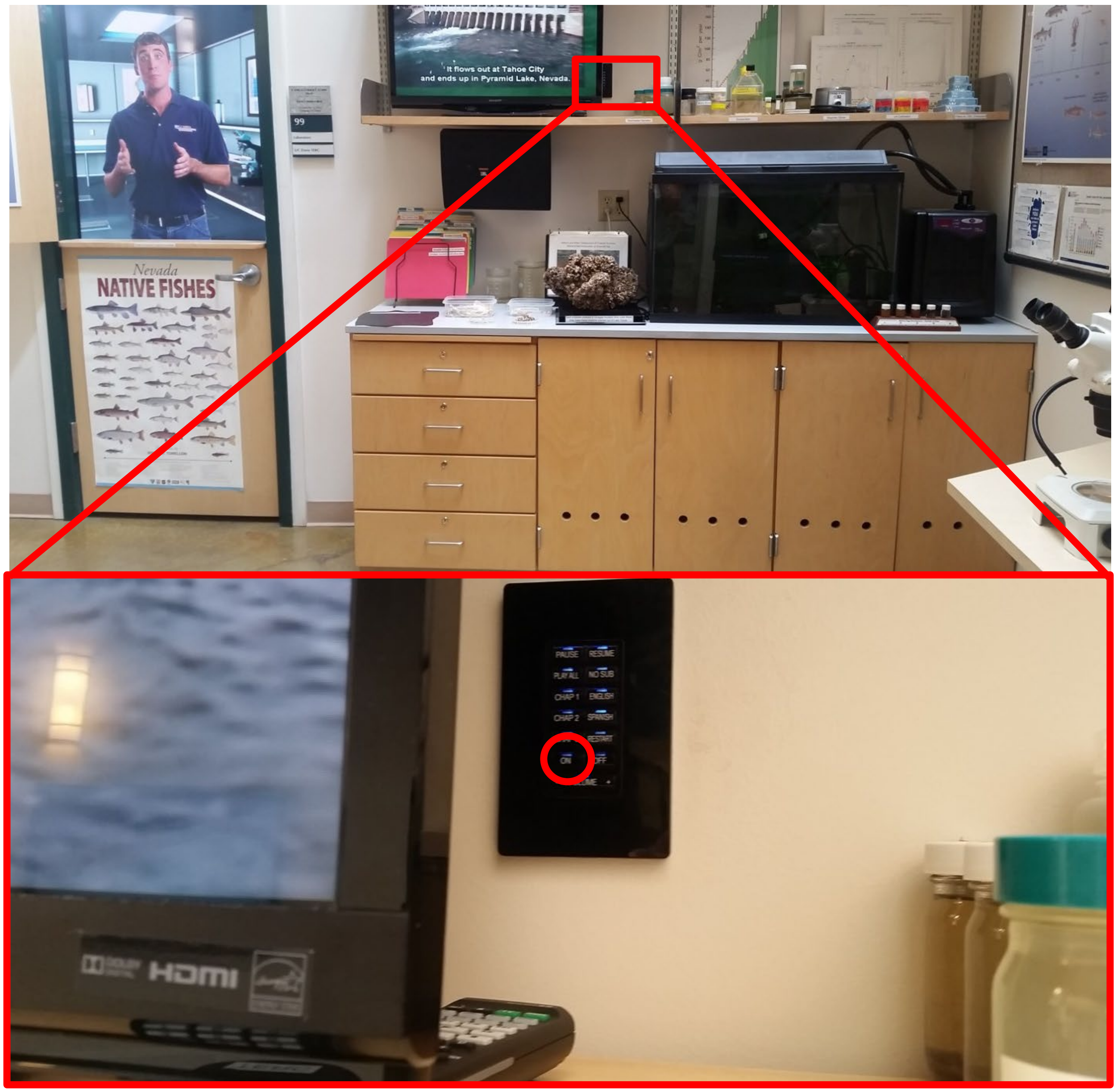


Figure 23

<u>Please note</u> that the same panel exists on the boat side of the exhibits, however, you should only turn the system on and off <u>from the lab side.</u> There is tape covering the 'On' and ‘Off’ Button on the boat side to try to prevent use of these buttons. Press the video you wish to play ([CHAP 1], [CHAP 2], [CHAP 3] or [PLAY ALL]).

After turning on all the equipment, there are a couple of other things to remember **when using the equipment:**

1) **Using the ‘Play all’ button** is generally discouraged on either sides of the education center. You should always inform visitors how long the video is (most of them are 2-5 minutes) and check for audience understanding by asking for any questions after each video. Each mini video packs a lot of information in a short time so guests watching the video for the first time may miss an important detail and that’s where TERC’s amazing docents come in. ‘Play all’ is only really necessary if you are balancing multiple groups at the same time and you need the extra time with another group.

2) **Do not press ‘Pause’ or ‘Resume’** on either sides of the education center. Not only will it disrupt the flow of the video to pause and resume, it also wreaks havoc on the video players for these exhibits. Please let all videos play all the way through during your presentation.

3) Changing subtitles: **Press either ‘Spanish’ or ‘English’ BEFORE** pressing a ‘Chap’ (Chapter) button to start a video. This must be done before pressing play a chapter button.

4) **Volume control**

Adjusting the Volume of the Boat exhibit: To adjust the volume, there is a dial (Fig. 24) located on the boat left of the large plasma screen depicting the boat’s cabin. Adjust the volume by turning the dial to the left to decrease the volume or to the right to increase the volume. Do not press down on the dial when turning as it will not adjust the volume when pressed.

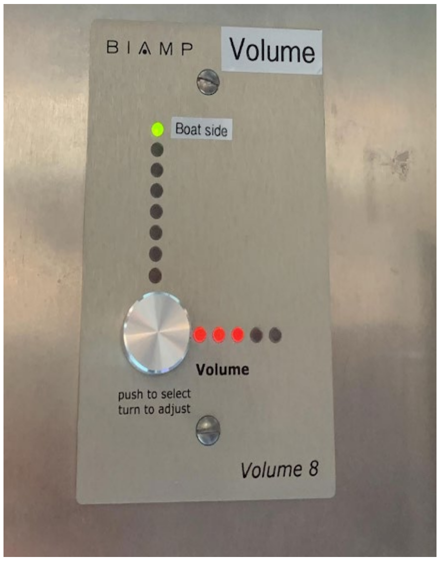


Figure 24

Adjusting the Volume of the Lab exhibit: To adjust the volume, there is a dial located in the rightmost cabinet (Fig. 25). It is a metallic panel with lights on it (Fig. 26). Adjust the volume by turning the dial to the left to decrease the volume or to the right to increase the volume. Do not press down on the dial when turning as it will not adjust the volume when pressed.

Figure 25

Figure 26

Turning Video Exhibits OFF

At the end of your shift, simply press the [OFF] button at the Virtual Lab wall-panel and this will turn the entire system off.

Troubleshooting the Exhibits

Below is a list of possible problems that may occur. If something unprecedented has occurred, please call Alison (ext. 7566) upstairs for assistance.

Figure 27

Problem #1: You've turned on the education center and after playing a test video you notice everything is working except the small screen on the lab or boat side (Fig. 27).

Solution: There is a remote located in the bottom drawer on the lab side (Fig. 28). Open the drawer and find the remote labeled "Boat Small TV" (Fig. 29). Take the remote to the LCD monitor that is not working and press the power on the button while aiming at the small hole in the metal frame located below the monitor (Fig. 30). It takes about 10 seconds for the "Sharp" logo to appear. Do not press the On/Off button again as you will actually turn the system off before it has a chance to boot up. Wait for the screen to turn on and return the remote to its original place.

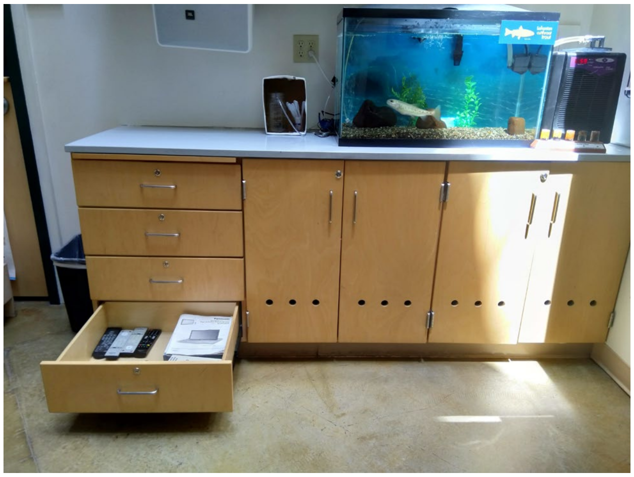


Figure 28

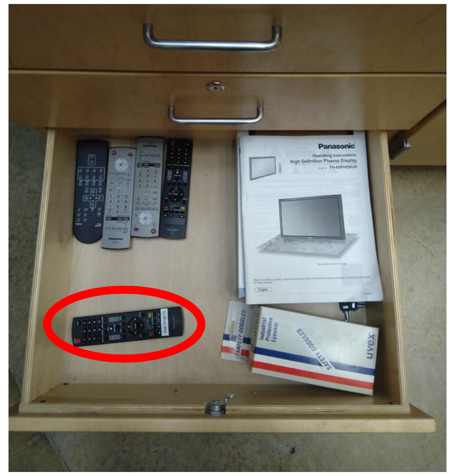


Figure 29

Figure 30

<u>Problem #2:</u> You have turned on the education center and after playing a test video you notice everything is working except <u>the small LCD screen on the Lab side</u>. Upon closer inspection you see that the power light is red indicating that it is off.

Solution: Because the small LCD TV screen isn't enclosed on the Lab side, you can manually turn it on. On the right side of the LCD TV screen are buttons for volume, channels, input, menu, and power (pictured left). Press the 'POWER' button to turn on the LCD screen. You don't necessarily need to be able to see the side; you should be able to feel the power button due to a small raised bump on the button. Look for the red light on the front of the TV (pictured below) to turn to green to indicate the power is on.

Figures 30 and 31

<u>Problem #3:</u> One of the large "Lake Tahoe in Depth" touchscreen exhibits freezes.

Solution: Retrieve a proper step stool in the field-trip room and locate the Mac Mini behind the top of the screen. Press and hold the power button for ten seconds to restart the program.

Figure 33

<u>Problem # 4:</u> There is nothing showing up on the TV screen above the microscope. The TV screen is blank or showing the message "No Connection".

Solution: Most likely the input set has been changed. To change it back, press the main menu button above the power button (Fig. 34). Select the "Input Select" option (Fig. 35) and select "S-Video" (Fig. 36).

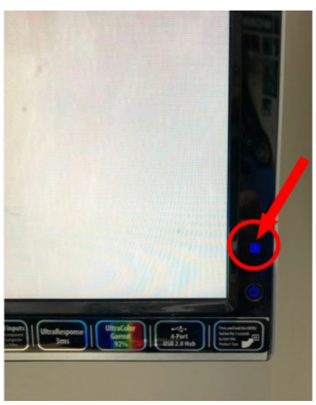


Figure 34

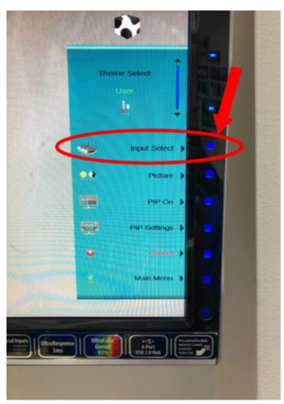


Figure 35

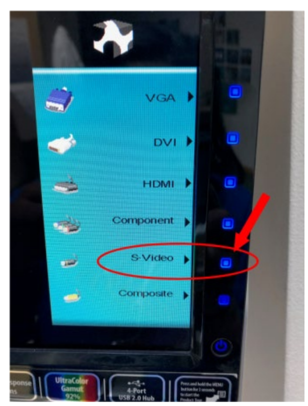


Figure 36

Problem #5: For any other problems…

Solution: Call upstairs for assistance.

- **Alison** ext. 7566
- **AmeriCorps** ext. 7474 and 7483
- **Heather** ext. 7562

Virtual Research Vessel Video Exhibit

Chapter 1: Introduction to Lake Tahoe

Become familiar with Lake Tahoe's unique characteristics and environmental threats (fine sediment and algae).

Exhibit Video Script

Hello and welcome aboard the UC Davis research vessel John Le Conte. Watch your step. Since 1976, scientists aboard the Le Conte have been taking measurements in Lake Tahoe. In fact, most of what is known about the lake has a connection with this boat.

Nature has set the conditions for Lake Tahoe's famously clear waters. The lake was formed more than 2 million years ago when a block of the earth's crust dropped down, forming a huge valley. The valley was blocked when volcanoes erupted on the north shore, and water started to fill the lake. Since that time, earthquakes, glaciers, and huge landslides have all played a role in shaping the mountains and the lake.

One thing you need to know is that Lake Tahoe is big! Lake Tahoe is 1,644 feet deep, making it the second deepest lake in the United States and the 11th deepest lake in the world. It is 22 miles long and 12 miles across and holds 41 trillion gallons of water.

If you took all the water out of the lake and spread it over California, it would cover the entire state up to your knees. And, it would take over 600 years for the lake to refill. That is really big!

Take a look at the screen to your left – our friends at NASA have some great pictures of Lake Tahoe looking back from space.

Did you know that Lake Tahoe was once one of the clearest and bluest lakes in the world? That's because there were so few soil particles and algae in it. These are what make the water of most other lakes seem cloudy. Let me show you what I mean.

See these two beakers of Lake Tahoe water? Adding just one spoonful of stormwater clouds the water on the right with very fine particles. Can you read the sign now? This is what flows into the lake every time it rains.

The large volume of water in Lake Tahoe compared to the small size of the mountain basin, or watershed, that surrounds it helped to keep Lake Tahoe clear for thousands and thousands of years. Meadows and marshes also helped keep nutrients and fine particles out of the lake because they functioned as filters.

In the last 30 to 40 years, the clarity of Lake Tahoe has decreased and you cannot see as far down as before. There are also many other changes in the lake. It's still beautiful and still clearer than most lakes, but if nothing is done to stop what is happening, we risk losing our beautiful clear blue lake.

The research at Lake Tahoe is aimed at restoring the lake's clarity. What we learn here is also being used at other lakes around the world. Many of the country's top limnologists (that's what people who study lakes are called) started as college graduate students like me, working here at Lake Tahoe.

I need to get back to my experiments, but stick around to hear about some of the research we do. Maybe I will see you later on if you visit the lab.

Chapter 1: Introduction to Lake Tahoe

Become familiar with Lake Tahoe's unique characteristics and environmental threats.

Talking Points

General features of the Tahoe Basin

- Lake Basin formed more than 2 million years ago.
- Graben faulting – grabens are produced from parallel normal faults. Lake Tahoe is considered a "half graben" resulting from a major fault along only one boundary and producing a valley with a distinct scarp (a steep cliff formed by movement along a fault).
- Volcanic activity occurred on the north shore.
- Earthquakes, glaciers, landslides, and erosion have all played a role in shaping the watershed.
- Lake Tahoe is 1,644 feet deep at deepest point.
- Average depth is 1,000 feet.
- The lake is 22 miles long, 12 miles wide, and 72 miles to drive around (75 miles of actual shoreline).
- Surface area is 192 square miles.
- Lake Tahoe holds about 39 - 41 trillion gallons of water: enough to cover an area the size of California to a depth of 15 inches.

Loss of lake clarity

- In the last 30 – 40 years, clarity has been reduced from 100 feet to around 70 feet.
- The waters of Lake Tahoe were clear to an average depth of 69.6 feet in 2008, according to UC Davis scientists who have monitored the lake since 1968. That keeps the clarity measurement in the range where it has been for about the past eight years. In 2007, UC Davis reported that data since 2001 suggested lake clarity was not declining as fast as it had been. In 2016, Secchi depth was 69.2 feet.
- More than 70 percent of the Tahoe Basin's wetlands and marshes have been lost to development.
- Wetlands act as a filter to reduce the amount of nutrients and fine sediments (particles) that enter the lake.
- Local restrictions now prohibit construction within wetland or stream environmental zone (SEZ) areas. Limnology – the study of lakes.

Chapter 1: Introduction to Lake Tahoe

Become familiar with Lake Tahoe's unique characteristics and environmental threats.

Discussion & Questions

Question: What do you call scientists who study lakes and other freshwater resources?

Limnologists. Limnology is the study of freshwater (as compared to oceanography, or marine science, which is the study of oceans).

Discuss: What makes Lake Tahoe so special?

Discuss: What do you think would happen if Lake Tahoe turned green or

brown?

Discuss: What do you think contributes to loss or gain of clarity in a lake?

Discuss: What has the human impact been on Lake Tahoe Basin over the last 200

years?

Question: Why is Lake Tahoe blue?

Part of the light you see is a surface reflection of sky light. The amount of reflection depends on things such as your viewing angle. Much of the color you see comes from the water's depths. Water absorbs longer wavelengths of light. Most of the longer wavelengths of light disappear within a few feet of the surface. The shorter wavelengths of light (the blue end of the spectrum) penetrate the water surface, and are scattered by the water molecules. This scattered blue light is what we see.

As we add more things to the water, more scattering occurs. The light that enters our eyes is coming from shallower and shallower depths, and we see more reflection and less scattering. Clay and silt reflect red light strongly, and many algae reflect green light strongly. The more fine silt and algae in Lake Tahoe, the less blue it will look to us.

Question: Does the lake ever freeze?

No, Lake Tahoe is such a large body of water, and the climate is so mild, that temperatures never get down low enough for the lake to freeze (except around the edges in very cold years). The coldest that Lake Tahoe gets is about 41 °F (5 °C).

Virtual Research Vessel Video Exhibit

Chapter 2: Lake Measurements

Watch a scientist demonstrate use of the Secchi Disk, Van Dorn Sampler, and plankton net. Learn about water clarity, zooplankton and remote sensing.

Video Script

Hi there. Did you know that Lake Tahoe has been losing clarity? Because we have been measuring water clarity in Lake Tahoe for a long time, we know for sure that it has been getting worse. Do you see that white disk hanging from the wire?

[Points to his left] That is called a Secchi disk and it is just one of the instruments we use to measure water clarity.

Let's head out on the lake. I'll leave you with captain Brant to see what a limnologist does...

Welcome aboard the UC Davis Research Vessel John LeConte. Today out here on the lake I'm going to be doing a Secchi disk reading... and the way we do this is to slowly lower the disk into the lake... and I measure the line, how much line has gone out off this meter wheel, so I know how deep it has gone. So I am going to start sending this down into the lake. So as the disk goes down into the lake, it gets more and more difficult to see. The reason for this is that there are fine particles and algae floating around in the water column, and as the disk gets deeper, these particles scatter the light and make it harder to see the disk.

There is a small white glow where I can still see the disk so we keep an eye on it till it gets down to where it is just about to disappear. Then I have to be real careful about stopping the line at the right place. And right there, it just went out of view. So that is going to be our Secchi reading today. If I look at the meter wheel I am at 18 meters and that is a good reading for today. That is 59 feet. I'm going to go ahead and bring it back up and we'll move on to some other tests.

This is another commonly used piece of equipment here at Lake Tahoe. It's called a Van Dorn Sampler. We use this to collect water from a specific depth in the lake. We lower the bottle down to the depth that we need to sample, and once it has reached that depth we send this weight down the line to close the bottle. As soon as the bottle closes we've captured water that we need for analysis. This sample came from 15-hundred feet deep in the lake. I'm going to send it back to the laboratory so they can analyze it for nutrients, fine sediment, and algae.

You see that research buoy over there? There are six of those on the lake. Each one is loaded with scientific equipment. That one is used by NASA and UC Davis scientists to check satellite data and to study water currents in Lake Tahoe. It is just about noon; that means the TERRA satellite ought to be passing by pretty soon.

[Plankton net] This is my favorite part of the sampling day. I'm bringing in the plankton net and in here we have the tiny creatures that eat the algae. Those creatures are called zooplankton. If you look in the end of the net you'll be able to see zooplankton jumping around. These guys are the tiny food for the fish that live in the lake.

Thanks Brant. Check out the equipment used on the boat. By taking all those measurements every ten days, we can see how the lake is changing over time. This graph shows how the Secchi depth has changed since 1968 when Dr. Charles Goldman began regularly taking these measurements.

Each of the white circles represents the average Secchi depth for that year. Back in the 1960's, the number was about 100, Meaning we could see down into the lake 100 feet. Now we can only see down about 70 feet. That is a loss of about 30 feet of clarity.

Look up to the skylight above you. The distance from where you are to the top of the skylight is about 30 feet. Now you know why we are worried.

Check out some of the other information around you or ask one of the docents to tell you what else is being done.

Chapter 2: Lake Measurements

Watch a scientist demonstrate use of the Secchi Disk, Van Dorn Sampler, and plankton net. Learn about water clarity, zooplankton and remote sensing.

Talking Points

Virtual Research Vessel Exhibit

- This "replica" represents a two-thirds scaled model of the stern of the real vessel.
- See "The Research Vessel (R/V) John LeConte" in the Additional Resources section.

The Boat Captain

- Captain Brant Allen is the captain of the research vessel.
- Prior to Brant, our boat captain was Bob Richards who retired after 37 years of working for the Tahoe Environmental Research Center.

Secchi Disk

- Point out the Secchi disk hanging from the rope (or pass around the extra disk).
- Father Angelo Secchi, scientific advisor to the Pope, was asked by Commander Cialdi, head of the Papal Navy, to test a new transparency instrument. He lowered a large canvas covered disk from the papal steam yacht, L'Immacolata Concezione in the Mediterranean Sea on April 20, 1865.
- Today, a similar instrument is used to measure water clarity at Lake Tahoe. Our "Secchi disk," a 10-inch opaque white disk, is lowered into the lake until it can be no longer seen by the observer. This depth of disappearance, called the Secchi depth, is a measure of the transparency of the water.
- Transparency decreases as suspended sediments or algal abundance increases.
- The readings are taken every ten days and are not precise. The main focus is the general trend of the readings.

Secchi Depth Measurements

- Measurements are taken approximately every ten days.
- Question: How many Secchi disk readings (individual measurements) are taken each year? Approximately 36 measurements (=365/10)
- Some measurements are discarded due to rough surface waters or cloudy

skies.

- All Secchi disk measurements are taken within the two-hour window around "solar noon" when the sun is directly overhead. The water needs to be relatively calm because waves cause difficulty for reading measurements.
- Boat captains are required to have their eyes checked regularly. Their results are regularly compared to results from other people.
- See "The Secchi Disk" in the Additional Resources section.

Other instruments (tools) used to measure clarity

- The Secchi disk may not seem like the most high-tech way to measure clarity, but it never fails, batteries never die, and it never requires technical support!
- Because this instrument has been used since the 1960s, the data can be compared across the years.
- In addition to the Secchi disk we also use the following more high-tech instruments which are mounted on the "Seabird" profiler:
    - (1) transmissometer measures how much light of a certain wavelength is received over a fixed path length (30 cm).
    - (2) optical backscatter (OBS) sensor measures how much light from a LED is scattered backwards by particles.
    - (3) photosynthetically active radiation (PAR) sensor measures the solar radiation (light) reaching different depths in the lake.
- Solar radiation at three different depths is measured at Buoy TB3 continuously throughout the day.
- Satellite remotely sensed images and instruments are also used to measure the lake "color" from space.

The clarity chart (also called the Secchi disk chart)

- Point to clarity chart.
- The graph has "zero" at the top unlike other graphs. The "zero" line represents the surface of the water. If the trend line goes up, it means clarity is reduced.
- We began collecting these measurements in 1968.
- Note the inter-annual variation due to differences in weather each year.
- Loss of clarity appears to be leveling off – The waters of Lake Tahoe were clear to an average depth of 68.9 feet in 2011, according to UC Davis scientists who have monitored the lake since 1968. That keeps the clarity measurement in the range where it has been for about the past eight years. In 2007, UC Davis reported that data since 2001 suggested lake clarity was not declining as fast as it had been.

Water sampling – Van Dorn Sampler

- Point to Van Dorn Sampler.
- This instrument allows us to collect water from a specific depth by lowering the open sampler on a line.
- Instrument uses a "messenger" (usually a brass weight) which is sent down the line. It releases a "rubber band" inside that snaps the sampler shut.
- Samples are regularly collected from various (i.e. 5m, 10m, 20m, 50m … 500m) depths.

Plankton net

- Net allows water to pass through it, but retains the small zooplankton in the collection cup at the bottom.
- Standard size of the ring allows us to calculate how much water is being filtered for each sample (area of ring x depth of collection = total volume of filtered water).
- Zooplankton are preserved in collection cup. Have a hand lens available to take a closer look.
- Mention you will have a chance to look at the zooplankton more closely in the Lab!

Research buoys

- Point to the buoy on photo mural.
- The University of California, Davis (UC Davis) and the National Aeronautics and Space Administration Jet Propulsion Lab (NASA/JPL) have 6 large research buoys on Lake Tahoe.
- Measurements are used to understand the factors affecting the health of the lake.
- Location of research buoys are shown on the map, although positions may vary by up to 500 feet depending on wind conditions.
- All buoys are equipped with navigation lights (1 flash every 4 seconds) and radar reflectors.
- Measurements include wind speed, wind direction, air temperature, atmospheric pressure, and water temperature.
- Real-time data is available online (http://www.laketahoeindepth.org) and at the "Lake Tahoe in Depth" touchscreen.
- There are also 6 meteorological stations on shore around Lake Tahoe.
- See "Research Buoys on Lake Tahoe" in the Additional Resources section.

NASA Collaboration

- Research buoys have a very sensitive radiometer (long arm pointing at water surface) which measures the surface temperature ("skin temperature") of the lake.
- NASA uses Lake Tahoe as a calibration site for its Earth Observation Satellites (EOS), such as TERRA, AQUA, ASTER, MODIS, etc. (See http://earthobservatory.nasa.gov for more info).
- Why Tahoe?
  - Large lake (35 km x 16 km)
  - High elevation (~2km), less interference
  - Available year round (does not freeze in winter)
  - Large annual temperature range (5-25 °C)
  - Freshwater (kind to instruments)
  - Good infrastructure (easy to access)

Glider

- TERC deploys an autonomous underwater yellow glider that oscillates up and down the water column from the surface level to a depth of 150 meters across the lake.
- Sensors measure temperature, light, algae, and dissolved oxygen.
- Data shows highly complex spatial structure exists in lake water quality (mixing, churning, swelling, and upwelling)
- Takes continuous measurements and provides real-time information to TERC's network of instrumented buoys, chase storm events to ultimately help round out the picture of the processes and impacts affecting Lake Tahoe.

Chapter 2: Lake Measurements

Watch a scientist demonstrate use of the Secchi Disk, Van Dorn Sampler, and plankton net. Learn about water clarity, zooplankton and remote sensing.

Discussion & Questions

Question: If Secchi disk readings are taken every 10 days, how many readings are taken in a year?

Approximately 36 readings are taken over the course of a year. While many of the readings are thrown out (bad weather, outliers, etc.), the remaining readings are averaged and that number represents the annual average clarity observed for the lake that year. The annual average is represented on the Secchi disk chart here.

Question: What accounts for the inter-annual variability (changes from year to year) seen in Lake Tahoe's clarity?

Numerous events, such as drought and flooding, can affect Tahoe's clarity from year to year. In 1997 the area experienced a large flooding event which decreased clarity by dumping a large amount of sediment into the lake in a relatively short period of time. During times of drought, the lake's clarity actually improves as less sediment makes its way into the lake.

Question: Why are water quality measurements important?

Water quality measurements provide a scientific basis to study Lake Tahoe as a living laboratory for studying freshwater lakes and their ecosystems.

Question: Why is it important to have a long-term data set (measurements over a long period of time)?

Forty years of research has shown that Lake Tahoe is threatened by loss of water clarity. It allows identification of the variables that impact clarity and allows for wise public policy decisions.

Discuss: How and what would you measure at Lake Tahoe in order to detect changes to the ecosystem?

Discuss: How would you measure clarity? Set up sampling protocols?

Discuss: What other research questions can you think of?

Virtual Research Vessel Video Exhibit

Chapter 3: Particles and Sediment Coring

Introduction to lake sediment as a way to measure sedimentation rates and show a historical timeline.

Exhibit Video Script

Hello. We all know how big Lake Tahoe is. What amazes me is that it is the very smallest things in the lake that are causing it to lose its clarity. Particles… tiny pieces of nonliving things like dust, soil, the stuff that comes out of your car's exhaust pipe… are the most important cause of clarity loss. Most of these particles are so small that we can barely see them with a microscope. To count the particles, we need to use special instruments that bounce laser beams off these tiny particles.

