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Snow-Impacted National Inventory of Dams by GAGESII Watershed

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PURPOSE: This Engineering Research and Development Center (ERDC) Technical Note describes the development of a set of locations within the contiguous United States (CONUS) where snowmelt is a component of the annual streamflow. The locations are selected from the US Geological Survey (USGS) Geospatial Attributes of Gages for Evaluating Streamflow II (GAGESII) and National Inventory of Dams (NID) data sets. The 30-year normal snow regimes were used to identify all GAGESII watersheds that have any of the basin delineated as transitional (rain/snow), snow dominated, or perennial snow zones. NID dams that are within snow affected GAGESII watersheds are included in the data set. The purpose of this ERDC Technical Note is to describe the development of a comprehensive data set of CONUS GAGESII and dam infrastructure affected by snow changing regimes.

BACKGROUND: Seasonal snowpacks develop over approximately 54% of CONUS annually (Zeng et al. 2018), primarily in the western US, northern Midwest, and Northeast. The snowpack in these regions is a critical water resource and economic driver for communities across the US, especially in the western US (Li et al. 2017; Sturm et al. 2017). However, these snowpacks are rapidly changing, with a CONUS-wide average of 34 fewer snow cover days annually between 1982 and 2016 (Zeng et al. 2018). These changes in snow-covered area, along with the timing of snow ripening, has introduced a rise in hazard from snow melt and rain-on-snow (ROS) events (Berghuijs et al. 2016). ROS events occur when liquid precipitation falls on an existing snowpack and depending on timing, location, and climatological variables, can induce significant flooding events (Brandt et al. 2022). While ROS occurs frequently, it often does not produce a significant flooding event; however, in future climate scenarios the rain/snow line will move upward in elevation and latitude, exposing deeper snowpacks to ROS events, while lower elevations and latitudes will lack significant preexisting snow, decreasing runoff potential (Hammond et al. 2023; Li et al. 2019). In addition to ROS, climate change is altering typical snowpack processes for accumulation and ablation through extreme low snow years and high elevation wildfire (Giovando and Niemann 2022; Huning and AghaKouchak 2020). In snow dominated watersheds, the potential for extreme flooding due to mixed-population runoff events (rainfall and snowmelt events; ROS events) or rapid snowmelt (wildfire) events have been shown to exceed standard rainfall design values, placing existing and future infrastructure at an elevated risk (Cho and Jacobs 2020). However, no comprehensive CONUS data set exists for dams that could be affected by changes in upstream snow conditions or processes.

METHODS

Step 1. Determining area of interest.

Climate data. The 30-year (1991–2020) normal CONUS snow regime classification developed by Tedesche et al. (2022) was the only climate data used for this effort. The snow regime classification raster (4 × 4 km spatial resolution) was developed using a thresholding ratio between maximum snow water equivalent (SWE) and cool-season precipitation. The classification system identified the following four snow regimes: Rain Dominated (RD), Transitional (R/S), Snow Dominated (SD), and Perennial Snow (PS).

Hydrologic units. Using the USGS 2-Digit Hydrologic Unit Code (HUC2) region boundaries (Seaber et al. 1987), we identified all CONUS HUC2 regions that included R/S, SD, and PS raster cells (Figure 1). Seventeen of the eighteen CONUS HUC2 regions were included in the analysis with only the Lower Mississippi (08) being excluded and the South Atlantic-Gulf Region (03), Tennessee Region (06), and Texas-Gulf Region (12) being predominantly Rain Dominated with minimal areas classified as Transitional.

