Iowa Drought Plan

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Authors:
Iowa Department of Natural Resources (DNR)
Iowa Department of Agriculture and Land Stewardship (IDALS)
Iowa Department of Homeland Security and Emergency Management (HSEMD)

Iowa's Drought Plan (IDP) was developed through a collaborative planning process between state, local, and federal partners. With input and feedback provided by stakeholders throughout 2022, a core team of representatives from the Iowa Department of Natural Resources (DNR), the Iowa Department of Agriculture and Land Stewardship (IDALS), and the Iowa Department of Homeland Security and Emergency Management (HSEMD) drafted the following pages with the full support of senior leadership from each respective state entity. This plan is therefore endorsed by the current Directors and Secretary of Agriculture:

Kayla Lyon
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Director Kayla Lyon, DNR

Secretary of Agriculture Mike Naig, IDALS

John R. Benson
Digitally signed by John R. Benson
Date: 2023.01.12 09:13:26 -06'00'

Director John Benson, HSEMD

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1.0 Executive Summary

This drought plan was developed as a tool to be used by local, county, and state agencies and governments before, during, and after droughts in Iowa. The process for development of this plan was started during meetings held during the summer of 2021 to address growing concerns over drought conditions in Iowa. Plan development began in earnest in early 2022 and culminated in this Iowa Drought Plan (IDP). In order to develop and implement this plan a Drought Planning Team was assembled, utilizing staff from the Iowa Department of Natural Resources (DNR), the Department of Agriculture and Land Stewardship (IDALS), and Iowa Department of Homeland Security and Emergency Management (HSEMD).

The IDP is intended to provide the State of Iowa with a planned and collaborative approach to plan for, identify, respond to, and recover from a drought. To accomplish these objectives the IDP addresses:

1.1 Drought Regions

The State of Iowa was divided into five drought regions based, in part, on the landform regions of Iowa. Landform regions largely reflect the diversity of geologic landscapes shaped by Quaternary age glacial deposition and post-glacial erosion over the last two million years or so. The different landform regions have similar topography, soils, geology and hydrology that make them appropriate for classifying drought regions in the state. The landform regions are irregular boundaries but the drought regions follow county boundaries for better state administration.

1.2 Drought Triggers and Actions

The IDP includes a data driven system for determination of drought status for each of the five drought regions of the state. Within each of the five drought regions, conditions will be assessed as Normal, Drought Watch, Drought Warning, or Drought Emergency. For any of these drought conditions, the IDP indicates specific actions and evaluations that will be done and communicated to state, county, and local officials so that appropriate activities can be undertaken. The IDP also indicates information and data that will be communicated to state, county, and local officials, as well as indicating which local and state agencies will be asked to participate in drought discussions during various levels of drought conditions.

1.3 Vulnerability & Impact Assessment

No portion of the State of Iowa is immune from drought conditions, but different regions and sectors are more or less vulnerable at different points in a drought. The five regions delineated in this plan are vulnerable to drought for different reasons: lower annual precipitation and fewer deep groundwater resources make the northwestern quadrant of the state more susceptible to precipitation deficits. The northeastern region has generally reliable precipitation and good groundwater resources, but still experiences agricultural losses at or above the average. The southern portion of the state is generally dependent on surface waters and shallow groundwater sources due to poor water quality in deeper aquifers, but the southeastern part of the state sees more precipitation than other regions.

Sectors such as water supply and agriculture generally feel the impacts of drought first and most strongly. In 2022 dollars, Iowa has seen over $5.3 billion in crop loss insurance claims from 1989 to 2022 due to drought. An added difficulty for water suppliers is that during dry times, demand for water often spikes, both to deal with concurrent heat waves and to irrigate crops and lawns suffering from the lack of precipitation.

Many industries in Iowa are dependent on water, such as food processing and chemical manufacturing. Depending on the severity and location of the drought, energy supply may also be impacted when power plants are unable to use and dispose of water to cool generators. The environment & recreation sectors are impacted by drought, since much of the outdoor recreation in Iowa is dependent on the quality and quantity of surface waters. Even non-water-based recreation is aided by healthy plant and animal life, which is negatively affected by drought. Public health can see negative impacts from disease both during and after droughts.

Drought poses threats to Iowa that can severely impact public health and social, environmental, and economic well-being. Iowa is expected to see droughts increase in frequency, intensity, and duration, given long-term atmospheric trends. As an agricultural state that largely depends on rainfall rather than irrigation, this poses serious consequences for the state's environment, economy, and society.

1.4 Mitigation & Response

Actions that can mitigate the effects of drought are often less obvious than actions that mitigate other natural disasters. When they are obvious, they can be expensive to implement (e.g., building additional water storage). Adding to the difficulty of mitigating drought, it is often hard to tell whether dry conditions constitute a drought, or if so, how long they are expected to last. Droughts are thus hard to prepare for in the short-term and it can be difficult to know the appropriate level of response.

A major element of drought preparedness, then, is public awareness of potential and current drought conditions, and capacity to respond on the local level. Consequently, coordinated state messaging and public education play a role in mitigating drought. To facilitate early warning and accurate information, monitoring networks could be improved and expanded (e.g., for soil moisture, stream levels, or precipitation measurements). Infrastructure, agricultural practices, and nature-based solutions also play an important role in improving resilience against drought. If implemented, the mitigation recommendations listed in Mitigation Recommendations are intended to reduce Iowa's vulnerability to drought.

1.5 Implementation

As part of implementing the plan, a Drought Coordinating Team (DCT), comprised of staff from the DNR, HSEMD, and IDALS will be responsible for confirming drought levels, coordinating state messaging on drought conditions, and creating materials for public information on drought preparedness and response. The materials currently expected to be developed are listed in Informational Material to Develop.

The Iowa Drought Plan is expected to undergo revisions and updates as capacities and conditions change, and as needed adjustments are recognized. The DCT will be responsible for updating the plan every five years, with one additional update expected within the first two years of implementation.

2.0 Iowa Drought Plan Purpose

The Iowa Drought Plan (IDP) is intended to provide the State of Iowa with a planned and collaborative approach to plan for, identify, respond to, and recover from a drought. To accomplish these objectives the IDP:

- Incorporates input from community and industry stakeholders, scientists, and policymakers
- Provides an overview of Iowa climate conditions and historical drought conditions, along with a history of drought planning in the state.
- Identifies and provides organizational guidance for the involvement of state agencies during all phases of drought.
- Provides an operational framework to be followed in addressing drought and drought-related activities, including a determination of communication mechanisms and strategies to be used by state agencies during all phases of drought.
- Defines regions of Iowa selected for monitoring for drought conditions, and defines the stages of drought selected for use in Iowa. The IDP also defines the data and information available and needed to identify drought status and triggers for regions and stages of drought.
- Provides a risk and vulnerability assessment by region and sector.
- Provides a response framework for regions and stages of drought.
- Identifies long- and short-term mitigation activities that can be implemented to prepare for drought and to minimize the impacts of future droughts.
- Provides a springboard for local and industrial drought planning and response efforts.
- Provides a mechanism for the updating of the IDP.
- Includes a future work section describing potential work that is outside of the scope of this plan.