Another way to learn about the particles that go into Lake Tahoe is to study what went into it in the past. All the particles that have ever fallen into Lake Tahoe eventually fall to the bottom of the lake and become part of the sediments. The very oldest particles are at the very bottom of the sediment layer. The newest ones – those that came in recently -- are closer to the top. In that way, the sediment layers are a history of Lake Tahoe.

Researchers use special hollow tubes, which are driven into the soft bottom sediments to collect sediment.

Hey Alan, what is that?

[ALAN – Winch noise] This is a sediment core… from the bottom of Lake Tahoe that we just took out here in the lake… bring it up and we'll put it down. Okay, down.

This is the type of mud that you see in the bottom of the lake. It accumulates a little bit at a time year by year and it layers up just like rings on a tree. We're concerned about the state of the lake now and the effects of houses and urbanization on the lake. But by looking at the sediments we can reconstruct what happened in the past and we know that the lake recovered from past disturbances, like the logging. So since the lake recovered then, we believe it can recover now if we do the right things.

That's really encouraging Alan. Our latest computer models show the same thing. Water quality could improve within 20 to 30 years if we reduce less than half of the particles and nutrients currently entering the lake.

Did you know that a single inch of sediment represents around 25 years of accumulation?

Each foot represents 300 years. So if I was a sediment core, the soles of my feet would be 1800 years old. Time to change my socks, I guess!

Please continue to look around the center, and check out all the other displays. Remember to ask questions – that is what scientists do!

Chapter 3: Particles and Sediment Coring

Introduction to lake sediment as a way to measure sedimentation rates and show a historical timeline.

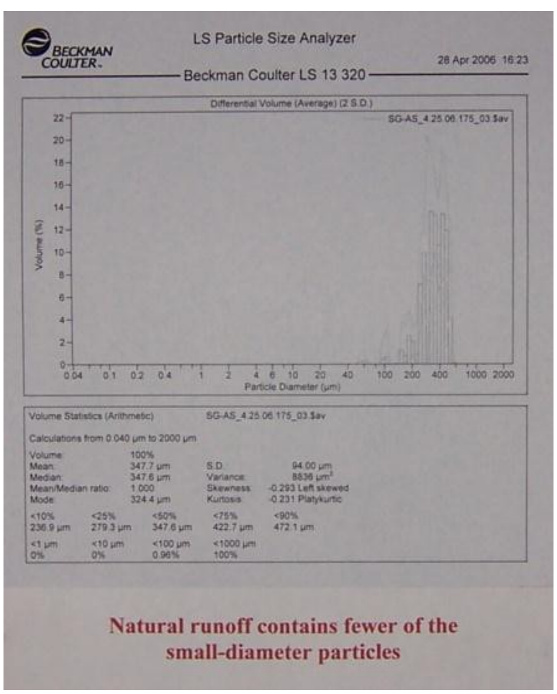
Talking Points

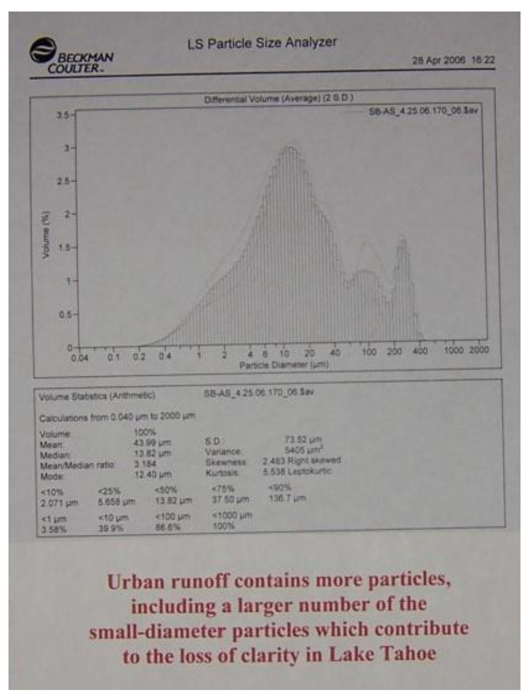
Particles are causing Lake Tahoe to lose clarity.

- Particles come from dust, soil, automobile exhaust, etc. (stirred up by wind, leaf blowers, cars, etc.)
- Particles scatter the light and make it harder to see the Secchi disk in the water.
- It is the very small (less than 20 microns in size), microscopic particles which scatter light and stay suspended in the water for a long time.
- Micron = micrometer (µm), one millionth of a meter. For comparison, the diameter of human hair ranges from 25 - 175 microns.
- Over time, fine particles can aggregate and become large enough to settle.

Laser Diffraction Particle Size Analyzer

- Laboratory equipment measures particle size in a water sample, to produce a particle size distribution (PSD).
- Compare measurements from natural forest storm water with urban storm water:





Sediment core

- Sediment accumulates at the bottom of the lake.
- Sediment currently accumulates about 1 inch per 25 years (or 1mm per year).
- Sediment cores are used to compare historical sedimentation rates such as after the Comstock Logging, to the recent period of urbanization.
- See also Sediment Core Talking Points.

Lake Clarity Modeling

- Computer model shows lake clarity could improve within 20 to 30 years if we reduce fine particle load into the lake by 70%.

Sediment Core Talking Points

This simulated core sample represents the Lake Tahoe sediment core taken by Alan Heyvaert when he was working on his Ph.D. with UC Davis. Dr. Heyvaert's research included a reconstruction of the paleolimnological (history of the lake) conditions using bio-geo- chemical analysis.

Why not use a real sample? Since the sediment core would be extremely wet upon extraction from the lake; it would get moldy inside the plastic tube. In addition to the possibility of creating a rather stinky exhibit, a wet sediment core would change colors over time and no longer look like the sediment core pulled from the lake. (Please note that this dry simulated sediment core is slowing compacting over time.)

How deep do sediments go? Estimates indicate that the sediment layers could be over 1,000 feet deeper than the bottom of the lake. In other words, the lake basin is approximately half filled with sediment.

Layers of sediment – the sediment accumulates at a rate of approximately 1/25-inch per year. However, over time the lower sediments are compressed by the weight of the sediment and water above and so this 6 foot core actually represents about 8,000 years.

Looking at the sediment core from the top to the bottom:

1) Dead Zooplankton: Above the sediments you may see some dead zooplankton, including the large (by comparison) Mysis shrimp. These zooplankton fall to the bottom and eventually become part of the sediments.

2) Oxidized Top Layer: The top layer of sediment is dark in color, orange-ish,

granular, and oxidized. Lake Tahoe is unique in that it has oxygen in the water all the way down to the bottom of the lake (average depth 1,000 feet). This oxygen allows the top layer of the sediment to remain oxidized, which appears as a “rusty” orange color. This oxidized layer on top of the sediment acts like a cap, holding the iron- phosphorus precipitates down and preventing the deeper layers of sediment from releasing phosphorus to overlying waters during deep mixing or turbulent storm events.

3) Redox Layer: Mixed black and dark granular-redox zone is not very visible in sediment core. Manganese (Mn) precipitates account for the black color. Iron precipitates account for dark reddish-brown granules.

4) Comstock logging/slash and burn charcoal period: Over two-thirds of the Tahoe Basin was clear-cut during the Comstock Era (1858-1900) as the lumber from Tahoe Basin trees were used to shore up the silver mines near Virginia City/Carson City areas. During this time, there was greatly increased deposition (7 to 12-fold). The Truckee Dam and the flume trail were constructed to move logs and water during this period. Trees that went unused were burned to create another layer of ash seen in the core. Wood chips, pine needles and saw dust are sometimes visible within this one to two inch portion of the sediments where the Comstock logging period is represented.

5) Natural Lake Sediment: Olive green sediment appears throughout the majority of the sample. This is what the sediment looks like in the absence of a disturbance. The greenish color is due to a lack of iron.

6) Drowned trees near Camp Richardson (first coarse layer from the bottom): Submerged tree stumps off Baldwin Beach are carbon dated to approximately 5300 years old. Trees are found 120 feet underwater in Fallen Leaf Lake. It is believed that these trees all died around 800 years ago when water levels rose above this historic lower level. Both indicate severe drought periods throughout history.

7) Past Disturbances: Turbidites are a mixture of sediment particles and water that flows down the steep side slope creating high density currents that can reach great speeds. These generally erode loose sediments from the lake floor beneath them. Flooding and earthquakes also create disturbances which all appear in the core as a coarser turbidite layer. There are three occurrences of

these disturbances reflected in the sample.

8) Mt. Mazama Ash Layer (white ash layer near bottom): This series of catastrophic eruptions occurred approximately 7,700 years ago and created Crater Lake (the deepest lake in the United States at 1,949 feet). While Crater Lake is a caldera, it has a similar geologic history to Tahoe; both have a history of volcanic eruptions and glaciers sculpting the landscape. Crater Lake is part of the Cascade Range Volcanic arc which stretches from British Columbia to Northern California. The whitish ash layer is tephra (fragments of volcanic rock and lava) from one of the series of eruptions that created Crater Lake, which Mt. Mazama was a part of. Winds during the eruption spread ash for roughly 500,000 miles. This actual Mt. Mazama ash sample was taken from West Central Nevada and provided by Desert Research Institute geologist Ken Adams.

Chapter 3: Particles and Sediment Coring

Introduction to lake sediment as a way to measure sedimentation rates and show a historical timeline.

Discussion & Questions

Discuss: Where do these "particles" come from?

Particles come from dust, soil, automobile exhaust, etc. (stirred up by wind, leaf blowers, cars, etc.).

Question: What would cause particles, or sediment, to accumulate in the lake faster?

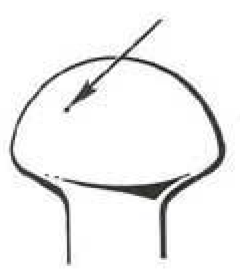
Bigger rainstorms, flooding conditions (such as rain on snow events), urbanized areas such as large parking lots, roads and urban drainage ditches can carry sediment pollution very quickly in "run off."

Question: What could slow sedimentation down?

Protect sensitive wetlands, stream zones, meadows and vegetated areas. Build constructed wetlands to filter stormwater. Install Best Management Practices (BMPs) to help control runoff. Low water years (drought conditions) also result in reduced sedimentation.

Question: Compare the size of sediment (< 20 microns) to other objects (e.g. hair, dust, etc.).

A micrometer or micron (symbol µm) is one millionth of a meter, or equivalently one thousandth of a millimeter. As a comparison, a strand of human hair is about 100 µm wide. Red blood cells are 7 µm in diameter. The size particles we are most concerned about are those less than 20 µm in diameter!



A Micron-Size Dust Particle on a Pin Head

Virtual Laboratory Video Exhibit

Chapter 1: Phytoplankton, Zooplankton and Introduced Species

Realize that Tahoe's food web has been greatly altered.

Video Script

Welcome to the UC Davis laboratory at Lake Tahoe. Actually, it is not just one lab, but several different types of labs. In the biology lab, we study the different types of plants and animals that live in the lake, streams, wetlands and forest.

See those microscopes on the bench? We use those to look at the phytoplankton and zooplankton that live in Lake Tahoe. Phytoplankton are also called algae. They are tiny little floating plants – the "phyto" part of their name means they need sunlight to grow, just like any other plant. The zooplankton are tiny little animals that live in the water and eat the phytoplankton.

There are many kinds of phytoplankton and zooplankton. Monika is an aquatic ecologist – she studies things like how and where the phytoplankton live, how they get their nutrition and which kind of zooplankton eat them. Hi Monika, what are you looking at?

Hello, I'm looking at lake water samples from Lake Tahoe. Right now I'm looking at phytoplankton samples that have been collected from 200 feet down. That's where a lot of the phytoplankton are in Lake Tahoe because that's where the nutrients are. So come on and let's see what we find there.

That must be a very powerful microscope. I can see lots of diatoms. Diatoms are the most common type of algae in Lake Tahoe. Zooplankton like to feed on them because they are very nutritious. There are so many other types of algae we can see – there are Cryptomonads, Chrysophytes, and Dinoflagellates. Zooplankton can be easily seen through a microscope without very much magnification. What do you see Monika?

[MONIKA] There are a lot of zooplankton. And right now I am looking at the zooplankton samples that have been collected with the plankton net in Lake Tahoe. Zooplankton are generally very important in lakes because they feed on algae.

By feeding on algae the zooplankton help to keep Lake Tahoe from turning green! You can see two different species that look as if they are jumping around. The red one is called Diaptomus and is very common during the summer in Lake Tahoe. The red pigment acts like a sunscreen and protects them from harmful sunlight. The grayish one you see is called Epischura.

There are also other less common zooplankton. This one is called Bosmina. And... what a surprise! There is a Daphnia. Daphnia are very important animals in lakes because they provide high quality food for fish and the fish really like to eat them. Nowadays, we don't find them very often because of changes in Lake Tahoe's food web caused by the introduction of the Mysis shrimp.

Speaking of which, this big guy is a Mysis shrimp. Let's ask Bob Richards, world renowned expert on Mysis shrimp, where this big-eyed creature came from.

[BOB] The Mysis shrimp were introduced into Lake Tahoe back in the 1960s to hopefully provide a food source of intermediate size to supplement the foods available to the different fishes in the lake. It turned out probably to not be such a great thing and the reason is that those zooplankton that were already here were providing a majority of the food sources for some of the Kokanee salmon and the juvenile fishes that live in the lake. So when Mysis came along and started preying on these other zooplankton they actually cut these food sources down instead of increasing the food source available for other fishes. The main lesson learned was that you really need to do good hard scientific research on things, especially if you are going to change the environment by introducing a foreign organism into the water, because they do bring about a lot of changes that you don't expect.

Thanks Bob, that's actually a great lesson for all ecosystems. Species introductions can have irreversible effects.

There are other introduced species in Lake Tahoe, many of which were accidently introduced. Water milfoil is an aquatic plant that first appeared in the Tahoe Keys, but has now spread to other shallow bays and marinas around the lake. It's a constant battle to keep it from spreading further.

Sudeep Chandra has been studying the fish that have been accidently introduced to Lake Tahoe. Sudeep, what do we know about these species?

[SUDEEP] The Bluegill and Bass species have been introduced into the lake some time in the last ten to fifteen years and we are concerned about these species because they affect native species by feeding on them, they can also compete with native fish species by eating their food. You really have to ask yourself a question, it is really more of a moral question. And the question is "do we want these non-native species within our Lake Tahoe?" We are already fighting pretty hard to protect the lake to keep it clear. And so, what I like to think about is we should also protect the lake by keeping its native biology intact.

Something to think about. Well, I need to prepare some more samples. See you next time you stop by the lab.

Chapter 1: Phytoplankton, Zooplankton and Introduced Species

Realize that Tahoe's food web has been greatly altered.

Talking Points

Microscopes – for viewing phytoplankton and zooplankton

- Diatoms – most commonly found type of phytoplankton.
- Daphnia (preserved sample, stained).
- Live sample of Daphnia from Daphnia Culture – Use pipette to collect. Recommend collecting one (1) Daphnia in one (1) drop of water.
- Live sample of Diaptomus and/or Epischura (if available from recent collection) – Use pipette to collect. Can be viewed with microscopes, ViewScopes, Loupes, or other similar tools.

Aquatic Species of Lake Tahoe – Point out poster on "door" of laboratory

- Fish, including non-native fish
- Zooplankton
- Phytoplankton

Phytoplankton (also commonly called algae)

- Algae are microscopic plants living in the water column or attached to surfaces (i.e. rocks, plants, sediments) which are at the base of the aquatic food web. Scientists measure the amount of chlorophyll, which is the green pigment that allows plants to carry out photosynthesis. Chlorophyll can be used as a measure of the amount of algae. The amount of algae in the water column affects Lake Tahoe's clarity.
    - Tiny, floating plants
    - Need sunlight to grow
    - Bottom of the food chain
    - Nutrients (nitrogen and phosphorus can stimulate growth)
    - Can grow in upper 300 feet of the lake
    - Over 300 species found in Lake Tahoe
- Primary types include:
    - Diatoms
    - Chrysophytes (golden algae)
    - Cryptophytes
    - Dinoflagellates
    - Chlorophytes (green algae)

Zooplankton

- Zooplanktons are tiny animals that live in the open water. They provide an important food source for fish and graze on algae, helping to keep the water clear.
    - Rotifer – requires special microscopes to see
    - Diaptomus – red with antennae
    - Epischura – gray with antennae
    - Bosmina – small hook "nose"
    - Daphnia – round, hard carapace shell, also called the "water flea" because of the type of movements it makes, you can see the green algae inside its stomach
    - Mysis Shrimp – larger, introduced non-native species. Mysis will swim 1000 feet each day and night ("diurnally")

Mysis Shrimp

- Introduced non-native species. Mysis will migrate 1000 feet vertically each day and night ("diurnally").
- Introduced by the Dept. of Fish & Game in the 1960s to provide a food source for game fish.
- However, this had the opposite effect… Mysis shrimp actually reduced the available food for fish, by eating many of the Bosmina and Daphnia.
- View Mysis shrimp preserved in formalin in jar.

Non-native Species Introduction Poster – located on corkboard on the side wall

- Non-natives introductions include Mysis shrimp.
- Several species of fish were purposely introduced as game fish, including lake trout, rainbow trout, brown trout, Kokanee salmon.
- Others were accidentally introduced, including bass, carp, bluegill, and sunfish.
- These are mostly found in warmer shallow embayments such as marinas, the Tahoe Keys, etc.
- View Asian clams in a jar or petri dish.
- View Quagga mussels in a petri dish. These are not yet in Lake Tahoe!
- Rack cards (e.g. Don't Move a Mussel, Tahoe Boat Inspection, Tahoe Keepers) are available in the brochure rack near the front desk.

Chapter 1: Phytoplankton, Zooplankton and Introduced Species

Realize that Tahoe's food web has been greatly altered.

Discussion & Questions

Question: What are the components of Tahoe's aquatic food web?

Phytoplankton → Zooplankton → little fish → bigger fish → osprey/bears/humans

Question: Describe the various native and non-native fish of Lake Tahoe. How many fish are native? Non-native?

See *Species of Lake Tahoe's Aquatic Food Web* poster.

Question: Why is it important to protect the native food web?

Each species has a special place within the food web. These species have evolved together over millions of years. If you take one species out, the entire food web can collapse or be modified forever. Extinction is forever and some non-native species can also become invasive and change the food web forever.

Discuss: Why would Mysis shrimp reduce the available food source to fish even though they were introduced in order to increase it?

Discuss: How do you think those accidentally introduced fish got into Lake Tahoe?

Some "introduced species" were purposely placed into the lake by Fish and Game. Others probably entered the lake accidentally from anglers' bait buckets, boat bilge pumps or from people dumping aquariums or gold fish tanks.

Question: How is climate change affecting Lake Tahoe's food web?

Climate warming is causing a shift in phytoplankton species composition because water in Lake Tahoe is unable to mix as intensely. This allows for less nutrient availability and makes it difficult for larger-sized diatoms to stay suspended. Small-sized diatoms have flourished with lake warming and have become more prevalent. This may affect clarity because smaller species stay at the surface longer, scattering light and making the water appear greener.

Question: How do invasive species affect Lake Tahoe?

Aquatic invasive species harm Lake Tahoe by:

- Competing with native species.
- Severely decreasing recreational uses, such as swimming, boating, water-skiing,

and fishing.

- Degrading boats by clogging propellers and cooling intakes.
- Facilitating invasions of other non-native species.
- Altering nutrient cycles and increasing algal growth in the lake by adding phosphorous to the water column thus contributing to clarity decline.

Aquatic invasive species (AIS) such as the Asian clam and Eurasian watermilfoil (aquatic plant) can also have negative impacts to Lake Tahoe's ecosystem. Researchers are currently studying benthic (bottom dwelling) ecologies to learn more about the potential impacts invasive species can have on native aquatic plant and animal species as well as on water quality.

Question: About Mandatory Watercraft Inspections.

Starting in 2009, all motorized boats and watercraft require inspection for aquatic invasive species (AIS) prior to launching into Lake Tahoe. The boat inspection program at Lake Tahoe is designed to intercept and decontaminate boats coming from outside the Tahoe Basin that might inadvertently carry AIS. This program is also educating boat owners on how to best clean their boats to avoid transporting AIS to any lake or waterbody. Knowingly transporting AIS into Lake Tahoe is against the law, and violators may be subject to fines.

Boaters are encouraged to Clean, Drain, and Dry their boats prior to arriving at inspection stations in order to save everyone time and money. Visit TahoeBoatInspections.com or call (888) 824-6267 for updates, details and information or follow @TahoeBoating on Twitter for real-time updates.

Question: *What about Non-Motorized Watercraft?*

Non-motorized watercraft such as kayaks, canoes, rafts and other inflatables must also be free of aquatic invasive species. A coalition of local and visiting Lake Tahoe paddlers, business owners and Tahoe Basin environmental groups are helping to stop the spread of aquatic invasive species by becoming Tahoe Keepers. Tahoe Keepers are paddlers who inspect and decontaminate their boats and gear every time they haul out and move between new waterbodies. Non-native species, such as quagga and zebra mussels could irreparably damage the Lake Tahoe watershed. These invasive species are spread through water and debris that can collect in cockpits and hatches, cling to outer hulls, rudders and paddles, and even hide out on footwear and gear long after paddling. Paddlers can learn how to self-inspect and decontaminate their canoes, kayaks, paddleboards and inflatables at TahoeKeepers.org.

Question: What potential impacts could invasive Zebra mussels or Quagga mussels have on Lake Tahoe?

Quagga and Zebra mussels are especially problematic, as they are known to multiply quickly and colonize underwater surfaces, including docks and piers, water supply and filtration systems, buoys, moored boats and even the beautiful rocky shoreline. They destroy fish habitat, ruin boat engines, and can negatively impact water quality and the local economy, recreation and ecosystem.

Invasive mussels have caused many ecological problems in other water systems. Lake Tahoe could face these same ecological problems if these invasive mussels found their way into the lake. Zebra and Quagga mussels are voracious filter feeders and remove large amounts of phytoplankton from the water column causing a reduction in food for native zooplankton species. Both can colonize on the surfaces of many things such as watercraft, docks, water pipes and native mollusks. Invasive mussels also cause biofouling which clogs water intake structures, such as pipes and screens, therefore reducing pumping capabilities for water treatment/pumping plants, costing industries, companies, and communities. Imagine sharp shells on the beaches of Lake Tahoe…you could no longer walk barefoot.

In January 2007, a Quagga mussel was found for the first time west of the Mississippi in Lake Mead, Lake Havasu, and the Colorado River. Most recently it has entered waterbodies in California. Once established, these mussels can cost millions of dollars to control. To report a sighting or for more information, call the Tahoe Aquatic Nuisance Species Hotline at 1-888-TAHO-ANS or visit http://www.tahoercd.org.

Question: What, if anything, is being done about the Mysis Shrimp in Lake Tahoe?

A 2018 UC Davis TERC project aims to reduce the abundance of Mysis shrimp to levels where they no longer impact the ecosystem of the lake. If the number of Mysis are reduced, native zooplankton species will be able to recover to levels not seen since Mysis was established. This could lead to a significant improvement in water clarity – one of the long-term goals for the lake.

Using Emerald Bay as the location of this pilot project, real-time remote sensing will be used to locate the position of high-density Mysis patches. TERC can then map out the natural variability in the distribution and migration of these organisms. Using a special zooplankton net specifically sized to the Mysis shrimp, field researchers can them remove these specific populations. If successful, the developed technology and tools will be used to provide real-time guidance for harvesting Mysis in the rest of the lake.

Virtual Laboratory Video Exhibit

Chapter 2: Nutrients and Eutrophication

Become familiar with the process of eutrophication and the significance of its acceleration at Lake Tahoe.

Video Script

Hello. Some of the most important chemical analyses we do in the lab are the nutrient measurements. Nutrients are what the algae, or phytoplankton, need to grow – just like your lawn needs fertilizer to stay green. There are two main nutrients that algae need – nitrogen and phosphorus.

See how we take samples of slimy periphyton to bring back to the lab? Periphyton is the algae that attaches itself to rocks in the shallow water near the edges of the lake. Periphyton blankets the rocks and can be slippery if you step on it on your way to go swimming. It is an indicator of where excess nutrients are coming into the lake.

Lakes that are clear usually have very small amounts of nutrients and very few phytoplankton – they are called oligotrophic lakes. If you add more nitrogen and phosphorus to an oligotrophic lake, it will very quickly grow more algae and start to look green.

Most lakes are green in color because they have so much algae growing. Such lakes are called eutrophic. It is a natural process for a lake to change from being oligotrophic to eutrophic, but it would normally take tens of thousands of years or longer.

What we are worried about here is that many of the activities that people do in the Tahoe Basin (like construction, driving cars, using fertilizer on lawns and golf courses) accelerate eutrophication.

The lake has changed a lot in just the last 40 years and eutrophication is one of the big concerns. The good news is that there are many things being done to reduce the amount of nutrients entering the lake… so that it doesn't turn green.

Ask what you can do to keep the nutrients out of Lake Tahoe and keep it looking clear and blue!

Chapter 2: Nutrients and Eutrophication

Become familiar with the process of eutrophication and the significance of its acceleration at Lake Tahoe.

Talking Points

Nutrients – There are two main nutrients:

- Nitrogen (N)
- Phosphorus (P)
- Both are needed for algae to grow

Nutrients - Compounds of nitrogen and phosphorus dissolved in water which are essential to photosynthesis (the process of converting sunlight into plant matter). Too much nitrogen and phosphorus act as pollutants and can lead to unwanted consequences - primarily algae blooms that cloud the water. Fertilizers, vehicle exhaust, atmospheric deposition, and runoff from streams and urban areas are possible sources of nutrients.

Algae – or phytoplankton or plankton. Simple microscopic plants that grow in bodies of water. Periphyton algae ("attached algae") is attached to rocks or hard surfaces.

Oligotrophic - Refers to water bodies or habitats with low concentrations of nutrients and consequently low concentrations of algae.

Eutrophic - Describes an aquatic system with high nutrient concentrations. These nutrient concentrations fuel algal growth. This algae eventually dies and decomposes, which reduces the amount of dissolved oxygen in the water.

Eutrophication - the process of excess nutrients accelerating the growth of algae, oftentimes ultimately depletes the water of oxygen.

Additional Information about Nutrients and Nutrient Pollution

What are nutrients? Nutrients, like nitrogen and phosphorus, occur naturally in water, soil, and air. Just as the nitrogen and phosphorus in fertilizer aids the growth of agricultural crops, both nutrients are vital to the growth of plants within the lake, streams and rivers.

How are nitrogen and phosphorous used in the ecosystem? Nitrogen is essential to the production of plant and animal tissue. It is used primarily by plants and animals to synthesize protein. Nitrogen enters the ecosystem in several chemical forms and also occurs in other dissolved or particulate forms, such as tissues of living and dead organisms.

Some bacteria and blue-green algae can extract nitrogen gas from the atmosphere and transform it into organic nitrogen compounds. This process, called nitrogen fixation, cycles nitrogen between organic and inorganic components. Other bacteria release nitrogen gas back into the atmosphere as part of their normal metabolism in a process called de- nitrification.

Phosphorus is another key nutrient in the ecosystem. Phosphorus occurs in dissolved organic and inorganic forms, often attached to particles of sediment. This nutrient is a vital component in the process of converting sunlight into usable energy forms for the production of food and fiber. It is also essential to cellular growth and reproduction for organisms such as phytoplankton and bacteria.

How can nutrients become pollutants to Lake Tahoe and surrounding streams? Although nutrients are essential to all plant life, an excess of these same nutrients can be harmful. This is called "nutrient pollution." Nutrients have always existed in the lake, but not at the present excessive concentrations. When the lake was surrounded primarily by forest and wetlands, very little nitrogen and phosphorus ran off the land into the water. Most of it was absorbed or held in place by the natural vegetation. Today, much of the forests and wetlands have been replaced by roads, urban areas, homes, etc. As the use of the land has changed and the watershed's population has grown, the amount of nutrients entering the Lake's water has increased tremendously.

Chapter 2: Nutrients and Eutrophication

Become familiar with the process of eutrophication and the significance of its acceleration at Lake Tahoe.

Discussion & Questions

Discuss: What can you do to keep nutrients out of Lake Tahoe?

Reduce fertilizer use, very careful fertilizer use, pick up after pets, stop erosion, BMPs, etc.

