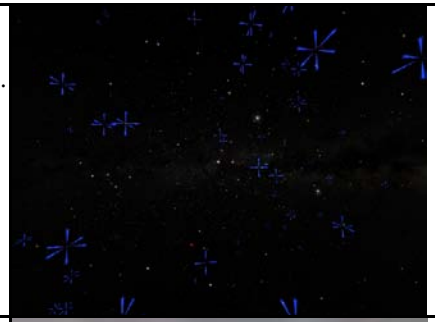
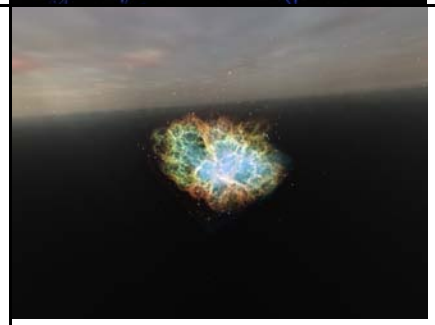
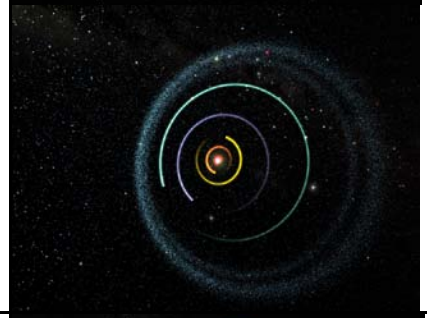
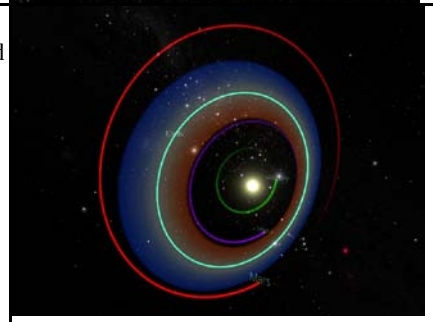
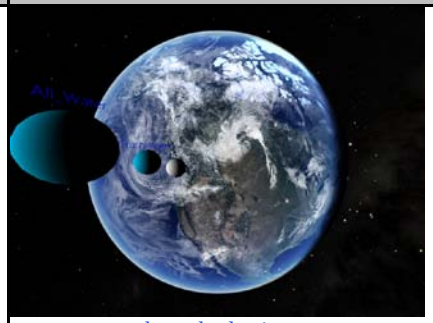
Issues of Today: A GLOBAL WATER STORY
Storyboard for Distribution for the Denver Museum of Nature & Science's Worldviews Network Water BCD

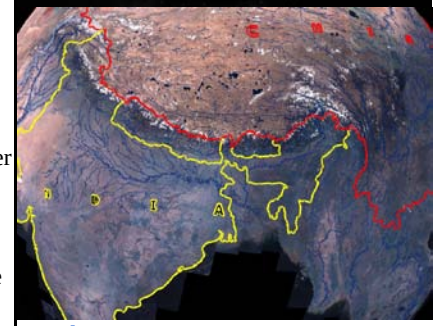
Scene	Narrative	Uniview Command	Visual (File name; hyperlink to FTP location)	Literacy Principle (C = Climate; ES=Earth Science)	Citation/Link
01	**1. COSMIC SCALE** (10 Minutes)				
01A	• **Discussion of Earth in a cosmic context.** We start off at the surface of the Earth, looking up into the summer night sky. This is something our species has done for hundreds of thousands of years. Unfortunately in modern society where electric lights have erased the dark, many of us are unfamiliar with the night sky, and have lost connection to the patterns of the cosmos. But that certainly wasn't the case in the past. Our ancestors looked to and understood the sky. They knew about the cycles that were important to life: the motions of the Moon and Sun, the marking of the passage of the seasons; celestial events to tell them when to plant, to harvest, and when to follow the migration of animals. They told stories to one another, to pass on the knowledge of the sky. As we sit here today, we are continuing that tradition, by sharing my knowledge about the cosmos with you. • **Summer Triangle** Above we see the Summer Triangle, marked by the brightest stars in what we know now as the constellations of Cygnus the Swan, Aquila the Eagle, and Lyra the Lyre. • **Lascaux depiction** But there's evidence that this and other patterns in the sky were noted by early humans long before the advent of agriculture. The earliest art-science collaboration could be from 17,000-20,000 years old from the Lascaux caves in France, with a depiction of the Summer Triangle as well as the constellation of Taurus.	**Custom Events:** • *00_Start*: Turn on time to show nightly motions while talking sky cycles. • *01_Lascaux*: Reset time. • *02_Lascaux*: Turn on Lascaux object. • *03_Pivot_Stars*: Turn off Lascaux			Lascaux outlines based on Rappenglück, M. (2002). The Milky Way: Its Concept, Function and Meaning in Ancient Cultures. In T. Potemkina & V. Obridko (Eds.), Proceedings of the Conference "Astronomy of Ancient Civilizations" of the European Society for Astronomy in Culture (SEAC) associated with the Joint European and National Astronomical Meeting (JENAM), Moscow, May 23-27, 2000 (pp. 270–279). Presented at the Astronomy of Ancient Civilizations, Sternberg Astronomical Institute, Moscow, Russia: Mockba Hayka.

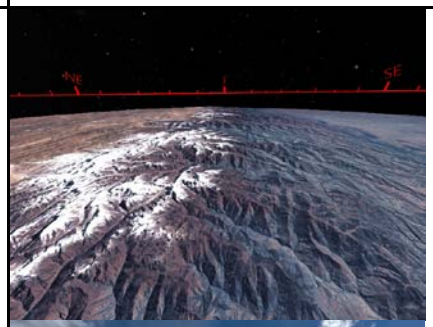
01B	**A view of the Night Sky: Where are we?** ● **Studying sky across electromagnetic spectrum** In the modern era, not only have we continued to look at the sky, but we have used our latest tools to help us build a three-dimensional atlas of the Universe to allow us to understand it better. Technological advances allow us to probe the electromagnetic spectrum beyond what is visible to our eyes. It is with these detectors that we find other connections with the cosmos. In visible light, our Milky Way Galaxy, home to our Sun and hundreds of billions of other stars, appears as a bright band, broken up by dark dust clouds in the foreground that block star light in the background. If we switch to viewing the sky in the near-infrared, the obscuration becomes transparent in many places. We can peer right through many of these gas and dust clouds, to see the band of stars that lay beyond. As we continue into the far infrared, the stars completely disappear since they emit little light at these wavelengths. Because they are relatively cold, the dust and gas clouds themselves start to glow in the far infrared. ● **Our origins from star stuff: Molecular clouds** We have learned that the cores of these clouds can collapse and form stars. It's from something like these that our Sun and its family of planets was born 4.5 billion years ago.	**Custom Events:** ● *04_2MASS*: Turn on near-infrared 2MASS all-sky. ● *05_IRAScomposite*: Turn on mid- and far-infrared IRAS all-sky. ● *06_FIR*: Turn on IRAS far-infrared all-sky.			

