Precipitation Evaluation of the Upper Deschutes Watershed

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Introduction

The purpose of this experiment was to assess the precipitation of watersheds within the Upper Deschutes basin. Catchments contributing to stream gages were delineated and the ratios of stream flow to precipitation were calculated.

Site Description

The Upper Deschutes Subbasin is a catchment (HUC8 1707301) in central Oregon that includes the cities of Bend, Redmond, Sunriver, and Sisters. Most of the municipalities within it are somewhat small, and approximately 110,932 people live within its boundaries. Therefore, there is a relatively small proportion of impermeable area. The area is approximately 2153.2 square miles. A large portion of the area is evergreen forest and brush land. The Western boundary of the watershed is the leeward side of the Cascade mountain range, which causes a rain shadow effect, making the precipitation of the area relatively low. 2.03 percent of the watershed is wetlands, and 55.1 % of the soils are considered well-drained for hydrologic purposes.

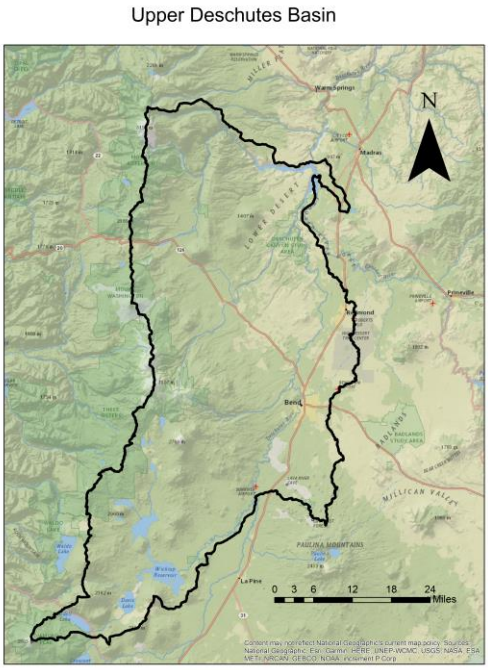


Figure 1: the outline of the basin over a National Geographic basemap

Data Description

3DEP DEM: 3 elevation rasters with cells 1 arc-second in length were taken from the USGS 3D Elevation Program website. Their Northeastern corners were at (44 N, 122 W), (44 N, 123 W), and (45 N, 122 W). They were not projected and based on an NAD83 geographic coordinate system.

NHD Watershed Boundaries: Area vector shapefiles of the HUC8, HUC10, and HUC12 catchments were obtained from the USGS National Hydrography Dataset. Their locations were defined relative to NAD83, and they were not projected.

NHD Flowline Boundaries: A line vector shapefile that includes all the stream lines within the HUC8 boundaries was taken from the USGS National Hydrography Dataset. It is not projected and based on an NAD83 geographic coordinate system.

Precipitation Stations: A vector including points representing NCDC precipitation monitoring stations will be generated from an Excel file for the mean annual rainfall of every station with more than six years of data around the catchment boundaries. Locations were listed for a NAD83 geographic coordinate system.

Stream Gages: A vector including points representing USGS National Water Information System stream gages will be generated from an excel file including the mean flow rates for bodies of water exiting each of the HUC10 watersheds. Locations were listed for a NAD83 geographic coordinate system.