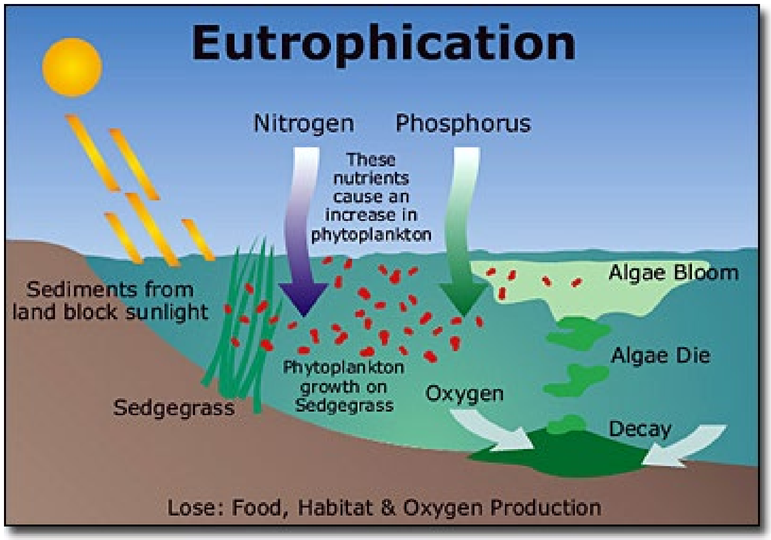
Question: If eutrophication is a natural process, why do we care about it happening at Lake Tahoe?

The speed at which the eutrophication of Lake Tahoe that would occur under normal (natural) conditions would be millions of years… we are seeing changes occur within our lifetimes.

Discuss: What other problems would the eutrophication of Lake Tahoe cause?

Eutrophication decreases the resource value of lakes resulting in reduced recreation and aesthetic enjoyment. If Lake Tahoe were to turn green or brown, this would lower property value, reduce tourism, and hurt the local economy. Water treatment plants would need to be installed to filter the water used by many in the Tahoe Basin for drinking water and would cost millions. Health-related problems can occur where eutrophic conditions interfere with drinking water treatment.

There would also be many occurrences of bad odor coming from the lake, mats of algae washed upon the beaches, and midges and other insects invading the near shore. Lake Tahoe is a long way from these conditions, but they are what typify a eutrophic lake.



The figure above is a visual of the eutrophication process.

Virtual Laboratory Video Exhibit

Chapter 3: Streams and Air of Lake Tahoe

Learn that scientists monitor creeks, streams, urban areas and atmospheric deposition.

Video Script

Did you know that there are 63 streams that flow into Lake Tahoe? Only one – the Truckee River – flows out. It flows out at Tahoe City and ends up in Pyramid Lake, Nevada. Scientists monitor creeks and streams by collecting water samples and performing other measurements. Let's go visit Scott to see what's involved.

Hi Guys, I'm at Ward Creek on the West Shore of Lake Tahoe. The flow right now is about four cubic feet per second. That's about typical for the summer baseline condition.

A lot of this erosion that you see here happened during the 1997 flood. We had very high flows; it was flowing about 1200 cubic feet per second, it caused a lot of the banks to be under-cut and a lot of these boulders fell in the stream. And you could actually hear the boulders rolling along the stream bottom during the flood, it was incredible. So this is some of the fine silt that erodes away from the stream bank at Ward Creek. It will eventually erode down into the stream and out into the lake.

What I do to take a sample is I set a line across the stream and use a depth integrated sampler that allows you to take a water sample up and down the water column, I'll move across the stream at equal widths and that allows you to get a representative sample of the stream flow. We are studying streams because they input both nutrients and fine sediments into the lake. The nutrients cause the algae to grow and the fine sediments cloud the water and both of those impact the clarity of Lake Tahoe.

Thanks Scott. The samples are taken back to the lab where the amounts of fine particles and nutrients from each stream are measured. Fine particles and nutrients can also come from other places. They can flow directly from the land into the lake. This often happens in populated areas during storms. We call this urban storm water.

My name is Andrea and I am a storm water hydrologist. This is an automated sampler. Automated samplers make it very easy for us to sample storms because you don't have to be out here to take every single sample by hand. We have tubes that suck water up into the sample bottle that we then take back to the lab to analyze for nutrients and sediments.

…And with information about the levels of pollution in the stormwater we can alert authorities to the biggest problem areas. One way to reduce the amount of polluted stormwater getting into the lake is to build new wetlands. These are called constructed wetlands. Our measurements have shown that wetlands can remove the

pollutants before they enter the lake – turning that brown water into clean water. Unfortunately, many of the wetlands were lost to development and now there simply is not enough flat land around Lake Tahoe to build all the wetlands we would need.

Research has shown how important wetlands and streams are to the health of the lake. That is why local regulatory agencies have implemented building regulations that protect these sensitive and important areas from further development.

The other important source of fine particles and nutrients is, believe it or not, the air. Where do the pollutants in the air come from? All sorts of places - highway dust, car exhaust, wood burning stoves or fireplaces, forest fires, leaf blowers, and agriculture from the central valley.

We have air samplers at many places around the lake and even on the research buoys on the lake.

Thanks for visiting the Tahoe Environmental Research Center. We hope you can use some of the things you have learned here to keep Tahoe blue and to keep all lakes, streams, wetlands and the air healthy. See you next time.

Chapter 3: Streams and Air of Lake Tahoe

Learn that scientists monitor creeks, streams, urban areas and atmospheric deposition.

Talking Points

Lake Tahoe is a closed watershed system

- Lake Tahoe has 63 streams (sub-watersheds) that flow into the lake.
- Only 1, the Lower Truckee River, flows out.
- Truckee River flows to Pyramid Lake (water never reaches the ocean) - Pyramid Lake is called a “terminal lake.”
- The watershed can be compared to a bowl; this is why it is called a basin. The map in the entrance lobby illustrates the Lake Tahoe Basin watershed boundaries.

Stream Monitoring

- TERC researcher, Scott Hackley, monitors three streams along the west shore of Lake Tahoe (Ward, Blackwood and General Creeks) and the Truckee River just downstream of the dam at Tahoe City.
- Regular sampling is done monthly with more frequent sampling during the spring runoff and rain events.
- Water samples are analyzed for nutrients, suspended sediment, temperature and dissolved oxygen.
- Information from this monitoring is used to estimate the annual nutrient and particle loads from streams and to discern trends in tributary water quality.

Atmospheric Deposition Monitoring

- Atmospheric Deposition: Gases and particles from combustion sources in the atmosphere settle as dust or fall in rain and snow.
- Historical data collected by TERC shows that atmospheric deposition of nitrogen (and to a lesser extent phosphorus) is an important source of nutrients to the lake.
- TERC currently monitors atmospheric deposition at four stations within the Tahoe basin. Two stations are located in Ward Valley, and two are located on research buoys near the middle of the lake.
- Data collection from the stations on land in Ward Valley includes precipitation amount, timing, nutrient (N and P) content and pH. From the lower Ward Valley station, both “wet” deposition (rain and snow) and “dry” deposition (deposition occurring during dry periods) are collected.
- The atmospheric deposition monitoring program provides ongoing information on nutrient loading via this important source of nutrients to the lake.

Sampling Equipment

- Integrated sampler – allows you to take a water sample from up and down the water column to get a representative sample of the stream flow.
- Urban stormwater sampling uses automated sampling equipment.

USGS Gage System

- The quantity and quality of water in most of the United States' rivers, streams, lakes, and reservoirs is monitored by the U.S. Geological Survey. The monitoring program is a cooperative effort that is funded jointly by numerous Federal, State, and local agencies.
- Real-time data for river and streams throughout the nation are available at http://waterdata.usgs.gov/nwis/rt.

Wetlands

- Wetlands are very important to Lake Tahoe.
- Wetlands contribute to flood control, for example, by collecting excess rainfall and releasing it slowly over time rather than in a torrent. Wetland soil and vegetation filter contaminants out of water as it percolates through, returning cleaner water to rivers, lakes, and underground aquifers. In addition, wetlands provide indispensable habitat for hundreds of species of amphibians, birds, mammals, and plants.
- Urbanization of the Lake Tahoe Basin has eliminated 75 percent of its marshes, 50 percent of its meadows, and 35 percent of its stream zone habitats.
- See "*Wetlands Q&A*" below and/or "*Wetlands 101*" in your Docent Manual.
- "Additional Resources" section.

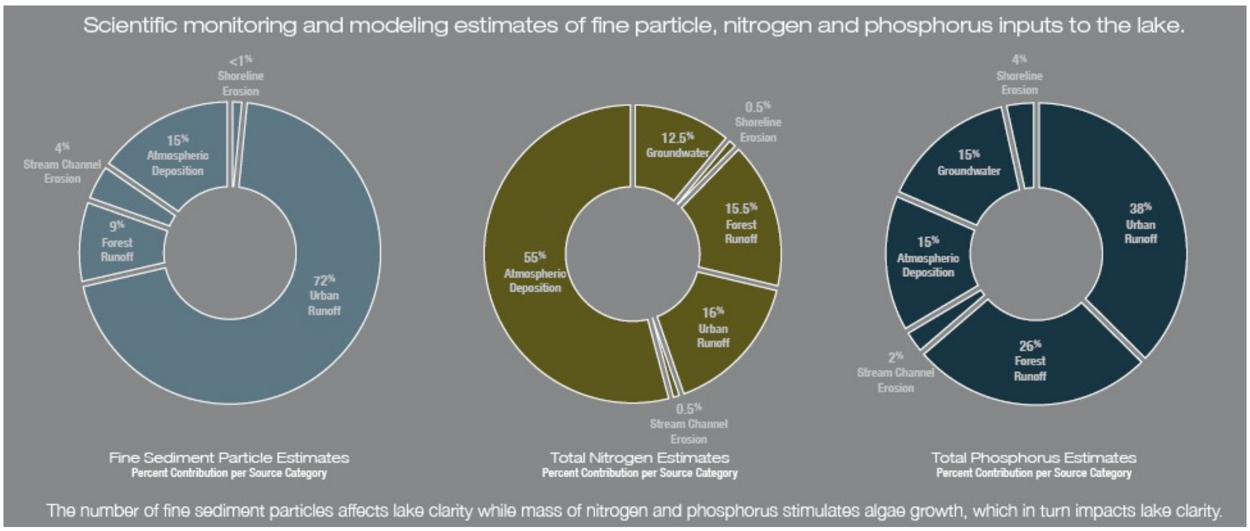
Chapter 3: Streams and Air of Lake Tahoe

Learn that scientists monitor creeks, streams, urban areas and atmospheric deposition.

<u>Discussion & Questions</u>

Discuss: Why do we regularly monitor streams, urban runoff, and the air?

It is important to know what is coming into the lake and streams in order to track sources of pollution. Urban runoff and atmospheric deposition are the main sources of pollution to the lake.



Source: Charting a Course to Clarity: The Lake Tahoe Total Maximum Daily Load, 2008-09

Question: Why are wetlands important to the Tahoe Basin?

They are the filters that remove pollutants from stormwater runoff and help to keep Lake Tahoe clear and blue. Wetlands also provide valuable habitat for many species.

Question: Do you know the location of any constructed wetlands near you?

Tahoe City “Y,” Tahoe Vista, South Lake Tahoe Cove East

Discuss: What can you do to protect wetlands?

Stay out of these sensitive areas. Do not ever drive through, bike, or hike through the wetlands. Never build in wetlands, do not remove vegetation or mow grasses, and use your vote to protect this valuable resource. Local Tahoe ordinances and regulations now prohibit construction within wetland or stream environment zones.

Discuss: What are your ideas about ways to keep Tahoe blue and to keep all lakes, streams, wetlands and the air healthy?

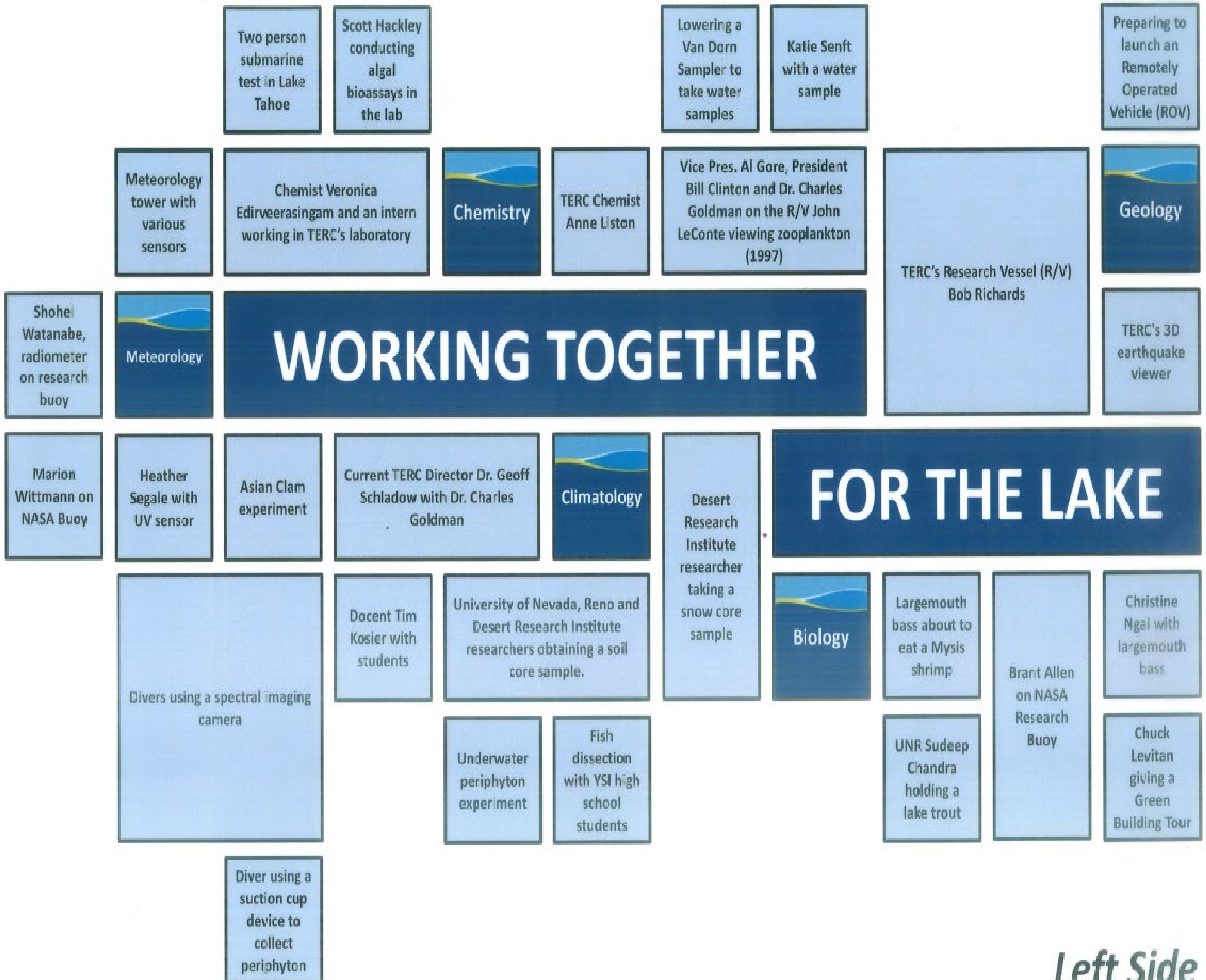
Discuss: How is science and monitoring important to protecting Lake Tahoe?

Research Photo Wall

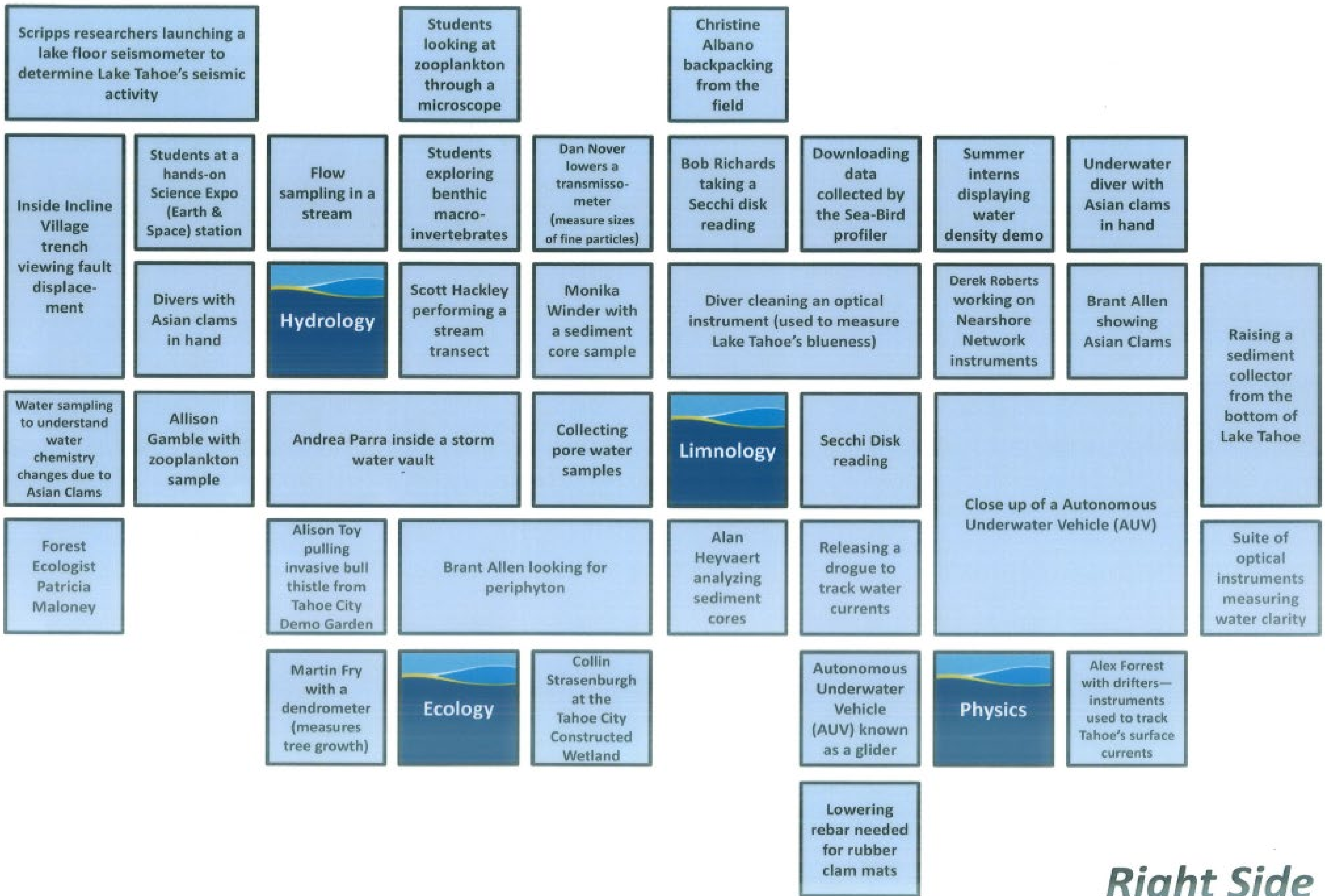
Photos of researchers from UC Davis, UNR, DRI, Scripps Institution of Oceanography and others are included on the wall to show visitors the broad range of scientific research conducted at Lake Tahoe. Descriptions of each photo are available on a separate laminated card in the Docent Room.

Student field trips sometimes include a scavenger hunt activity where students are acting as "visiting researchers" from the following research fields:

- Ecology: The study of where living organisms are found, and the interactions between these organisms and their environment.
- Geology: The study of the physical history of the earth, the rocks it is made of, and the changes the earth goes through.
- Biology: The study of life and of living organisms, including their structure, function, and growth.
- Chemistry: The study of matter and its interactions.
- Hydrology: The study of water, its effects on the earth's surface (soil, rocks) and in the
- atmosphere.
- Limnology: The study of bodies of fresh water, such as lakes and ponds.
- Meteorology: The study of the atmosphere, especially weather and weather conditions.
- Climatology: The study of the weather over long periods of time.
- Physics: The study of matter and energy and their interactions.


Two person submarine test in Lake Tahoe
Scott Hackley conducting algal bioassays in the lab
Lowering a Van Dorn Sampler to take water samples
Katie Senft with a water sample
Preparing to launch an Remotely Operated Vehicle (ROV)
Meteorology tower with various sensors
Chemist Veronica Edirveerasingam and an intern working in TERC's laboratory
Chemistry
TERC Chemist Anne Liston
Vice Pres. Al Gore, President Bill Clinton and Dr. Charles Goldman on the R/V John LeConte viewing zooplankton (1997)
TERC's Research Vessel (R/V) Bob Richards
Geology
Shohei Watanabe, radiometer on research buoy
Meteorology
WORKING TOGETHER
TERC's 3D earthquake viewer
Marion Wittmann on NASA Buoy
Heather Segale with UV sensor
Asian Clam experiment
Current TERC Director Dr. Geoff Schladow with Dr. Charles Goldman
Climatology
Desert Research Institute researcher taking a snow core sample
FOR THE LAKE
Divers using a spectral imaging camera
Docent Tim Kosier with students
University of Nevada, Reno and Desert Research Institute researchers obtaining a soil core sample.
Biology
Largemouth bass about to eat a Mysis shrimp
Brant Allen on NASA Research Buoy
Christine Ngai with largemouth bass
Underwater periphyton experiment
Fish dissection with YSI high school students
UNR Sudeep Chandra holding a lake trout
Chuck Levitan giving a Green Building Tour
Diver using a suction cup device to collect periphyton

Left Side


Scripps researchers launching a lake floor seismometer to determine Lake Tahoe's seismic activity
Students looking at zooplankton through a microscope
Christine Albano backpacking from the field
Inside Incline Village trench viewing fault displace-ment
Students at a hands-on Science Expo (Earth & Space) station
Flow sampling in a stream
Students exploring benthic macro-invertebrates
Dan Nover lowers a transmisso-meter (measure sizes of fine particles)
Bob Richards taking a Secchi disk reading
Downloading data collected by the Sea-Bird profiler
Summer interns displaying water density demo
Underwater diver with Asian clams in hand
Divers with Asian clams in hand
Hydrology
Scott Hackley performing a stream transect
Monika Winder with a sediment core sample
Diver cleaning an optical instrument (used to measure Lake Tahoe's blueness)
Derek Roberts working on Nearshore Network instruments
Brant Allen showing Asian Clams
Raising a sediment collector from the bottom of Lake Tahoe
Water sampling to understand water chemistry changes due to Asian Clams
Allison Gamble with zooplankton sample
Andrea Parra inside a storm water vault
Collecting pore water samples
Limnology
Secchi Disk reading
Close up of a Autonomous Underwater Vehicle (AUV)
Forest Ecologist Patricia Maloney
Alison Toy pulling invasive bull thistle from Tahoe City Demo Garden
Brant Allen looking for periphyton
Alan Heyvaert analyzing sediment cores
Releasing a drogue to track water currents
Suite of optical instruments measuring water clarity
Martin Fry with a dendrometer (measures tree growth)
Ecology
Collin Strasenburgh at the Tahoe City Constructed Wetland
Autonomous Underwater Vehicle (AUV) known as a glider
Physics
Alex Forrest with drifters—instruments used to track Tahoe's surface currents
Lowering rebar needed for rubber clam mats

Right Side

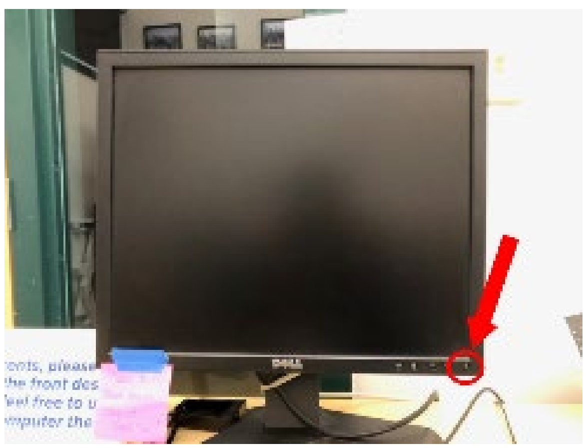
Operating the 3D Visualization Lab

Turn System On

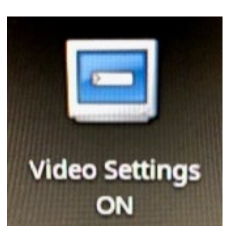
Both projectors are controlled by one remote control.

- Stand near the projector screen and point the remote at both projectors. Try and aim at the input infrared remote (IR) sensor is located at the bottom/front of each projector. If you stand directly below the projectors you might miss the IR sensor.
- Press the green [ON] button ONCE to turn both projectors on. If only one projector turns on, aim as best as you can at the one that isn't on and press the green [ON] button once more. This can be done repeatedly until both projectors are on.
- It will take a minute or two for the projectors to warm up, look for the light emitting from both projectors.

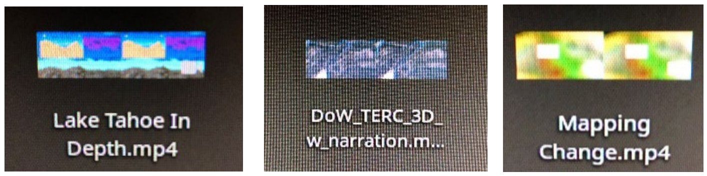
Computer procedure is minimal as the TERC education team always tries to have the education center fully functioning before the docent arrives. Make sure the monitor is on by pressing the small button on the lower right hand portion of the screen, it will be lit when on.



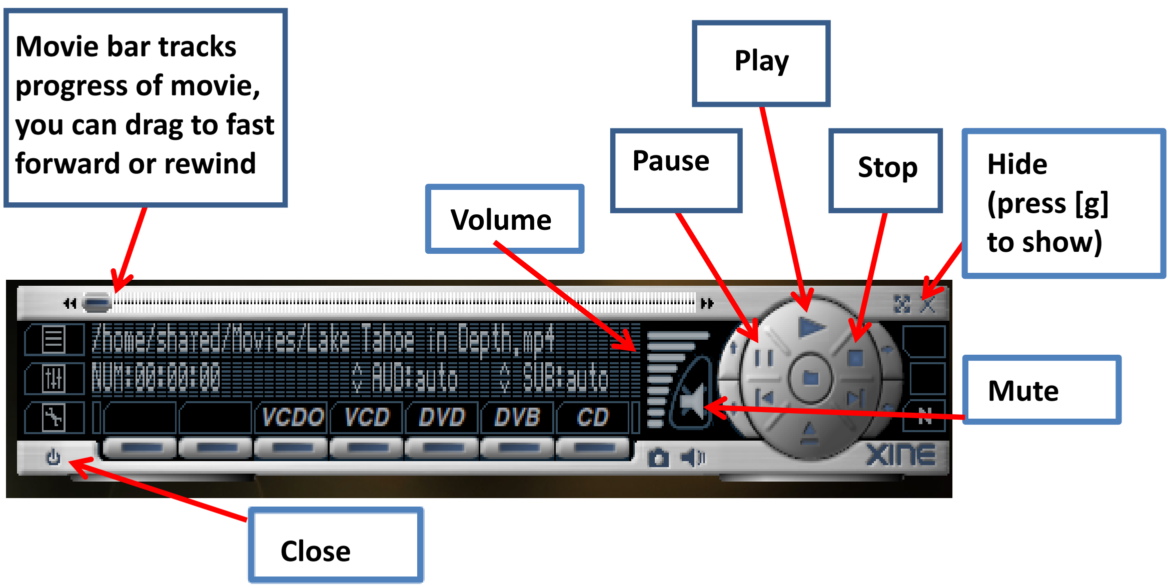
- If the computer screen prompts a login, use the following:
    - Login username: OEM user
    - Password: terc3d
- Several movies are available on the desktop.
- Double-click "Video Settings ON" icon. This configures the correct display settings for 3D theater operation.



- Double-click on “Lake Tahoe in Depth” icon or any of the following icons to start a Movie.



- A control bar that looks similar to a car radio console will appear and allow you to control the movie(s) as indicated below.
- Press Play.



- The player works best if the control bar is closed after every showing and then reopened.

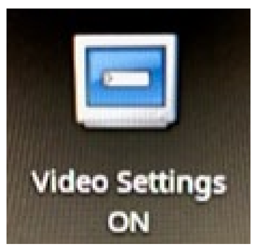
3D Troubleshooting

Problem #1: Cursor not visible on the screen. The two projectors are set to simulate two more screens "virtually located" to the right of the desktop monitor.