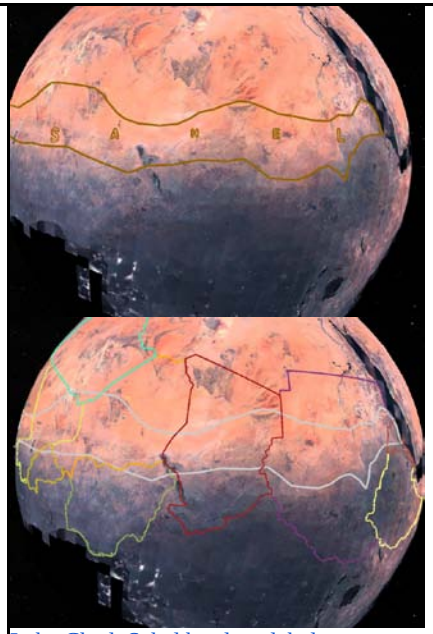
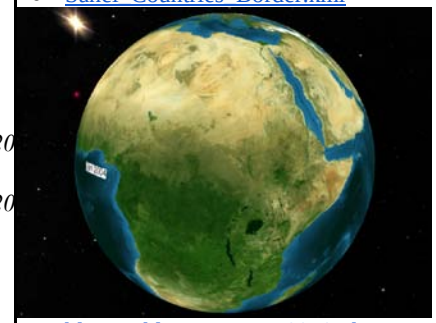
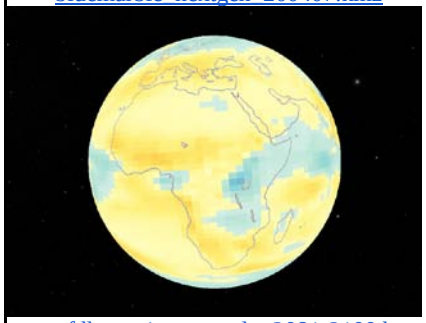
01C	• **Extrasolar planets** We also long believed that the processes that led to the formation of our Solar System was common throughout our Galaxy. In recent years, we have confirmed this with the discovery of planets around other stars. In the last fifteen years, over 500 planets have been found. Recent news from the Kepler satellite mission has added 1200 new potential planets.	**Custom Events:** • *07_Visible*: Turn back on visible Milky Way; turn off all other layers. Turn on exoplanets.			
01D	• **Supernova remnants** Our connection to the cosmos is not only through star birth, but also via the death of stars. Here is the Crab Nebula, the remnant of a supernova that was observed by Chinese and Arab astronomers in 1054 AD. A supernova is the explosive death of a massive star. Except for hydrogen and helium, almost every other element has been forged inside a star. This includes the carbon, oxygen, and nitrogen that are found in organic molecules, and every other element heavier than those. Supernovae explosions disperse these elements across the galaxy, where they can become incorporated in the next round of star and planet formation. We and everything we are familiar with are literally made up of star-stuff, elements that have been processed in the interiors of stars.	**Custom Events:** • *08_Target_Crab*: Turn camera lock to Crab Nebula. • *09_Crab_CloseUp*: Fly up to Crab Nebula.l			
01E	• **Distance to Exoplanets** We fly back toward the Sun. As we do so, we note that these exoplanetary systems are vastly farther than any other place we've sent spacecraft to. At our current technology, it would take tens to hundreds of thousands of years to send a robotic probe to the nearest stars. It could be hundreds of years before it is even technologically and energetically feasible for us to develop probes to reach the nearest star within a human lifetime.	**Custom Events:** • *10_SolSystem*: Set target to Solar System.			

01F	• **Water in the Solar System** As we near the Sun, we fly through the Oort Cloud, a spherical shell of several trillion icy comets. Then we see the Kuiper Belt, a toroidal band of several billion icy bodies that lie outside the orbits of Neptune and Pluto. These are the remnants of planet formation, leftover debris from the early Solar System. These bodies, along with many icy moons of the outer planets, contain substantial amounts of water – more than 99% of the water in the Solar System. But the water here is frozen, and inaccessible to life.	**Custom Events:** • *10_Exo_OFF*: Turn off exoplanets; manually fly up to Oort Cloud, and then Kuiper Belt.	 		
01G	• **The Habitable Zone** When we get into the inner Solar System, we see a visualization of its habitable zone, the region where liquid water can exist on the surfaces of rocky planets. Note that the Earth is right in the middle of the zone. We think that Earth, Mars, and Venus actually started with similar conditions early in the Solar System's history. However Mars' and Venus' locations at the outer edges of the habitable zone has allowed both of them to dry out. Mars has evolved into a cold dusty desert world, while Venus has a surface hot enough to melt lead. Both planets are places that we have sent robots to explore. Perhaps people will travel to explore Mars as well in coming decades. But even it is too inhospitable. Colonization could be possible for no more than a few people, and at immense expense.	**Custom Events:** • *11_HZ*: Turn on habitable zone, and leave inner planet orbits on. • *12_HZ_OFF*: Turn off habitable zone and inner planet orbits; manually fly up to Earth.		ES 2.5 ES 5.2	

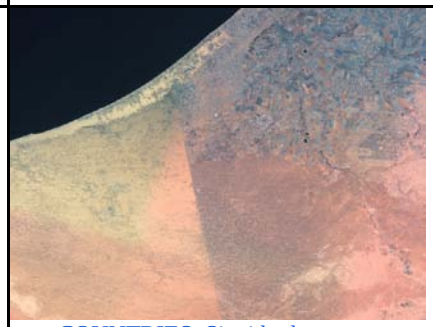
01H	• **Earth is in the magic place for liquid water** Our voyage through the cosmos returns us back to the Earth, a blue marble that is an island in the sea of space. It has just the right conditions, with sufficient water, atmosphere, and active geology that has allowed life to evolve, persist, and thrive for billions of years. It has been, and for the foreseeable future, will be our only home in the Universe. We are part of the first generation to be able to view the Earth in total from the vantage point of space. We are also the first generation to have satellites orbiting in space, and observing the Earth across the electromagnetic spectrum. Our spacecraft can look out to study the rest of the Universe, and help us understand our place in it. But they can be turned to look in as well, to allow us to better understand the interlocking systems of our home world, from the atmosphere to the oceans, the flows of water and rock, the cycles of biology and climate. And increasingly, our species' growing impact on our world.			CL 3E ES 3.1 ES 5.1	
02	**2. GLOBAL SCALE** (15 Minutes)				
02A	• **Earth is the Water Planet but water is not evenly distributed** If a gallon represents all of the water on the Earth, then 3 shot glasses worth is all of the freshwater. However that shot glass has two ice cubes locking up two thirds of the freshwater. Of the remainder, much of the water is subterranean. The accessible surface water is equivalent to a single M&M. We are going to give you an entire presentation about that M&M of liquid fresh surface water. We are going to talk about its distribution on the surface of the planet, from a continental scale, from a regional scale in the western part of North America, and then in our home region in Colorado and the Rocky Mountains. The primary message is that the freshwater is not randomly distributed: it is in patterns that we can understand and through our knowledge and our insight, we can better understand its distribution and make better use of it.	**Custom Events:** • *15_Water_ON*: Turn on water spheres. • *15_Water_OFF*: Turn off water spheres.	 • water_sphere_kmls.zip	ES 5.2 ES 5.8 ES 7.4	Water sphere visualizations created by Ka Chun Yu.

