2022 Water Course

Introduction to Colorado Hydrology
Colorado Mesa University
Ruth Powell Hutchins Water Center
1. Define hydrology as a discipline within the lenses of science, engineering, and policy
2. Define and explore watershed properties
3. Contrast weather and climate in Colorado.
4. Explore the drivers of hydrology and water resources in Colorado (Snow and Flow)
5. Discuss how water is distributed across the State
6. Discover how climate change may impact our water supply
What is Hydrology?

Study of the distribution and movement of water in physical and biological systems
What is Hydrology?
Measurement
What is Hydrology?
What is Hydrology?

Engineering
What is Hydrology?

Dynamic Ecosystems / Hazards
What is a Watershed?

• Definition
  • “An area that contributes water to a particular location on a channel” (Novotny, 2003)
  • “The land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean.” (EPA, 2008)

Image: Tracey Saxby IAN Image Library (ian.umces.edu/imagelibrary)
What is a Watershed?
Powell’s Vision for the West
Watersheds – Hydrologic Units
Major Colorado River Basins
Major Colorado River Basins

Continental Divide

- North Platte
- Yampa/White/Green
- Colorado
- Gunnison
- Rio Grande
- San Juan/Dolores
- South Platte
- Metro
- Arkansas

Colorado River

Mississippi River
Watershed Water Balance
Sublimation

Evapotranspiration

Surface and Subsurface Runoff

Infiltration:
Soil and Ground Water

OUTPUTS / STORAGE
Water Balance

Input – Output = Change in Storage

Inputs
- Precipitation

Outputs
- Evapotranspiration
- Sublimation
- Runoff (stream flow)

Storage
- Soil Moisture
- Groundwater
Colorado Climate:

30 year Normal Precipitation 1981-2010

http://www.prism.oregonstate.edu/
The new U.S. Climate Normals are here. What do they tell us about climate change?

Focus areas: Weather, Climate, Satellites
Topics: Climate Normals, historic climate record, climate data, temperature rankings

May 4, 2021
How to define “normal”?

We often compare hydrologic and meteorological data to the average of a recent 30-yr period.

1971-2000 = 30 years

1981-2010 = 30 years

“The new normal” = warmer, drier, lower streamflow.
The New Normal

1991-2020 = New 30 Year Normal

Warmer and drier than 1981-2010 Normal

Continued trend of warmer, drier, and lower stream flows
Colorado Climate:

100-year (1% Annual Chance)

60-minute duration Rainfall Depth

https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html
Flood Intensity in Colorado

Data Source: USGS NWIS
Climate vs Weather

<table>
<thead>
<tr>
<th>Climate</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>It'll probably hit 90. I'd better take lots of water.</td>
<td>It's 90!!! I'm glad I brought lots of water.</td>
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Climate vs Weather

- Climate vs Weather

- Climate:
  - It'll probably hit 90. I'd better take lots of water.

- Weather:
  - It's 90!!! I'm glad I brought lots of water.

- Chart with highs and lows showing climate trend.
Climate & Hydrology of the Colorado River Basin

34% of watershed receives < 10 in/yr
84% of watershed receives < 20 in/yr

Most of the runoff is produced by only 15% of the drainage area.
Runoff Distribution in Colorado

80% of Colorado’s water is generated in the Colorado River Basin.
Runoff Distribution in Colorado

What do we do when we don’t have water when and where we need it?
Water Use and Allocation in the Upper Colorado River Basin

Statewide Water Withdrawals

- Agriculture, 86.7%
- Municipal & Industrial, 6.7%
- Non-Consumptive, 5.5%
- Self-Supplied Industrial, 1.1%

Chart recreated from Colorado Water Plan (2015).
Trans-basin Diversions
Storage

Blue Mesa Dam and Reservoir
940,700 ac-ft capacity

Dillon Dam and Reservoir
257,000 ac-ft capacity

McPhee Dam and Reservoir
381,195 ac-ft capacity

Lake Granby (539,800 ac-ft), Shadow Mtn. (18,400 ac-ft) and Grand Lake

Photos from USBR

From High Country News
Snow and Flow
Snow and Snowmelt

Snowmelt is a significant contributor to runoff and water supplies over much of the Northern Hemisphere, and changes in snowmelt runoff will be one of the most pronounced hydrologic responses to global warming.