Solution: Find the cursor by moving the mouse left until it reappears on the desktop. If the projectors are on, you should see the cursor moving across the screen in the theater.

Problem #2: The video is not in 3D. You can tell the film is not in 3D if the projection is clear and not showing two side-by-side images (without glasses on) or if one eye is showing only black when viewed through the 3D glasses.

Solution 1: Close the control bar by pressing the "power" icon on the lower left. First, double-click "Video Settings ON" and then start the play sequence again.



Solution 2: Only one of the two projectors is on. Point the 3D theater remote at the projectors located above the benches and press the green [ON] button ONCE to turn on the other projector.

Problem #3: If the control bar does not appear, it may already be open and "Hidden".

Solution: Press [g] or find it at the bottom panel on the left side, right click and select "close". This is case sensitive, so make sure you don't have caps lock on. If pressing [g] doesn't work, drag the cursor all the way to the right so that you can see the arrow on the projected screen, right click, and select "Display Control".

Turning System Off

Projectors: After your shift is completed stand in front of the projectors and point the remote control at the projectors. Press the red [OFF] button at least once to turn both projectors off. One turns off immediately and one projects a notice that it is turning off. If only one turns off, try to position yourself so you can point directly at IR sensor area of the projector and press the red [OFF] button again. Repeat process if necessary. Look for the lights to shut down. You will still hear the projector fans operating to cool the system down.

Computer: Turn the monitor of the computer off using the small button on the lower right hand portion of the screen. The desktop computer located on the ground under the desk should be left on.

Visualization Lab: Earthquake Viewer

Please note that it is not essential to run the Earthquake viewer. This program is mostly used during school field trips focused on geology. However, this is still a comprehensive how-to guide of the 3D Earthquake Viewer for anyone who is interested.

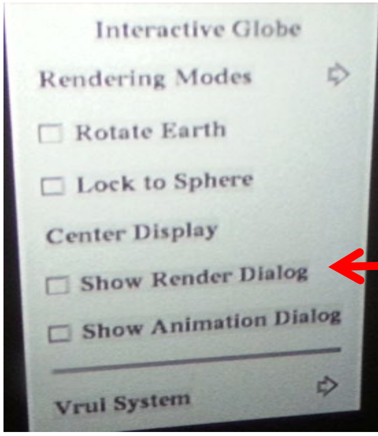
Starting Earthquake Viewer

- Open Earthquake Viewer by double-clicking on the [Earthquake Viewer] icon to run this data set. Currently, we are utilizing the [Joystick] version of this visualization.
- A 3-D image of the Earth will appear on screen and provide visitors with an opportunity to view the earth from various angles, from inside and outside.
- Wear your 3-D glasses for a clear view and to make sure that both projectors are operating correctly.
- Close your left eye and right eye to make sure both screens are visible.
- You will also be using the [Joystick] to navigate through the earthquake viewer.

There are *two main modes* for navigating though the Earthquake Viewer. **"Mouse mode"** is used when opening up menu items, adjusting views and transparency, rendering Earthquake data set, and shutting down program. **"Navigation mode"** is used controlling the position and movements of the earth. (rotation, spinning, zooming into and away from the earth, moving the earth up, down, right, and left)

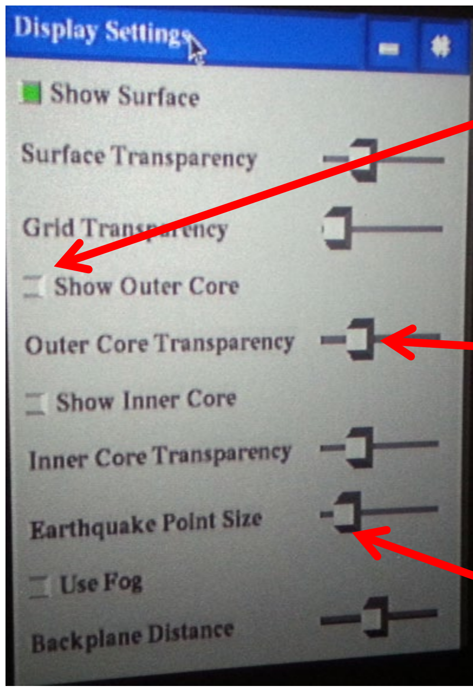
"Mouse Mode"

- Click button #7 to move the small cursor (arrow) from its starting position near the bottom of the globe, this is "mouse mode."
- Use the joystick to control the cursor and move the cursor.
- To adjust the view of earth click and hold the trigger button. This action will bring up an [Interactive Globe Menu], you must hold down trigger while moving cursor to [Show Render Dialog] (see figure 1). This will open up [Display Settings] you will see options all to adjust the level of transparency (see figure 2).
- Make the Earth's surface transparent and click to show the inner and outer core of the earth and adjust the transparency to your liking.
- Be sure to also adjust the Earthquake Point Size to ensure the many earthquake points aren't too large, we recommend smallest (bar set far left) size for the best visuals.
- The same task can be completed through [Rendering Modes] (see figure 3) by holding down trigger and dragging cursor to rendering modes and then dragging the cursor while still holding the trigger button only releasing when you're hovering over the box you would like to select i.e. "outer core transparent" or "inner core transparent."
- If you ever lose track of the cursor press button #6 on the top of the joystick and the cursor will return to its starting location.



Select by holding down trigger button in "Mouse mode" to bring up [Display Settings] which will allow you to adjust the visuals of the globe.

Figure 1

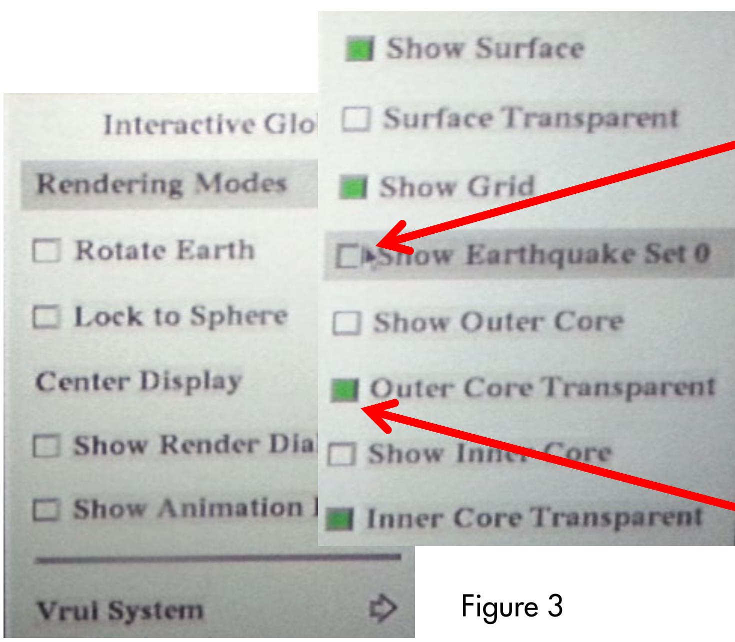


Select using trigger button in "Mouse mode" to show the outer core, can do the same with inner core. You can do the same through [Rendering Modes] (see figure 3)

Hold down trigger in "Mouse mode" to select and drag left to increase transparency and drag right to decrease transparency.

Select holding down trigger in "Mouse mode" to drag left decrease size of earthquake points and drag right to increase transparency.

Figure 2



This box needs to be green (selected) in order to make sure the earthquake points appear on the earth. Select in "Mouse mode" by holding down trigger button while dragging cursor until it hovers over the box and then release trigger

An alternative method to display the outer and inner core. Select in "Mouse mode" by holding down trigger button while dragging cursor until it hovers over the box and then release trigger.

Figure 3

“Navigation Mode”

Press button #8 in order to enter “Navigation Mode.” Once you are in this mode, you will notice that you can control the rotation of the globe by moving the joystick up, down, left, right, and twisting. To physically move the globe up and down use the [top hat controller] located at the very top of the joystick. By using the [top hat controller] and changing the location of the globe it also changes the way it rotates, it will always rotate around the center axis point. To zoom into the globe use the [throttle] please note that it is very sensitive to a change from its central point. Pushing the throttle forward will zoom into the earth and pulling the throttle back will zoom out from the earth. There will be cross hairs that appear if the throttle is not centered, and thus will continue to either zoom in or out. Make sure to settle the throttle in the center so that there are no longer crosshairs to ensure you keep the position of the earth you would like to see.

You will have to switch between “Navigation” and “Mouse” mode, so be comfortable with knowing that pressing button #7 will put in you “Mouse mode” and pressing button #8 will put you in “Navigation mode.”

Earthquake Animations

After you have adjusted the Earth visually to your liking (see “Mouse mode”) then you may choose to simulate the earthquakes occurring around the globe starting in the late 1890s.

- In “Mouse mode” hold the trigger button and while holding the trigger button move to select [Rendering Modes], while still holding onto the trigger button slide cursor to hover over the [Show Earthquake Set 0] and select. (See figure 3)
- Next select [Show Animation Dialog] (see figure 4) under the [Interactive Globe] menu it will bring up two sliding bars, the top one controls the date and time, you can move slide it right to look at more recent earthquakes. (see figure 5)
- The bottom slide bar is a logarithmic control of how quickly time will elapse. Far left will make time pass very slowly (good if you’re trying to pinpoint a specific earthquake) and far right will allow time to pass quickly (good if you want to see an overview of all the earthquakes that are happening around the globe at the same time. You can drag the little menu box by selecting the top of the toolbar with the trigger button and dragging it to whatever location you select.
- Click on [play animation] when you would like to show the earthquake points though time.

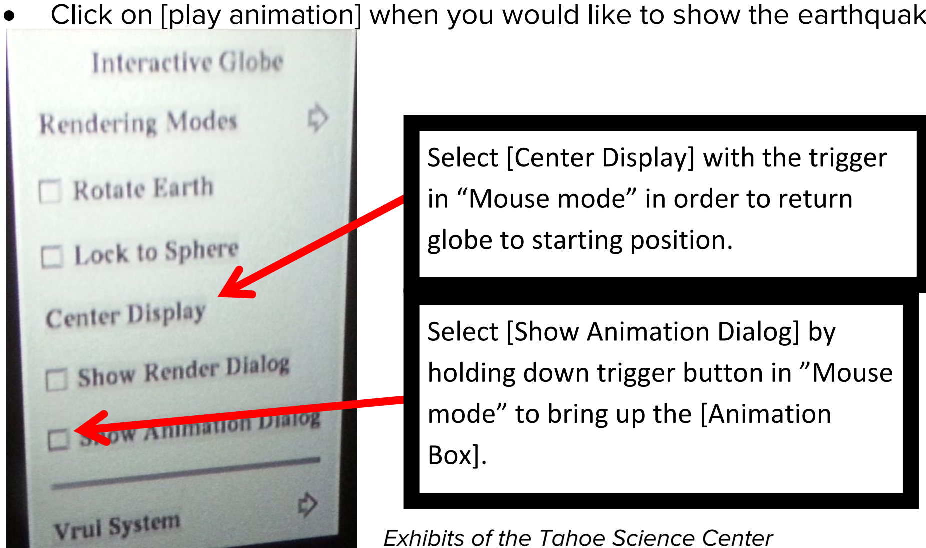


Figure 4

Select using trigger in “Mouse mode” and hold down while dragging to the right to find the desired point in time.

Select using trigger in “Mouse mode” and hold down while dragging to the right speed up time, dragging left to slow time.

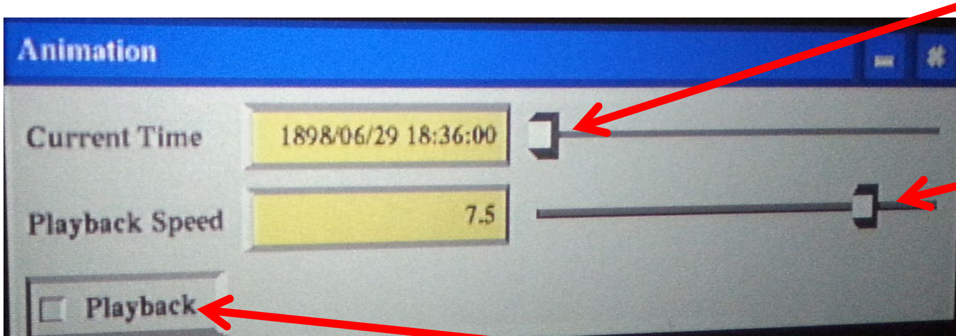
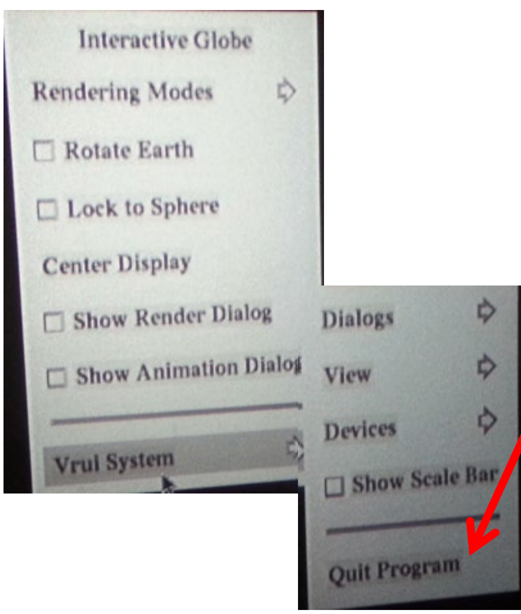


Figure 5

To start earthquakes use trigger button in “Mouse mode” to click on [Playback] if you click again it will pause.

Exiting Program

In “Mouse mode” you will hold down the trigger button to bring up the [Interactive Globe Menu] click on [VRUI System] and select [Quit Program] (See figure 6)



While in “Mouse mode” hold down trigger button to open [Interactive Globe] menu. Then while still holding down the trigger button drag cursor to [VRUI system] and then across to quit program, release trigger button when cursor is hovering over “Quit Program” to shut down

Figure 6

Using the Joystick

According to the programmer who set up the system, it takes between 20-60 minutes of operating the joystick to become comfortable with the movements.

#7—Pressing this button will put you in **"Mouse mode"** so that you can control the movements for the cursor and open up different menus, adjust the earth visually, and run earthquake data set.

#10—**"Mouse mode" and "Navigation mode"** by pressing this button you will lose site of the globe and put you in flight mode. This mode is not recommended, to return to original centered view, in "Mouse mode" press the trigger button to bring the [Interactive Globe] Menu and select [Center Display] the globe will return to its starting location.

#8—Pressing this button will put you in **"Navigation mode"** so that you can control the movements, rotations, and zooming of the earth mainly using the joystick, top hat control, and throttle.

#9—"Mouse mode" and "Navigation mode" Pressing this button after pressing #10 will allow you to navigate through screen while in "flight mode," which allows you search for the globe. This mode is not recommended, to return to original centered view, in "Mouse mode" press the trigger button to bring the [Interactive Globe] Menu and select [Center Display] the globe will return to its starting location. Display] the globe will return to starting location.

Throttle— "Mouse mode" - no function

"Navigation mode" will allow you to zoom into and away the earth. It is very sensitive, so use a delicate touch. As you zoom in and out you will notice cross hairs appearing, it will only stop zooming in our out when you have centered the throttle you will see the crosshairs disappear, and the movement will stop.

#5—"Mouse mode" brings up [Tool Selection Menu] which you will generally not use.

#6— **"Mouse mode"** If you lose sight of your cursor <u>clicking this button will return cursor to starting location</u> below the globe.

#4—"Mouse mode" brings up [Tool Selection Menu] which you will generally not use.

#3—"Mouse mode" brings up [Tool Selection Menu] which you will generally not use.

Top Hat control— **"Navigation mode"** will <u>physically move globe up, down, left and right.</u> Which will also change how the earth will rotate when using the joystick. It will always rotate around the center axis. If it is centered it will stay in one spot and spin. If it is off centered it will make a circular path around the axis.

Thumb button— "Navigation mode" when zooming in using the throttle you can slow down the zooming process by simultaneously holding down this black thumb button.

Trigger—**"Mouse mode"** <u>is used to open up the [Interactive Globe] menu.</u> You will hold down the trigger button as you navigate through the menu. Trigger can also be used to grab an open dialog box by clicking on the top bar of the box and dragging it to the desired location.

Joystick—"**Mouse mode**" will control the cursor's movements. <u>**"Navigation mode"** this allows you to rotate the earth.</u> Pushing the joystick forward will cause the globe to rotate bottom to top, pulling will cause it to rotate top over bottom. Pushing joystick to the left/right will cause a rotation in that direction. Twisting the joystick causes a diagonal rotation. All of the rotations will occur at the center of the axis so instead of simple rotation you could see the earth travel a circular path around the axis.

Earthquake Viewer Talking Points

Talking Points

- Earthquakes go down approximately 700 kilometers (or approximately 450 miles); they stop here because below this the Earth is composed of different materials not ideal for the transfer of energy.
- Earthquakes can occur both on plate boundaries as well as within a plate. Approximately 90 percent of earthquakes occur along plate boundaries while 1-percent occur within a plate.

A. The Core

At the center of Earth is the core, which is separated into the liquid outer core and the solid inner core. The outer core is 2300 km thick and the inner core is 1200 km thick. The inner core is about four-fifths as big as Earth's moon and slightly bigger than Mars. The outer core is composed mainly of a nickel-iron alloy, while the inner core is almost entirely composed of iron. Earth's magnetic field is believed to be controlled by the liquid outer core.

B. The Mantle

The layer beneath the crust which extends down approximately 1,800 miles is the mantle. This layer is composed mainly of ferro-magnesium silicates and is where most of the internal heat of the Earth is located. Large convective cells in the mantle circulate heat and may drive plate tectonic processes. Earth's crust floats on the mantle much as a board floats in water. Just as a thick board would rise above the water higher than a thin one, the thick continental crust rises higher than the thin oceanic crust. The slow motion of rock in the mantle moves the continents around and cause earthquakes, volcanoes, and the formation of mountain ranges.

C. The Crust

The outermost layer of the Earth is the crust. It has variable thickness and comprises the continents (30-50 km or 20–30 miles thick) and ocean basins (5-10 km or 3-6 miles thick). Both the continental and oceanic crust "float" on the mantle. Because the continental crust is thicker, it extends both above and below the oceanic crust, much like a large iceberg floating next to smaller one.

D. Earthquake Records

From 1940 to 1963, the only earthquakes recorded were located in North America. This is because modern seismometers were not placed around the globe until 1963-1964 when atomic testing was of concern!

E. Earthquake Data Set

The Earthquake Viewer data set represents earthquake “foci” (or hypocenters) from 1901 through 2012. Earthquake data points shown range between magnitudes 5 – 9 (on the Richter Scale):

Yellow	=	5.0
Green	=	6.0
Blue	=	7.0
Magenta	=	8.0
Red	=	9.0

Throughout recorded history there have only been six 9.0 or greater earthquakes:

Location	Date	Magnitude
Valdivia, Chile	May 22, 1960	9.5
Prince William Sound, Alaska, USA	March 28, 1964	9.2
Andreanof Islands, Alaska, USA	March 9, 1957	9.1
Kamchatka, Russia	Nov. 4, 1952	9.0
Off western coast of Sumatra, Indonesia	Dec. 26, 2004	9.0
Tohoku, Japan	March 11, 2011	9.0

F. Seismometers

Seismometers (in Greek seismos = earthquake and metero = measure) are used by seismologists to measure and record the size and force of seismic waves. By studying seismic waves, geologists can map the interior of the Earth, and measure and locate earthquakes and other ground motions. Seismograph is often interchangeable with seismometer.

G. Richter Scale

The Richter magnitude scale, or local magnitude ML scale, assigns a single number to quantify the amount of seismic energy released by an earthquake. It is a base-10 logarithmic scale obtained by calculating the logarithm of the combined horizontal amplitude of the largest displacement from zero on a seismometer output. Events with magnitudes of about 4.6 or greater are strong enough to be recorded by any of the seismographs in the world.

The following describes the typical effects of earthquakes of various magnitudes near the epicenter. This table should be taken with extreme caution, since intensity and thus ground effects depend not only on the magnitude, but also on the distance to the epicenter, the depth of the earthquake's focus beneath the epicenter, and geological conditions (certain terrains can amplify seismic signals).

Description	Richter Magnitudes	Earthquake Effects	Frequency of Occurrence
Micro	Less than 2.0	Microearthquakes, not felt.	About 8,000 per day
Minor	2.0-2.9	Generally not felt, but recorded.	About 1,000 per day
Minor	3.0-3.9	Often felt, but rarely causes damage.	49,000 per year (est.)
Light	4.0-4.9	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.	6,200 per year (est.)
Moderate	5.0-5.9	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings.	800 per year
Strong	6.0-6.9	Can be destructive in areas up to about 100 miles across in populated areas.	120 per year
Major	7.0-7.9	Can cause serious damage over larger areas.	18 per year
Great	8.0-8.9	Can cause serious damage in areas several hundred miles across.	1 per year
Great	9.0-9.9	Devastating in areas several thousand miles across.	1 per 20 years
Great	10.0+	Never recorded.	Extremely rare (Unknown)

(Based on U.S. Geological Survey documents.)

H. Pangaea

Pangaea was the supercontinent that existed during the Paleozoic and Mesozoic eras about 250 million years ago, before each of the component continents were separated into their current configuration.

Ask: Why do these earthquakes appear to line up? Answer: Tectonic plate boundaries

I. Tectonic Plates

The lithosphere is broken up into what are called tectonic plates. In the case of Earth, there are currently eight major and many minor plates.

Major Plates:

- African Plate covering Africa - Continental plate
- Antarctic Plate covering Antarctica - Continental plate
- Australian Plate covering Australia - Continental plate
- Indian Plate covering Indian subcontinent and a part of Indian Ocean - Continental plate
- Eurasian Plate covering Asia and Europe - Continental plate
- North American Plate covering North America and north-east Siberia - Continental plate
- South American Plate covering South America - Continental plate
- Pacific Plate covering the Pacific Ocean - Oceanic plate
- Notable Minor Plates:
- Arabian Plate
- Caribbean Plate
- Juan de Fuca Plate
- Cocos Plate
- Nazca Plate
- Philippine Sea Plate
- Scotia Plate

J. Three Types of Plate Boundaries

Tectonic plates move in relation to one another at one of three types of plate boundaries: convergent or collisional boundaries; divergent boundaries, also called spreading centers; and transform boundaries.

1. Divergent – At divergent boundaries, two plates move apart from each other. Molten rock rises, pushing two plates apart and adding new crustal material from molten magma that forms below at their edges. This type of plate boundary is usually found in oceans and has earthquakes at shallow depths. Example: Mid-Atlantic Ridge

Mid-Atlantic ridge
This ridge dissects the Atlantic Ocean and is splitting through the center of Iceland. Known as a spreading center, it is where new crust is formed at a rate of 5-10 cm per year. The Mid-Atlantic Ridge is part of a 40,000 km long essentially continuous system of mid-ocean ridges on the floors of all the Earth's oceans.

2. Convergent - Convergent faults occur where two plates collide. The nature of a convergent boundary depends on the type of lithosphere in the plates that are colliding.

a. Oceanic + Continental: Where a dense oceanic plate collides with a less- dense continental plate, the oceanic plate is typically thrust underneath because of the greater buoyancy of the continental lithosphere, forming a subduction zone. As a consequence, the plate being forced under is melted and destroyed. At the surface, the topographic expression is commonly an oceanic trench on the ocean side and a mountain range on the continental side. An example of a continental-oceanic subduction zone is the area along the western coast of South America where the oceanic Nazca Plate is being subducted beneath the continental South American Plate.

   Cascadia subduction zone
   This stretches from Mendocino (central California coast) to the British Columbia coast. It has the potential to create a tsunami as large as the 2004 Indonesian tsunami in the event of a 9.0 earthquake with very little warning.

b. Continental + Continental: Where two continental plates collide the plates either buckle and compress or one plate delves under or (in some cases) overrides the other. Either action will create extensive mountain ranges. The most dramatic effect seen is where the northern margin of the Indian Plate is being thrust under a portion of the Eurasian plate, lifting it and creating the Himalayas and the Tibetan Plateau beyond.

   Himalayas
   The Himalaya Range stretches across six countries (Afghanistan, Bhutan, China, India, Nepal and Pakistan) and is among the youngest mountain ranges on the planet. It formed by a continental collision of the Indo- Australian Plate and the Eurasian Plate. It is referred to as a fold mountain. The Himalayas are home to Mt Everest, the world's highest mountain.

c. Oceanic + Oceanic: When two plates with oceanic crust converge they typically create an island arc as one plate is subducted below the other. The arc is formed from volcanoes which erupt through the overriding plate as the descending plate melts below it. The arc shape occurs because of the spherical surface of the earth (nick the peel of an orange with a knife and note the arc formed by the straight-edge of the knife). A deep undersea trench is located in front of such arcs where the descending slab dips downward, such as the Mariana trench near the Mariana Islands. Other good examples of this type of plate convergence would be Japan and the Aleutian Islands in Alaska.

   Aleutian Island Arc
   The Aleutian Islands are a chain of more than 300 small volcanic islands forming an island arc in the Northern Pacific Ocean. It extends from the Alaska Peninsula to the Kamchatka Peninsula in Russia.

   Mariana Trench
   Located north of Papua New Guinea and south of Japan, this is the deepest trench in the world at 6.86 miles deep. If Mount Everest were set in the deepest

part of the Mariana Trench, there would still be 6,810 feet of water above it!

Tonga Trench
Located in the Pacific Ocean, this trench at its deepest is 35,702 ft deep. It is an active subduction zone where the Pacific Plate is being subducted underneath the Tonga Plate and the Indo-Australian Plate at a rate of 10 inches per year (the fastest plate velocity on the planet!).

3. Transform faults – Transform faults occur when two plates slide past each other. During this movement, crust is neither destroyed nor created. Stress is built up in each plate and can cause fracturing in the upper crust, movement along the fault, and earthquakes. Examples: San Andreas Fault

San Andreas Fault
The San Andreas Fault in California stretches about 800 miles long. It forms the tectonic boundary between the Pacific Plate and the North American Plate. The stress of this fault has led to many notable earthquakes, including the 1906 San Francisco which was estimated to be a magnitude 7.8.

K. Hotspots – Stationary spots within a plate boundary that allows magma to erupt. As the plate moves, new landforms are created along the path of the hotspot. One example of hotspots is the Hawaiian Islands which experience earthquakes and volcanoes even though they do not located on a plate boundary. This also occurs in Yellowstone in the form of hot springs and geysers.

L. Ring of fire – The Pacific Ring of Fire is an area of frequent earthquakes and volcanic eruptions encircling the basin of the Pacific Ocean. About 80% of the earth's earthquakes occur here and it is home to about 75% of the earth's volcanoes, both dormant and active.

For additional information, see the Geology Section of your Docent Manual (located in Additional Resources) for details about the Structure of the Earth and Earthquakes.

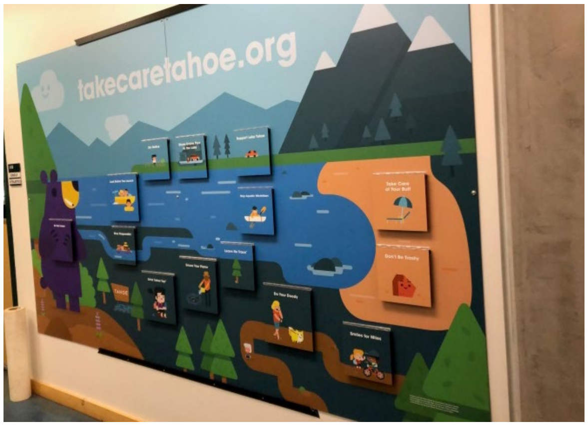
Self-Guided Exhibits for Science Center Tour Extensions

Take Care Tahoe Exhibit

Take Care Tahoe is a collective group of more than 30 organizations that love Lake Tahoe and want to see more people connect with this beautiful natural environment. For more information on the program, visit www.takecaretahoe.org.

The display on the left side of the hallway is a pledge board. The messages for Take Care were created to address the key impacts humans are having on our environment: litter, dog waste, bears, fire safety, and aquatic invasive species. Visitors can pledge to participate by placing a bead in the one or more category. Take Care stickers and postcards are also available at this exhibit.

Pledge Display



Take Care Flip Panel Display

The informational Take Care Tahoe flip panel display is located on the right side of the hallway. Visitors can learn more about each initiative by flipping the panels on the flip chart exhibit.