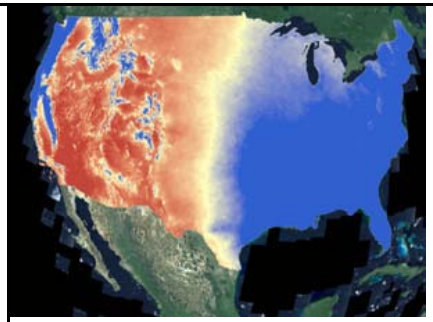
	• **Distribution of water on Earth controls distribution of life** We don't live in the oceans. Not in the deserts, nor the poles. We actually live in a narrow range of habitats on the surface of the Earth, as well as within a narrow range of altitudes. (We don't live in the clouds either, or at the top of the Himalayas.) In fact the habitable zones of the Earth are small, and precious. Each one of them has a supply of potable water.				
03	**3. CONTINENTAL SCALE** (15 Minutes)				
03A	**ASIA** • **Distribution of water** We see the sub continent of India below, the main Tibetan plateau up at the top with the Himalayan mountain chain in between. You can see a fundamental difference in the color of the surface of the earth: much of India, Bangladesh, indo-China, and much of the south China plain is in blues and greens in strong contrast with the Tibetan plateau and the Taklimakan desert up to the north. The difference of course is the presence of vegetation. Vegetation is a proxy for the presence of water. The vegetables grow where the water is and the people live where the vegetables are. At this distance from the Earth, you can start to see something like the habitable zone mentioned earlier is present here on Earth as well. There are places on Earth that are habitable, meaning you can live there, and places on Earth that are inhospitable, or almost uninhabitable. There are people that live in Tibet of course but not very many. I've walked around parts of Tibet and it is a broad windswept plain with very few people because the conditions are harsh and fresh water is very sparse and not available. Many of these lakes up here are brackish water. • **Monsoons and River Drainages** The mountain tops are highlighted by white snow. The warm moisture laden air comes off the Indian ocean in a monsoonal pattern and crosses the India sub-continent. As that moist air cools it rains and as those moist air bodies move up towards the north they produce snow on	**Geoscope:** • *Himalayan_Streams.kmz* to turn on all streams from rivers originating from Himalayas. • *Basin_Ganges.kmz* to turn on basin boundary for Ganges River. • *Ganges021.kmz* to turn on Ganges River streams. • *Basin_Brahmaputra.kmz* to turn on basin boundary for Brahmaputra River. • *Brahmaputra021.kmz* to turn on Brahmaputra River streams. • *Basin_Indus.kmz* to turn on basin boundary for Indus River. • *Indus021.kmz* to turn on Indus River streams. • *Yellow021.kmz* to turn on Yellow River streams. • *Yangtze021.kmz* to turn on Yangtze River streams. **Custom Events:** • *16_Asia*: Jump to position over Asia. • Click on *planetFXtoggle* to make Earth visible since we're on nighttime side.	  Himalaya Rivers KMLs: • Himalayan_Streams.kmz • Basin_Ganges.kmz • Ganges021.kmz • Basin_Brahmaputra.kmz • Brahamaputra021.kmz • Basin_Indus.kmz • Indus021.kmz • Yellow021.kmz • Yangtze021.kmz	ES 7.4	River data from Natural Earth.

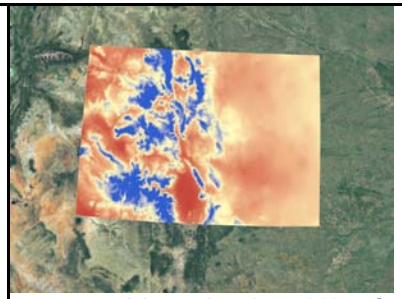
	the Himalayan mountains. The snow pack is the water storage and it feeds some of the major river systems in the world that have their sources in the Himalayas. The Indus river drains down through Pakistan down through Karachi. The Ganges river system has tributaries flowing across the Ganges plain out to the Indian Ocean. The Brahmaputra river shows up in orange which comes across the northern part of the Himalayas, flips around comes down through India and joins the Ganges and drains into the Indian Ocean. Then we also have the major rivers of China: the Yangtze river system and the Yellow river system that have headwaters up in the eastern most part of the massifs. Huge numbers of people, in excess of 1.2 billion people, in the subcontinent, in excess of 1.3 billion people in China live in these drainages that come off the Himalayas.				
03B	● **Landing at Everest, melting glaciers** We are standing at the foot of Mt Everest, and its adjacent high peaks. You can see the glacial masses literally pouring off these mountains, coming down to the foot of the mountains and they are actually melting. You can see the water pools at the foot of the glaciers and these are some of the headwaters of some of the river systems that we have been talking about. Not just here but worldwide, the glaciers are shrinking as it gets warmer. The high mountains are not really effected above certain levels but lower parts of the mountains are starting to feel the effect of warming. Historical photographs taken over the last 50 – 60 years show not only retreat of the noses of these glaciers, but their dramatic deflating effectively as they melt and lose mass. So as the world warms we lose some of our stockpile of fresh water that has been frozen in the mountain massifs. Here in the case of the Himalayas not terribly significant in the near term because there is an awful lot of ice up there. But if you go to the Andes Mountains in South America, there are serious issues with the melting of the glaciers that are providing the drinking water for cites like Lima, Peru and La Paz, Bolivia.	**Object Tree:** ● *Earth→Tito Dupret→Kala Patthar* to turn on Everest panorama. **Custom Events:** ● *16_Everest_0*: fly to surface. ● *17_Everest_1*: fly into panorama.	 ● Kala Patthar Everest Panorama PNG	C 4D C 7B	Panoramic image provided by World Heritage Tours, copyright Tito Dupret.