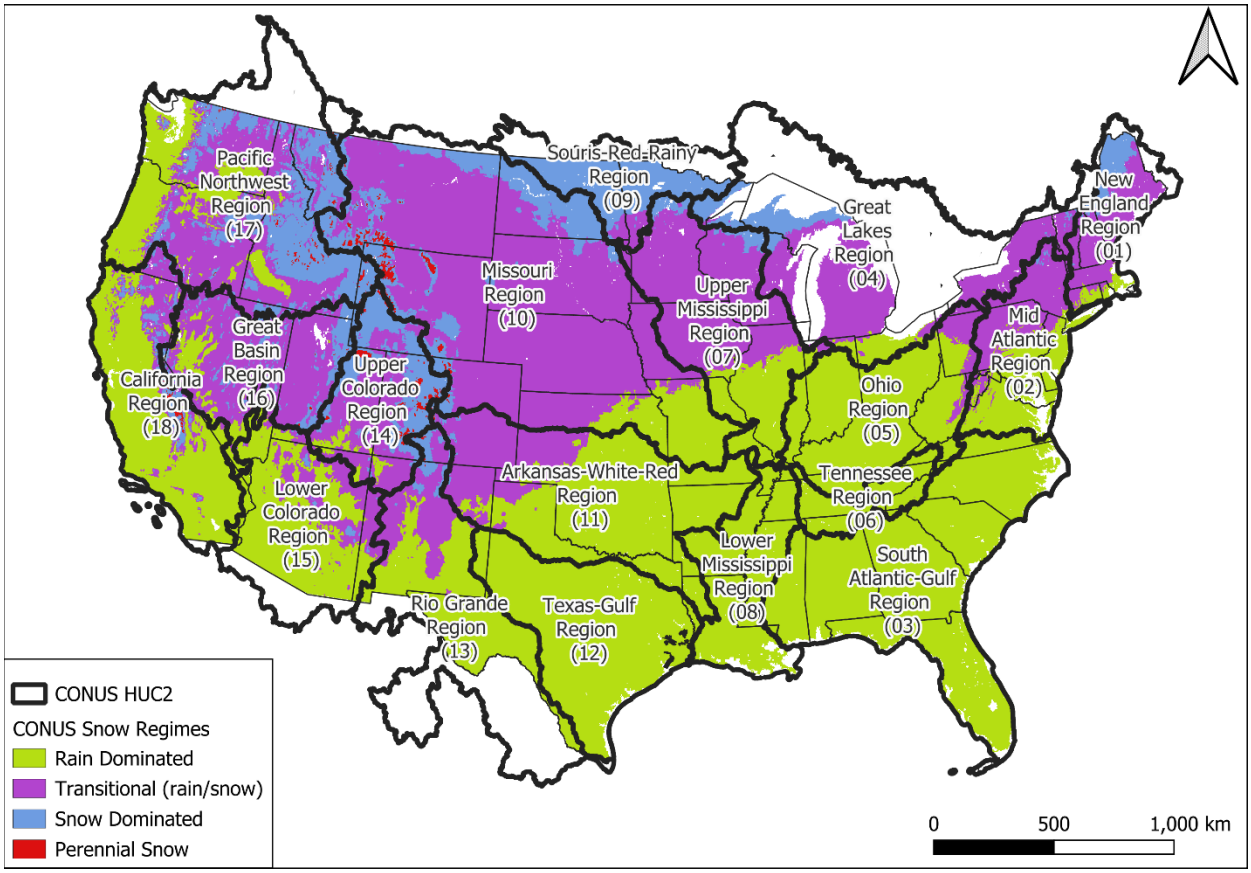

Figure 1. Contiguous US (CONUS) 30-year normal snow regimes and the US Geological Survey (USGS) 2-Digit Hydrologic Unit (HUC2) Regions that include Transitional, Snow Dominated, or Perennial Snow classifications.

Step 2. Identifying snow influenced watersheds.

Filter GAGESII watersheds by snow influence. We downloaded USGS GAGESII watersheds using the *nhdplusTools* R library (Blodgett and Johnson 2022) for each state that is included in the snow affected

HUC2 regions. Using the *Zonal Statistics* tool in QGIS (https://www.qgis.com), we calculated the minimum, maximum, and majority (mode) 30-year normal snow regimes for each GAGESII watershed. Finally, we filtered out any watersheds that only contained rain dominated areas, leaving just the GAGESII watersheds with snow influence (Figure 2).