Green Building Exhibits

The Green Building Exhibit highlights the U.S. Green Building Council LEED Categories. It also discusses specific green features of the Tahoe Center for Environmental Sciences building including energy-saving, water-conserving, and indoor environmental air-quality features, and includes samples of recycled building materials used. Visitors are welcome to go on a more in depth Green Building tour upon request. More Green Building information is located at the last section of this chapter.

Forest Health and Fire Exhibit

The Forest Health Exhibit contains information concerning tree pathology, forest fire risk and prevention, and Tahoe's forest history. Visitors can receive alerts and view wildfire cameras at [http://www.alertwildfire.org/tahoe/.](http://www.alertwildfire.org/tahoe/)

Tree Identification Exhibit

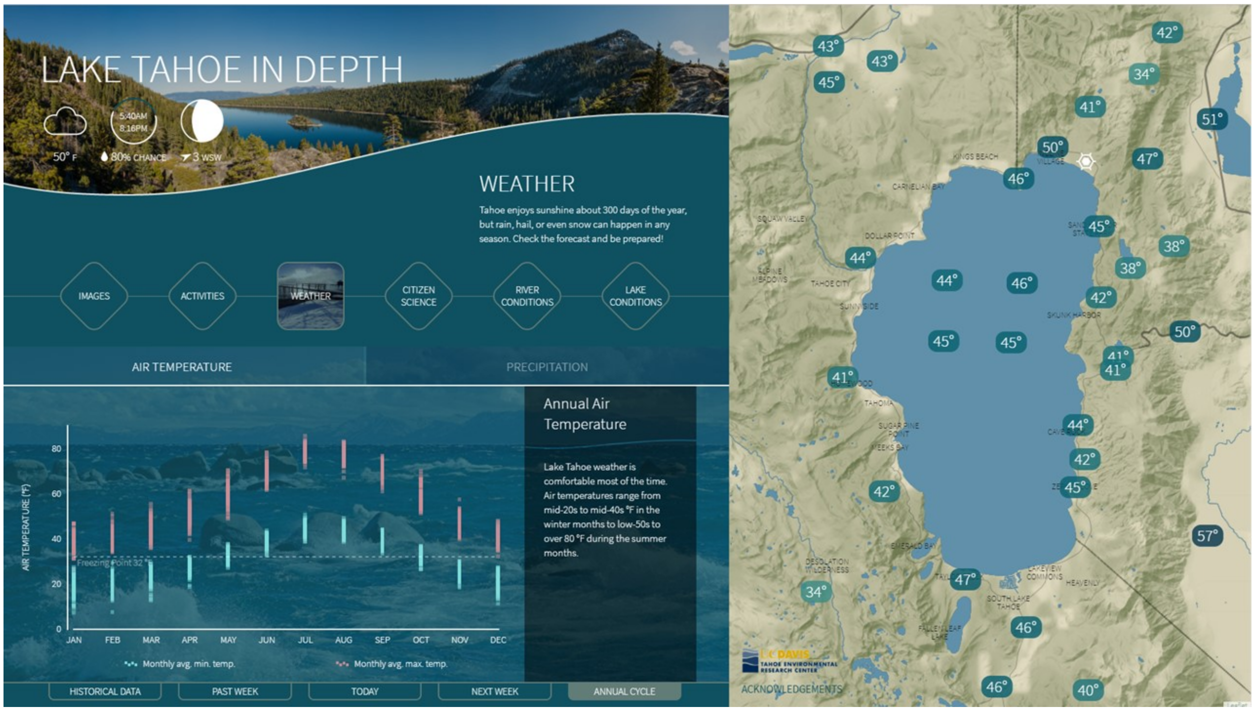
This exhibit displays the eight evergreen trees native to the Tahoe basin (Sugarpine, cedar, red fir, white fir, whitebark pine, lodgepole pine, Jeffrey pine, and Ponderosa pine). Visitors can examine the needles, bark, cones, and read information cards to learn more about each variety.

Lake Tahoe In Depth Touchscreen Exhibits

The “Lake Tahoe in Depth” touchscreen exhibits are available at the UC Davis Tahoe Science Center, Tahoe City Visitor Center, and Tahoe Maritime Museum.

The categories include the following:

1. **Images** - From professional photographers to Instagrammers, everyone loves to photograph Lake Tahoe. Explore these images, and check out the live streaming videos from the mountaintops!
    a. Seasonal photos from around the lake
    b. Live videos with 24-hour time-lapse
2. **Activities** - Tahoe is one of America’s primary destinations for fun! Explore the many activities you can enjoy here, while protecting this pristine environment.
    a. On the water
    b. On the mountain
3. **Weather** - Tahoe enjoys sunshine about 300 days of the year, but rain, hail, or even snow can happen in any season. Check the forecast and be prepared!
    a. Air temperature
        i. The Zephyr Cove air temperature gauge is located on the black-top and so regularly records a much higher air temperature.
    b. Wind speed
    c. Historical cycle
        i. Air temperature - Have weather patterns changed over time? Tahoe researchers have recorded weather patterns since 1910 at Tahoe City and the trends are apparent. Climate change, especially here, is measurable.
        ii. Precipitation varies greatly from year to year. Since 1910, annual precipitation has ranged from less than 10 inches in 1977 to nearly 70 inches in 1982 at Tahoe City. Over the past century, snowfall as a percentage of total precipitation has declined by almost 20 percent. Precipitation has been measured at Tahoe City since 1910.
    d. Annual cycle
        i. Air temperature - Lake Tahoe weather is comfortable most of the time. Air temperatures range from the mid-20s to the mid-40s °F in the winter and between the low-50s to over 80 °F during the summer.
        ii. Precipitation varies by season and location. Over 75 percent of the precipitation occurs between November and March. Summers are dry with less than a 10 percent chance of significant precipitation.



4. **Citizen Science** - Non-scientists contribute to our understanding of the Lake by recording water, land, and air conditions. Join the fun! Contribute to the results and discussion of science by downloading the “Citizen Science Tahoe” app.
   a. Algae observation - Algae follows a natural cycle encircling the lake’s rim, but human-related inputs such as lawn fertilizer, dog poop, and detergents can increase the growth of algae and harm lake clarity. What can you see here about current and recent algae conditions observed by citizen scientists to Lake Tahoe?
   b. Beach conditions - Tahoe has the best freshwater beaches in the world! But some people seem to think that the beach is their ashtray or wastebasket. Do you notice any patterns in citizen scientist observations about beach trash over the course of the past year?
   c. Water quality - Lake Tahoe’s water is known for its clarity and its bold blue colors that darkens as it deepens. Sometimes, though, the water can appear brown, green, or even yellow. What causes these color changes? Check out our citizen scientists’ observation to discover correlations between human activities and water clarity.

5. **Rivers & Creeks** - There are 63 streams that feed into Lake Tahoe. The Truckee River, the only outflow from the lake, allows rafting if the lake level is high enough to flow out at the Tahoe City dam.
   a. Historical - No two years are ever the same. Wet years correspond to the higher peaks. Drought years can result in little to no streamflow. Peaks in the streamflow usually coincide with the snowmelt in late spring.

b. Past Year - Rainstorms can be seen as sharp “spikes” or high, short-duration flows when they occur. Most of the streamflow occurs during the spring and early summer, coinciding with snowmelt.
c. Previous Week
d. Current Conditions

6. **Lake Conditions** – The combination of wave height, water temperature, algae concentrations, clarity, and lake levels create a complex and ever-changing freshwater environment.
   a. Wave Height - Lake Tahoe can be perfectly flat and serene, or blustery winds blowing across the lake can churn up six-foot high waves. The highest waves occur on the downwind side of the lake, which is typically the north and east shores at Lake Tahoe. Wind and waves are usually higher in the afternoon, so be prepared and stay safe.
   b. Water Temperature - Lake Tahoe water is cold for most swimmers, with surface temperatures ranging from 42 degrees in the winter to over 70 degrees in July and August. Though refreshing on a hot day, a plunge into Lake Tahoe can literally take your breath away. Swimmers should always prepare for dangerously cold conditions.
   c. Algae - Underwater instruments measure the interaction of light with chlorophyll from free-floating algae (phytoplankton) in the water. The apparent daily declines in algae concentrations are due to the interference from bright sunlight.
   d. Clarity
      i. Historic: Annual Average Secchi Depth - Water clarity measurements have been taken every 10 – 15 days by UC Davis TERC since 1968, when a white disk, called the Secchi disk, could be seen at a depth of 102.4 feet. Secchi depth is the most widely used method of clarity measurement.
      ii. Current - Turbidity is a measure of how cloudy the water is. Sediment from erosion makes the water less transparent. In most areas of Lake Tahoe, the water is generally very clear (turbidity values near zero), but afternoon waves can stir up sediment and increase turbidity in the nearshore.
   e. Lake Level
      i. Historic - The natural rim of the lake is at an elevation of 6,223 feet above sea level. When the lake is below the rim, outflow via the Truckee River ceases. The maximum legal limit for the lake is 6,229.1 feet. The 6.1 feet above the natural rim provides a reservoir for downstream users.
      ii. Current - Lake level varies throughout the year. Lake level rises due to high stream inflow, groundwater inflow, and precipitation directly on the lake surface. The level falls due to evaporation, water withdrawals, groundwater outflows, and outflow via the Truckee River at Tahoe City.

What Can You Learn From TERC's Nearshore Network?

Within the "Lake Tahoe in Depth" exhibit you will see the patterns of water quality data, including:

Wind/wave patterns – The prevailing winds at Lake Tahoe blow out of the southwest. This pattern results in 2 to 8-inch (5 to 20 cm) waves along the north and east shores of the lake. Winter/spring conditions may be very calm for days on end, but when storms hit the lake, the winds tend to be much more powerful. We have recorded waves as high as 6 feet (1.8 m) at Tahoe Vista and Dollar Point during winter.

Sediment resuspension – When waves are large enough, the sensors record increases in turbidity, algae, and dissolved organics, as waves re-suspend sediments and churn particles and attached algae up into the water column. Wind waves are the dominant driver of turbidity in the nearshore of Lake Tahoe.

Upwelling – Upwelling occurs when strong, sustained winds drive surface waters to the downwind end of the lake, slightly increasing the lake depth (about 1 inch maximum). There is a compensating back-flow and deep water flows toward the upwind end of the lake and rises to the surface. Since Tahoe's deep water is (comparatively) rich in nitrate, upwelling plays a role in internal nutrient cycling in the lake (see information on Project UPWELL).

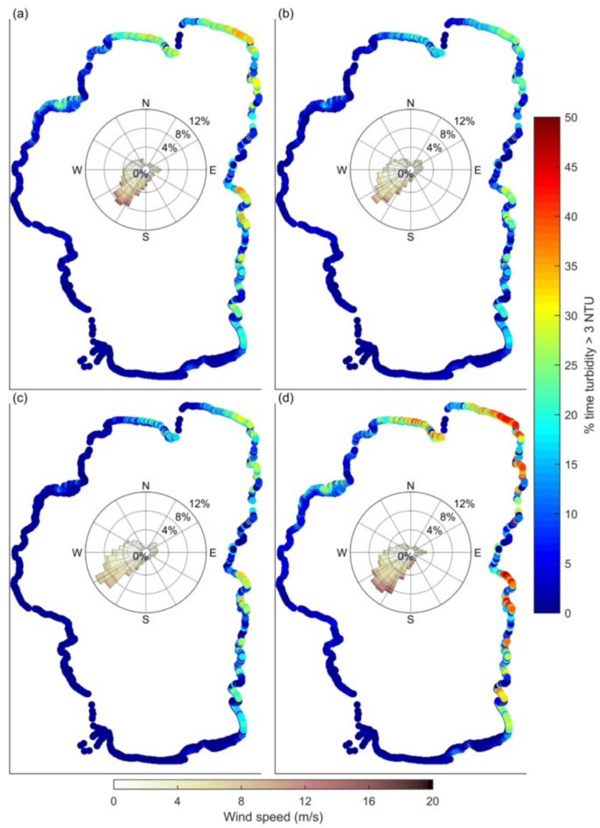


Figure 1 – Seasonal percent-time exceedance of 3 NTU turbidity due to wind-waves. 2016 seasons: (a) January 1 – March 31; (b) April 1 – June 30; (c) July 1 – September 30; (d) October 1 – December 31. Wind rose coloring corresponds to wind speed; length corresponds to percent-time of wind data at a given direction.

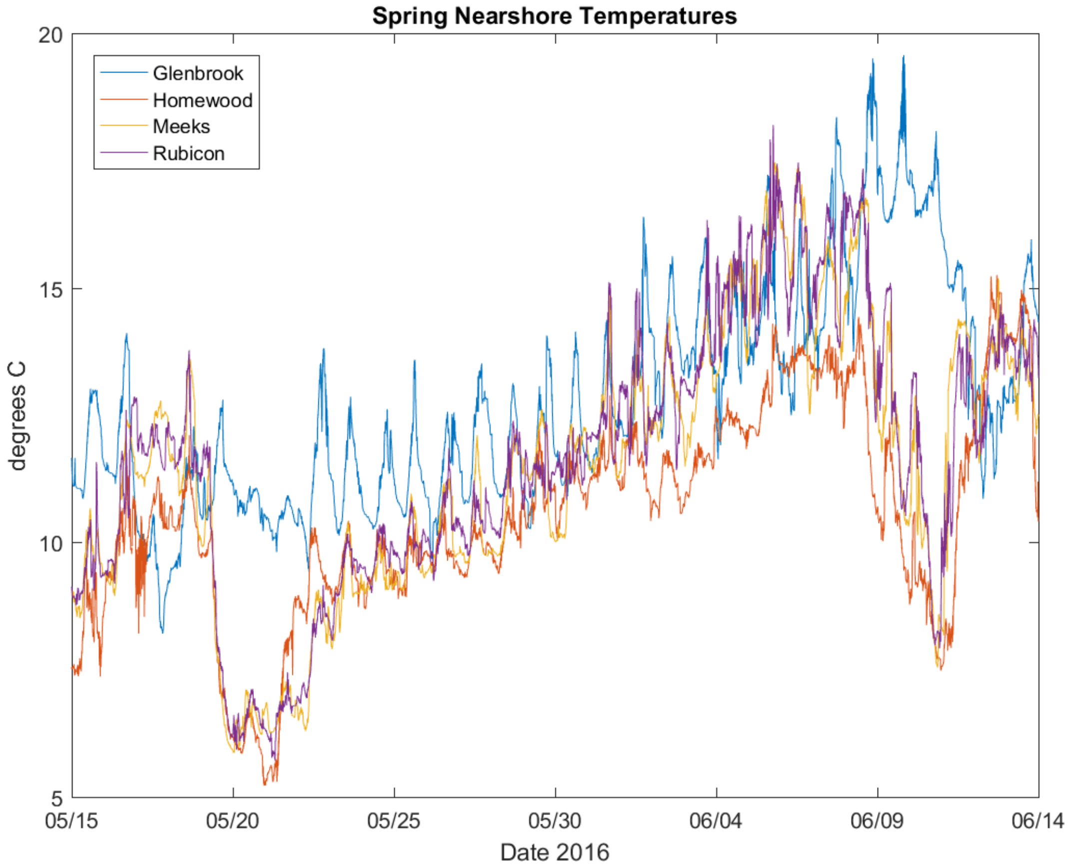
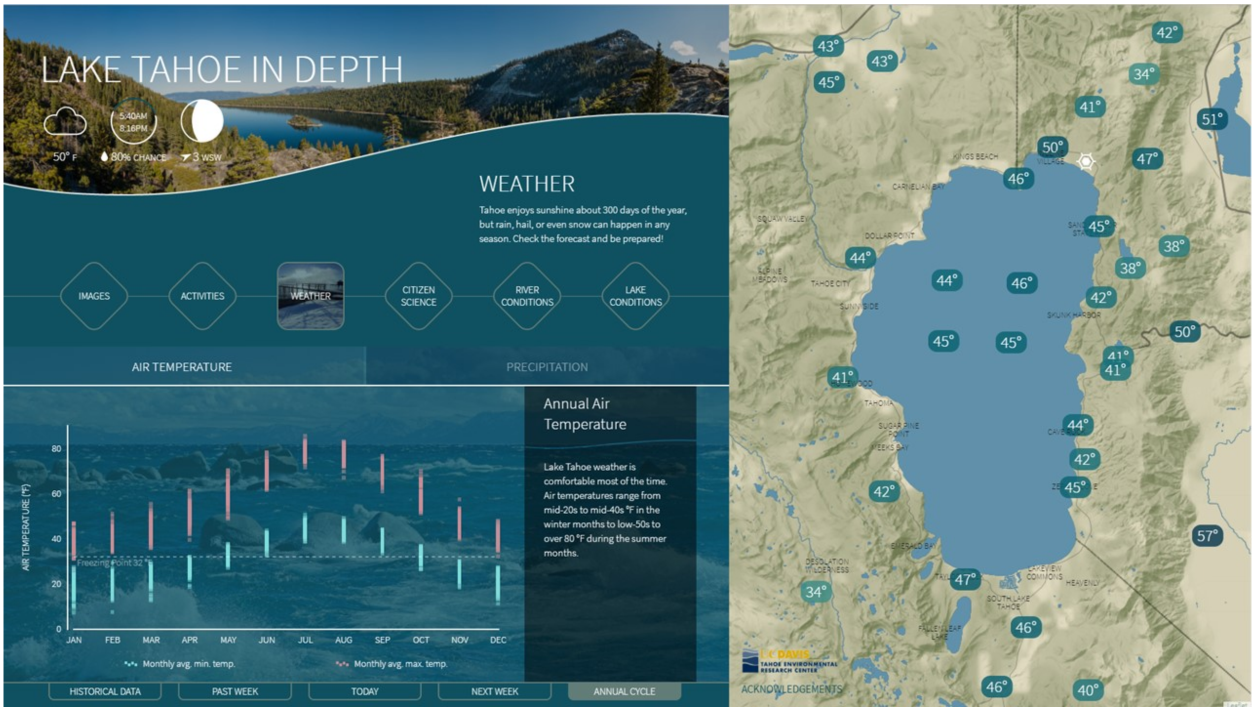
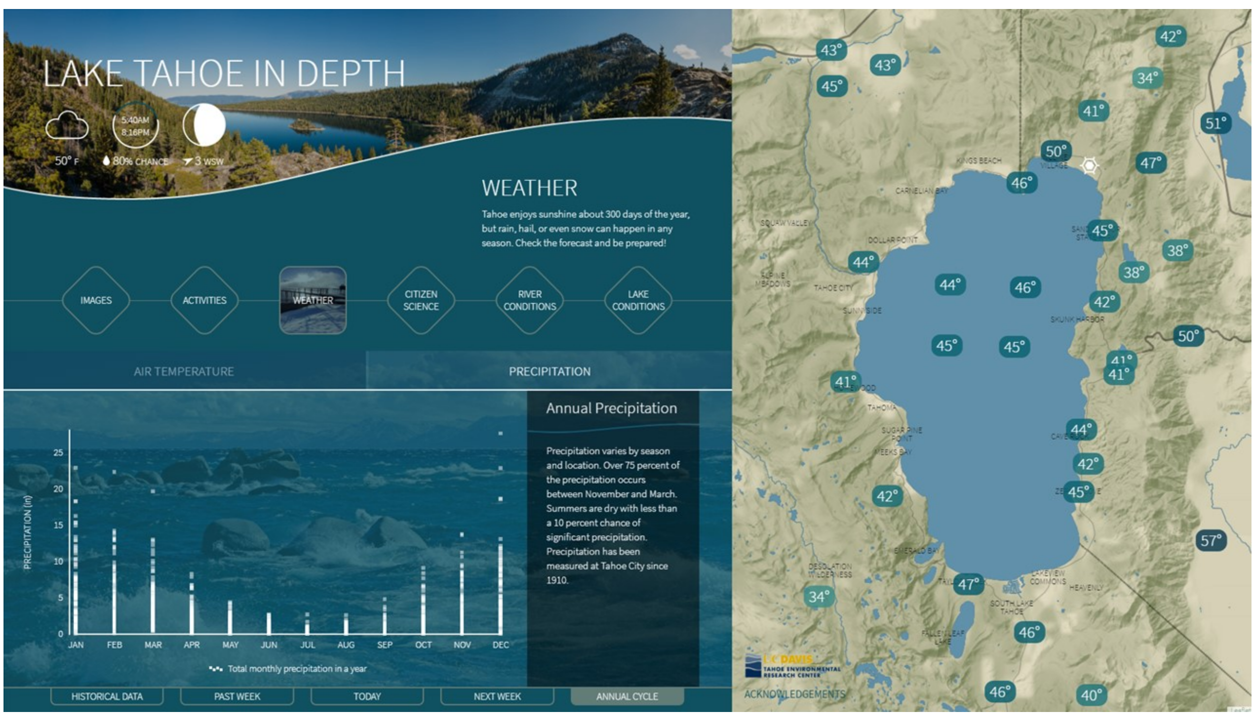


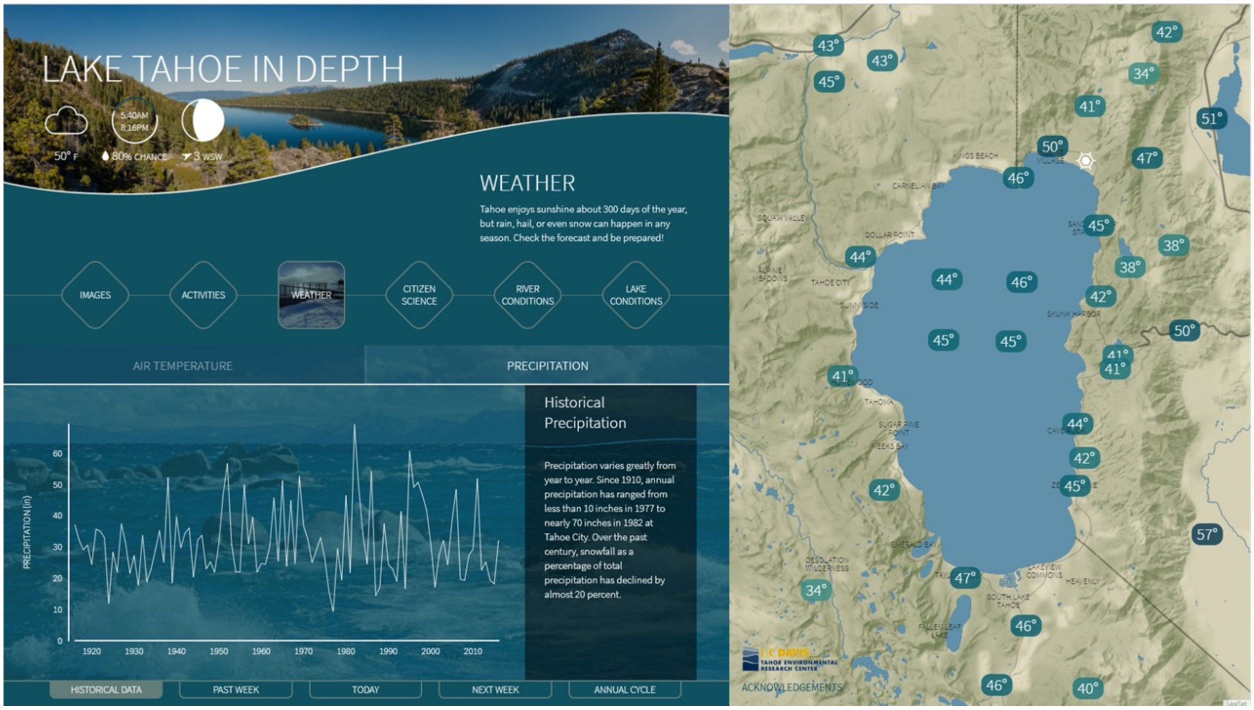
Figure 2 – Nearshore temperatures at three west-shore stations (Homewood, Meeks, and Rubicon) and one east-shore station during two upwelling events in late-spring 2016. Note how the west shore temperature drops rapidly while the east shore temperatures remain stable.



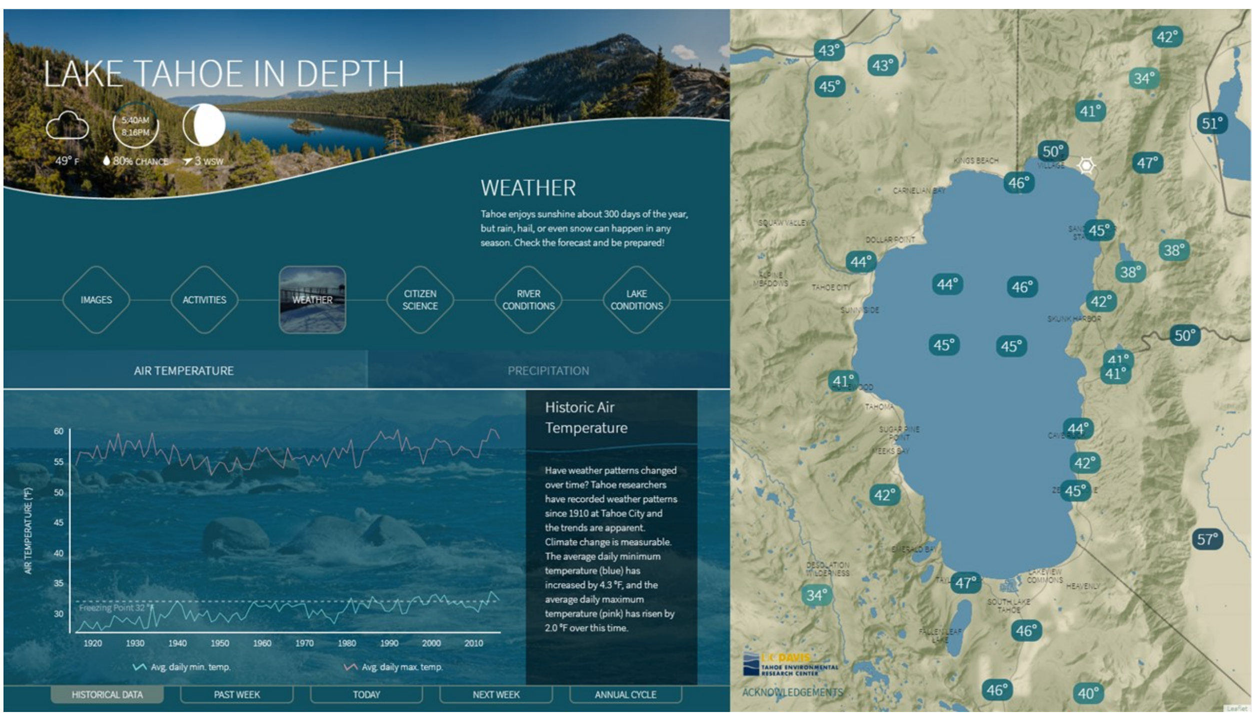
Annual Cycle of Air Temperature (by month since 1910)



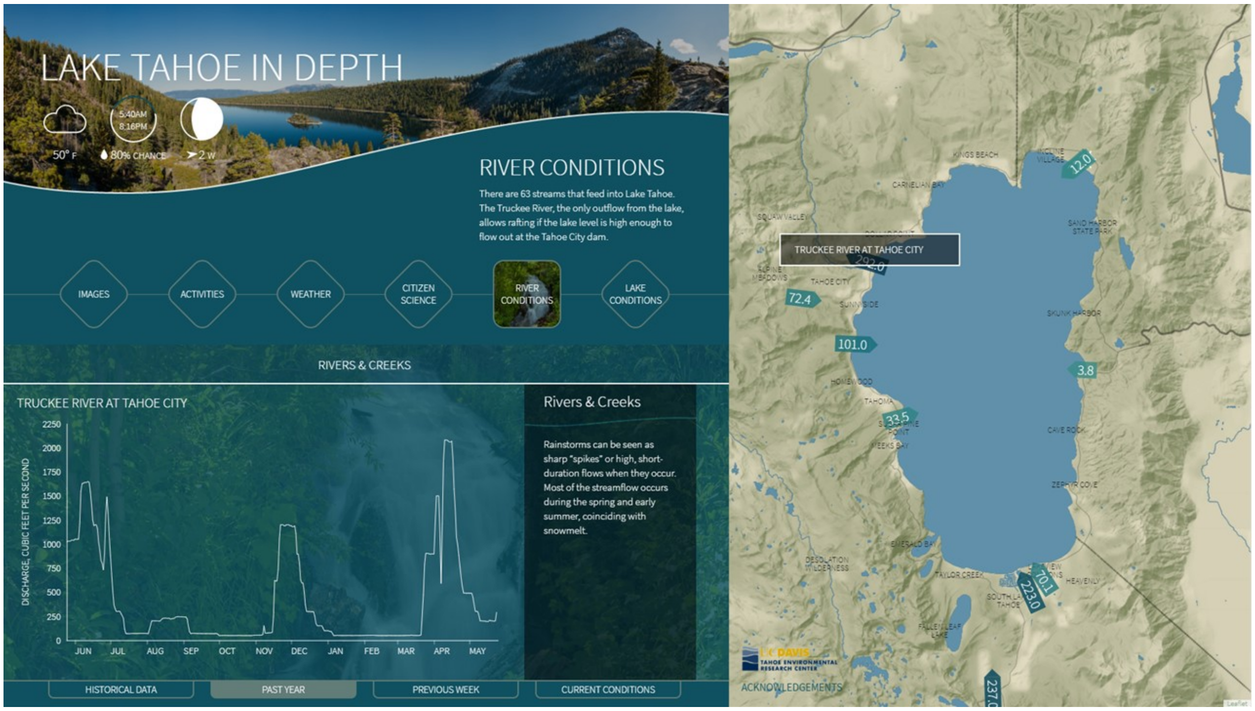
Annual Cycle of Precipitation (by month since 1910)