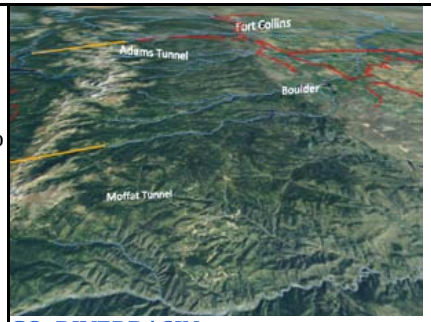
,03C	**AFRICA** **Sahara, desertification** As we cross western Asia into the Middle East and northern Africa, note how dry it is in this area, including Afghanistan, Iran, southern Kazakhstan, Iraq, Saudi Arabia, the Emirates, and in Oman. These are areas that are brightly colored because they're reflecting solar radiation, and there's little or no vegetation to absorb it. The water distribution in these areas is extremely localized. For example, the Nile River is the source of water for Egypt. It has its headwaters in the Ethiopian plateau with the Blue Nile providing the lion's share of the water. The Blue Nile flows down, meets the White Nile at Khartoum and then they flow together with almost no tributaries whatsoever into the nation of Egypt where it provides the sole source of water for 80 million people in this region. The challenge that the people face in these countries is that their demand for water is going up as their populations go up and their supply of water is relatively limited and finite. The countries of Ethiopia and Somalia are in the Horn of Africa. This is a land that is harsh. and dry. The people live by agriculture and by fishing. There is a finite water supply on land. There is finite fish in the sea and a lot has been caught by foreign trawlers and deep marine fishing vessels. These are the people that have turned to piracy as a way of making a living and the people from Somali have emanated from the east coast and captured ships as far away as the Pakistani coast up to the north and Madagascar to the south. The lifestyle of the people in these regions that we are looking at is impacted strongly by the availability of resources, in this case water on land and fish off-shore. **Sahel: Seasonal rainfall, vegetation as proxy** The Sahara desert forms the bulk of northern Africa and the Congo basin, a green and vegetated area, forms the bulk of central Africa. The transition between dry in the north and wet in the south is often call the Sahel. It represents the southern fringe of the Sahara desert. The Sahara has been expanding through time. There is 22 million people that live in the vicinity of Lake Chad and the broader area.	**Geoscope:** ● *LAKE_Chad.kml* ● *TEXT_Sahel.kml* ● *BORDER_Sahel.kml* ● *Sahel_Countries_Border.kml* **Custom Event:** ● 17_BluMarble ON **Object Tree:** Toggle between ● *Earth→GeoLayers→bluemarble_20 0401* ● *Earth→GeoLayers→bluemarble_20 0407* **Custom Event:** ● *17_BluMarble OFF* **Object Tree:** Toggle on/off ● *Earth→GeoLayers→gfdl_precip_2 081-2100* **Custom Event:** ● *17_Precip ON* **Custom Event:** ● *17_Precip OFF*	 Lake Chad, Sahel borders, labels: ● LAKE_Chad.kml ● TEXT_Sahel.kml ● BORDER_Sahel.kml ● Sahel_Countries_Border.kml  ● bluemarble_nextgen_200401.kmz ● bluemarble_nextgen_200407.kmz  ● gfdl_precip_anomaly_2081-2100.kmz	C 7B C 7C C 7F ES 7.4 ES 7.5	Country borders from KMLfactbook.org. Physical outline borders by Ka Chun Yu. Next Generation Blue Marble GFDL CM2.1 model (using IPCC SRES A1B scenario where CO2 levels increase from 370 to 717 ppm) showing 20-year average precipitation projected for 2081-2100 minus the 1951-2000 fifty year average. Blue areas are projected to see an increase in annual precipitation amounts; brown areas are projected to receive less precipitation in the

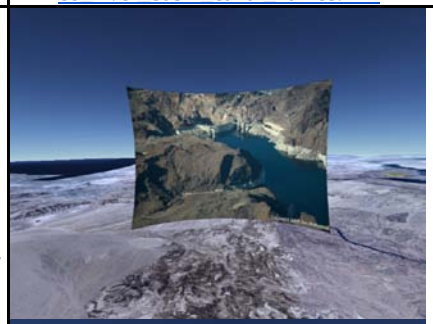
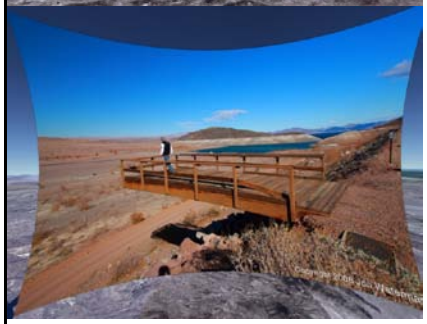
	These people are struggling as it gets dryer. One of the things happening as the world gets warms is the areas that are dry are getting dryer. Some of the areas that are wet tend to get wetter but the drier zones are anticipated and shown by computer models to get increasingly dry. Here is a computer model illustrating with yellow color the areas that are going to get drier by the year 2100. You can see there might be some additional moisture in the central African rift valley lakes area around Lake Victoria, but much of the Middle East, much of the Sahel area of southern Sahara are anticipated to get dryer. • **Darfur, Lake Chad** This is an area that is not very industrialized; the people live a rural lifestyle and there are two different lifestyles. There are the sedentary people that try to make a go of farming or in some cases actually fishing in Lake Chad. These people stay put and grow crops. Other people live nomadic existences. They are typically the herders, with sheep or cattle or even camels. The nomadic people live a very different lifestyle then the sedentary people. One of the causes for conflict in the Darfur area, in southern Sudan, is the conflict between the sedentary people and the nomadic people. When there is abundant rainfall and abundant vegetation, farmers can grow their crops just fine and the herders can herd their animals which graze on the hillsides. But as it gets drier you can imagine what happens. The animals that are herded are tempted to chew on the shrubbery in the peoples fields. So there is conflict in the lifestyle of the nomadic people and the sedentary people in these drier areas. There are other issues as well and I don't want to oversimplify it. These include culture, religion, and tribal issues in Darfur. If it would just rain more and if we just had more water, some of the problems that the people face in Somalia, Ethiopia, Darfur, and central Chad would be alleviated. When I was a student in Ethiopia in the 1970s, there were famines and people would often go to a refugee camp nearby. A lot of them would suffer and often die in				future. Prepared by Ned Gardiner.

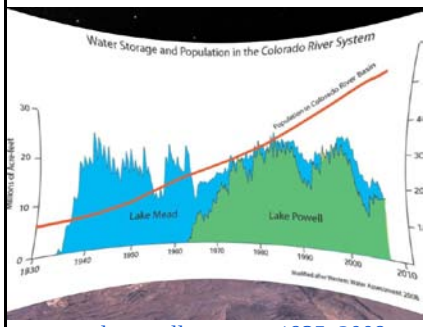
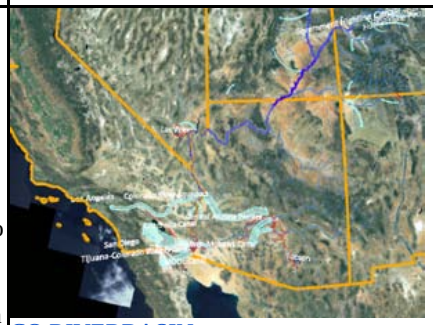
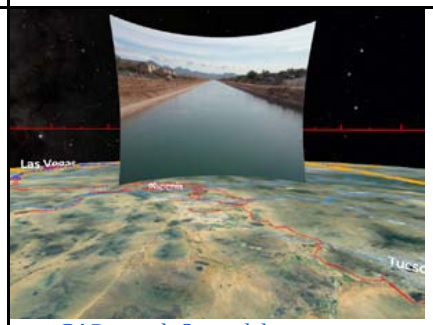
	place. That's not happening anymore as much. People are more connected, via social media, the Internet, and other communications. People are moving now, whereas before they may have been unable to extract themselves from difficult conditions. Today these people are migrating, with broad scale migration happening out of these areas of hardship where there is inadequate water supplies into areas where there is more water. The people's lifestyle is being modulated across this part of the world by the availability of water. People are moving away from the dry areas towards the wetter areas. This brings with it a variety of conflict as you can imagine. The distribution of water in this part of the world critically controls people's lives. We are going to see more of that.				
03D	**MIDDLE EAST** ● **Land Use Management: Impacts from over-grazing** Here is the border between Egypt and Israel, with the Sinai peninsula of Egypt on the left and the Negev desert of southern Israel on the right. There is a fence on the border: I stood on one side of that fence and went across. On the ground you can hardly see a difference but from space you can really see a stark difference, due to grazing differences. People in the Sinai, the Bedouin people in Egypt, have goats and they graze very heavily. The more goats you have the wealthier you are, and the more goats you have, the more grazing there is. You graze to a point where there is hardly any vegetation left. However if you cross the fence, there is a very different lifestyle with mechanized agriculture, where much of the population are urban people, and where technology is being used to maximize the water – a point we will come back to at the end of the presentation. You can see from space the fundamental difference in the reflectivity of the earth's surface associate with land use practices.	**Geoscope:** ● *COUNTRIES_Sinai.kml*: to turn on Egypt and Israel borders. **Custom Events:** ● *17_SinaiBorder0* for medium distance view. ● *17_SinaiBorder1* for up-close view.	 ● COUNTRIES_Sinai.kml	ES 9.5	Country borders from KMLfactbook.org.