3.0 Iowa Drought Team Structure

Drought Core Team: The Drought Core Team (DCT) has primary responsibility for overseeing the implementation and maintenance of the IDP. The DCT is made up of staff from three primary state agencies but can call other state agencies into drought discussions on an as needed basis, or in accordance with the schedule included in the IDP.

Drought Coordinator
State Climatologist
Iowa Department of Agriculture and Land Stewardship
Justin Glisan
justin.glisan@iowaagriculture.gov

Primary Agency Member
Iowa Department of Homeland Security and Emergency Management
Sarah Eggert
sarah.eggert@iowa.gov

Primary Agency Member
Iowa Department of Natural Resources
Tim Hall
tim.hall@dnr.iowa.gov

Science and Data Team: The Science and Data Team (SDT) has primary responsibility for overseeing selection and use of data and information for implementation of the IDP. The SDT selected the data used to trigger levels of drought designated in the IDP, and will work to update data sources as appropriate. The SDT will be consulted with questions related to the interpretation of data. As new data sources become available, the SDT will make determinations regarding how that new data will be used to make drought condition designations for the state of Iowa under the IDP.

Drought Coordinator
State Climatologist
Iowa Department of Agriculture and Land Stewardship
Justin Glisan
justin.glisan@iowaagriculture.gov

State Geologist
Iowa Geological Survey
Keith Schilling
keith-schilling@uiowa.edu

Iowa Department of Natural Resources
Water Supply Engineering
Chad Fields
chad.fields@dnr.iowa.gov

National Weather Service
Senior Service Hydrologist
Jeff Zogg
jeff.zogg@noaa.gov

Des Moines Water Works - Operations
Kyle Danley
danley@dmww.com

Communication Team: The Communication Team (CT) has primary responsibility for developing and communicating information before, during, and after a drought as indicated in the IDP. The CT will be made up of technical and communications staff from the primary agencies of the DCT.

4.0 State Drought Regions

In order to effectively evaluate and respond to drought conditions, the State of Iowa was divided into five drought regions based, in part, on the landform regions of Iowa delineated in Landforms of Iowa by Jean C Prior, University of Iowa Press, 1991. The landform regions largely reflect the diversity of geologic landscapes shaped by Quaternary age glacial deposition and post-glacial erosion over the last two million years or so. Each landform region has similar topography, soils, geology and hydrology, making landform regions appropriate for classifying drought regions in the state. The landform regions have irregular boundaries but the drought regions follow county boundaries for planning and administrative purposes. Each of the regions are described below.

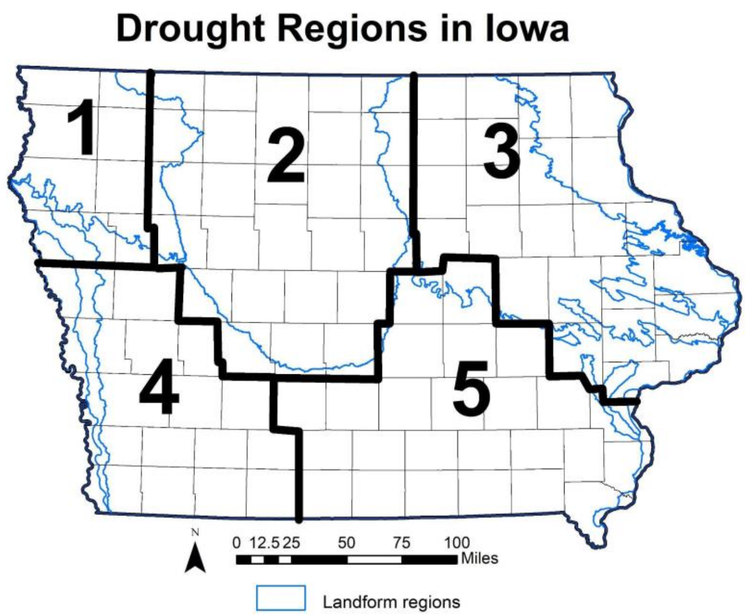


Figure 1. Map of Drought Regions in Iowa

4.1 Drought Region 1

This region encompasses eight counties in northwest Iowa in a landform area that corresponds to the Northwest Iowa Plains. The gently rolling landscape consists of wind-blown silt (loess) overlying fine-textured glacial till. The area is drier than elsewhere in Iowa and the intensely agricultural region relies heavily on groundwater obtained from shallow alluvial aquifers or deeper bedrock aquifers for irrigation, livestock watering and municipal and private water supplies. A reliance on shallow groundwater sources makes the region more vulnerable to water supply shortages during drought. In this region, many private and public water users rely on Rural Water Districts that distribute water from centralized sources.

4.2 Drought Region 2

This region corresponds to the Des Moines Lobe region of Iowa, a landscape region of recent glaciation (<12,000 years old) consisting of a flat to gently undulating, poorly drained flat till plains marked by numerous small, poorly drained depressions and wetlands. Dominant soils consist of silty and loamy soils formed in glacial till and wetlands. Poor drainage characteristics and high water table levels in the region necessitated the building of widespread artificial drainage systems of subsurface tiles and ditches to improve the land for crop production. Today the land use in the region is dominated by corn and soybean production and the area is among the most productive crop regions in the world. The intense cropping in the region is vulnerable to drought-induced impacts to yields. Bedrock aquifers are available in the region for water supply and additional groundwater resources are available from alluvial sand and gravel aquifers.

4.3 Drought Region 3

Two landform regions of Prior (1991) in northeast Iowa, the Iowan Surface and Paleozoic Plateau, were combined to form Drought Region 3. Both areas consist largely of shallow sedimentary bedrock (mainly limestone, dolomite, shale) mantled by fine-textured to coarse sandy soils. Many areas underlain by shallow limestone bedrock are characterized by numerous caves, springs and sinkholes. The northeast Iowa region is considered rich in water resources with many options for groundwater sources including layered bedrock aquifers and sand and gravel alluvium along the major rivers. Because of the plentiful water resources, drought impacts in the region are less prominent compared to other areas of the state.

4.4 Drought Region 4

Drought region 4 consists of 16 counties in southwest Iowa where the thick deposits of silt (loess) form steeply sloping hills and narrow valleys. The loess thins from a thickness of more than 100 feet along the Missouri River margin to tens of feet to the east tier of counties. The loess overlies fine-textured and dense glacial till. Bedrock groundwater resources are very poor in the region and characterized by highly mineralized and poor-yielding Pennsylvanian shales, limestone and sandstone. Deeper bedrock formations also contain poor water quality. Primary aquifers in the region consist of shallow sand and gravel deposits along major rivers and these units are particularly susceptible to overuse and drought. Many private and public water users rely on Rural Water Districts that distribute water from centralized sources collected from lakes, impoundments and developed well fields.

4.5 Drought Region 5

Drought region 5 is similar to region 4 in many respects. The shallow geology similarly consists of loess over glacial till, except the loess thickness thins substantially to the eastern part of the state. The area is characterized by steeply rolling hills and a well-developed dendritic drainage system. Water resources are poor in the south-central portion of the region, but improve somewhat to the east where shallow carbonate rock and deeply buried rocks are used for water supply. Many communities rely on shallow alluvial aquifers or surface water obtained from rivers and impoundments for their water needs. Like Region 4, many private and public water users rely on Rural Water Districts.