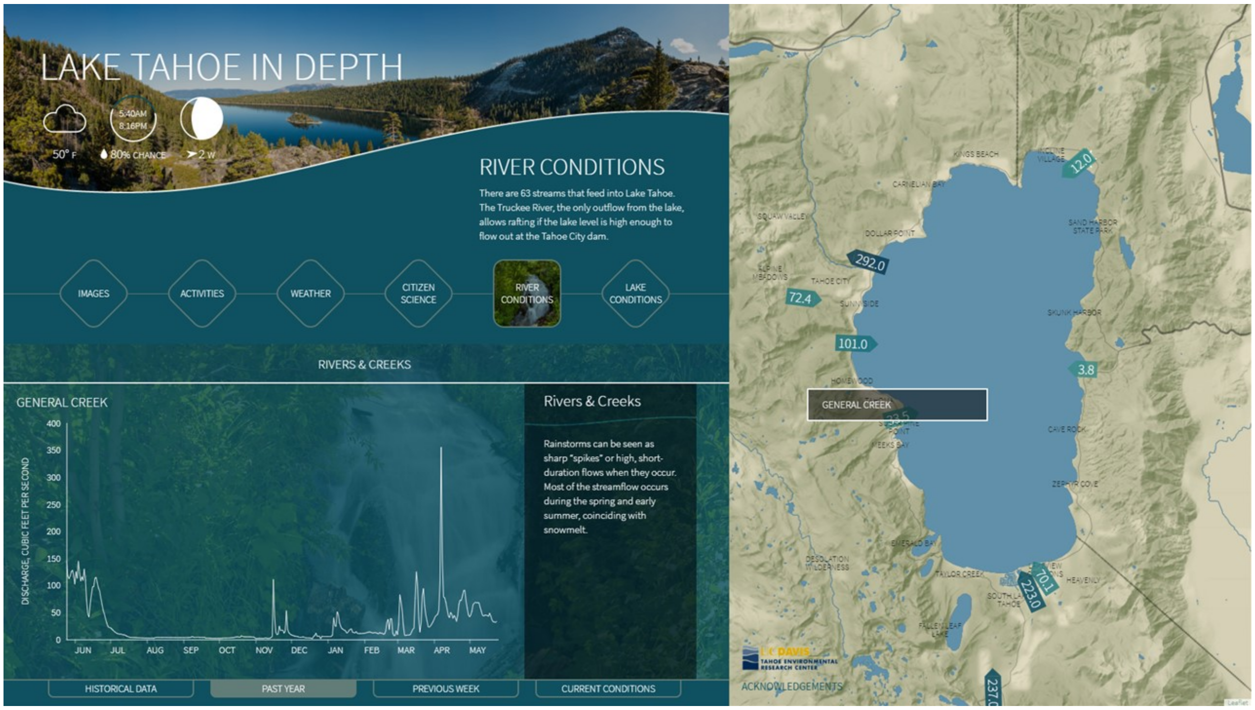
Historical Precipitation (since 1910)



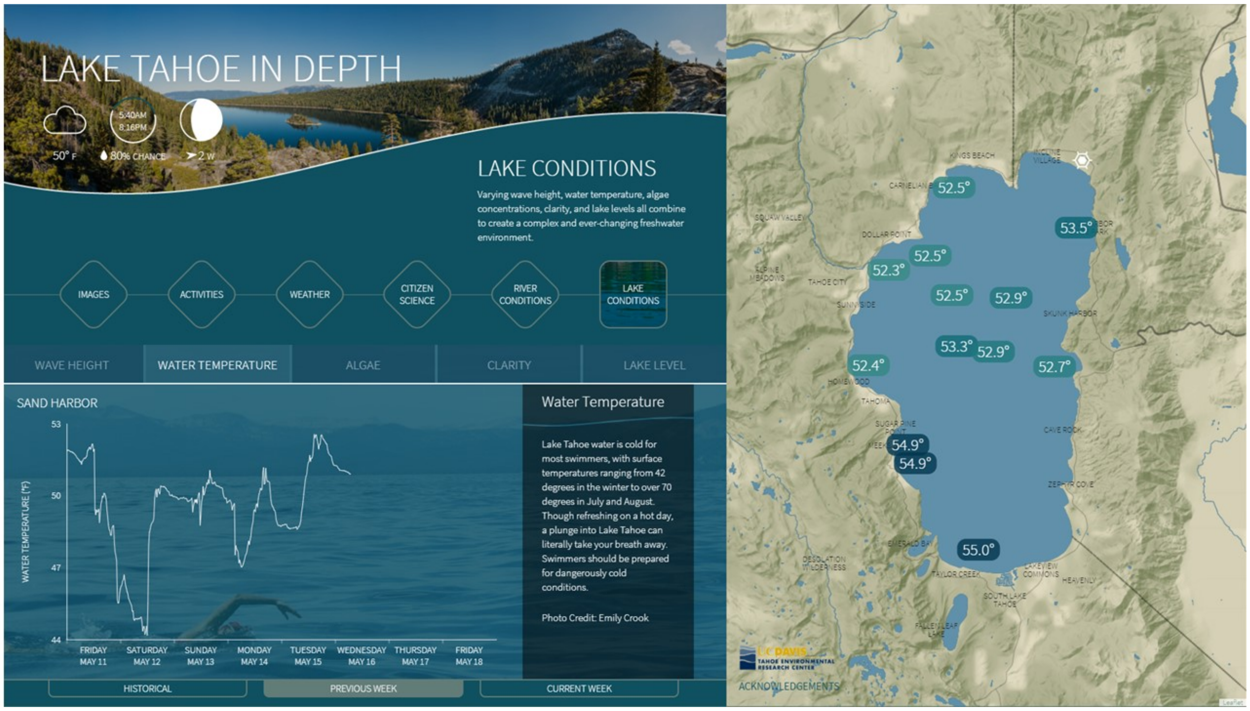
Historical Air Temperature (since 1910)



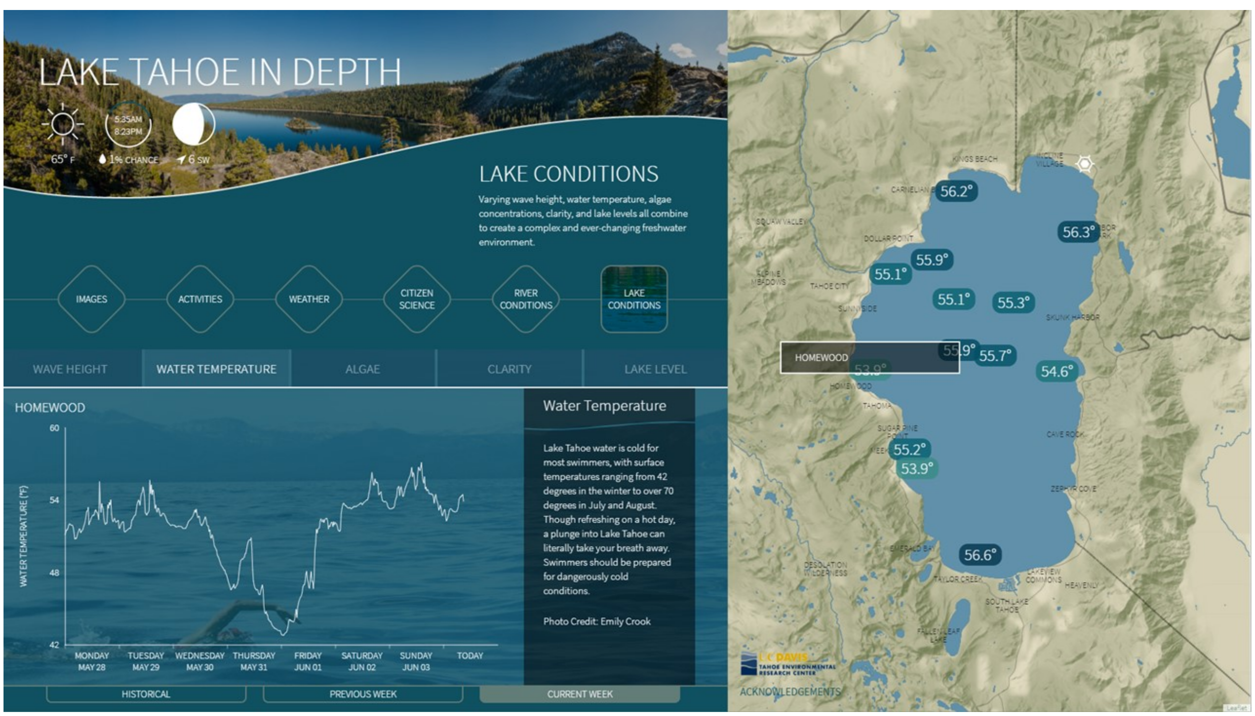
Annual Cycle of Creek Flow



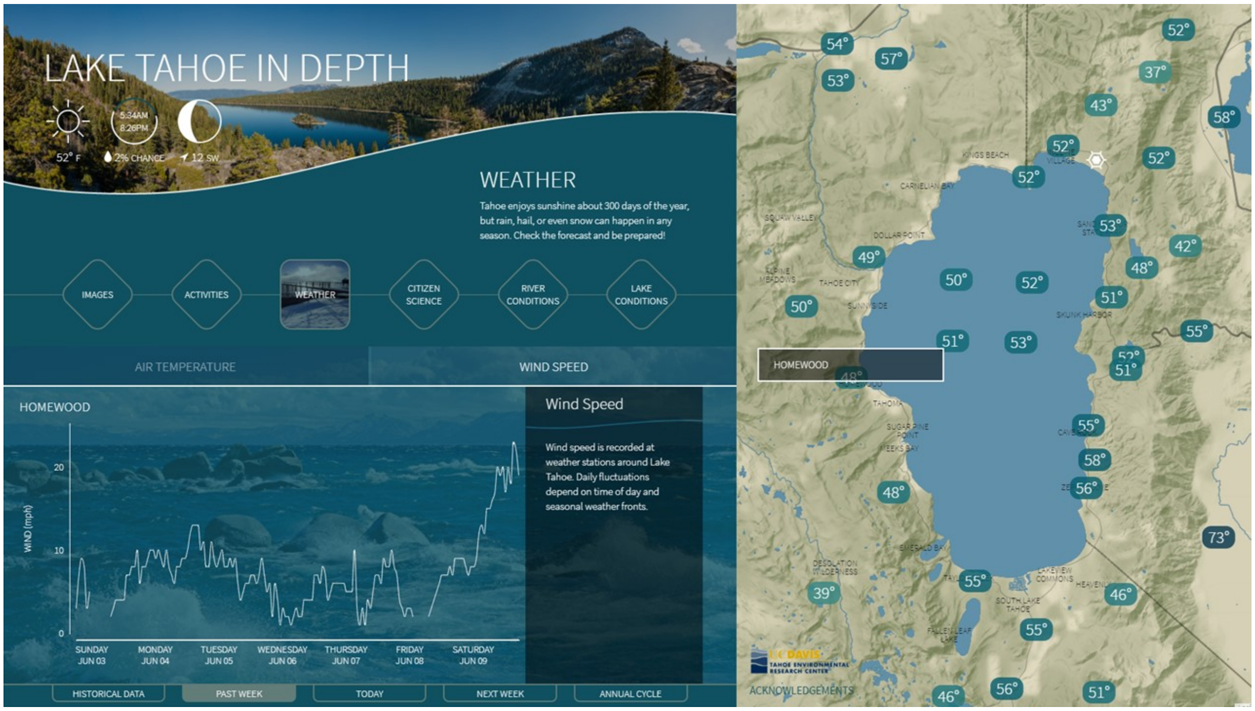
Annual Cycle of Creek Flow (General Creek)



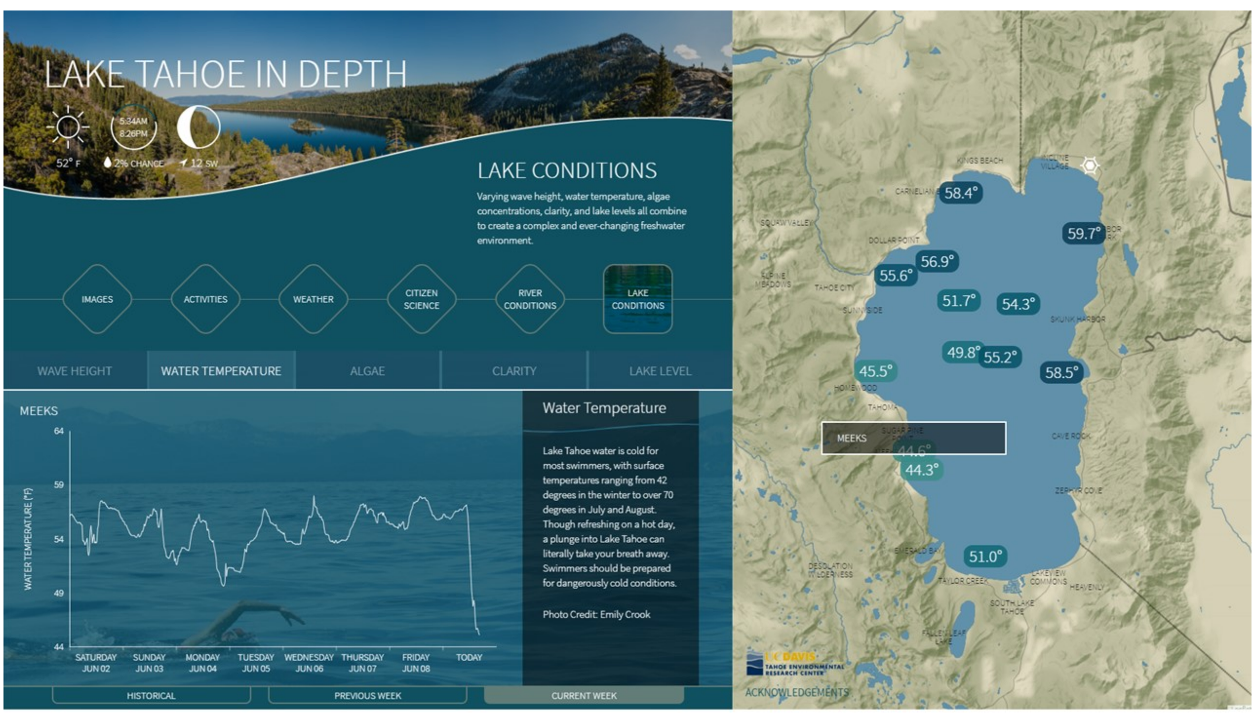
Water Temperature Shows Upwelling Event (Sand Harbor, May 11-12, 2018)



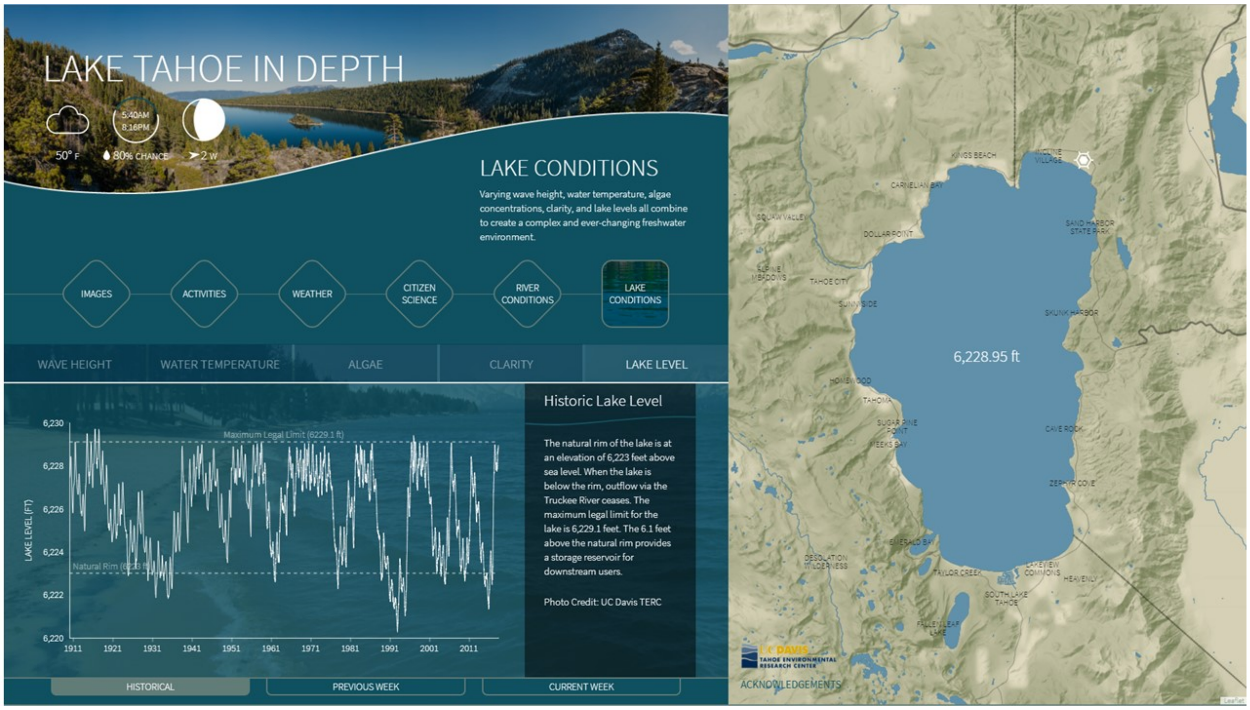
Water Temperature Shows Upwelling Event (Homewood, May 30-31, 2018)



Wind Causes Upwelling Events (June 9, 2018)



Water Temperature Shows Upwelling (Meeks Bay, June 9, 2018)



Historic Lake Levels, shows periods of drought and lake recovery

Green Tour Introduction

The Tahoe Center for Environmental Sciences represents a unique collaboration between Sierra Nevada College and UC Davis. It provides a world-class center for scientific research in the understanding of alpine lakes and watersheds and the preservation of their environmental quality.

The facility is the first building in the Tahoe Basin designed and built to achieve certification under the Green Building Council's LEED (Leadership in Energy and Environmental Design) rating system, striving to obtain the highest rating, "platinum."

The green tour highlights many of the green (or environmentally friendly) building features of the TCES. "Green Points of Interest" signs are posted along the tour route with information about these features.

The objectives of the tour are for visitors to learn:

- The three themes of green building technology—energy conservation, minimum environmental impact, and building occupant comfort and health.
- The TCES building was designed and constructed with the highest possible energy efficiency and environmental design (going for platinum LEED certification). LEED emphasizes state of the art strategies for sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality.
- "Green buildings" such as TCES are high-performance, sustainable buildings.
- About the materials used in a green building such as TCES.
- Ideas that they can incorporate into their own lives to be green, live green and build green.

Included in the Docent Manual are Green Tour Talking Points and Building Systems. All the tour talking points have "Green Points of Interest" signs located throughout the building and are presented in order of a possible tour route. Student tours would include an abbreviated route with less detail and more interactivity.

Also included is information about the various systems in the building. This covers the solar hot water, heating, cooling, rain and snowmelt and air handling systems.

Green Building Information

Adapted from Green Building Communication from Bill Starr, UC Davis Architects & Engineers and lead UC Davis architect on the Tahoe Center for Environmental Sciences Building project

Why Green Building?

While fundamental to human activity, buildings and their associated land development dramatically alter existing ecosystems, consume energy, use water and deplete resources. Present-day designs clearly consume large quantities of physical resources such as materials, energy and money in their construction, maintenance and use.

Data from the US Energy Information Administration illustrates that buildings are responsible for almost half (48%) of all energy consumption and global greenhouse gas (GHG) emissions annually; globally the percentage is even greater. Each day 5 billion gallons of drinking water are used to flush toilets.

Construction and building operations consume tremendous amounts of raw materials and their associated waste streams use landfill space, increase eutrophication of water bodies and degrade soils. In addition, the quality of indoor environments is fundamental to people's health and well-being, with people in the US on average spending upwards of 90% of their time indoors.

Green Building practices offer tremendous potential to improve the overall environmental performance of buildings while increasing the quality of the indoor environment for the occupants. Applied in an integrated manner, these practices also can generate operational savings as well.

Tahoe Center for Environmental Sciences (TCES)

Because of their focus on environmental science, Sierra Nevada College and the UC Davis Tahoe Environmental Research Center strove to create a world class teaching and research facility that would be a model of best practices in Green Building.

LEED

The United States Green Building Council's Leadership in Energy and Environmental Design (LEED) program was the tool used during design and construction to measure the environmental performance of the building's design and construction.

The TCES is the first building in Nevada to earn a LEED Platinum Certification, the highest certification level available. With exemplary performance in major categories that include:

- Energy and Atmosphere
- Water Efficiency
- Materials and Resources
- Indoor Environmental Quality
- Sustainable Sites
- Innovation and Design

Examples of the green building practices particular to this building include:

- Using 60% less energy vs. a similar building built to code
- Providing 10% of building energy from on-site renewable sources
- Using 65% less potable water use vs. a similar building built to code
- Diverting 86% of the construction waste from landfill disposal
- Using materials with high recycled content and low toxicity from regional and sustainable sources.
- Providing indoor environments with access to views and daylight that are ventilated with 100% outdoor air.

SUSTAINABLE SITES

Many of the best practices listed in the LEED site requirements are already mandated locally by the Tahoe Regional Planning Agency. These include stringent erosion control measures, stormwater infiltration and limitations on land coverage. This project included the following additional best practices related to site development.

Alternative Transportation: **Bike racks and showering/changing facilities** are provided at the building. These combined with **local bus and campus shuttle** stops provide occupants an array of alternative transportation options.

Exterior lighting is directed down and/or to the sides, **preventing light pollution** in the night sky.

WATER EFFICIENCY

Landscaping: In addition to local requirements for low water use landscaping, the landscaping here is designed with **native plants to go without irrigation** after being established with temporary irrigation for the first 3 years. Once established, native plants require no irrigation or fertilization and are resistant to most pests and diseases,

Efficient Fixtures: **Low flow faucets** with automatic sensors powered by batteries that are recharged by small solar cells receiving energy from the bathroom ceiling lights. **Low flow showers** use a nozzle design that increases the velocity to provide similar shower sensation with only 60% of the water. **Dual flush toilets** have two different buttons and it uses 0.8 and 1.6 gallons of water, depending on the flush. This half flush/full flush technology can reduce water usage by up to 67% compared with the traditional toilet that uses 2.9 gallons in a single flush.

Alternative Water Sources: **Rainwater and snowmelt** from the roof are collected in a tank in the basement, filtered, sanitized and pumped to flush the toilets.

ENERGY AND ATMOSPHERE

The TCES is one of the most energy efficient laboratories in the world. To achieve this level of performance, a comprehensive approach was needed that included:

Demand Reduction
- Understand the needs: Research and quantify occupant needs
- Passive strategies: Incorporate passive strategies including high performance building envelope, daylighting, solar heating, natural ventilation and cooling
- Design: Choose high efficiency designs and details
- Equipment: Choose efficient Equipment
- Controls: Create control strategies that optimize equipment operational efficiencies

Alternative Sources
- Capture waste energy
- Capture renewable energy

Like most buildings, the TCES building uses energy for heating and cooling, ventilation, hot water, lighting and equipment. Unlike most buildings, it also uses energy to sterilize lab utensils, purify lab grade water, pump and filter rainwater on site.

During the planning of the TCES building, monitoring of the equipment used in existing university laboratory space identified that typical lab cooling requirements would result in oversized cooling equipment for the actual cooling needs of the occupants. By validating a reduced cooling demand, smaller and more efficient cooling systems were possible.

Passive Systems

Well insulated building skin shell including the walls, ceiling, and basement walls has a high resistance to heat flow (high R-value). The windows are insulated glass with a low-e coating (reduces heat transfer across the glass) and argon gas in between the panes of glass.

Free **day light** enters atrium skylights and perimeter room windows, prompting photo sensors to turn off the electric lights when enough day light is present.

Ventilation

100% outside air is filtered, de-humidified of humidified (depending on the season) and delivered to the rooms via **personally adjustable floor level outlets** in the offices, sidewall outlets in the classroom spaces and ceiling mounted induction diffusers, “chilled beams” which provide supplemental heating or cooling (see Cooling below). The use of water based supplemental cooling and heating allowed the volume of air to be dramatically reduced (less air is needed to deliver heating/cooling) which allows the use of 100% outside air in lieu of re-circulated air (see Indoor Environmental Quality below).

Carbon dioxide sensors in classrooms and conference rooms monitor the rooms and increase the amount of outside air delivered to these rooms when the number of occupants increases.

Heating System

Heat is provided primarily from two 93.5% efficient natural gas-fired **condensing boilers** (vs. 80% efficiency for standard boilers). Additional “waste” **heat is recovered** from the laboratory exhaust stream and the casing and flue of the natural gas-fired co-generation microturbine (see Alternative Sources below). The heat is added to the incoming outside air and additional heating is delivered to spaces through **radiant floors** in the lobby, **radiant ceiling panels** in offices and induction coils in the laboratories.

Hot Water

Domestic hot water is pre-heated by **solar hot water panels** on the outdoor Trex enclosure, stored in a hot water storage tank in the basement and then heated to final temperature by the 97% efficient natural gas-fired water heater and circulated throughout the building.

Cooling

Cooling is provided by chilling water outside with “free cooling“ through evaporation during nighttime hours via a cooling tower. This water is collected into two 25,000 gallon underground tanks. This cold water adds cooling to the incoming outside air and additional cooling is delivered to spaces through **radiant floors** in the lobby**, radiant ceiling panels** in offices and induction coils in the laboratories. This strategy eliminates the use of refrigerants (and their associated environmental impacts on global warming and ozone depletion) and is extremely efficient (refrigerant cycles are usually only 30% efficient).

Lighting
After making use of **daylighting** (as described under Passive Systems above), diffusing, **light colored walls, ceilings and laboratory counter tops** were chosen to allow lighting power to be reduced while improving visual acuity. **High-efficiency light fixtures** (that direct light downward and upward to reflect off of the ceilings) are **controlled by sensors** that dim the lights when daylight is present or turn the lights off when rooms are unoccupied.

Fume Hoods
Because of the huge volume of air flow through laboratory fume hoods, large amounts of heat would normally be lost through the roof vent. In order to diminish this heat loss, the TCES lab hoods have variable flow, almost completely stopping air flow when closed and out of use. Other TCES hoods turn off completely or recycle air within a room.

Power Generation
Electricity is generated on site by a microturbine and solar photovoltaic shingles. The **gas-fired microturbine** can generate approximately 21 kw of electricity (40% of the average building demand).

Generation on-site eliminates typical utility transmission loses of 7.2 % and allows the capture of waste heat from combustion to heat the building's living spaces. This table shows the percentage of energy each source produces for TCES in both the summer and winter seasons.

TCES Energy Source	Winter	Summer
Utility	54%	48%
Photo Voltaic (PV)	2%	12%
CoGen	44%	40%
Total	100%	100%

The **solar shingles** cover the southeast facing roof with a total capacity of 20kw (Direct Current rating). This is fed to inverters in the basement that convert the Direct Current electricity into Alternating Current that can be fed to the building electrical service, and is predicted to provide more than 10% of the buildings annual energy cost, avoiding the use of the most inefficiently-produced utility -- electricity.