03E	**NORTH AMERICA** ● **Distribution of Rainfall** As we cross the Atlantic Ocean, patterns in North America on a continental scale set the stage for our later analysis of our own region. The North American continent is relatively bright in the west and relatively darker in the east. The eastern area is vegetated and is green. In the west there is vegetation, mostly on the high mountains. The Colorado plateau, much of Nevada, Southern California, and Northern Mexico are very arid with colors that are not unlike colors we just saw in the Sahara desert. In the rainfall map, the blues represent high rainfall and the reds and yellows represent low rainfall. We use this just to stress the fact there are really two halves to the continental United States. The eastern side tends to be relatively wet.. The part from the 100th meridian west tends to be relatively arid with the exception being the mountain tops. Not unlike what we saw in the Himalayas, the moist air is coming off the Pacific Ocean, comes across the western part of the US and snows heavily in the mountains, including the Yellowstone Plateau, the Wind River Mountains, the Colorado Front Range, and the San Juan Mountains. ● **Diminished snow storage** About 80% of our moisture is received as snowfall upon these mountain peaks. The bulk of the moisture comes in the winter time, accumulates as snow, where it is effectively stored for us. One of the challenges that we face as it gets warmer is that the amount of snow is going to be diminished. We are going to get more of our fall moisture as rainfall. Our late winter moisture and spring is going to come as rainfall. There is concern that the snow is going to melt more rapidly as it gets warmer. The computer models suggest that there is going to be less surface water available in the river systems because of increased evaporation. These models suggest we could see a 10%-15% diminution of water in the Colorado river system.	**Geoscope:** ● *PrecipNA_PRISM1971-2000v.2.kml*: to turn on North American precipitation map ● *100west.kml* to turn on 100th meridian	 ● PrecipNA_PRISM1971-2000v.2.kmz ● 100west.kml	C 7B	Derived from, US Precipitation annual average 1971 - 2000, PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 31 October 2008. Image created March 2011 by Lindsay Irving.
04	**4. STATE AND CATCHMENT SCALE** (15 Minutes)				

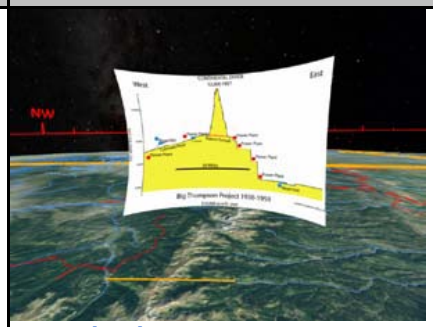
04A	**Colorado's Water** ● **80% of Surface Water West of the Divide** ○ **Orographic effect, mountain storage** ○ **Continental Divide** ○ **Colorado sheds (and shares) water in all directions** Here we're looking at the state of Colorado using the same color code where the red's are dry areas of very limited rainfall. The slightly yellowish areas are more like we're living up here in Denver, where we get about 14 inches of rainfall. The continental divide, the middle of the Rocky Mountains, runs through the blue regions, with the rivers to the east – the South Platte and Arkansas River systems – flowing into the Mississippi drainage to the right, and areas to west flowing into the Colorado and Gunnison river drainages to the left. The bulk of the moisture is accumulating in those high peaks, with 80% of it in Colorado falling to the west of the continental divide. The people in general live on the east side of the continental divide, along the Front Range ranging from Fort Collins in the north down to Colorado Springs and Pueblo to the south. ○ **Surface water renewable** ○ **Groundwater 30,000 years old**	**Geoscope:** ● *PrecipCO_PRISM1971-2000v.2.kml*: to turn on Colorado precipitation map. ● *CO_Counties.kml* to turn on county map of Colorado. ● *CO_Cities.kml* to turn on major cities in Colorado. ● *CO_14ers.kml* to turn on major 14,000+ foot peaks in Colorado.	 ● PrecipCO_PRISM1971-2000v.2.kmz Colorado borders and places KMLs: ● CO_Counties.kml ● CO_Cities.kml ● CO_14ers.kml		Derived from, US Precipitation annual average 1971-2000 derived from, PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 31 October 2008. Image prepared by Lindsay irving, March 2011.
04B	● The COLORADO RIVER SYSTEM ○ Source in Colorado ○ Flows from water rich to water poor states ○ Water arrives as Snow (80%) Turn on city labels. ■ Stored in Mountains ○ Most is used for Irrigation (86%) in Colorado ● User communities span Farmers, Municipalities (6%), Industry, Recreation, and Ecosystems ○ Each contributes to our quality of life as people move to where water is scarce	**Geoscope:** ● *riogrande_watershed_streams.kml* to turn on Rio Grande streams. ● *platte_watershed_streams.kml* to turn on South and North Platte Rivers streams. ● *arkansas_watershed_streams.kml* to turn on Arkansas River streams. ● *co_riverbasin_0.5-500cms.kml*to turn on Colorado River basin streams. ● *CO_headwater_rivers.kml* to turn on only the largest streams for the rivers originating from Colorado. ● *Colorado_Rivers_Stream_Flows.kml* or *CO_Simplified_StreamFlows.kml* to turn on arrows showing stream flows of rivers leaving Colorado.	 Watersheds: ● riogrande_watershed_streams.kml ● platte_watershed_streams.kml ● arkansas_watershed_streams.kml ● CO_headwater_rivers.kml CO_WATER_FLOWS: ● Colorado_Rivers_Stream_Flows.kml ● CO_Simplified_StreamFlows.kml		Based on Colorado Historic Average Annual Stream Flows map, prepared by the Hydrographic Branch, Office of the State Engineer, Colorado Division of Water Resources. Prepared by Ka Chun Yu.