5.0 Drought Indicator Levels and Actions

5.1 Drought Levels

The IDP and its Science and Data Team has adopted these designations for drought conditions in Iowa. These are not tied directly to any other designations (such as the US Drought Monitor designations of D0, D1, etc.).

Drought Level	General Description
Normal	Routine monitoring of water supply and meteorological indicators. All conditions are generally stable and normal.
Watch	Conditions are characterized by short-term dryness that may slow growth of crops or pastures. Focus placed on voluntary reductions in demand through increased public awareness.
Warning	Conditions may cause the near-term development of water shortages. Conditions may lead to large surface water levels dropping and crop/pasture losses. Local utilities may request users to voluntarily reduce water use.
Emergency	Conditions can be characterized by shortages of water in reservoirs, streams, wells and widespread crop/pasture losses. The governor could issue emergency declarations for localized areas as conditions deteriorate. Local utilities could require users to reduce water use.

Note: this plan does not necessarily follow the U.S. Drought Monitor or the USDA/FSA's designation of drought emergencies. They may or may not be in exact alignment with the plan. The FSA loan program is outside the purview of the State of Iowa.

5.2 Drought Triggers

The Science and Data Team (SDT) examined and reviewed data that are currently used to evaluate climate conditions and drought. The SDT selected four initial data types to use as triggers, with the potential to incorporate a fifth, pending future data collection. The SDT will also be using the experience gained through the use of this plan to determine how to designate when a Drought Region is moving out of drought, and will add that information to this plan.

Streamflow: The Standardized Streamflow Index (SSI) was selected to evaluate streamflow drought. The SSI is a metric that compares current streamflow against the historical record to determine how far away the current streamflow value is from the river's historical mean observed on the same date. It can also be applied to longer time scales, such as a river's previous 30 days of streamflow. The SSI metric has been used around the world to quantify drought.

For the Drought Plan, the SSI was modified to make the index applicable to Iowa's drought regions. To create a regional SSI, daily streamflow yields from approximately six to 12 rivers in a region were averaged to create the region's mean daily flow. Streamflow data measured at gauges were divided by their watershed areas to standardize water yields in mm/day. The SSI was then calculated from the mean regional flows to create an index that could be applied to the entirety of the region, as well as specific rivers. The regional streamflow is compared to historical streamflow since 1960 to determine how current streamflow fits into historical context. This tool establishes an index number for each region - or watershed - describing how anomalous current flow is compared to historical observations. Drought values typically range from 0 (streamflow is the same as the mean) to -3, which indicates the current streamflow is three standard deviations less than the historical mean for the period. Positive SSI values indicate wetter than normal or flood-level flows. Additional data and details related to the SSI is available through the State Geologist at the Iowa Geological Survey.

USDM: The National Drought Mitigation Center classifies drought in one of five categories. D0, Abnormally Dry is the least severe category of the USDM. D0 designates an area that is going into drought, with short-term dryness slowing planting, growth of crops or pastures. D1, Moderate Drought, is used for areas that show some damage to crops, pastures, and where water levels in streams, reservoirs, or wells are low. D2, Severe Drought, designates areas where crop or pasture losses are likely, and water shortages are common. D3, Extreme Drought, designates areas of major crop/pasture losses, and with widespread water shortages. D4, Exceptional Drought, is the most extreme category used in the USDM, and designates areas with exceptional and widespread crop/pasture losses and shortages of water in reservoirs, streams, and wells creating water emergencies. The USDM map is issued every Thursday morning by the National Drought Mitigation Center in Lincoln, Nebraska, and will be evaluated for the Iowa drought regions. The Science and Data Team will also provide feedback on Iowa conditions to the USDM authors to improve the USDM map for the state.

Precipitation: Precipitation values from statewide networks monitored and evaluated by the State Climatologist will be used to determine this trigger level based on deficits and time scales shown in the table.

Standardized Precipitation Index (SPI): The SPI is an index based on accumulated precipitation for any time scale. The Standardized Precipitation Index (SPI) is the most commonly used indicator worldwide for detecting and characterizing meteorological droughts. The SPI indicator measures precipitation differences based on a comparison of observed total precipitation amounts over the period of interest with the long-term historical rainfall record for that period. Droughts are characterized by negative SPI values, while positive SPI values indicate wet periods. The range of SPI values is between -2 and +2. The concept is similar to SSI—using precipitation instead of streamflow.

Soil Moisture: Iowa's current system for measuring soil moisture is not adequate for use in the IDP at this time, but it is an important element in drought monitoring and triggering. The SDT will continue to look at available sources for soil moisture data and recommend adding a trigger for soil moisture in the future. Likewise, the SDT will be evaluating the use of water table wells and data from those wells to be potentially included at a later date as a trigger. Currently insufficient data exists for this to occur.

Ranges

Three of the Four Individual Trigger Levels must be exceeded in order to trigger the level for each region.

Category	Streamflow - SSI	USDM Drought Designation	Precipitation	Standardized Precipitation Index - SPI
Normal	USGS rated as normal flow, or SSI above noted levels.	No designation, or D0 for three weeks or less	Greater than 75% of normal for three to six months	SPI: > -0.9
Watch Regional	SSI-30 or SSI-365 for region between <-1-<-1.5	D0 (Four weeks) D1 (one week)	≤ 70% of normal (three months)	-1.0 to -1.4 (three months)
Warning Pay attention to watershed specifics	SSI-30 for region or individual river between <-1.5-<-2 Calculate SSI for individual rivers in region SSI-365 <-1.5: Expect drought duration of months to years	D2 (Four weeks)	>51% to 60% of normal (six months)	-1.5 to -1.9 (three months)
Emergency Smaller areas or site specific locations	SSI for individual river <-2 SSI-365 <-2: Expect drought duration of year or more	D3-D4 (one week) D2 (eight weeks)	≤ 50% of normal (six months) ≤ 25-50% of (three months)	≤-1.6 (six months) ≤-2.0 (three months)

5.3 Internal Communication Actions

The frequency of DCT meetings will increase with the severity of drought conditions and indicators. Under normal conditions, it is expected that the team will meet twice annually, in the spring and fall, to coincide with the NWS's spring flood outlook. As parts of the state enter drought conditions, it is expected that the team will meet more frequently to confirm the correct drought status for various parts of the state, and to coordinate external communications.

The member agencies of the DCT will also vary, depending on drought conditions. Under normal or watch conditions, it will not be necessary to involve every state agency and stakeholder, but stakeholders outside the DCT may be invited to DCT meetings at the team's discretion. Moving toward more severe conditions, other agencies will play necessary roles in responding to drought.

As part of external communications, member agencies of the DCT will be responsible for communicating with relevant stakeholders (e.g., regulated communities, field offices, federal partners). At times, these stakeholders may be invited to attend information-sharing meetings as well. Given the high importance of communication in drought preparedness, it is expected that public information officers (PIOs) from involved agencies will play a key role in DCT meetings.