Methodology

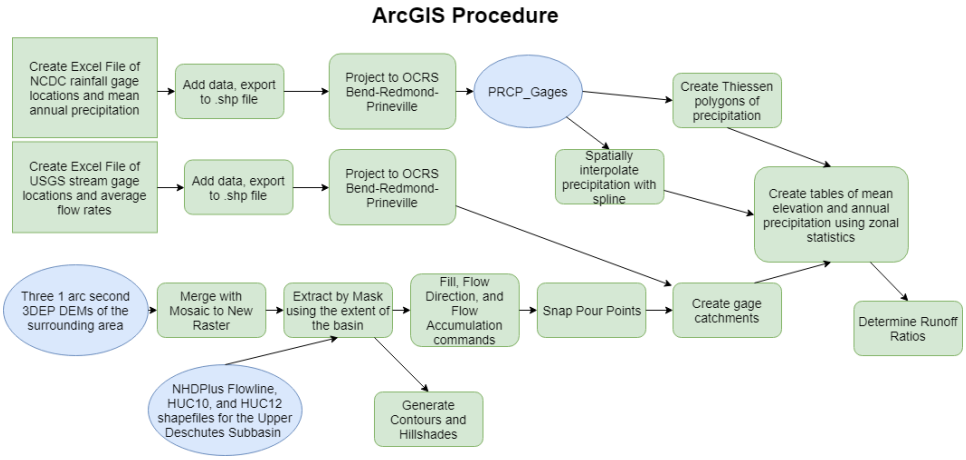


Figure 2: Flow Chart of GIS Methodology

Projections were made to the Oregon Coordinate Reference System Bend-Redmond-Prineville zone. This projection was selected because it covers Jefferson and Deschutes County. Additionally, the reduced linear distortion made it more appropriate for the flow direction calculation, which was critical for multiple subsequent steps (Armstrong et al. 2017).

Information on the locations and mean annual precipitation from National Climate Data Center rain gages was taken from the Climate Data Online website. Stations from Deschutes, Jefferson, and Linn County that had six or more years of data on record were compiled in an Excel file. The file was added to the map, and its XY data were displayed, exported as a layer, and projected. Thiessen polygons approximating areas of equal rainfall were generated and converted to a raster of precipitation depth. Another raster for rainfall estimation was created using the Spline tool to interpolate rainfall at each point.

Digital elevation models with one arc-second cell lengths for the area around the subbasin were downloaded from the USGS 3D Elevation Program website. They were projected into 30 meter rasters and combined with the Mosaic to New Raster command. The resulting DEM was cut to the extents of the subbasin using an Extract by Mask command. Rasters were created using the Flow Direction and Flow Accumulation commands.

Stream gage data were obtained from the United States Geodetic Survey National Water Information System website. An Excel file including each site's name, NAD83 longitude and latitude, drainage area, and average flow rate taken from the most recent five to ten years on record. The file was added to the map, and the XY data were displayed and exported to a shapefile. To account for discrepancies with points of high flow accumulation and the location of the body of water being observed, gage locations were moved manually using the Editor tool. Snap Pour Point was to mark the pixels with the highest flow accumulation within 50 meters of a gage. Then, the flow direction and gage snap rasters were used to delineate the catchments contributing to each gage. An issue with calculating flow direction made the Deschutes river discontinuous for the flow accumulation and flow direction rasters. Consequently, the catchment generated for the Deschutes River at Benham Falls near Bend is smaller than it should be, and there is a large gap in the resulting polygon. Attempts to solve this problem by testing different z-limits for Fill from one to eight meters did not work. So, a watershed that should be more representative was approximated by making a layer from a selection of every other catchment and using the Erase function to take the areas of the HUC12 polygon in the location that do not overlap. Then, a Dissolve function was used to aggregate them into one watershed. Another area that was left out was a portion of the Odin Falls-Deschutes River subwatershed. A similar process was performed to make it a separate catchment. The area and precipitation volumes found for it were added to the values for the Deschutes River Near Culver catchment. Mean elevations and precipitation through both Thiessen and spline approximations were recorded using Zonal Statistics as Table. Runoff ratios were calculated by dividing the total annual streamflow volume by the volume of precipitation contributing to stream gage.