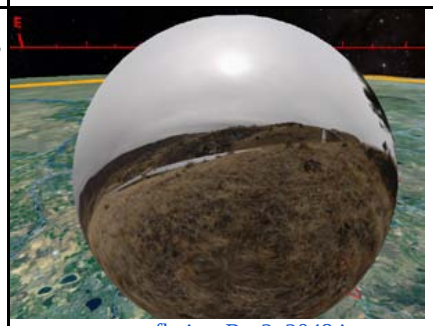
04C	• Infrastructure and Adaptation
	  ○ Regional Trans Mountain Diversions, Canal Systems, Reservoirs
	  ○ Legal systems allocate use
	  ■ Prior Appropriation
	  ■ Requirement for beneficial use
		Geoscope:
		• *natgeo_WaterInfrastructure.kml* to turn on man-made pipes and canals within the Colorado River Basin.
		• *co_river_basin_canal_names.kml* to turn on names of man-made pipes and canals.
			
			CO_RIVERBASIN:
			• natgeo_WaterInfrastructure.kml
			• co_river_basin_canal_names.kml
				ES 9.4	Based on National Geographic Colorado Basin_Map. Prepared by Ka Chun Yu.

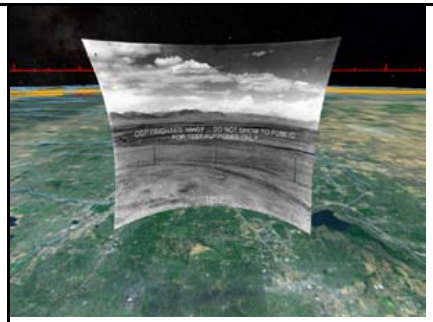
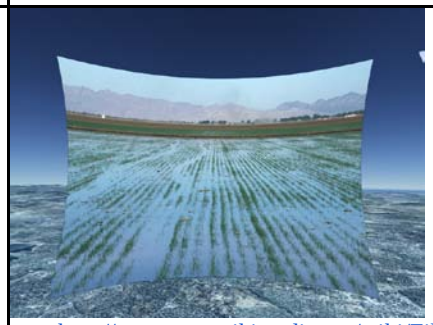
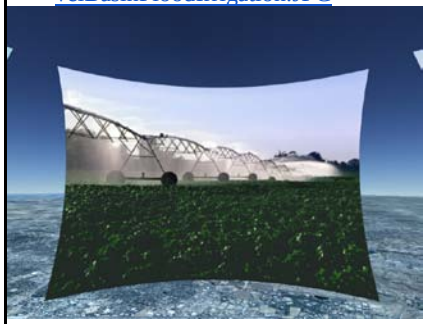
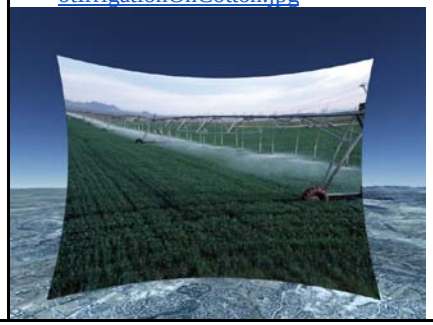
04D	**Colorado River System** • **Impacts of Climate Change on runoff (already past Peak Water)** • **Decreased surface flow (-20 to -40% at Lee's Ferry by 2060)** We store the water in the Colorado river system in two huge reservoirs: Lake Powell in Southern Utah and Lake Mead in Arizona and parts of Nevada. These reservoirs were designed to hold the water and they are hydro-electric projects. The water they hold is precious water: it comes from Colorado but we share it with those downstream states. The Colorado River compact was established based on flow patterns which has been measured at Lee's Ferry for many years. The volume appears to be diminishing through time and some of the people from NOAA suggest we passed peak water in the Colorado River system. The flow rates, which are noisy, vary from year to year, but as you average them though time there is a gradual diminishing of water coming into the reservoirs. The consequence is that the water levels have fallen. If you've been to Lake Powell or Lake Mead recently you'll see a bathtub ring around these reservoirs. This is a picture of Hoover Dam which is located near Las Vegas. If you look at Hoover Dam you will see a white stripe around the reservoir that is Lake Mead. That is where the water used to be. The city of Las Vegas is drilling a new tunnel to get water out of Lake Mead. People will come out to the dock to look for their boat and all they will see is sage brush. • **Lake Mead: bathtub ring, reservoir volumes vs. growing demand**	**Object Tree:** • *Earth→Jon Waterman→Hoover Dam-1: Aerial Shot 2* • *Earth→Jon Waterman→Hoover Dam-2: Bathtub Ring* • *Earth→Jon Waterman→Hoover Dam-3: Dock to Nowhere* • *Earth→Worldviews Network→WVN01 Water(03) Lakes Mead and Powell Annual Volume Flow Rates* **Custom Events:** • *18_Lake_Mead* to fly to Lake Mead bubble slide point.	   Lake Mead and Hoover Dam pics • hoover_aerial_2_640.jpg • hoover_bathtub_ring_640.jpg • dock_to_nowhere_2_640.jpg	C 5C C 6D C 7B	Photographs by Jon Waterman

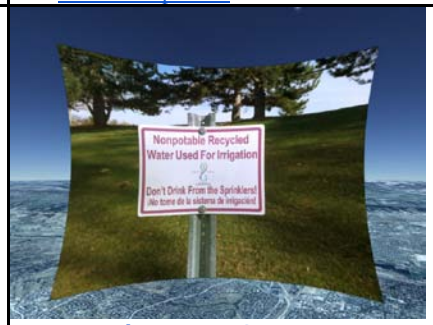
	This graph shows the volume contained in those lakes. In the late 30's we built the Hoover Dam , and filled Lake Mead up. There are variations from year to year, but you can see starting back in 1990 the year 2000 we had a long series of drier years, culminating in the drought of 2002. In this graph, we see an increasing demand for water shown as the red line, due to not only from intrinsic population growth in the Colorado River basin but also from people moving in. The demand is going up at the same time that the water is tending to go down. From our climate models, we are going to see increases in drying in dry areas in the Southwest just like in the Sahara.		 • mead_powell_storage_1935_2008.png		Plot of reservoir volumes derived from Western Water assessment. Prepared by Bob Raynolds.
04E	• **Lower Colorado River Basin** • **Obligations for Mexico's water** At the regional scale, the Colorado River goes down to the Gulf of California. The network of red lines are the artificial canal systems that we have built. The Central Arizona Project brings water to Tucson, and a whole system of canals bring water over to the Los Angeles basin area. The Salton Sea is actually Colorado River water that spilled into a trough. These are areas that have become agriculturally wonderful. Cities have been built based on our engineering and our ability to move water. We are doing something similar to what the Romans did with their aqueducts: we are building a huge canal network here to move water out of the Colorado River to allow the habitable zone to spread into areas like Tucson and Los Angeles. These are areas that wouldn't have the lifestyles we are accustomed to if we didn't have the water, and weren't able to move the water.	**Geoscope:** • *co_riverbasin_0.5-500cms.kml*to turn on Colorado River basin streams. • *natgeo_WaterInfrastructure.kml* to turn on man-made pipes and canals within the Colorado River Basin. • *co_river_basin_canal_names.kml* to turn on names of man-made pipes and canals. • *co_riverbasin_boundary.kml* to turn on boundary of Colorado River basin. • *CO_RiverBasin_Water_Names.kml* to turn on names of water features. • *CO_RiverBasin_States.kml* to turn on outlines of seven states. • *CO_RiverBasin_Cities.kml* to turn on positions of major cities.	 CO RIVERBASIN: • co_riverbasin_0.5-500cms.kml • natgeo_WaterInfrastructure.kml • co_river_basin_canal_names.kml • co_riverbasin_boundary.kml • CO_RiverBasin_Water_Names.kml • CO_RiverBasin_States.kml • CO_RiverBasin_Cities.kml	ES 9.4 ES 9.5	Based on National Geographic Colorado Basin Map.
04F	• **CAP canals** We've got canal systems not only to Las Vegas, but also canal systems out of Lake Havasu which take water to Arizona and to Los Angeles. The red lines are the canals. This picture is one I took a few years ago of the CAP just to show how we move water. I do it because it is frustrating. This picture was taken at the northern edge of Scottsdale just on the edge of Phoenix. It shows the CAP is this huge open ditch that moves water across the torrid desert and	**Object Tree:** • *Earth→Worldviews Network→WVN01 Water(04) CAP Open Air Irrigation Canal* **Custom Events:** • *18_CAP_Canal* to fly to CAP bubble slide.	 • CAP_canal_Scottsdale.png	ES 9.4 ES 9.5	Photograph by Bob Raynolds.