The Drought Science and Monitoring Team, which helped develop this plan, will continue to participate in drought mitigation and response on an ad hoc basis. At times, there may be a need for additional data or analysis that would be best provided by experts, but these times may prove to be too infrequent to expect regular meetings of this team.

	Normal	Watch	Warning	Emergency
Drought Coordinator	State Climatologist	State Climatologist	State Climatologist	State Climatologist
Drought Coordinating Team	DNR HSEMD IDALS	DNR HSEMD IDALS IGOV	DNR HSEMD IDALS IGOV	DNR HSEMD IDALS IGOV IDPH IUB
Local External Groups	Water utilities, wastewater utilities, ag producer groups, key industries, public health, county EMA, major industries, recreation groups, fisheries, cities, counties, special districts (schools, drainage, levee), county conservation boards, ISU extension, members of Iowa's Watershed Planning Advisory Council (WPAC), and non-profits working on environmental and water resource issues.			
Drought Science & Monitoring Team	(Ad hoc)	DNR, NWS, USGS, USDA		

5.4 Action Matrix & External Communications Actions

In each of the planning team's meetings with stakeholders, it was emphasized that consistency in state messaging is needed. To that end, this external communications plan emphasizes a coordinated approach to communication among the various state agencies involved in drought mitigation and response.

The actions assigned to the DCT, Drought Coordinator, and state agencies in this action matrix are intentionally flexible. Each agency continues to be responsible for its statutory duties, but the DCT gives them a forum to discuss and respond to drought conditions prior to a drought emergency.

Note that at some points, different parts of the state will be in different conditions. The state may be operating under normal, watch, and warning conditions simultaneously. Consequently, the roles outlined below are cumulative across drought levels. The actions outlined in the watch and warning sections are very much similar. The difference between them is primarily in the frequency of meetings and agencies' attention to detailed data, both of which increase for drought warnings.

This Plan does not assign actions or responsibilities to entities outside of Iowa state government, such as to local governments, the federal government, or private sector non-profit and for-profit organizations. Still, the most important action in this table may be the provision of information to be disseminated, which will include actions that sectors and local jurisdictions can take to respond to drought conditions.

Recognizing the varying impacts that drought can have on different sectors in Iowa, this plan considers sector-specific vulnerabilities, communication channels, and relationships. Agencies identified in the action matrix as liaising with stakeholders should take action to inform those affected by drought of current conditions and actions that may be taken by stakeholders to reduce drought impacts. The following sectors were identified and grouped according to common interests, regulatory agencies, and responsibilities under the Iowa Emergency Response Plan.

SECTORS: Agriculture and Irrigation (key agency: IDALS, DNR ESD)
Water Supply (key agency: DNR ESD, DOT)
Energy (key agency: DNR ESD, DOC)
Industry (key agency: DNR ESD, DOC, IEDA, HSEMD, IDALS)
Recreation & Environment (key agency: DNR CRD, DNR ESD)
Public Health & Safety (key agency: IDHHS, HSEMD)

In addition to this sector-based communication approach and publishing drought conditions in the DNR's Eco Newswire, the DCT should consider conducting public awareness campaigns and communicating with media regularly and/or strategically in the drought cycle. This would shift the strategy for drought preparedness education from a come-to-us model to a take-it-to-them model. The slow-moving and hard-to-spot nature of drought makes it a disaster type that individuals and communities might not otherwise consider before the drought is already impacting them.

Normal
Ongoing Efforts and Normal/Wet Conditions (Statewide)

Agency	Actions	Internal Communication	External Communication
Drought Coordinator	• Monitor drought conditions • In the event of forecasted drought conditions, notify the Drought Team and convene additional meetings as necessary.	• Convene Drought Coordinating Team as appropriate	• Regularly update and post current drought data/information on drought.iowa.gov.
Drought Coordinating Team	• Convene twice annually (spring and fall) to assess drought conditions statewide. • Modify and update drought plan as needed	• Communicate any changes in personnel or points of contact to the rest of the Drought Coordinating Team	• Publish drought conditions bulletin twice annually to update conditions using DNR Eco NewsWire and other Agency websites. • Coordinate, collate, and routinely distribute educational material from state agencies on water resources and conservation by region
DNR Fisheries Water Trails Wildlife Water Use	• Monitor drought conditions • Maintain and coordinate contacts for drought science & monitoring	• Participate in Drought Coordinating Team meetings. • Maintain point of contact for Drought Coordinating Team.	• Publish monthly Water Summary Updates
HSEMD	• Coordinate drought mitigation efforts • Maintain State Hazard Mitigation Plan	• Participate in Drought Coordinating Team meetings. • Maintain point of contact for Drought Coordinating Team.	• Seek and assist applications for mitigation assistance.
IDALS Livestock Crop Issues	• Continue drought mitigation actions		• Seek and assist applications for agriculture-related mitigation assistance.

"Drought Watch" describes a state in which conditions are favorable for the development of a drought. Since watches are declared on a regional basis, some areas under a Drought Watch may be experiencing drought already, while others might not. This drought level is intended to give communities advance notice of the possibility of drought conditions or the potential for longer or more severe drought conditions.

Watch
(Regional)

Agency	Actions	Internal Communication	External Communication
Drought Coordinator	• Convene Drought Coordinating Team quarterly to assess conditions in affected regions (or more frequently as needed) • Continue monitoring drought conditions and data	• Provide detailed updates to DCT as needed	
Drought Coordinating Team	• Notify Public Information Officers from core agencies of current conditions and DCT meeting schedules • Monitor for steps up or down in drought level	• Collect and share data and information from affected agencies and stakeholders as appropriate • Confirm appropriate Drought Level	• Communicate current drought levels to affected sectors and jurisdictions on a no less than monthly basis. • Provide affected sectors and jurisdictions with appropriate [prepared statements] for consistent public information • Provide consistent messaging tools to state agencies; ensure agencies not currently involved in DCT are aware of resources
DNR	• Monitor drought conditions • Contact likely affected water utilities to seek additional information	• Participate in Drought Coordinating Team meetings.	• Serve as preferred liaison to appropriate stakeholder groups • Publish current drought condition in weekly Eco NewsWire and monthly Water Summary Update
HSEMD	• Monitor drought impacts as reported by county EMAs in WebEOC	• Push drought condition out through Alert Iowa; maintain list of necessary recipients • Participate in Drought Coordinating Team meetings.	• Serve as preferred liaison to appropriate stakeholder groups • Notify county EMA coordinators of current conditions
IDALS	• Monitor drought conditions through field observations	• Participate in Drought Coordinating Team meetings.	• Serve as preferred liaison to appropriate stakeholder groups
Drought Science Team	• Evaluate data as requested by DCT		

“Drought Warning” describes a state in which the designated region(s) or county(s) are currently experiencing impacts from drought conditions or impacts are considered likely to occur in the immediate future. This may be the result of the exacerbation of long-term drought conditions, or it may be the result of a more intense, short-term drought, whether current or anticipated. A Drought Warning may typically be preceded by a Drought Watch, but this is not always true when conditions develop rapidly.