Results

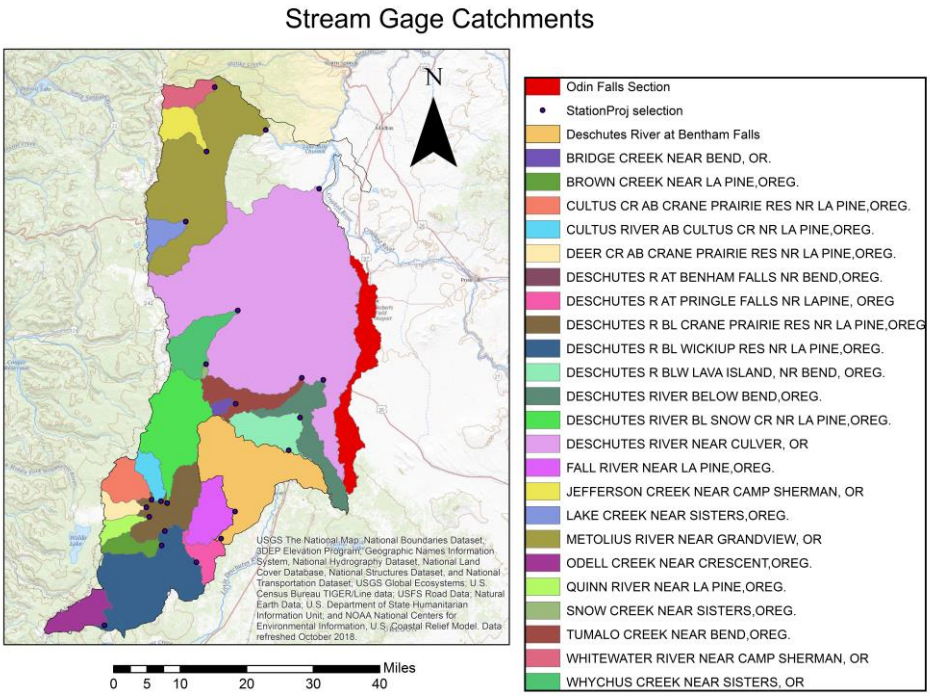


Figure 3: Catchments delineated for each stream gage

Appendix A includes layouts for hillshade and contour maps created for the site.

The runoff ratio for the watershed as a whole could not be assessed because there was not stream gage data appropriate for generating an outlet. Stations for the Deschutes River that were not included either had insufficient flow data or were too far downstream and connected to other basins. This also means the catchments on the Northwest corner of the watershed terminating in the Metolius River gage are not connected to the other watersheds.

Most of the catchments delineated for the stream gages have areas similar to those listed on the NWIS website (shown in the USGS Area column on Table 1). The greatest differences are for the Deschutes River at downstream locations. Most notably, the Deschutes River near Culver station has an area listed that is greater than that of the Upper Deschutes basin. This suggests that there is some form of error in the NWIS records. Additionally, locations like the Deschutes River below Bend and near Culver have flow rates that are far lower than upstream locations. However, this may have been due to errors from when the data were gathered. Years that were uncharacteristically low or based on incomplete information could have led to incorrect inputs. In future experiments, a more strict minimum of years on record is necessary.

Table 1: Watershed properties

Name	Mean Elevation (m)	Watershed Area (mi^2)	Contributing area (mi^2)	USGS Area (mi^2)	Flow (cfs)
DESCHUTES RIVER BL SNOW CR NR LA PINE	1765.70	110.54	110.54	132	134.99
CULTUS RIVER AB CULTUS CR NR LA PINE	1550.23	19.92	19.92	16.5	61.85
CULTUS CR AB CRANE PRAIRIE RES NR LA PINE	1589.45	32.81	32.81	33.2	20.80
DEER CR AB CRANE PRAIRIE RES NR LA PINE	1625.91	15.12	15.12	21.5	6.94
QUINN RIVER NEAR LA PINE	1640.20	14.93	14.93	0.6	23.32
DESCHUTES R BL CRANE PRAIRIE RES NR LA PINE	1457.07	63.65	256.96	254	219.18
BROWN CREEK NEAR LA PINE	1576.36	19.71	19.71	21	37.07
ODELL CREEK NEAR CRESCENT	1712.04	35.95	35.95	39	84.98
DESCHUTES R BL WICKIUP RES NR LA PINE	1483.82	147.99	460.62	483	700.61
DESCHUTES R AT PRINGLE FALLS NR LAPINE	1345.08	21.85	482.47	507	853.60
FALL RIVER NEAR LA PINE	1392.32	46.26	46.26	45.1	131.76
DESCHUTES R AT BENHAM FALLS NR BEND	1468.00	162.93	691.6594	1759	1367.90
DESCHUTES R BLW LAVA ISLAND, NR BEND	1447.86	46.93	741.5894	1829	1418.60
DESCHUTES RIVER BELOW BEND	1356.33	64.06	805.65	1899	383.75
BRIDGE CREEK NEAR BEND	1883.31	5.84	5.84	6.58	28.02
TUMALO CREEK NEAR BEND	1719.26	41.61	47.45	47.3	68.46
SNOW CREEK NEAR SISTERS	2186.59	1.64	1.64	1.65	5.91