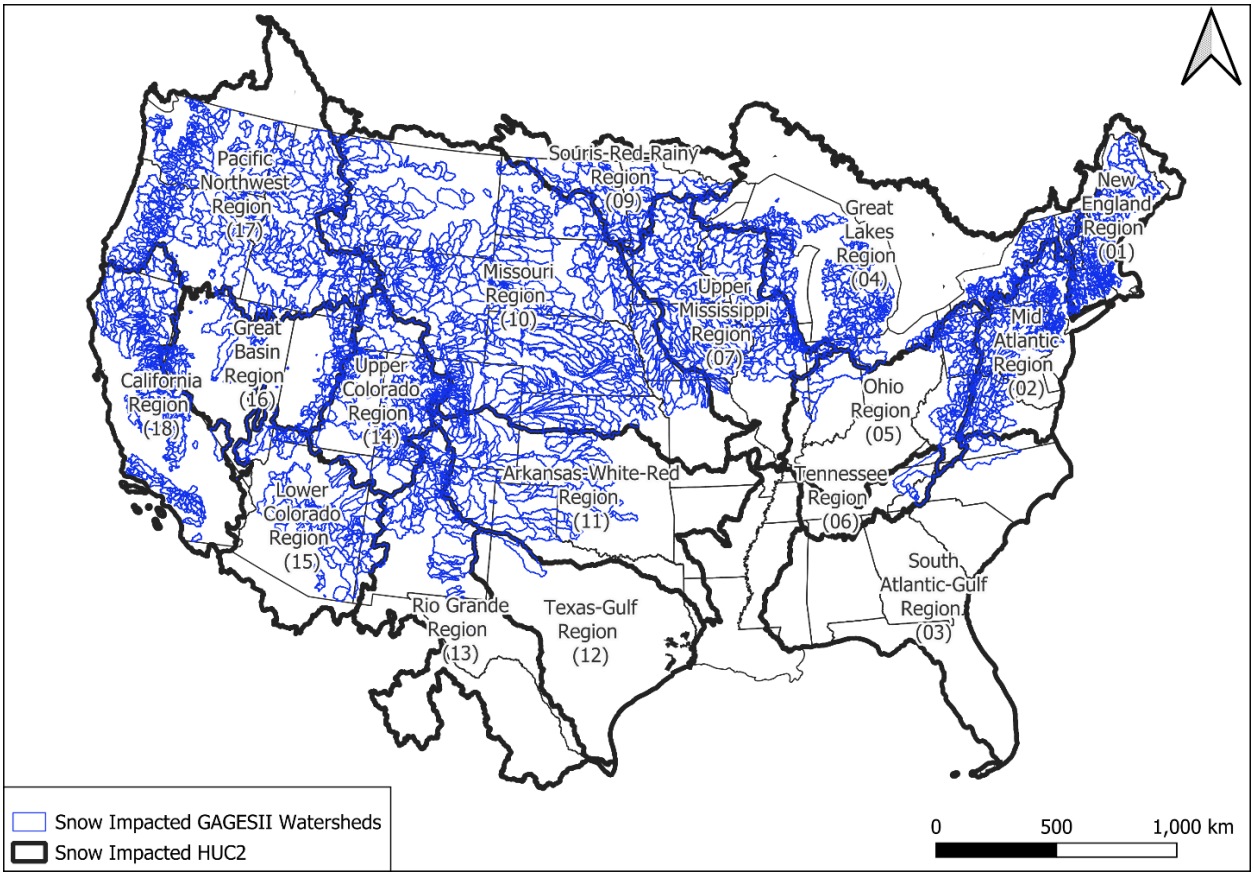

Figure 2. CONUS snow affected USGS Gages for Evaluating Streamflow II (GAGESII) watersheds.

Calculate snow influence in GAGESII watersheds. We then converted each of the snow regime classification areas to single part polygons using the *Polygonize (raster to vector)* and *Dissolve* tools in QGIS. With the single part polygons, we used the *Intersect* tool to calculate the individualized snow regime area within each of the GAGESII watersheds. Merging the snow regime areas for each of the four snow regimes to the total GAGESII watershed area allowed us to produce a percent area value for each of the four snow regimes within individual watersheds. All GAGESII locations with upstream 30-year snow affected areas were included in the data set. This resulted in many nested watersheds along the same stream or river, or within larger watershed areas (Figure 3).