Warning
(Regional and/or County level)

Agency	Actions	Internal Communication	External Communication
Drought Coordinator	• Convene Drought Coordinating Team quarterly to assess conditions in affected regions (or more frequently as needed) • Continue monitoring drought conditions and data	• Provide detailed updates to DCT as needed	
Drought Coordinating Team	• Convene quarterly to assess conditions in affected regions, or more often as appropriate • Notify Public Information Officers from core agencies of current conditions and DCT meeting schedules • Monitor for steps up or down in drought level	• Collect and share data and information from affected agencies and stakeholders as appropriate • Confirm appropriate Drought Level • Make recommendation to the Governor’s Office regarding emergency proclamations	• Communicate current drought levels to affected sectors and jurisdictions • Provide affected sectors and jurisdictions with appropriate prepared statements for consistent public information • Provide consistent messaging tools to state agencies; ensure agencies not currently involved in DCT are aware of resources
DNR	• Monitor drought conditions, including ecosystem health and water recreation condition updates. • Contact likely affected water utilities to seek additional information and provide technical assistance.	• Participate in Drought Coordinating Team meetings.	• Serve as preferred liaison to appropriate stakeholder groups. • Publish current drought condition in weekly Eco NewsWire and monthly Water Summary Update

Agency	Actions	Internal Communication	External Communication
HSEMD	• Monitor drought impacts as reported by county EMAs in WebEOC	• Push drought condition out through Alert Iowa; maintain list of necessary recipients • Participate in Drought Coordinating Team meetings. • Convey EMA reports to Drought Team as needed	• Serve as preferred liaison to appropriate stakeholder groups. • Notify county EMA coordinators of current conditions
IDALS	• Monitor drought impacts	• Participate in Drought Coordinating Team meetings.	• Serve as preferred liaison to appropriate stakeholder groups.
IDPH	• Add any necessary public health information to other agencies' communications	• Participate in Drought Coordinating Team meetings.	• Serve as preferred liaison to appropriate stakeholder groups.
Drought Science Team	• Evaluate data as requested by DCT		
Governor's Office	• Monitor conditions closely • Consider and prepare for emergency proclamation or presidential disaster declaration	• Participate in Drought Coordinating Team meetings. • Meet with Drought Team to review potential state and local actions. • Request further information from DCT as desired	• For consistency, make use of DCT data and information as needed in communications

A "Drought Emergency" is reserved for the most severe and impactful of drought conditions. This level may or may not coincide with a Proclamation of Disaster Emergency issued by the Governor. If this level is reached, the Director of Homeland Security and Emergency Management (or a designee) may activate the State Emergency Operations Center (SEOC) in accordance with the Iowa Emergency Response Plan. While the Iowa DNR is authorized by Iowa Code to allocate water for priority uses, this authority has never been utilized to date. However, a drought emergency could be an instance where use of such authority could be required to protect health and safety.

Emergency
Declare as needed (targeted jurisdictions and/or sectors)

Agency	Actions	Internal Communication	External Communication
Drought Coordinator	• Convene Drought Coordinating Team weekly to assess conditions in affected regions (or more frequently as needed) • Continue monitoring drought conditions and data		

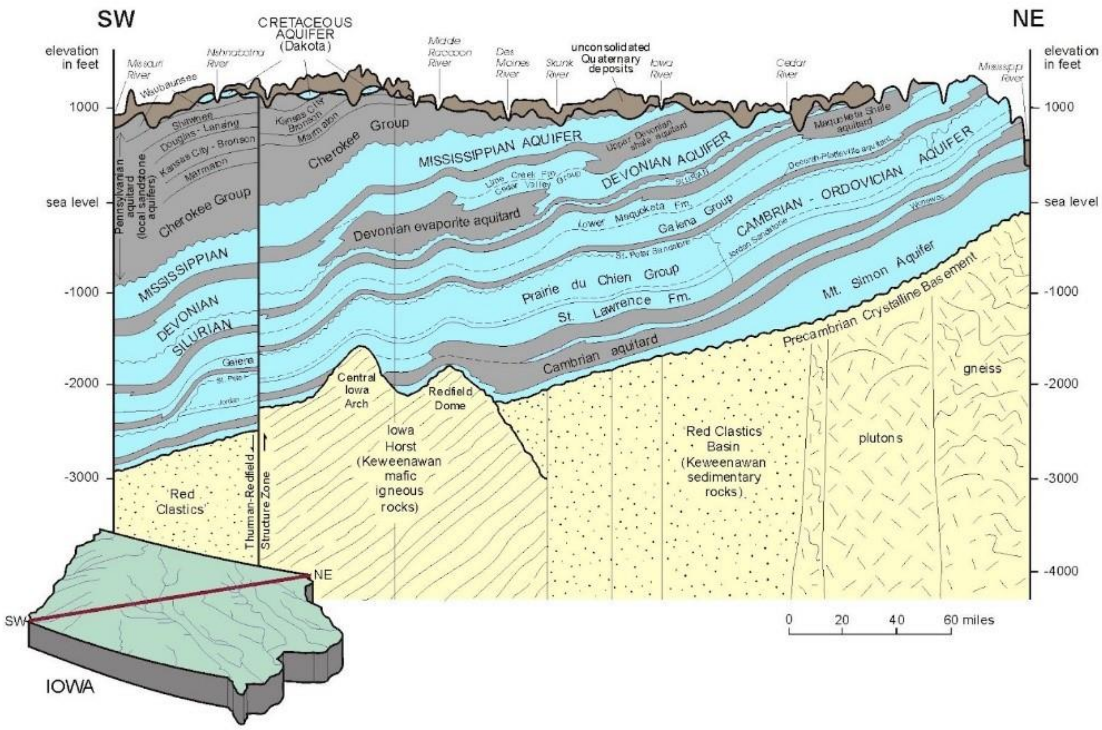
Agency	Actions	Internal Communication	External Communication
Drought Coordinating Team	• Convene weekly • Notify department heads and Public Information Officers from core agencies of current conditions and DCT meeting schedules • Monitor for step down in drought level	• Collect and share information from affected agencies and stakeholders as appropriate • Make recommendation to Governor on whether to issue, modify, or rescind emergency proclamation	• Prepare press releases as appropriate • Coordinate communications from state agencies on drought to ensure consistency
DNR	• Activate water allocation authority as appropriate		• Serve as preferred liaison to appropriate stakeholder groups.
HSEMD	• Activate emergency response plans if needed • Coordinate efforts to minimize water allocation impacts • Survey impacts and recommend presidential disaster declaration as appropriate.		• Serve as preferred liaison to appropriate stakeholder groups.
IDALS			• Serve as preferred liaison to appropriate stakeholder groups.
Drought Science Team	• Provide weekly updates to Coordinating Team, or as requested		
Governor’s Office	• If appropriate, use emergency powers to alleviate drought impacts		• Issue, modify, or rescind Disaster/ Emergency Proclamation as appropriate