Operation
This building has undergone enhanced **commissioning**, a methodical process to

ensure that the building functions as intended and will be checked regularly through ongoing measurement and verification. This is extremely important because of the level of complexity and connectedness of many of the building's systems.

MATERIALS

The TCES has recycling stations on each floor. During construction, over **85% of the construction debris was sorted and recycled** on site or shipped to a recycler instead of the landfill.

Materials re-used from site clearing:

- Mulch
- Landscaping rock
- Wood trim (milled from trees cleared from building site

The new materials included in the building were selected for high levels of post-consumer and post-industrial recycled content resulting in over **25% of the construction material (on a cost basis) being recycled.**

Materials containing recycled content (not a complete list):

- Trex synthetic lumber (wood pulp)
- Concrete (fly ash from power plants)
- Structural Steel (cars)
- Batt Insulation (denim scraps)
- Carpet tile (soda bottles)

In order to reduce the environmental impacts of excessive transportation of construction materials, regional materials were selected whenever possible. On a cost basis, over 46% of the materials were manufactured within 500 miles and over 33% had their raw materials extracted within 500 miles.

Finally, to ensure that the building supported healthy forestry practices, over 52% of the wood materials used on the project were harvested from sustainably managed forests certified by the Forest Stewardship Council.

INDOOR ENVIRONMENTAL QUALITY

Americans spend on average 90% of their time indoors, where levels of pollutants may run two to five times — and occasionally more than 100 times — higher than outdoors, according to the U.S. Environmental Protection Agency. Hazardous pollutants may include carbon monoxide, radon, formaldehyde, mold, dirt and dust, pet dander, and residue from tobacco smoke and candles. In addition to standard best practices like restrictions on smoking indoors, other factors were taken into to consideration to attain high indoor environmental quality.

High indoor air quality was targeted in the design with higher than typical ventilation rates and good design details that ensure delivery of that ventilation to the occupants. This quality was supported during construction by using products with no or low levels of volatile organic compounds, keeping the ductwork sealed during construction, and flushing the building with outside air prior to occupancy.

Lighting design was also emphasized. Over 90% of floor areas have direct views outdoors and all rooms have some natural lighting. This exposure to outside conditions can also enhance occupant health. Electric lights are low-glare and adjustable to occupant desires.

Careful consideration of occupant needs to adjust their environment to optimize comfort resulted in a combination of operable windows, individually adjustable floor diffusers in the offices, thermostats and zoned light switches in each of the work areas.

Sources:

- Bill Starr, UC Davis Architects & Engineers, communication 2009
- Architecture 2030 (www.architecture2030.org)
- US Green Building Council, 2009 LEED Reference Guide for Green Building Design and Construction
- US Green Building Council, The Green Home Guide

Green Building Tour
Talking Points

Collaborative Laboratory Building Goes Platinum

August 2007

The U.S. Green Building Council (USGBC) awarded a Leadership in Energy and Environmental Design (LEED) Platinum certification for the Tahoe Center for Environmental Sciences building. The building was the first building in Nevada to earn this recognition, one of five laboratories, and one of only 26 facilities in the world to have earned the highest tier of recognition possible for energy- and environmental-design excellence under the LEED program for New Construction (LEED-NC) at that time.

In order to achieve this recognition, the project design needed to achieve over 52 credits in 6 subject areas that include Sustainable Sites, Energy & Atmosphere, Water Efficiency, Materials & Resources, Indoor Environmental Quality, and Innovation & Design Process. TCES received 56 points, well above the amount needed.

Located in Incline Village, Nevada, the Tahoe Center is a 45,000-square-foot facility that houses Sierra Nevada College's science program (teaching laboratories and classrooms); UC Davis research laboratories (Tahoe Environmental Research Center) and public education center; and office space for the Desert Research Institute and University of Nevada, Reno's Academy for the Environment. All of these functions are focused on understanding and preserving the unique ecology of the Lake Tahoe watershed. Achieving Platinum certification not only shows congruence with that focus but proves that sustainable, energy-efficient design is possible even for complex, critical-use buildings such as laboratories.

Laboratory buildings typically use more than four times the amount of energy used by an office building of the same size. In addition, labs typically have major environmental impacts in other areas such as water use, exhaust emissions, material use, and waste disposal. In order to focus on improving the environmental performance of laboratories, a program named Labs 21 was formed as a joint project of the U.S. Environmental Protection Agency and the U.S Department of Energy Labs. With the support of the conceptual framework promoted by Labs 21, the mechanical engineering firm of Rumsey Engineers developed a highly integrated and innovative design that provides safe and effective heating, ventilation, and air conditioning with extremely low-energy use. The energy efficiency of the mechanical system was complemented by a well-insulated building with high-performance windows, advanced lighting and lighting controls, and partial use of daylighting to offset the use of electric lighting. Lighting design was by David Nelson & Associates of Littleton, Colorado, and the project's electrical engineering firm was Integrated Design Associates of San Jose, California.

The result is a building that uses 60% less energy than a building of the same function, climate, and size designed to current code standards. These deep reductions in energy usage made it feasible to use photovoltaic roof panels to provide 10-20% of the building's annual energy demand and for the college to purchase renewable power from other sources to make up the remainder.

Potable water use was reduced 65% through the use of drought-tolerant native plant species in landscaping, water-efficient plumbing fixtures, and the use of treated rainwater for toilets. Sustainable site features include low-glare lighting, retention basins to slow down and treat storm water runoff, and reduced areas of site disturbance during construction.

The building design includes materials with high levels of recycled content as well as materials that come from local sources (reducing the environmental impacts of associated transportation). The concrete in the structural frame substituted 25% of the cement with fly ash, a by-product of coal combustion in power plants. In addition, over 85% of the construction waste was recycled.

In order to support the productivity, health, and well-being of the students, researchers, and others who use the building, special effort was made to increase occupant comfort by using materials with low or no emissions, providing a high level of individual control over lighting and cooling levels, and giving access to daylight and views of the outdoors.

Wherever possible, these systems have been expressed rather than hidden to educate the public on the applications and benefits of green building. Docent-led tours provide the public with a working example of sustainable design, construction and landscaping.

Green Tour Introduction

LEED (Leadership in Energy and Environmental Design): The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ is the national benchmark for high performance green buildings. LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health:

1) **Water savings:** TCES uses two-thirds less water than other buildings the same size.
2) **Energy efficiency:** TCES uses two-thirds less energy than other buildings the same size.
3) **Materials selection:** Building materials were either collected on-site from the buildings footprint (wood trim, woodchips for mulch, rocks for landscaping and BMPs). Most were manufactured within 500 miles.
4) **Indoor environmental quality**: CO2 monitors, lots of natural lighting and plenty of fresh air in the building help to keep visitors, students and employees happy and healthy.
5) **Sustainable Sites:**

Reduced Site Disturbance: The TCES site was chosen to reduce the environmental impact of the building. For example, the building is well out of the 100-year floodplain and the site does not include sensitive site elements or restrictive land types (e.g. riparian or wetland areas).
Footprint: The building was designed with the smallest footprint possible. The parking area was also minimally sized based on local zoning requirements in order to reduce overall disturbed land.
Construction Pollution Prevention: Construction pollution such as soil erosion, waterway sedimentation, and airborne dust generation were controlled using temporary and permanent seeding, mulching, earth dikes, silt fencing, sediment traps and sediment basins.
Construction Materials Recycled: Special dumpsters were brought to the site to recycle various construction wastes.
Alternative Transportation: A bus stop is located within 100 yards (across Country Club Drive from the TCES driveway) to encourage use of public transportation.

For more information, visit the US Green Building Council: https://new.usgbc.org/

TCES Outside Front

1) <u>Light Pollution:</u> All light is directed down and/or to the sides, preventing light from shining up into the night sky.
   - Light pollution is excess or obtrusive light created by humans. Among other effects, it can cause adverse health effects, obscures stars to city dwellers, interferes with astronomical observations, wastes energy and disrupts ecosystems.
   - Energy audit data demonstrates that about 30 to 60 percent of energy consumed in lighting is unneeded or gratuitous (en.wikipedia.org/wiki/Light_pollution).

2) <u>Bicycle Storage:</u> Racks and showering/changing facilities are provided to encourage building occupants to use alternative transportation.

3) <u>Native Plants:</u> Only native plants were used in the landscaping. Once established, native plants require no irrigation or fertilization and are resistant to most pests and diseases.
   - Ask what defines a native plant and why we would want to plant them?

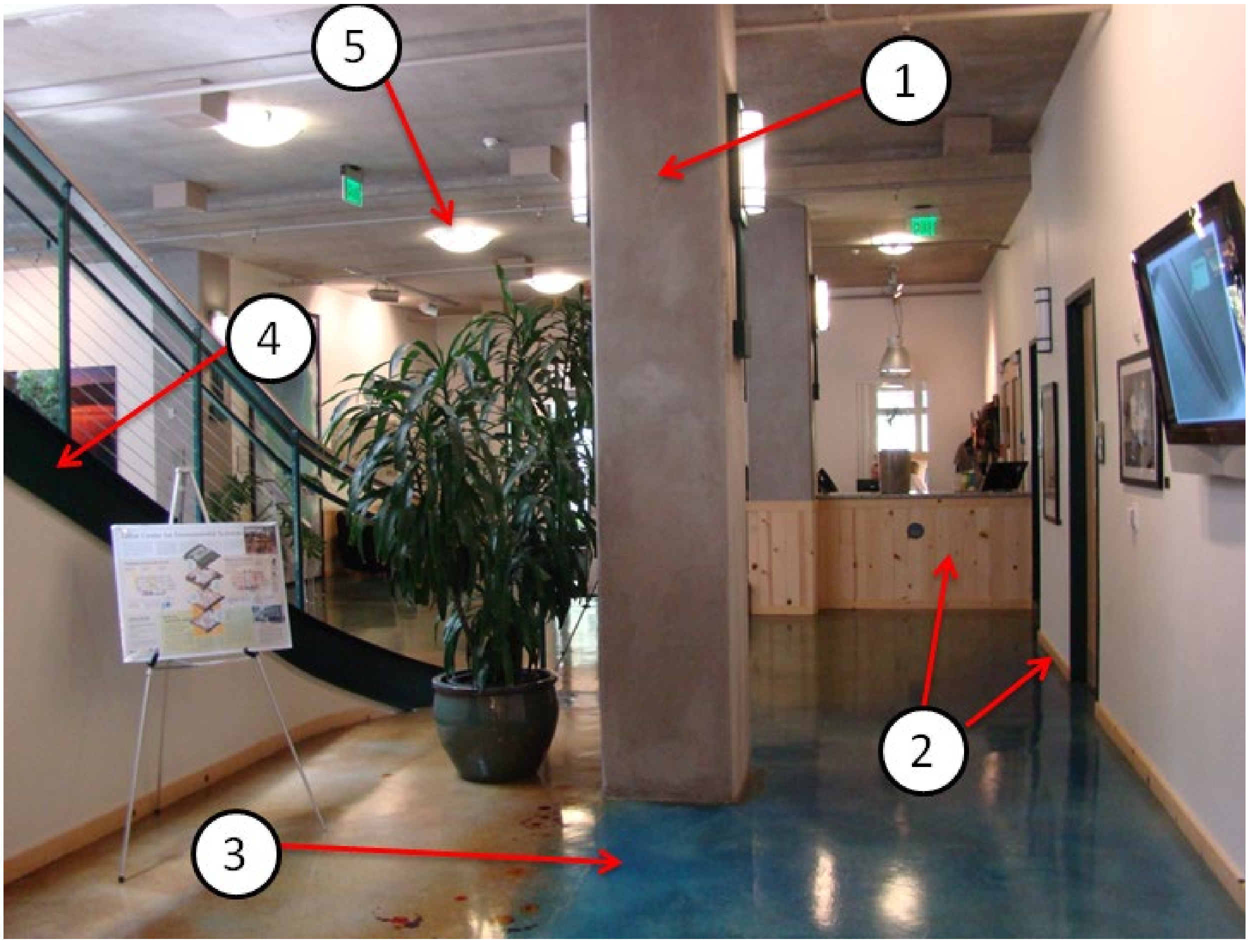
4) <u>Mulch:</u> Chips and branches from the trees in the building's footprint were mulched and used for planting areas

5) <u>Heat Island Effect:</u> Light colors and careful landscaping were used to increase shading and reduce the "heat island effect" that large asphalt parking areas can cause.
   - "Heat island" refers to urban air and surface temperatures that are higher (up 10 degrees F) than surrounding rural areas.
   - Increased heat causes increased energy use (for cooling) and thus an increase in CO2 emissions. It can affect human health by decreasing air quality and increasing ground-level ozone production (www.epa.gov/heatislands).

Best Management Practices

1) Landscape Rock and Stone: All of the rock and stone used in exterior landscaping and BMPs came from the hole dug for the foundation.
2) Stormwater Management: The most stringent Best Management Practices (BMPs) were used to ensure that water is infiltrated on site and does not contribute to the run-off polluting Lake Tahoe.
   - Best Management Practices (BMPs) are methods to help developed properties function more like natural, undisturbed forest and meadowland. Water that is conveyed to a lake by an undisturbed watershed is usually very clean, because the watershed's soils and plants act as a natural water purification system. BMPs help developed properties mimic natural conditions, preventing sediment and nutrients from entering our surface waters.
   - By implementing BMPs, property owners can help slow the loss of lake clarity. BMPs prescribed for residential properties usually fall into the following categories: vegetating and mulching bare disturbed soils; infiltrating stormwater runoff from impervious surfaces; paving dirt driveways and roads; and stabilizing or retaining steep slopes and loose soils.

TCES Inside Lobby



1) <u>Fly-ash Concrete:</u> Concrete containing fly-ash, a byproduct of burning coal, is stronger and reduces the waste going to landfills.

2) <u>Local-Origin Materials:</u> Trees harvested from the building's footprint were milled on-site and used for interior trim.

3) <u>Concrete Floor:</u> The stained concrete floor eliminated the need for linoleum and adhesives.

4) <u>Recycled Steel:</u> The steel used for the third floor structure above the concrete line is at least 95% recycled.

5) <u>Compact Florescent vs. Incandescent</u>: CF light bulbs do not lose as much energy as heat as incandescent bulbs, which means they are more efficient.
   - **Ask** if they have ever touched a light bulb. How did it feel? Hot. Explain why. Have them push the button to turn on the CF bulb and touch it. How does it feel? It should feel cooler. Why do they think that is?
   - All the lights in the building are turned on by motion sensors. ***Ask*** *why this would save energy.*

TCES Inside Lobby

1) <u>Radiant Hydronic Heating:</u> Water warmed by a gas-fired generator moves through pipes in floor and ceiling panels to heat the building.

2) <u>Recycled Insulation:</u> Blue jean insulation is an example of recycling a product that would otherwise become waste.

3) <u>Atrium:</u> Large skylights provide natural daylight, which reduces the need for electrical lighting, and the open space allows air circulation.
   - Natural light also has health benefits and increases work productivity

4) <u>Air Vents:</u> 100% fresh air is constantly being circulated in the building.
   - CO_2 detectors tell the system to increase fresh air flow into a room if levels become high because too many people are in a space.

Bathrooms

1) Solar-powered Automatic Faucets with Low-flow Nozzles: Sink faucets are aerated and turn off automatically to reduce water waste.

2) Dual Flush Toilets: A high (1.6 g)/low (0.8g) flush toilet uses up to 80% less water than a standard toilet every year.

3) Rain and Snow: These toilets get their water from a system on the roof that captures rainwater and snowmelt.

4) Waterless Urinals: Anti-bacterial, odor-absorbing cartridges eliminate the need for water.

Greenhouse

1) Greenhouse: The greenhouse's large south-facing windows let light pass through into the student lounge and can open to reduce overheating in warm weather.

2) Dual-Paned Windows: These windows are designed to insulate, with argon gas between the panes to provide an additional barrier.

3) Low-Emissivity (Low-E) Coating: Controls heat transfer through windows and can reduce energy loss by 30-50%.

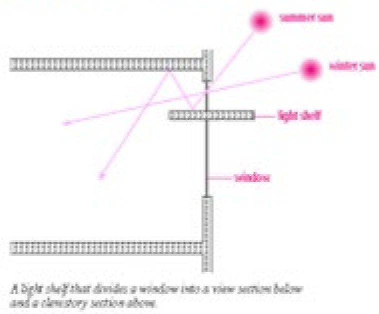
    - A low-E coating is a microscopically thin, virtually invisible, metal or metallic oxide layer deposited directly on the surface of one or more of the panes of glass to a cooler pane.

    - To keep the sun's heat out, the low-E coating is applied to the outside pane of glass. For cold climates, the low-E coating is applied to the inside pane of glass to keep the heat in. In this instance, the low-E coating has been applied to both sides of the windows.

TCES Outside Back

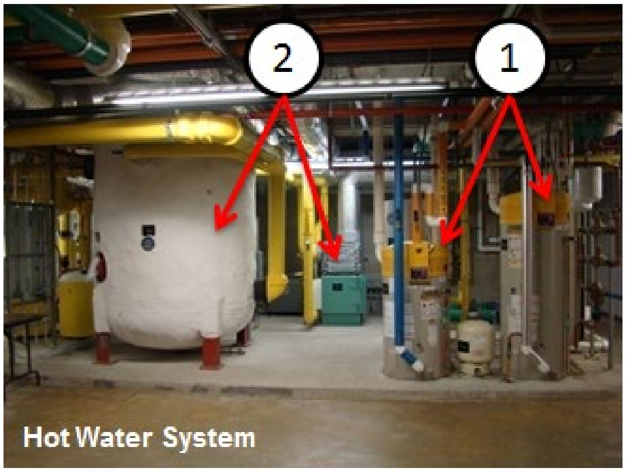
1) <u>Concrete Paneling:</u> The “wood” siding is actually a concrete mixture called Hardiboard. It is long lasting, fire resistant, low maintenance and saves trees.
   - Concrete buildings are more energy efficient than wood-frame buildings and therefore require less energy to heat and cool.
   - Concrete is made of some of the Earth’s most common and abundant minerals. The amount of land used to extract the materials needed to make concrete is only a fraction of that used to cut down our forests for lumber. Sources of aggregates are plentiful: sand, gravel, crushed stone, and many consumer and industrial byproducts.
   - For information about what makes concrete a sustainable building material, visit www.concretenetwork.com/concrete/greenbuildinginformation/what_makes.html.
2) <u>CNG Fueling Stations</u>: Compressed Natural Gas (CNG) provides alternative fuel.
3) <u>Cold Water Storage Tanks</u>: Two underground tanks each hold 25,000 gallons of water chilled by nighttime ambient temperatures.
4) <u>Trex Enclosure:</u> Trex is made of recycled plastic and waste wood and resists moisture, insects, and sunlight.
5) <u>Solar Thermal Panels</u>: Using only the sun, two panels capture thermal energy used to pre-heat hot water. (Note: Use of solar thermal for pre-heating water is one of the most cost-effective ways for residents to “green” their homes.)
6) <u>Cooling Tower</u>: The evaporative cooling tower replaces traditional air-conditioning and uses only 5-10% of the energy.
   - ***Ask*** *what happens when people get hot (they sweat). How is the cooling tower like sweat? Explain that as water evaporates, it takes heat with it.*

TCES Outside Back



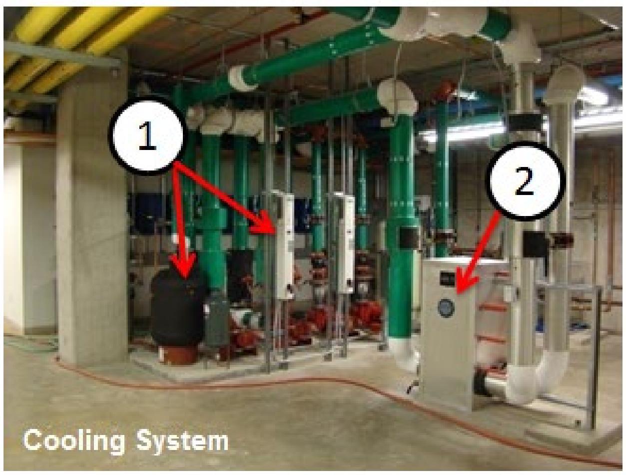
1) <u>Light Shelves</u>: Located on the south side of the building, light shelves act as eaves to shield windows from direct sun, but also reflect natural light into the building up to 25 feet.
   - A light shelf is a passive architectural device that permits daylight to enter deep into a building, thereby reducing electricity use and increasing occupant comfort and productivity. Light shelves may be interior or exterior; exterior light shelves may also function as sunshades.
2) <u>Photo-Voltaic Panels:</u> 875 solar panels collect energy from the sun to provide electricity used in the building.
   - The solar array can generate up to 20kW and TCES uses about 60kW
   - **Ask** which direction the solar panels are facing (south). Ask why they would be facing that way (the sun is in the south in the northern hemisphere). Which way would they face if we were in the southern hemisphere? (north)
3) <u>Landscaping</u>: Deciduous trees were planted on the south side of the building to provide shade in summer, but not in winter.
   - **Ask** why it would be important to plant trees that lose their leaves (deciduous) on the south side of the building?

Basement



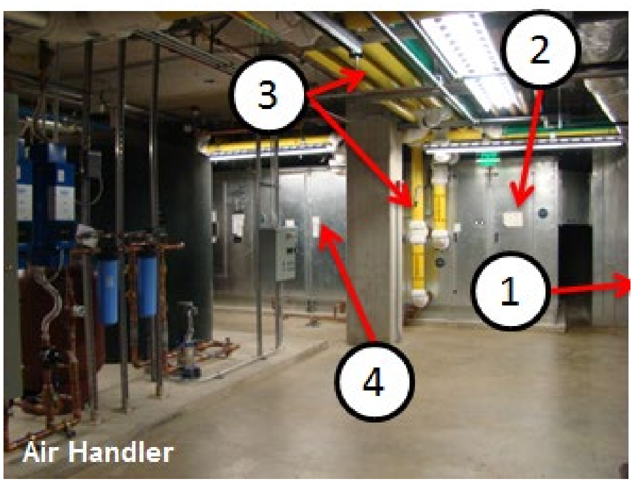
Hot Water System:

1) Hot Water: Pre-heated water is piped to two high-efficiency, gas powered water heaters: one for domestic and one for industrial (laboratory use).
2) Co-generation system: Heat from the gas-fired generator is captured and used to heat the building.
   - **Ask** why is this green? It generates electricity the same as any other generator and it captures heat that would otherwise be wasted.



Cooling System

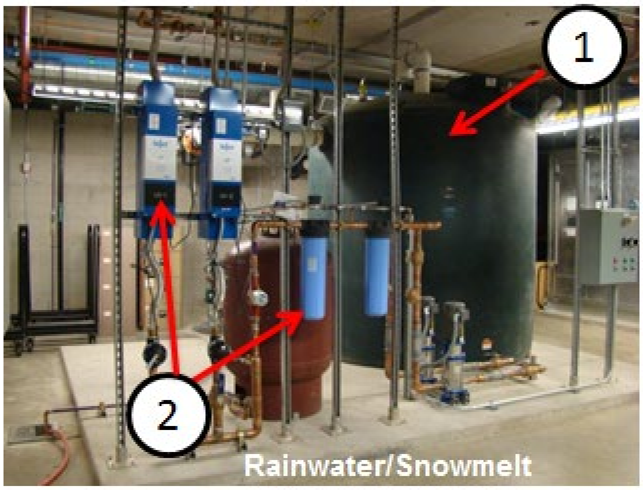
1. Chilled Water Circulation System: Pumps chilled water from outdoor storage tanks to the heat exchanger.
2. Heat Exchanger: Uses water from outside to cool water in a second separate system which piped through the building for cooling.



Air Handler System

1) Plenum: Brings 100% fresh air into the building.
2) Air Filter: Air from the plenum is filtered to remove dust and pollen.
3) Heat Recovery Loop: Water warmed by roof exhaust pre-heats the air.
   - Have guests look at thermometers on the in and out pipes to observe temperature difference.
4) Humidifier: After the air is filtered, it is humidified for occupant health.

Basement

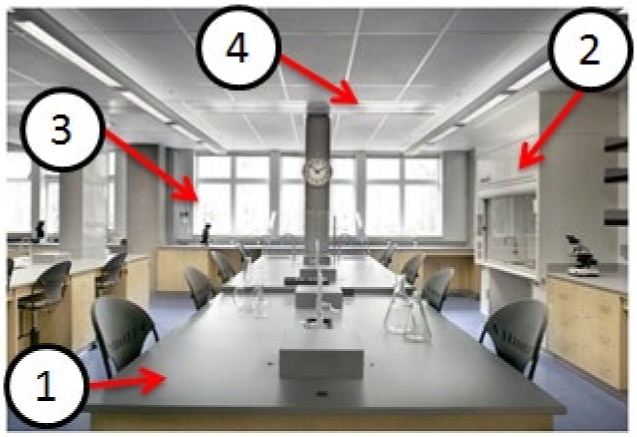


1) Rain/Snowmelt Storage Tank: This 3000 gallon tank holds rainwater and snowmelt before it is filtered and sterilized for the building's toilets.
   - For students on the tour ask them how much water they think the tank holds.
   - Ask how students would figure out how much water the tank holds if you couldn't see the markings. (They would need the height and diameter or radius of the tank to figure out the volume.)
   - This system supplies enough water for approximately 80% of our flushes a year
2) UV and Charcoal Water Filtration System: Sterilizes water for the building's toilets.

Note: Water in the toilets may appear yellowish during the spring and summer due to pollen that blows onto the roof and ends up in the Rain/Snowmelt Storage Tank. While the pollen is filtered from the water, the pigment from the pollen does not get filtered, leaving the water yellow.

1) Photo-Voltaic Panel Inverters: These blue boxes convert the direct current (DC) from the solar panels on the roof into alternating current (AC)—the kind of electricity in your home.

Laboratory



1) <u>Gray Countertops</u>: Light-colored countertops reduce the lighting requirements in lab spaces because they don't absorb the light the way traditional black countertops do.

2) <u>Fume Hoods</u>: When not is use, fume hoods stop or reduce air flow to save energy.

3) <u>North-Facing Windows</u>: Large north-facing window are not standard in historic green building design, but were added for occupant comfort.

4) <u>Induction diffusers:</u> Also known as "chilled beams," these ceiling mounted induction diffusers provide supplemental heating or cooling for the laboratories.
    - Almost completely eliminated need for reheat energy
    - Reduced size of air-handling system and ductwork by 40%

Green Materials in TCES

Green building materials are those produced from recycled or re-used materials or those manufactured within 500 miles of the site. These materials where used whenever possible during the construction of TCES.

Re-Use: Many of the natural materials removed from digging the building's footprint were re-used on site:

- Landscape Rock and Stone (material removed from building footprint)
- Wood Trim (trees removed from footprint were milled onsite for use)
- Mulch (produced from removal of trees)

Recycled Content: Over 25% of the construction materials (on a cost basis) used in the construction of TCES were made from materials containing high levels of post-consumer and postindustrial recycled content, including:

- Trex synthetic lumber (wood pulp)
- Concrete (fly ash from power plants)
- Structural Steel (cars)
- Building Insulation (recycled denim blue jeans)
- Carpet tiles (recycled soda bottles and comes in tiles for easy replacement and less waste)

Energy Saving Devices: Energy saving devices and systems were also installed throughout the building, including:

- Compact Fluorescent Lightbulbs (CFL) last up to 10 times longer than an incandescent and use 50-80% less energy
- Motion sensors automatically turn lights on and off to reduce electrical consumption
- Siemens Building Monitoring System (monitors building systems and adjust automatically as needed)

Reducing VOCs: Materials containing low amounts of Volatile Organic Compounds (VOC's) were used inside the building to improve indoor occupancy health. The paint, adhesives, carpet, linoleum, and furniture are virtually odor-free and do not release volatile organic compounds.

- The Environmental Protection Agency (EPA) has identified indoor air pollution as one of the four greatest risks to human health. The World Health Organization estimates that 30% of new and remodeled buildings worldwide experience indoor air quality problems. These problems translate into lost productivity and illnesses costing businesses billions each year.
- Volatile organic compounds (VOCs) are organic chemical compounds that vaporize at normal temperature and pressure and enter the atmosphere. VOCs are often used in paint, plastics and cosmetics.