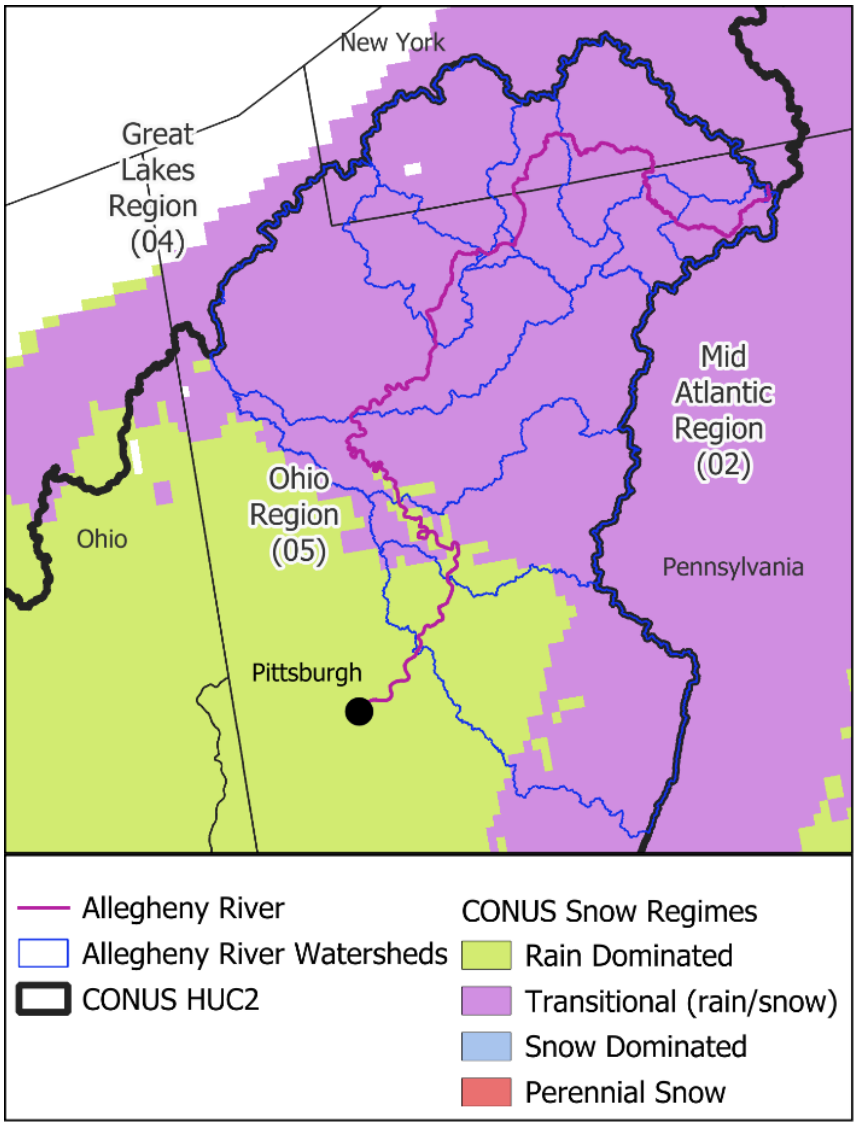

Figure 3. Example of eleven nested GAGESII watersheds along the Allegheny River in western Pennsylvania. Note, the Allegheny River flows from north to south and confluences with the Ohio River in Pittsburgh, Pennsylvania. Only the Allegheny River is shown for clarity.

Step 3. Identifying snow influenced infrastructure.

Identify National Inventory of Dams within snow affected GAGESII watersheds. We then imported the NID (USACE 2024) data set which includes over 91,000 dam structures across the United States. Using the *Select by Location* tool in QGIS, we then selected all dam structures that intersected the snow affected GAGESII watersheds identified in Step 2. Finally, using the *Join by Location* tool, we merged the dam structure data to the GAGESII watershed data based on which GAGESII watershed(s) each dam was located within.

SUMMARY: Through this analysis, two primary CONUS-wide data sets were developed to be used when considering the impacts of snow regimes on flooding, water resources, and downstream dam infrastructure. Within the 17 HUC2 regions included in the data set, we identified 4,998 GAGESII locations and 34,995 dams that had snow influence.

Snow impacted GAGESII watersheds. This data set includes two shapefiles, a point file of each of the GAGESII locations (snowImpacted_GAGESII_points.shp) and a polygon file of the GAGESII delineated watershed (snowImpacted_GAGESII_polygons.shp). Both files are in horizontal geographical coordinate system World Geodetic System 1984 (WGS 84). The attributes included in both shapefiles are identical and a definition of each attribute is included in Table 1.