6.0 Risk Assessment and Vulnerabilities

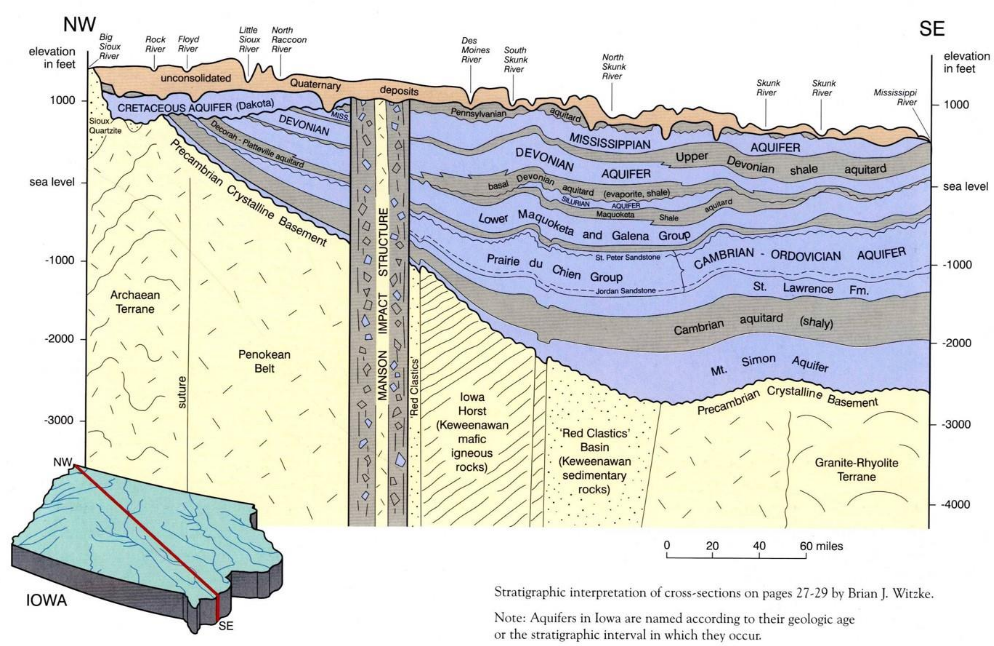
No portion of the State of Iowa is immune from drought conditions. Vulnerability to drought is the result of multiple factors. Different communities or sectors draw water from different sources, and each source has different vulnerabilities to shortages based on precipitation, watershed size, infiltration rates, inflow or throughflow (whether riverine or underground flow), and hydrogeological factors like porosity, permeability, etc. Some communities have access to more water sources than others. In Iowa, there is a general geological trend of having access to fewer aquifers in the north and more aquifers in the south. Figure 2 illustrates this trend with cross-sections of the aquifers running through Iowa. The difference is especially pronounced in the Northwest to Southeast cross-section. Communities in northwest Iowa may have access to only shallow groundwater, or one or two aquifers, whereas southwest Iowa generally has access to multiple aquifers. These aquifers vary in quality and chemistry, so even communities that can draw from a different aquifer during drought may experience additional costs, health risks, or general unpleasantness from water quality issues.

In addition to the varying drought risks different communities face due to geological or climatological reasons, some individuals and communities are also more vulnerable than others due to a lack of capacity to prepare and respond. This may be due to shortages of financial resources, staff, training, transportation, insurance, internet access, linguistic accessibility, etc. These issues can even lead to a difficulty in requesting help from state or federal agencies. Drought can severely impact local economies reliant on agriculture, tourism, or industry, and the public health effects of drought may be felt more among individuals lacking health insurance, employment, or mobility. It is important to recognize an affected community's vulnerabilities and capacity at the local level.

Bedrock Aquifer Systems across Iowa
Southwest to Northeast



Bedrock Aquifer Systems across Iowa
Northwest to Southeast



Stratigraphic interpretation of cross-sections on pages 27-29 by Brian J. Witzke.

Note: Aquifers in Iowa are named according to their geologic age or the stratigraphic interval in which they occur.

Iowa's Groundwater Basics

(From: Jean Prior's *Iowa's Groundwater Basics, 2003*)

Figure 2. Cross-sections of aquifers running through Iowa

6.1 Sectoral Risk

The most significant impacts associated with drought in Iowa are those related to water intensive activities such as agriculture, wildfire protection, municipal usage, commerce, tourism, recreation, and wildlife preservation. The following subsections explain drought with regard to the major impact sectors of agriculture and irrigation; water supply, energy, and industry; environment and recreation; and public health and safety. This sectoral look includes some discussion on most vulnerable jurisdictions, but a section specifically looking at regional drought vulnerability follows below (see: Regional Risk).

Agriculture and Irrigation Sector

The agriculture and irrigation sector is usually the first sector to be affected by drought conditions. Farmers and ranchers who depend on rainfall for watering crops may be severely affected by even short-term, moderate drought events. In the event of a drought, ranchers lose pasture and forage lands and need to buy expensive supplemental feed. Increased costs often reduce herd sizes, and depleted availability of water for livestock adds additional pressure. Industries that support agriculture are indirectly affected by these stressors. Agriculture and agriculture-related industries accounted for 31% of Iowa's economy in 2017 (Iowa Farm Bureau, 2019).

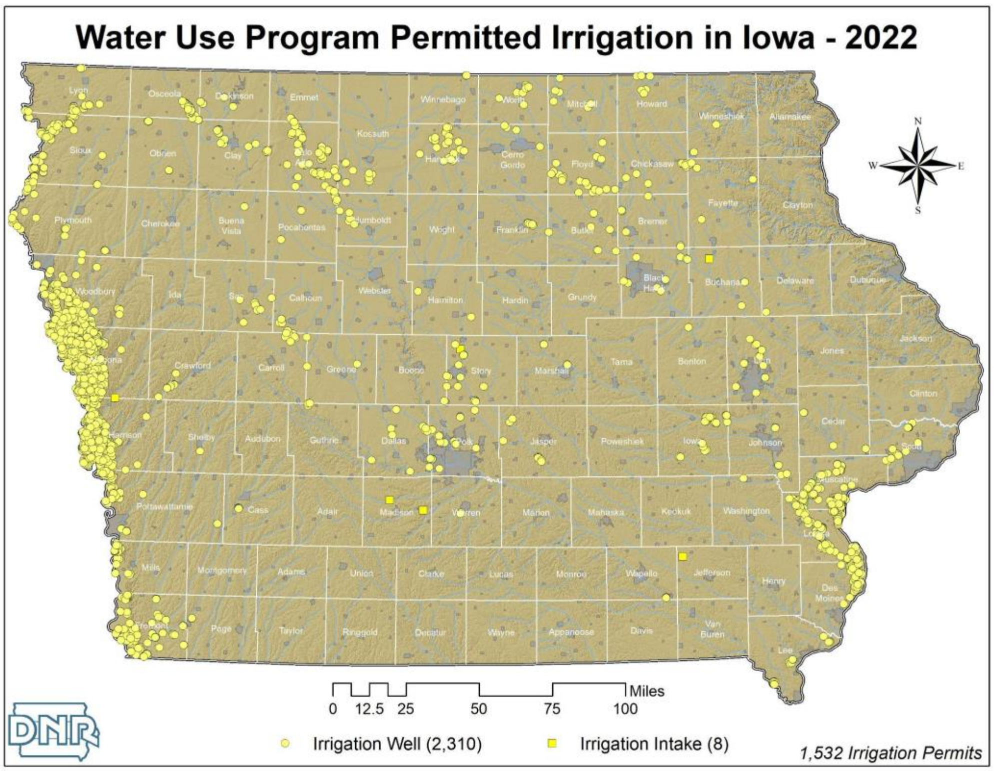


Figure 3. Map of irrigation wells and irrigation intake permitted in Iowa, 2022.