Solar Hot Water Heater

Solar Thermal Panels
(Trex enclosure)

- These panels transfer heat from the sun to ethylene glycol (one of the main ingredients in anti-freeze)
- The heated ethylene glycol is piped into the basement where the heat is transferred to water

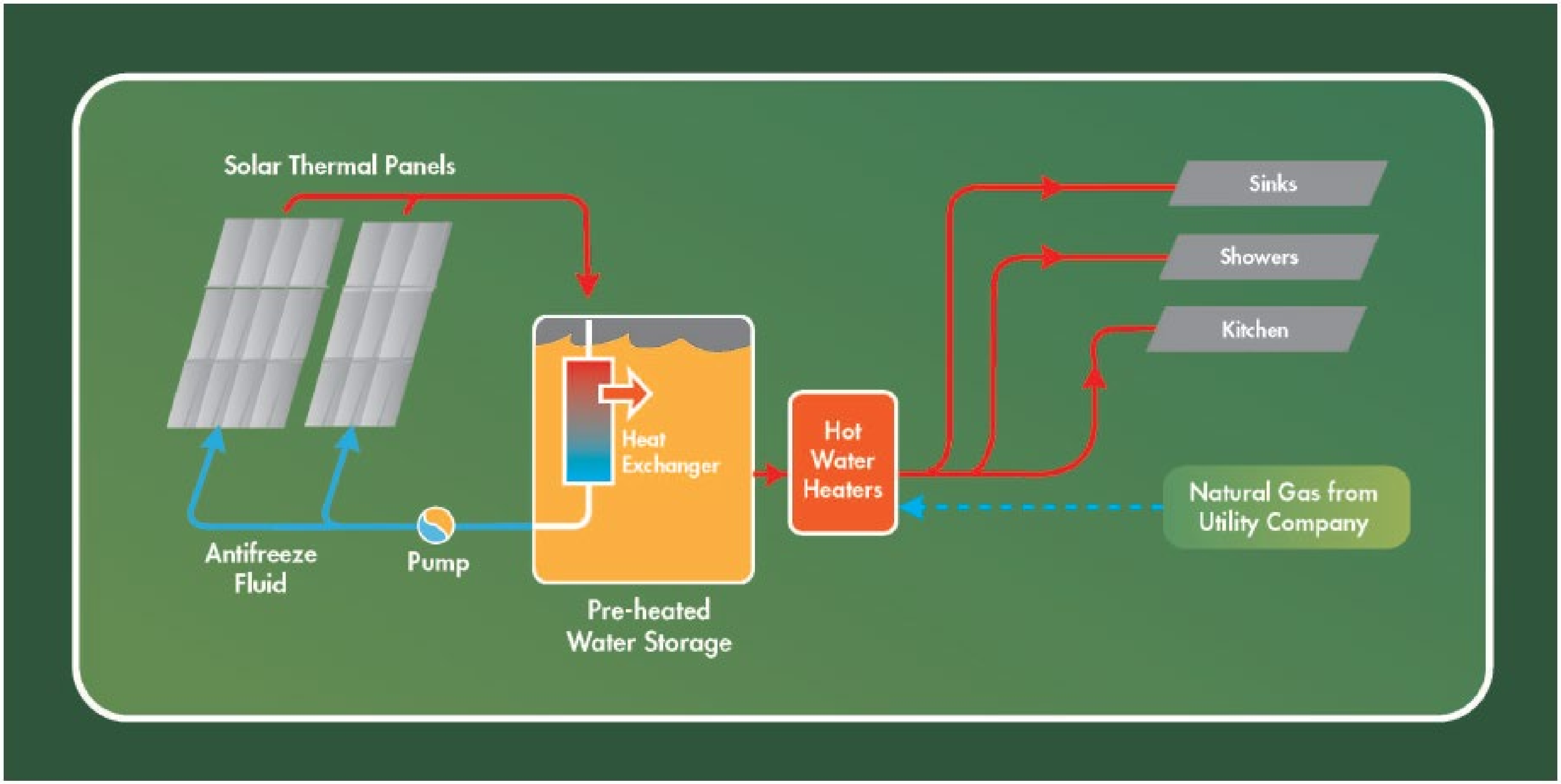
Hot Water Storage Tank

- The water is pre-heated by the ethylene glycol and stored in this well-insulated tank

Hot Water Heaters

- These two high efficiency, gas-powered water heaters further heat the water to the appropriate temperature before sending it out to the building
- The smaller one is for domestic use and the larger one is for the labs (industrial)

Domestic Hot Water Heating



Heat Recycling System

Heated Ethylene Glycol Pipes

Venting Tower (roof)

- Venting towers capture heat from the exhaust leaving the building and transfer it to ethylene glycol

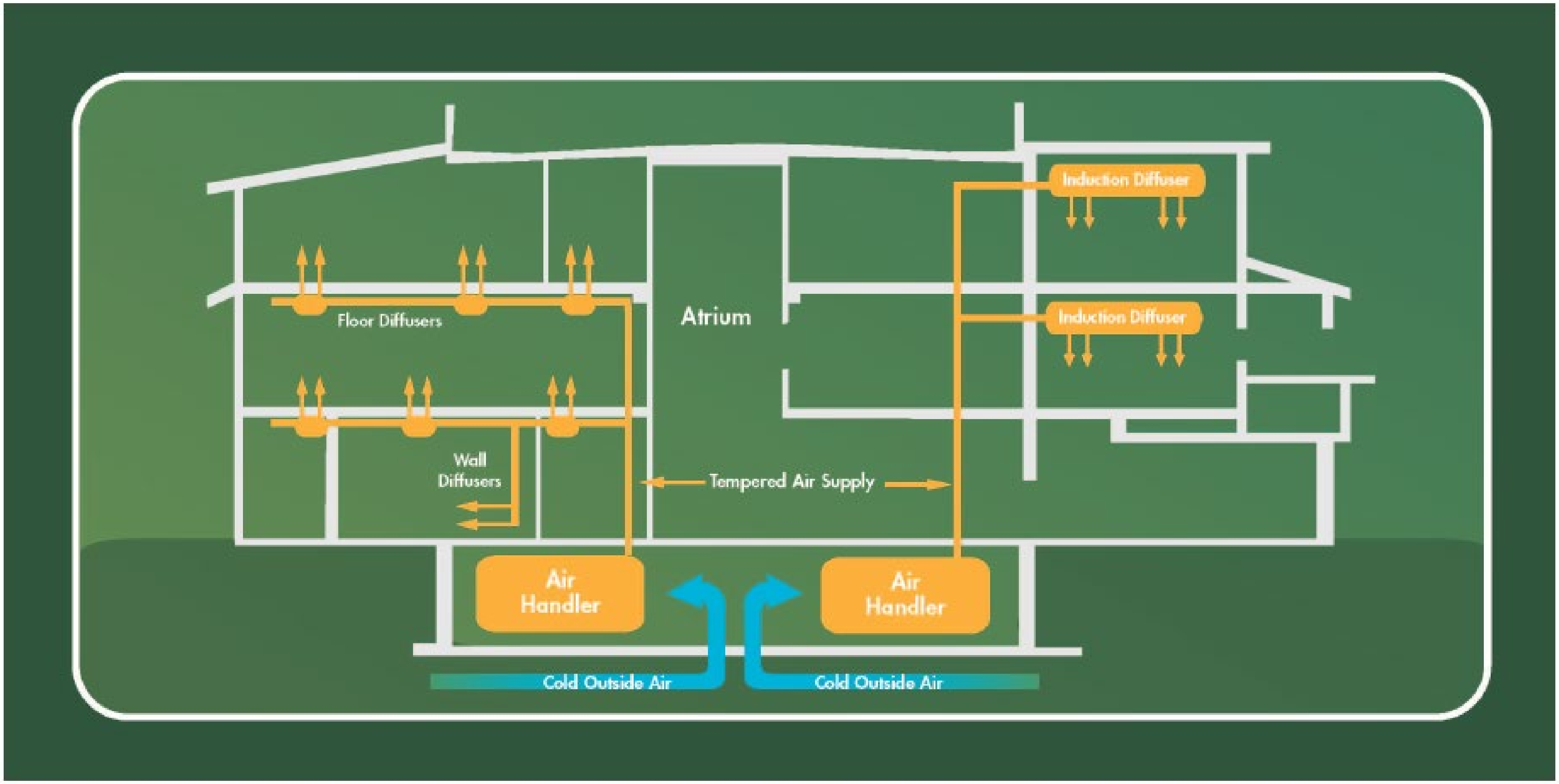
Air Handler (Basement)

- The heated ethylene glycol flows to the basement to pre-heat the air before it is distributed around the building

Cooled Ethylene Glycol Pipes

- The now cool ethylene glycol goes back to the roof

Ventilation Air Supply



Heating the Building

Gas-powered Microturbine

• Uses natural gas to create electricity

• Provides electricity to the building when solar panels not enough

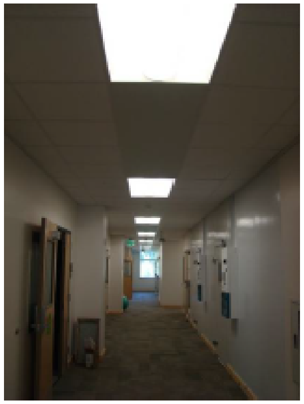
• Generates heat energy

Co-generation Unit

• Captures heat from generator and transfers it to water

Water Storage Tank
• This insulated tank stores heated water before it is circulated through the building

Gas Boilers
• Two gas boilers can be used to supplement heat supplied by the cogeneration system

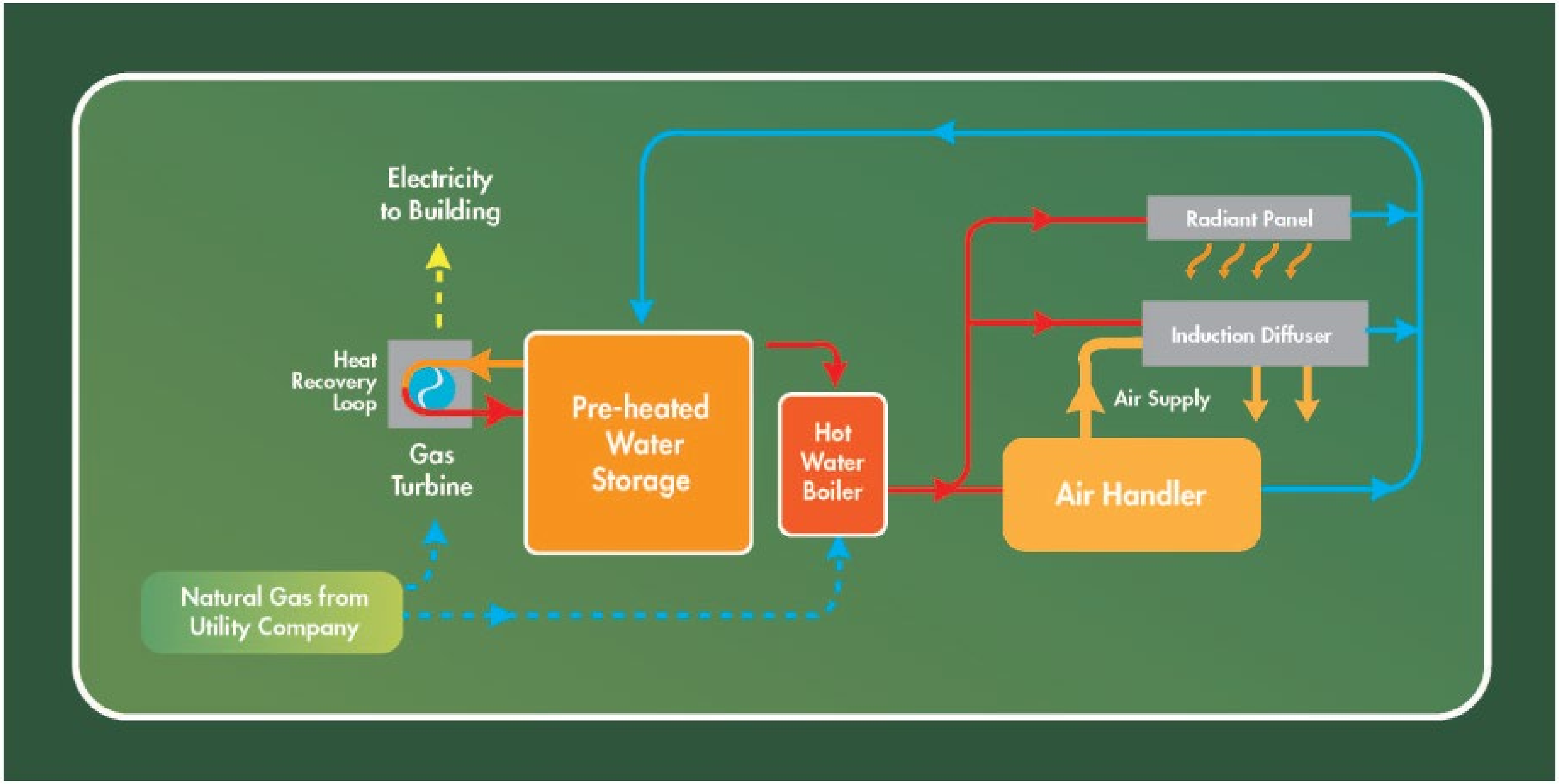


Radiant Panels (ceilings), Radiant Floors (first floor) and Induction Coils (labs)

• Heat is delivered to spaces through radiant floors in the lobby, radiant ceiling panels in offices and induction coils in the laboratories.

• Pipes in ceilings, floor or labs carry hot or cold water, depending on need

Heating Hot Water



Cooling the Building

Evaporative Cooling Tower
(Trex enclosure)

- Water drips down the tower at night and evaporation cools the water

Storage Tanks
(underground)

- This cooled water is stored in two 25,000 gallon tanks below the manhole covers

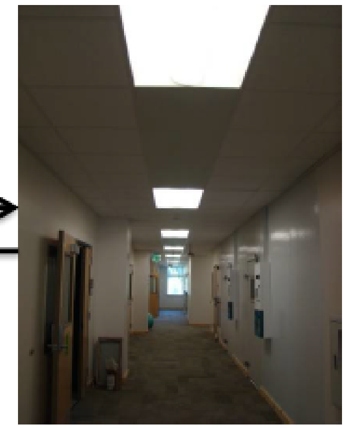
- The water is filtered before passing through the heat exchanger

Heat Exchanger
(HX-1; basement)

- The heat exchanger uses the water from outside to cool water in a second, separate system

Pumps

- A system of pumps moves this cooled water around the building



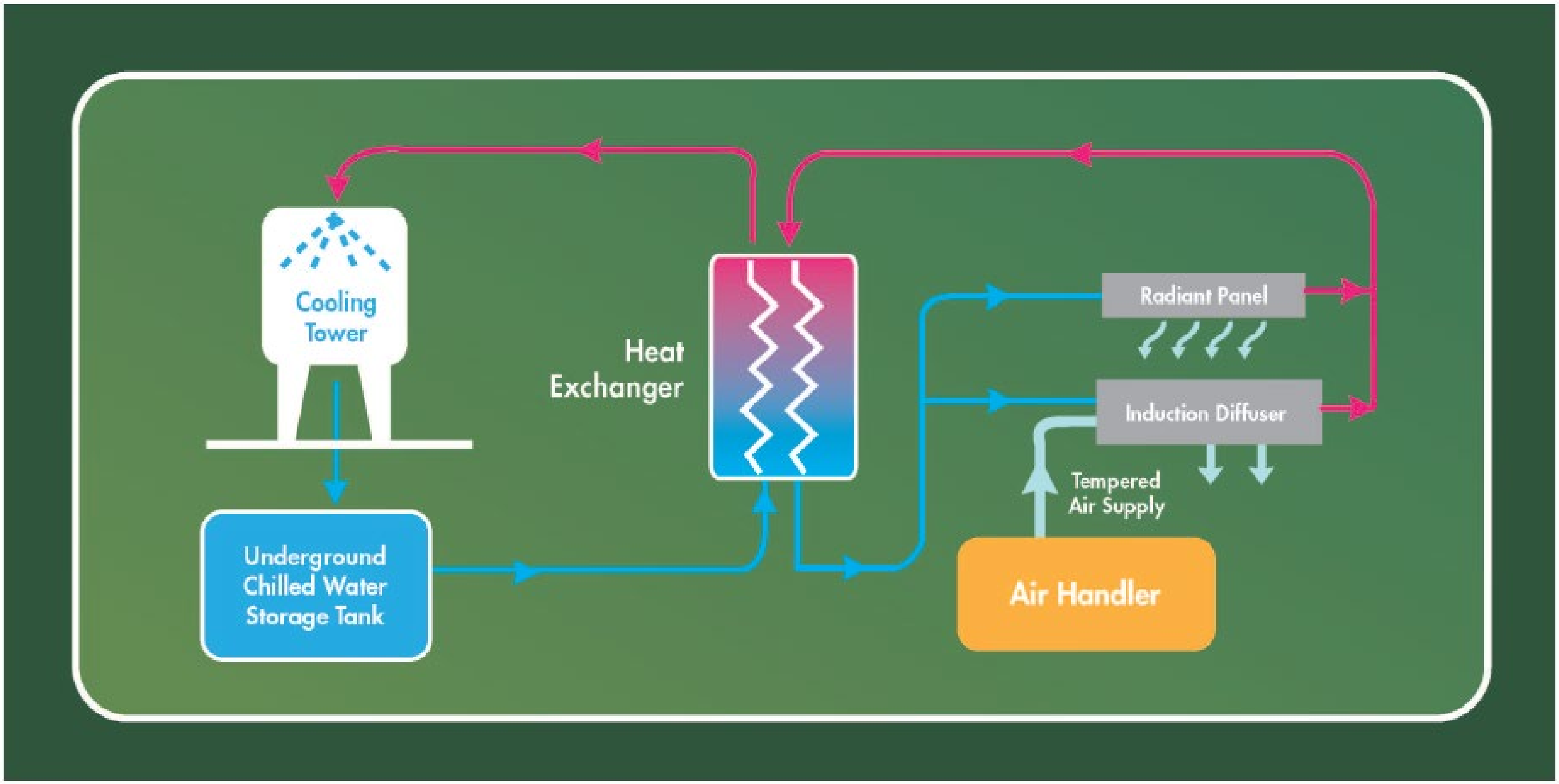
Radiant Panels (ceilings), Radiant Floors (first floor) and Induction Coils (labs)

- Heat is delivered to spaces through radiant floors in the lobby, radiant ceiling panels in offices and induction coils in the laboratories.

- The building has no traditional AC

- This system uses approximately 5-10% of the energy of a traditional AC system

Chilled Water



Using Rain and Snow

TCES Roof

Storage Tank
(SWT-1; basement)

• Rainwater and snowmelt from the roof is collected in the 3000 gallon tank

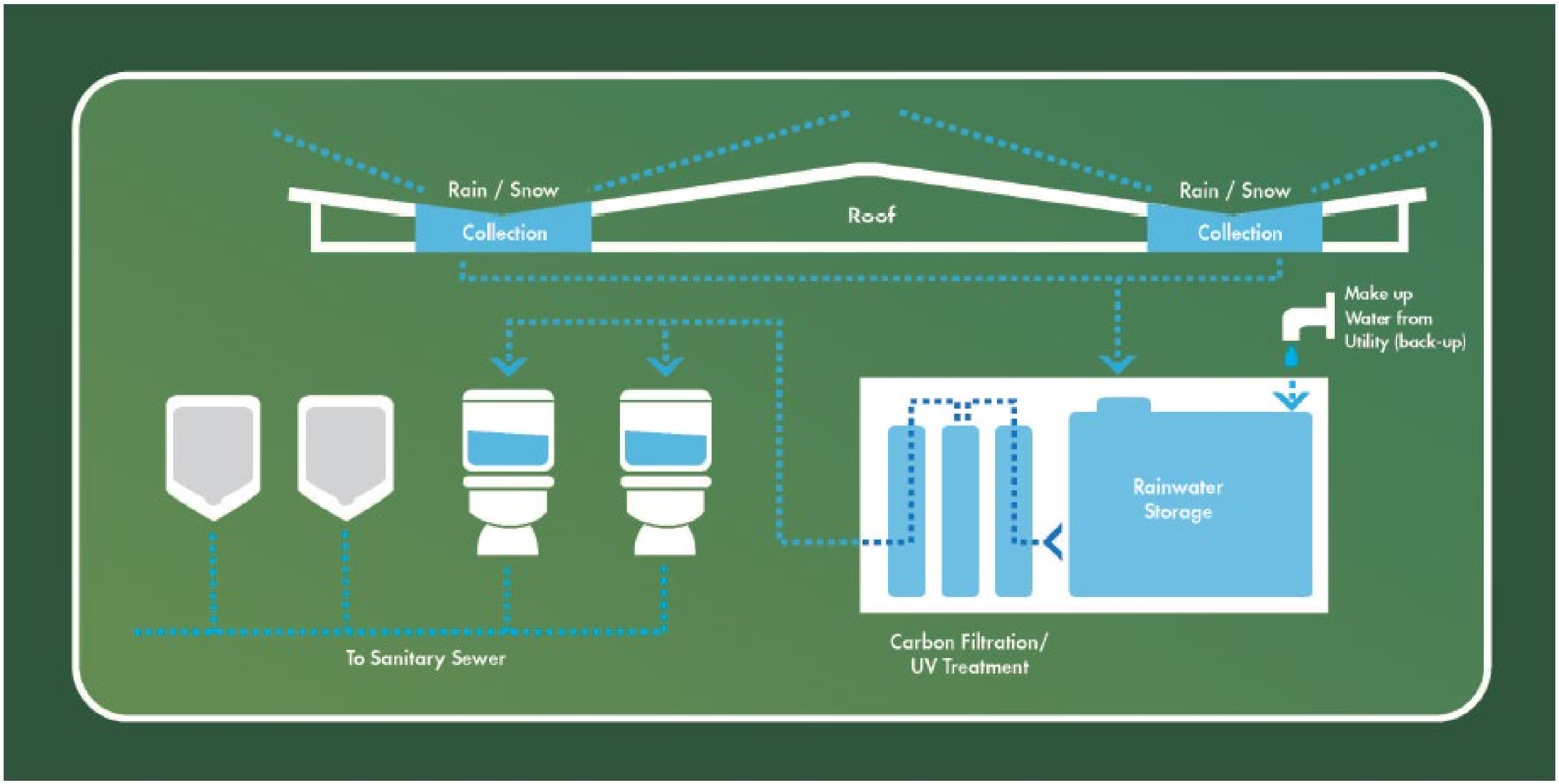
Filtration

• The water is pressurized and passed through carbon (right) and UV (left) filters

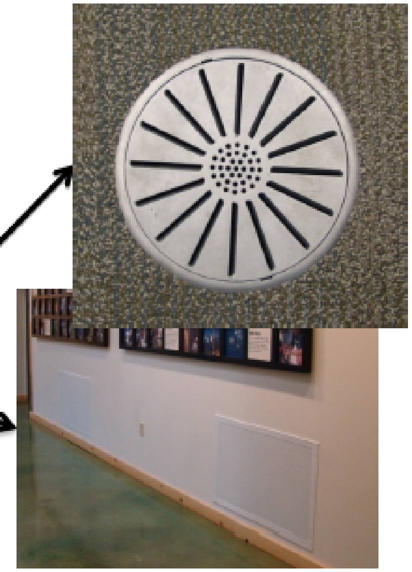
Toilets

• Low-flow, dual-flush (1.6/0.8 gallons) toilets use up to 80% less water than a standard toilet every year

Water Capture System



Air Handlers



Plenum
(basement)

• Brings fresh air into two separate air handlers: one for domestic and one for Industrial (laboratory)

• 100% fresh air is constantly circulating in the building

Filter and Humidifier
(basement)

• Filters out particulates (dust, pollen, etc.)

• Humidifies the air for occupant comfort

• Air is also pre-heated before being circulated (see Heat Recovery System)

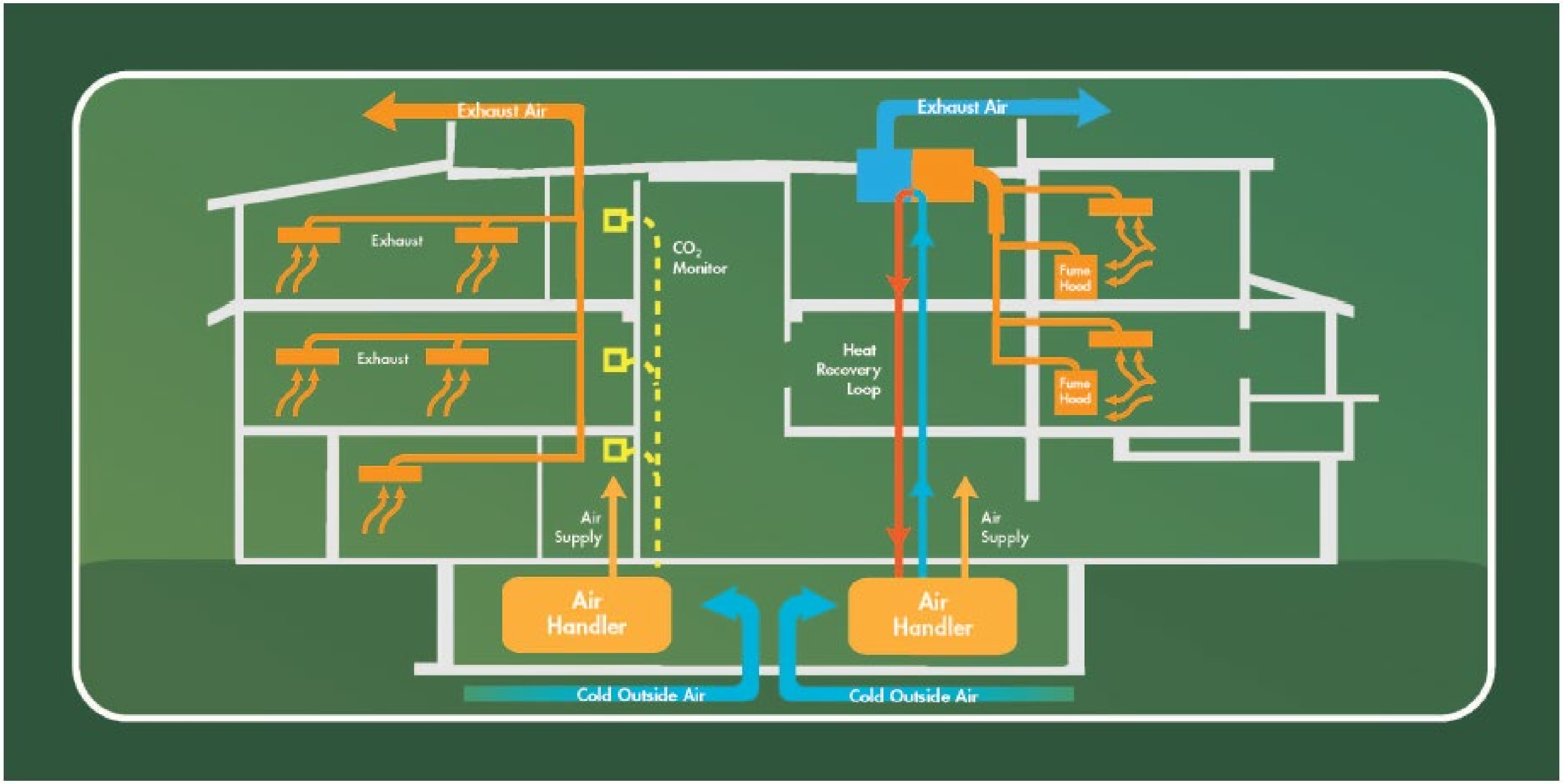
Diffusers
(floors and walls)

• Diffusers are located in the lower wall on the 1^{st} floor and in the floor on the 2^{nd} and 3^{rd} floors

• Air is exhausted through vents in the ceiling

• Cross-room flow avoids stagnant air spots

Air Vents


Exhaust Air
Exhaust Air
Exhaust
Exhaust
CO2 Monitor
Heat Recovery Loop
Fume Hood
Fume Hood
Air Supply
Air Supply
Air Handler
Air Handler
Cold Outside Air
Cold Outside Air

Photovoltaic Energy

Photovoltaic Solar Panels
(roof)

• 875 panels on the south facing side of the roof collect solar energy during the day

Photovoltaic Panel Inverters
(basement)

• These blue boxes convert the direct current (DC) from the solar panels on the roof into alternating current (AC) – the kind of electricity in your home

Electric Generation