Table 1. Snow-affected GAGESII point and watershed polygon attribute field definitions.

Field Name	Field Definition
STAID	USGS GAGESII Station ID
STANAME	USGS GAGESII Station Name
HUC02	USGS 2-Digit Hydrologic Unit Code of the GAGESII Station
STATE	State the GAGESII Station is located within
AGGECOREGI	Aggregated Ecoregion
LAT_GAGE	Latitude (decimal degrees) of the GAGESII Station
LNG_GAGE	Longitude (decimal degrees) of the GAGESII Station
DRAIN_SQKM	Drainage area (sq. km) of the GAGESII Station
RD_SQKM	Area (km^2) of the rain dominated (RD) classified area within the GAGESII watershed
RS_SQKM	Area (km^2) of the transitional (RS) classified area within the GAGESII watershed
SD_SQKM	Area (km^2) of the snow dominated (SD) classified area within the GAGESII watershed
PS_SQKM	Area (km^2) of the perennial snow (PS) classified area within the GAGESII watershed
RD_PCT	Percentage of the rain dominated (RD) classified area within the GAGESII watershed
RS_PCT	Percentage of the transitional (RS) classified area within the GAGESII watershed
SD_PCT	Percentage of the snow dominated (SD) classified area within the GAGESII watershed
PS_PCT	Percentage of the perennial snow (PS) classified area within the GAGESII watershed

Snow Impacted NID Dam Infrastructure. The data set includes a point shapefile of each NID dam within GAGESII watersheds with snow influence (snowImpacted_NID_GAGESII_points.shp). This file is in horizontal WGS 84. The attributes included in this shapefile are defined in Table 2.

Table 2. National Inventory of Dams (NID) within snow-affected GAGESII watersheds point attribute field definitions.

Field Name	Field Definition
DAMNAME	Name of dam infrastructure from NID
OTHERNAME	Additional name of dam infrastructure from NID
FORMERNAME	Former name of dam infrastructure from NID
NIDID	NID ID
FEDERALID	Federal ID for dam infrastructure
OWNERNAME	Owner of the dam infrastructure from NID
LAT_DAM	Latitude (decimal degrees) of the dam
LNG_DAM	Longitude (decimal degrees) of the dam
STAID	USGS GAGESII Station ID
STANAME	USGS GAGESII Station Name
HUC02	USGS 2-Digit Hydrologic Unit Code of the GAGESII Station
STATE	State the GAGESII Station is located within
AGGECOREGI	Aggregated Ecoregion
LAT_GAGE	Latitude (decimal degrees) of the GAGESII Station
LNG_GAGE	Longitude (decimal degrees) of the GAGESII Station
DRAIN_SQKM	Drainage area (sq. km) of the GAGESII Station
RD_SQKM	Area (sq. km) of the rain dominated (RD) classified area within the GAGESII watershed the dam falls within
RS_SQKM	Area (sq. km) of the transitional (RS) classified area within the GAGESII watershed the dam falls within
SD_SQKM	Area (sq. km) of the snow dominated (SD) classified area within the GAGESII watershed the dam falls within
PS_SQKM	Area (sq. km) of the perennial snow (PS) classified area within the GAGESII watershed the dam falls within
RD_PCT	Percentage of the rain dominated (RD) classified area within the GAGESII watershed
RS_PCT	Percentage of the transitional (RS) classified area within the GAGESII watershed
SD_PCT	Percentage of the snow dominated (SD) classified area within the GAGESII watershed
PS_PCT	Percentage of the perennial snow (PS) classified area within the GAGESII watershed

ADDITIONAL INFORMATION: This Engineering Research and Development Center Technical Note (ERDC-TN) was prepared as part of the US Army Corps of Engineers (USACE) Post-Wildfire Research and Development Program's Rain-on-Snow Work Unit by Mr. Wyatt Reis and Dr. Jeremy Giovando, US Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL); and Dr. Travis Dahl, ERDC-Coastal and Hydraulics Laboratory (CHL). Questions pertaining to this ERDC-TN may be directed to Mr. Wyatt Reis (wyatt.k.reis@usace.army.mil).

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