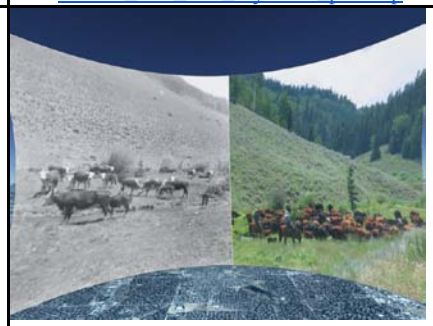
	of course is losing a lot of water through evaporation. It's built as an open ditch because that was the least expensive way to move the water. It may someday come to pass they will cover it and save the evaporation. But right now we are using the water relatively inefficiently. Those of you that are familiar with the cities of Arizona know that we have built them in the desert, with golf courses, artificial ponds, and reservoirs. Some of the water is used extravagantly in some of these areas.				
05	STATE OF COLORADO WATER				

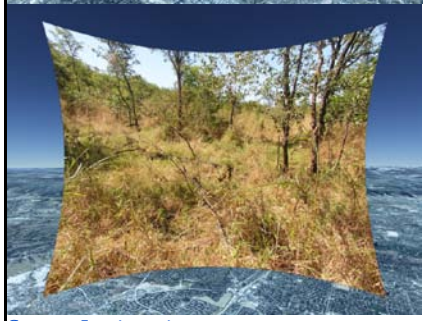
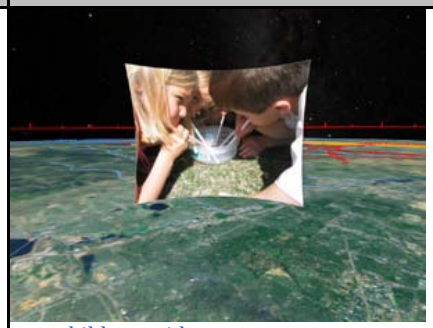
05A	• Historic Activity
	  ○ Trans-basin diversion, Big Thompson Project
	  ■ Cross-section of Big Thompson Project
	Back in Colorado, the headwaters of the Colorado river system are up in Rocky Mountain National Park. One of the things we have done is that we have tunnels that bring the Colorado river water underneath the continental divide to the Front Range, including a tunnel system that comes from Grand Lake and Granby, across and underneath Rocky Mountain National Park. A cross sectional view shows the Granby and Grand Lakes to the west, and the Adams tunnel through the continental divide. This Big Thompson Project was built in the late 1940's and 1950's, and allowed for the growing of sugar beets in Greeley, and helped establish many of the communities on the front range from Ft Collins down to the area north of Denver.
		Object Tree:
		• *Earth→Worldviews Network→WVN01 Water(06) Colorado Big Thompson Project*
		Custom Events:
		• *18_TransMountain* to fly to Big Thompson Project bubble slide
			
			• co_bigThompsonProject.png
				ES 9.4	Graphic by Bob Raynolds.

05B	• Ground panorama of pipes This panorama is a photo of the tunnel system north of Longmont near Carter Lake. A pair of pipes, each about 5 feet in diameter, comes out of the mountains dropping Colorado River water to the bottom of the hill here where there is a power station that generates hydro-electricity. It then drops down to Horsetooth reservoir, then towards Carter Lake, and then ultimately out to the high plains. Originally used for growing sugar beets, the water is now divided between municipal (over 51%) and agricultural use.	**Object Tree:** • *Earth→Ka Chun Yu→FlatironRes2* **Custom Events:** • *18_BigThompsonPAN* to fly to Big Thompson Project panorama.	 • water_to_flatironRes2_2048.jpg	ES 9.4	Equirectangular image for panorama provided by DMNS.

05C	• Historic vs. present day landscape in Westminster 1892 vs. 2000 Here we look north towards Westminster, first in a photo taken in 1892, when there wasn't much there, except for a few cottonwoods on the valley floor. Here is a picture taken in 2011. Look at the change: we built a city, developed homes, schools, businesses, industries, all predicated on the use of water that is brought in large part from the other side of the continental divide from the Colorado river system. Even in Denver, about 50% of the water is Colorado River water.	**Object Tree:** • *Earth→Worldviews Network→WVN01 Water(07) Westminster 1892, WH Jackson* • *Earth→Worldviews Network→WVN01 Water(07) Westminster 2011-04-08, DMNS* • *Earth→Worldviews Network→WVN01 Water(07) Westminster 2011-05-17, DMNS* **Custom Events:** • *18_Westminster* to fly to Westminster, CO bubble slides.	 • W.H. Jackson 1892 image • westminster_2011_04_08_annot.jpg • westminster_2011_05_17_annot.jpg	ES 9.4 ES 9.5	1892 image (WHJ 566 from the William Henry Jackson Collection, "Snowy Range from Denver") copyright by Colorado Historical Society. To seek permission for use and licensing information, email photos@state.co.us, call (303) 866-3759, or write to Photo Librarian, 1200 Broadway, Denver CO 80203. Westminster images provided by DMNS.
05E	■ Effective Agriculture actions • Optimize irrigation practices The vast majority of the water – about 86% -- in Colorado is used for irrigation. On the left of this series of slides is furrow irrigation or field irrigation. Often practiced in many places where there is abundant water supply, field irrigation is where water is just placed in the field. Crops like corn are grown using this method in Boulder County. Some could argue that maybe corn shouldn't be grown in Boulder county. In the middle is a center pivot system. It is spraying water from quite a height onto the fields and this is a very water intensive way of irrigating because a lot of the water evaporates. In a drier or desert area, if you spray the water from 6 or 8 feet high, a lot of the water evaporates before it gets to the ground. This has been improved on in the scene to the right. You see a center pivot system with these hoses hanging down. Considerable water saving can happen using this technology, and **is** happening using this technology. County extension agencies in these areas can also use satellite images, like we are showing you today, to look at fields and even a portion of a field to identify the drier areas. They give advice to the farmers to tell them how much water to put on which part of the field. As we get more effective in our usage of technology we can use our water supplies more effectively and more carefully to still produce crops and grow our food.	**Object Tree:** • *Earth→Worldviews Network→WVN01 Water(09) Wasteful Irrigation* **Custom Events:** • *19_Irrigation*	 • http://commons.wikimedia.org/wiki/File:LevelBasinFloodIrrigation.JPG  • http://commons.wikimedia.org/wiki/File:PivotIrrigationOnCotton.jpg 		Images credits: Wikimedia Commons.