WHYCHUS CREEK NEAR SISTERS	1792.14	49.43	51.07	45.2	85.23
DESCHUTES RIVER NEAR CULVER	1115.70	694.65	1598.82	2705	923.35
LAKE CREEK NEAR SISTERS	1349.21	20.79	20.79	22.2	48.66
JEFFERSON CREEK NEAR CAMP SHERMAN	1576.91	27.26	27.26	27.8	93.72
WHITEWATER RIVER NEAR CAMP SHERMAN	1586.59	23.24	23.24	22.8	83.02
METOLIUS RIVER NEAR GRANDVIEW	1194.99	243.13	293.63	316	1610.70

The observed runoff ratios varied significantly. Values for the Southwestern locations were typically low while the Northwestern locations yielded runoff ratios greater than one. This may be a result of the aforementioned errors when compiling stream gage data, especially for the low values yielded for the below Bend and near Culver locations. However, it can also be related to the lack of rainfall data within the basin's boundaries. There were very few stations with more than six years on record and they were far apart in both location and rainfall depth. This issue was exacerbated by the spline interpolation, which appears to have large areas of very low or negative rainfall. Therefore, the results from Thiessen polygon analysis are likely more realistic even though they have very similar problems.

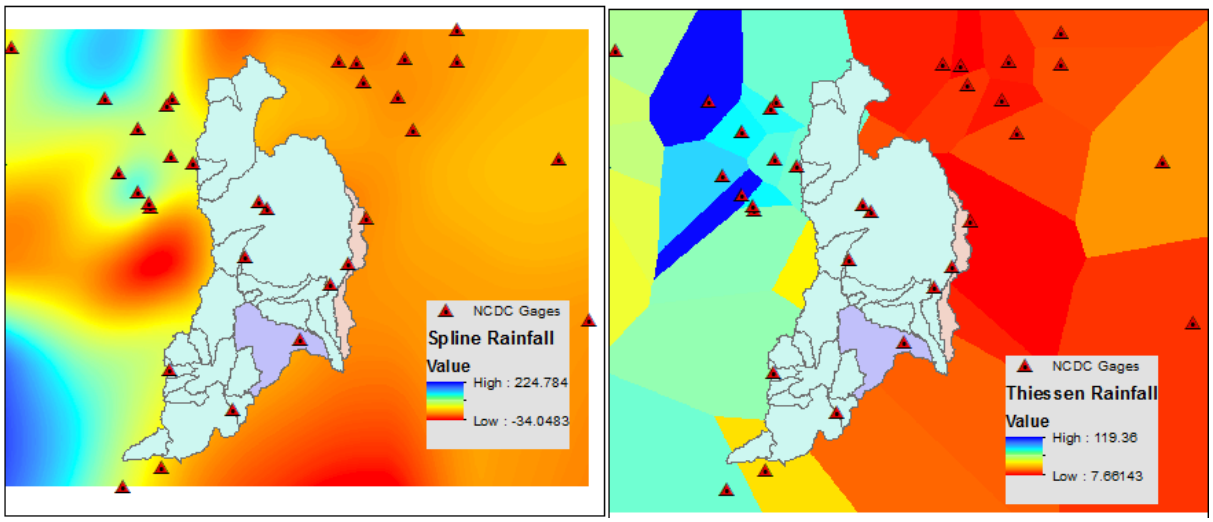


Figure 4: Rasters of rainfall values generated using spline interpolation (left) and Thiessen Polygons (right)