Dingman, 2015, Physical Hydrology

SNOw TELemetry (SNOTEL) Station

Measuring: Snow Water Equivalent (SWE)
Snow properties

Snow Water Equivalent (SWE)

Example of Water Yield from a Volume of Snow

\[ 10 \text{ units} \times 20\% = 2 \text{ units} \]

Snow/Water Relationship

<table>
<thead>
<tr>
<th>Snow Type</th>
<th>Percentage of Water Content</th>
<th>Ratio of Snow Depth to Liquid Water Equiv.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary new snow immediately after falling in still air (-10°C)</td>
<td>5%</td>
<td>20:1</td>
</tr>
<tr>
<td>Settling snow</td>
<td>10%</td>
<td>10:1</td>
</tr>
<tr>
<td>Drifted snow</td>
<td>33%</td>
<td>3:1</td>
</tr>
<tr>
<td>Ripe snow (Close to melting point) (0°C)</td>
<td>50%</td>
<td>2:1</td>
</tr>
</tbody>
</table>

Doesken and Judson, 1997
Snowmelt process


Doesken and Judson, 1997
Snowmelt process

Snow melts from the top down
- Solar radiation
- Air temperature
- Wind


Doesken and Judson, 1997

Slide from: Gigi Richard
2022 Water Year

Calendar Year

Water year is named for the year in which it ends

Slide from: Gigi Richard
Snowmelt process

Snow melts from the top down

- Solar radiation
- Air temperature
- Wind


Slide from: Gigi Richard
Rank of Feb-Mar 2019 precip at SNOTEL sites

Source: NRCS Interactive Map; https://www.nrcs.usda.gov/wps/portal/wcc/home/quicklinks/imap

Slide from: Jeff Lukas
WY 2019 SWE plot – Lake Powell 104 Group

130% of median peak SWE

Source: NOAA CBRFC; https://www.cbrfc.noaa.gov/station/sweplot/snowgroup.php

Slide from: Jeff Lukas, 2019
Lees Ferry water-year natural flows: 2019 good, but not great

2019 est. 17.5 maf (118% of average)
What is an acre-foot?

One acre-foot is the amount of water it would take to flood one acre to a depth of one foot.

One acre-foot of water is enough to support the municipal use of six Texans for one year.

By 2020, Texas is projected to have a demand of 18.5 million acre-feet of water for all water uses per year.

For games and animation, visit our TWDB Kids website.

http://www.twdb.texas.gov/kids
One of the biggest snow years....

What happened to runoff in 2019???
Upper CO River Basin Oct-May precip vs. Lees Ferry flows, 1900-2019

$R^2 = 0.67$

Slide from: Jeff Lukas, 2019
Upper CO River Basin Oct-May precip vs. Lees Ferry flows, 1900-2019
Upper CO River Basin Oct-May precip vs. Lees Ferry flows, 1900-2019

UCRB Oct-May precip, in.

Lees Ferry WY natural flow, maf

1906-1999

2000-2019
2019 Water Year: Inputs
Evapotranspiration

Sublimation

Infiltration: Soil and GW

Surface and Subsurface Runoff

2019 Water Year: Outputs / Storage
Hot Drought

Water Resources Research

The twenty-first century Colorado River hot drought and implications for the future

Trends

- Flows reducing
- Precipitation stable
- Temperatures increasing

Dry Drought (Lack of Precipitation)

- Low Flows
- Low Precipitation
- Average Temperatures

Hot Drought

Water Resources Research

The twenty-first century Colorado River hot drought and implications for the future

Research Article | Free Access

The twenty-first century Colorado River hot drought and implications for the future

First published 17 February 2017 | https://doi.org/10.1002/2016WR019638 | Cited by 36


• Low Flows

• Average Precipitation

• Temperatures increasing
Hot Drought

Colorado River flow down 20% 2000–2014.

One-third or more of the decline was likely due to warming.

Unabated greenhouse gas emissions will lead to continued substantial warming, translating to twenty-first century flow reductions of 35% or more.

More precipitation can reduce the flow loss, but lack of increase to date and large mega drought threat, reinforce risk of large flow loss.

Source: Jeff Lukas, Western Water Assessment
This giant climate hot spot is robbing the West of its water
United States of America

DEPARTMENT OF STATE

To all to whom these presents shall come, Greeting:

I, (Secretary of State), in the name of the United States of America, do hereby certify that the document hereunto annexed is a true copy of the original in the custody of this Department.

(Colorado River Compact signed November 24th, 1922, at the City of Santa Fe, New Mexico.)

In testimony whereof I, (Secretary of State), have hereunto caused the Seal of the Department of State to be affixed and my name subscribed by the Chief Clerk of the said Department, in the District of Columbia, this ______ day of ______, 1922.

[Signature]

Secretary of State

[Signature]

Chief Clerk
The States of the Upper Division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of ten consecutive years reckoned in continuing progressive series beginning with the first day of October next succeeding the ratification of this compact.
Colorado is warming (especially the Western Slope)

Total precipitation (annual rain and snow depths) may not change.

Precipitation variability in the Colorado Basin has increased by 10% since 1980.
  - Individual storms will tend to be "juicier" in a warmer climate
  - More warm/dry and warm/wet years.

Warmer summer temperatures will dry out land surface faster.

Even if precipitation remains the same, runoff may reduce due to evaporation and dry soils.
  - Hot Drought

Slide information from: Jeff Lukas
Restoring our Headwaters
Restoring our Headwaters
Restore our Headwaters
- SNOTEL Data
- USGS Stream Flow Data
- Colorado Water Plan