			• http://commons.wikimedia.org/wiki/File:PivotWithDrops.JPG		
05D	■ Front Range 2002-2004 drought leading to effective municipal actions [bubble slides?] • Public Education (Use what you need) • Modified metering and billings • Recycled water (City Park 1million gal/day) • Aurora $750 million recycling project • Denver Museum saves 25% with new fixtures Another thing happening is in City Park right outside the Denver Museum of Nature & Science. Here is a sign illustrating that we now irrigate City Park with water that has been recycled. It comes in purple pipes and it isn't potable, meaning it has been treated but not treated and chlorinated to a standard that is drinkable. You'd probably be all right if you drank a little bit of it but it's not designed for common drinking. It's carried in a separate set of pipe systems than potable water. Even in the Museum we have changed our fixtures. If you have been to our restrooms you can see that we have low flush toilets and we have water in the sinks that only comes on when you put your hands in the sink. We have saved about 25% of our water usage in the Museum by implementing a higher level of technology in our restrooms.	**Object Tree:** • *Earth→Worldviews Network→WVN01 Water(09) Wasteful Irrigation*	 • cityPark_irrigationSign.jpg		Photograph by Ka Chun Yu.
05F	• Middle East greenhouse and drip irrigation examples We want to emphasize that our use of technology can make significant impact on how we can handle the land surface. We've got some scenes from irrigation in the Middle East. The first is a scene from southern Jordan, where I've been looking at water usage. These are olive trees that are being grown with drip systems on a land that otherwise is barren, if you can bring a little dripper down to each tree you can grow olives in the desert. You can grow tomatoes under these little Quonset huts, which are 8-10 inch high plastic domes, where a pipe system brings the water in. In the margins of the Dead Sea, an extremely arid place, tomatoes are being grown. Further to the right is a scene from the Negev desert in southern Israel. A larger greenhouse with a plastic roof, plastic walls, plastic floor, and the water come in a	**Object Tree:** • *Earth→Worldviews Network→WVN01 Water(09) Middle East Greenhouses* **Custom Events:** • *19_Greenhouses* to fly to start of bubble slides showing Middle East irrigation and greenhouses.			Photographs by Bob Raynolds.

	series a pipes underground to each of these vines. If you walk into this greenhouse ... you hit your head on this melon growing from the roof. The Negev desert is a place that is so dry it's shocking. You couldn't find two sticks to make tea, yet they are growing melons that hit you on the head by using water more effectively. Some of these technologies that are being developed in the Middle East and other parts of the world will be used here. It's already happening: you can go to the irrigation stores along the Front Range and buy drip systems that come from some of these water challenged countries.		   • middle_east_bob_raynolds_pics.zip		
05G	Holistic Management • Savory Institute As we study the way the animals interact with the land, it is clear that we should modify the way cattle graze. In the past before people arrived in the west, large bands of herbivores traveled the landscape and grazed very intensively but very episodically. Today we typically have more cattle spread over a large area and they graze continuously often to the detriment of the grass. New ways of managing the landscape through "holistic management" from Allan Savory and his group. Here is a scene from Zimbabwe, where cattle have been grazing in a traditional manner and have grazed the vegetation almost entirely. Now the next scene is what happens if the animals	**Object Tree:** • *Earth→Worldviews Network→WVN01 Water(10) Allan Savory Colorado Example* • *Earth→Worldviews Network→WVN01 Water(11) Allan Savory Zimbabwe 2006* • *Earth→Worldviews Network→WVN01 Water(12) Allan Savory Zimbabwe 2007* **Custom Events:** • *19_Savory_1*to fly to first bubble slide showing holistic management.		ES 9.5	Photographs provided by Savory Institute.

	are managed more carefully, so that they are moved periodically and the land has an opportunity to recover and rest. Although both pictures appear to be totally different, they are actually the same exact scene. There are individual trees and bent branches that are the same in both images. The scene on the right shows that land can recover if the grazing animals are managed correctly. And once recovered, you can increase the number of animals can be supported by the same land once it's been improved.		  Savory Institute images: ● savory_colorado.jpg ● savory_africa_before.png ● savory_africa_after.png		
06	**5. CONCLUSION (5 Minutes)**				
06A	○ We live in the Habitable Zone (situational awareness at many scales) ○ It is made habitable by water availability ○ There is enough water for all if we allocate it and use it effectively ○ Need for collaboration and education (learn from Middle East) ○ Upstream to downstream users needs must be respected ● Adaptive strategies can allow all users to share a finite water resource This was an experiment we did on the lawn of the Museum a couple of years ago. We were trying to illustrate that there is a limited amount of water and lots of people are trying to put their straws in it. As the kids were doing this, they were delighted by the idea of the experiment, until we started to notice food particles floating around in that bucket. There was some implication of backwashing going on.	**Geoscope:** ● *Earth→Worldviews Network→WVN01 Water(13) Final Slide* **Custom Events:** ● *19_Conclusion* to fly to final slide.	 ● children_with_straws.png		Photograph by Bob Raynolds.

	But they were using the water efficiently, taking only what they needed, use what you need. They were all sharing the same water supply.				
06B	• End Credits We live in a dry area. We have water challenges, but really it's an engineering challenge. We've got wonderful technology. We can look at the whole ecosystem of western US and the western North America and we can put together a vision of the future. Though we recognize that it is getting warmer, and we recognize there is going to be diminished surface water supplies, we can find technological ways and we can adapt to the changes that are coming. It might not be easy; it may involve changes in the way we water our golf courses and wash our cars, things that we take for granted today. There is adequate water supplies in the area; it just needs to be used more carefully. You are going to hear anxiety as we move forward with big development projects like new sub-divisions going up in Douglas County, and a pipeline discussed for a pipeline between Pueblo Reservoir and Colorado Springs. It is going to require careful skills and careful management for educated and enlightened people to more lightly live on this landscape. But there is a land here and our children will enjoy Colorado. There will still be water for our kids and grandkids; they will just have to use it more carefully. They will also have to share it with the people that are coming to Colorado and the people that live downstream from Colorado. That sharing will involve collective wisdom and collective uses of water in more efficient fashions.	**Geoscope:** • *Earth→Worldviews Network→WVN01 Water(14) End Credits*	 • credits.jpg		