Table 2: Runoff ratio calculations generated using spline interpolated raster

Name	Mean Annual Rainfall (in)	Precipitation Volume (ft^3)	Runoff Ratio
DESCHUTES RIVER BL SNOW CR NR LA PINE	49.83	12795858021.52	0.33
CULTUS RIVER AB CULTUS CR NR LA PINE	58.44	2704773137.85	0.72
CULTUS CR AB CRANE PRAIRIE RES NR LA PINE	65.08	4960701962.02	0.13
DEER CR AB CRANE PRAIRIE RES NR LA PINE	64.27	2257130904.21	0.10
QUINN RIVER NEAR LA PINE	59.42	2061289408.22	0.36
DESCHUTES R BL CRANE PRAIRIE RES NR LA PINE	45.83	31556420253.56	0.22
BROWN CREEK NEAR LA PINE	48.96	2241791371.23	0.52
ODELL CREEK NEAR CRESCENT	58.08	4851081708.76	0.55
DESCHUTES R BL WICKIUP RES NR LA PINE	31.60	49514660541.88	0.45
DESCHUTES R AT PRINGLE FALLS NR LAPINE	19.13	50486028555.93	0.53
FALL RIVER NEAR LA PINE	29.53	3173555517.86	1.31
DESCHUTES R AT BENHAM FALLS NR BEND	27.91	64224805731.90	0.67
DESCHUTES R BLW LAVA ISLAND, NR BEND	25.27	66979406606.96	0.67
DESCHUTES RIVER BELOW BEND	13.60	69004186240.14	0.18
BRIDGE CREEK NEAR BEND	44.59	604568354.72	1.46
TUMALO CREEK NEAR BEND	35.37	4023561893.64	0.54
SNOW CREEK NEAR SISTERS	48.01	182655192.78	1.02
WHYCHUS CREEK NEAR SISTERS	39.29	4694443316.10	0.57
DESCHUTES RIVER NEAR CULVER	15.53	104336896586.56	0.28
LAKE CREEK NEAR SISTERS	64.45	3112351504.68	0.49
JEFFERSON CREEK NEAR CAMP SHERMAN	22.46	1422651041.38	2.08
WHITEWATER RIVER NEAR CAMP SHERMAN	8.85	477624145.96	5.48
METOLIUS RIVER NEAR GRANDVIEW	36.39	25568367901.96	1.99