Agriculture

Iowa has historically been known for its prime topsoil and its plentiful rainfall and widespread river systems, making it an ideal place for agriculture. Ironically, the plenitude of rain also makes the state vulnerable to drought, since farmers are able to forgo irrigation in most years. Iowa has been said to have a "high risk" rating for drought vulnerability, based on the factors of exposure, sensitivity, and adaptive capacity (Engstrom, 2020). Iowa's lack of a comprehensive and ongoing drought plan prior to 2022 has not helped this susceptibility.

Livestock requires significant amounts of water to stay healthy, especially during extended periods of intense heat. Row crops in most of the state depend on predictable precipitation. In meteorologically drier parts of the state, where irrigation is more common, unfortunately there is the added problem of limited groundwater resources (i.e., they are also geologically drier). Whereas much of Iowa has access to multiple aquifers if one drills deep enough, northwest Iowa is dependent on shallower groundwater resources. If these dry up, the region is doubly vulnerable.

Irrigated crops are, on one hand, less immediately affected by drought, yet the crops that are irrigated in Iowa are often high-value food crops. If the source water for irrigated crops is compromised by drought, it can have severe impacts for producers, especially for smaller operations that may lack crop insurance, and the communities that depend on this food.

Indicators that can be used to evaluate severity in this sector include reservoir storage levels, surface water and ditch flow levels, soil moisture, observed impacts to crops and livestock, and pasture/ forage conditions. Past drought impact data is available for the agriculture sector from reported losses recorded by the U.S. Department of Agriculture Farm Service Agency and Risk Management Agency (RMA) as part of relief programs. According to the RMA's crop insurance data, the fifteen counties with the greatest losses by dollar value (after adjusting for inflation) in the past 32 years are Carroll, Plymouth, Sac, Crawford, Greene, Calhoun, Pottawattamie, Woodbury, Webster, Guthrie, Hamilton, Butler, Benton, Sioux, and Keokuk (Figure 4).

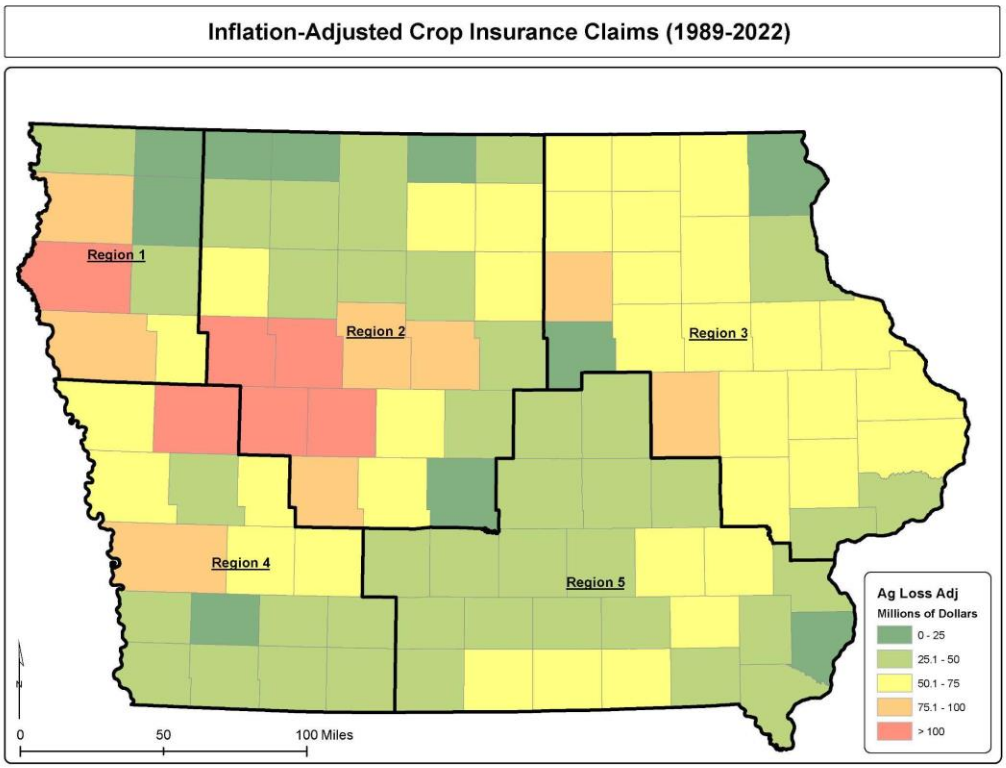


Figure 4. Inflation Adjusted Crop Insurance Claims (1989-2022)

The following maps summarize an analysis of drought vulnerability from FEMA's National Risk Index (NRI). The analysis considers expected annual loss (EAL), a social vulnerability index (SoVI[1]), and community resilience. The drought risk score for an area is computed by multiplying EAL by the SoVI and dividing by the community resilience rating. These scores are relative to nationwide scores, so Iowa's best or worst ratings may still be worse or better than national averages. The map nonetheless gives an idea of the most vulnerable jurisdictions. EAL is calculated by multiplying exposure by annualized frequency and historic loss ratio. Exposure is the representative value of agriculture potentially exposed to a drought.

Unfortunately, the data in the NRI drought risk index are based on agricultural loss data alone, so effects on urbanized areas are generally ignored in these maps. However, this focus is not entirely inaccurate, since agriculture in Iowa is often the first sector to be affected, leaving rural and agricultural areas generally more vulnerable to drought.

[1] SoVI is an index of social vulnerability developed by the University of South Carolina and should not be confused with the SVI developed by the U.S. Centers for Disease Control and Prevention (CDC).