Table 3: Runoff ratio calculations generated using Thiessen polygon raster

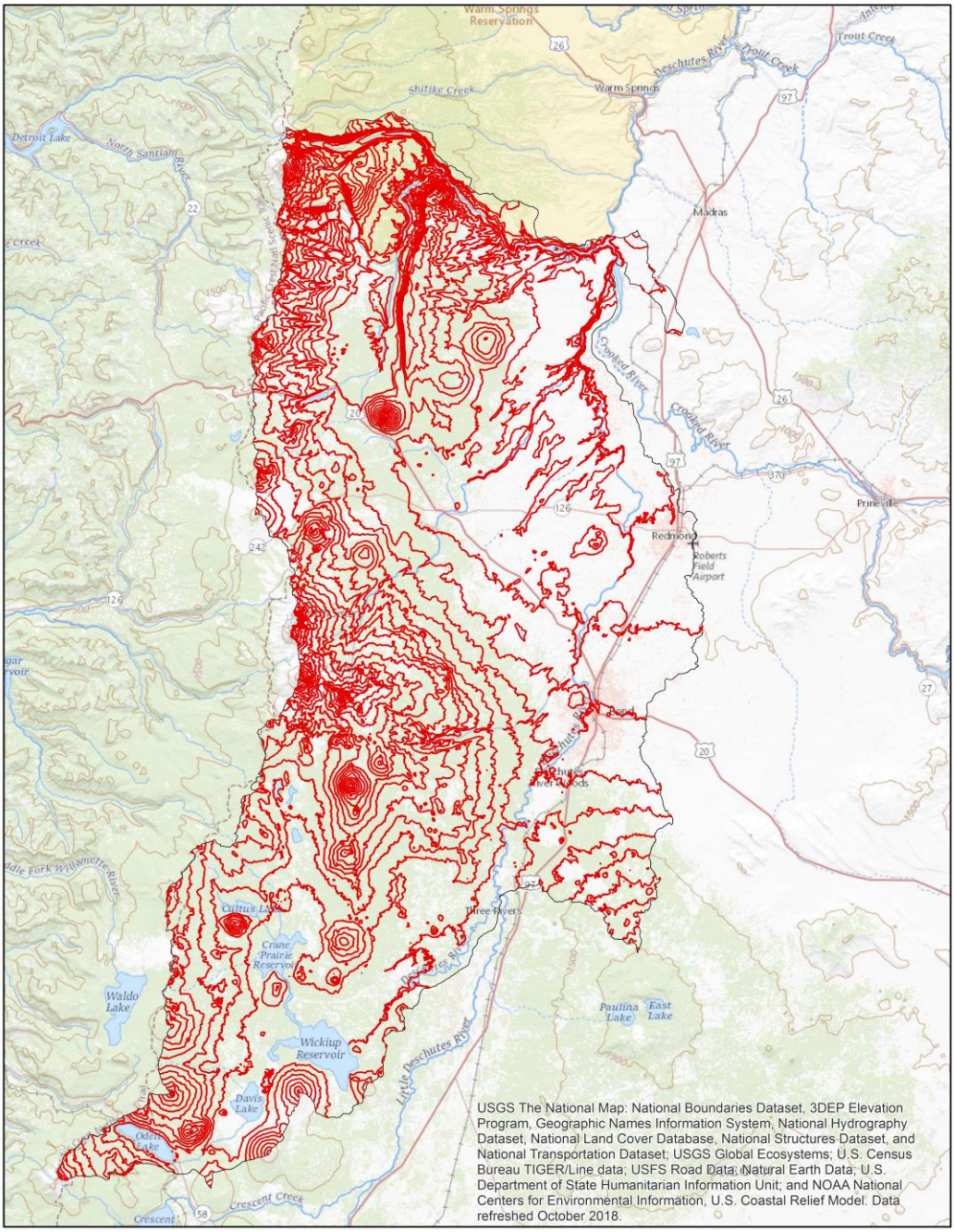
Name	Mean Annual Rainfall (in)	Precipitation Volume (ft^3)	Runoff Ratio
DESCHUTES RIVER BL SNOW CR NR LA PINE	50.91	13073253376.64	0.33
CULTUS RIVER AB CULTUS CR NR LA PINE	67.75	3135521275.94	0.62
CULTUS CR AB CRANE PRAIRIE RES NR LA PINE	67.75	5164117724.44	0.13
DEER CR AB CRANE PRAIRIE RES NR LA PINE	67.75	2379576615.40	0.09
QUINN RIVER NEAR LA PINE	67.75	2350478680.41	0.31
DESCHUTES R BL CRANE PRAIRIE RES NR LA PINE	46.35	32956721288.49	0.21
BROWN CREEK NEAR LA PINE	56.53	2588489910.89	0.45
ODELL CREEK NEAR CRESCENT	42.17	3522842340.48	0.76
DESCHUTES R BL WICKIUP RES NR LA PINE	31.56	49919718005.32	0.44
DESCHUTES R AT PRINGLE FALLS NR LAPINE	19.24	50896253244.28	0.53
FALL RIVER NEAR LA PINE	19.13	2055957340.90	2.02
DESCHUTES R AT BENHAM FALLS NR BEND	19.86	60469597448.54	0.71
DESCHUTES R BLW LAVA ISLAND, NR BEND	18.83	62522626283.71	0.72
DESCHUTES RIVER BELOW BEND	15.11	64771419625.45	0.19
BRIDGE CREEK NEAR BEND	42.95	582328703.40	1.52
TUMALO CREEK NEAR BEND	34.62	3928661243.17	0.55
SNOW CREEK NEAR SISTERS	42.95	163412633.47	1.14
WHYCHUS CREEK NEAR SISTERS	41.60	4940549712.14	0.54
DESCHUTES RIVER NEAR CULVER	17.57	103978564957.14	0.28
LAKE CREEK NEAR SISTERS	72.81	3516259104.14	0.44
JEFFERSON CREEK NEAR CAMP SHERMAN	73.20	4636273989.25	0.64
WHITEWATER RIVER NEAR CAMP SHERMAN	73.20	3952193845.22	0.66
METOLIUS RIVER NEAR GRANDVIEW	59.55	45742690176.79	1.11

Works Cited

Armstrong, M.L., Thomas, J., Bays, K., & Dennis, M.J. (2017). *Oregon Coordinate Reference System: Handbook and Map Set*. Oregon Department of Transportation, Salem, OR.

Appendix A: Additional Figures

100 Meter Contours



DEM Hillshade