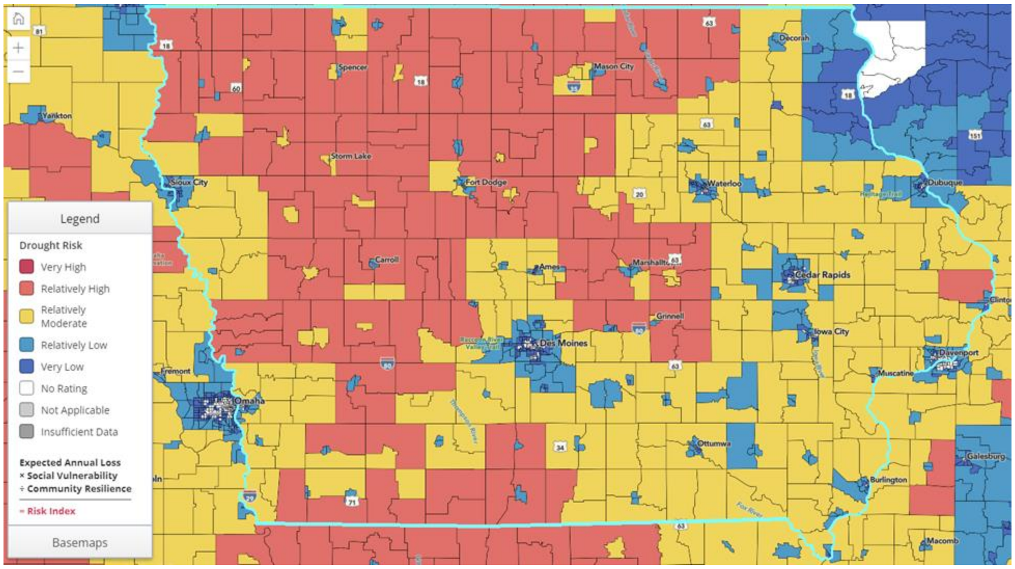


Figure 5. Drought Risk Index by census tract in Iowa, from FEMA NRI, showing generally less risk in urban areas and in southeastern and eastern Iowa.

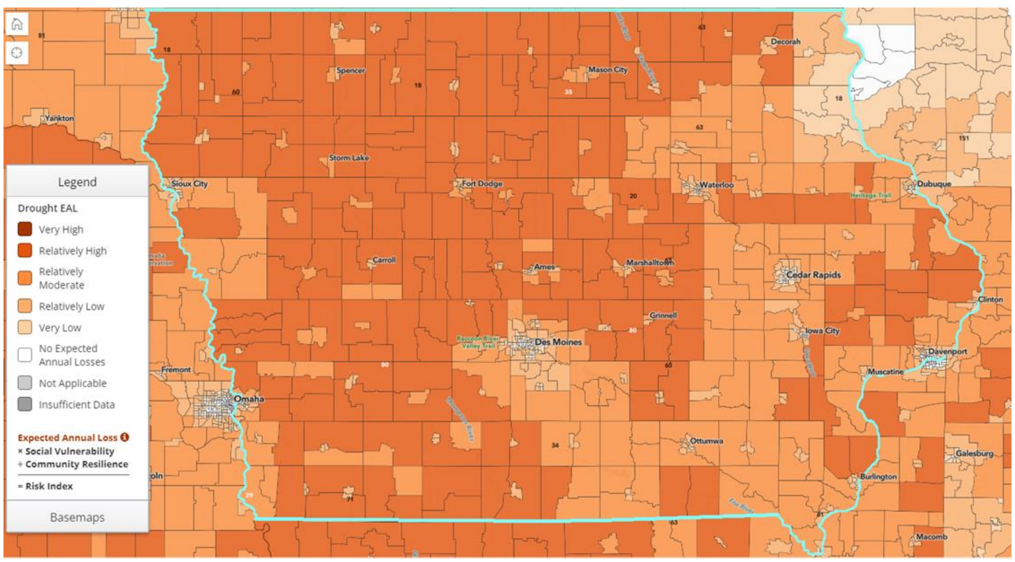


Figure 6. Expected Annualized Losses by census tract in Iowa, from FEMA NRI, showing generally less risk in urban areas and in southeastern and eastern Iowa.

These maps suggest that most of the jurisdictions more vulnerable to drought are in Drought Regions 1, 2, and 4. According to FEMA's county-based NRI drought risk map (not depicted here), notably at-risk counties include Audubon, Buena Vista, Calhoun, Carroll, Cass, Cerro Gordo, Cherokee, Crawford, Floyd, Franklin, Greene, Hamilton, Hancock, Ida, Kossuth, Marshall, Mitchell, Osceola, O'Brien, Palo Alto, Pocahontas, Poweshiek, Ringgold, Sac, Tama, Webster, Winnebago, and Wright. No census tract in Iowa falls under the "Very High" levels of EAL indicated in the map legend. Most are either relatively high or relatively moderate on the nationwide scale.

Unlike many other industries in Iowa, agriculture is one that is often insured against drought. The damages sustained thus might not register as a declared disaster under FEMA disaster relief programs or even USDA disaster relief programs. The economic impact to the agricultural sector as a whole, then, is absorbed to an extent by insurance. This is not a long-term solution to potential crop shortages that may result from a dependence on crop insurance as a drought mitigation measure. Additionally, many other industries in Iowa are dependent on productive cropland (e.g., ethanol, livestock, food processing, chemical processing, etc.), as discussed below. A vulnerable agricultural sector means a vulnerable economy in Iowa, even with crop insurance.

Water Supply, Industry, and Energy Sector
Water Supply & Water Treatment
Water supply is at the root of drought resilience for many sectors addressed in this plan, but this sector can itself be vulnerable to drought. Precipitation, streams, rivers, lakes, reservoirs and groundwater are used to meet a diverse set of water resource needs within the State. Each of these water sources can be impacted during drought periods, resulting in a complex interlinked array of environmental, economic and societal impacts. The following points summarize drought impacts related specifically to the state's water resources.

- Lower precipitation - During dry periods, precipitation in the form of both rain and snow is below normal, resulting in less moisture in the soil, less runoff into the streams and less recharge to the underlying aquifers.
- Lower stream flows - Reduced runoff results in lower stream flows which can reduce water availability to water users that divert directly from the stream. Reduced streamflow can also bring water levels below diversion intake elevations and result in a variety of adverse impacts to river navigation, hydroelectric power production, water quality, and aquatic habitat.
- Lower lake and reservoir levels - Less runoff can result in lower lake and reservoir levels causing a variety of recreational and environmental impacts. Water supply availability can also be stressed in regions where water users rely on reservoir storage to meet their needs.
- Decline in groundwater levels - Groundwater levels can decline, increasing well pumping costs and causing shallow wells to dry up. Natural systems such as wetlands that depend on shallow groundwater can also be adversely impacted.

Various water supply systems in Iowa may depend on streamflow, aquifer levels, shallow groundwater, and lake & reservoir levels. Some depend on more than one. A public water supply system might be considered most vulnerable if it relies solely on groundwater found in alluvial sand and gravel from an interior body of water, or if the loss of wells pulling from these sources could not be compensated by other wells in the system accessing other source waters. Such vulnerable systems, shown in Figure 7 below, are more sensitive to a loss of streamflow, which is affected by precipitation. A drought may be especially challenging for these systems. Certain counties have significant populations served by these systems, clustered primarily on the western edge of the state and in a belt across the center of the state. Clay, Jasper, Linn, Polk, and Wapello counties have more than 15,000 people on sole-source water supply systems; while Boone, Crawford, Dallas, Poweshiek, Sioux, and Story counties have between 7,000 and 15,000 people on these systems.[2]

[2] Some water supply systems serve populations across county boundaries. The number, but not the exact location, of the population served is centrally recorded. Where the GIS point for systems was clearly in a different county from the primary community served, the community's county was used for tallying population served per county. Due to the cross-county service of many water supply systems, some county sums of population served are not exact, but give a general idea of where these systems exist in the state and how many are served by them.

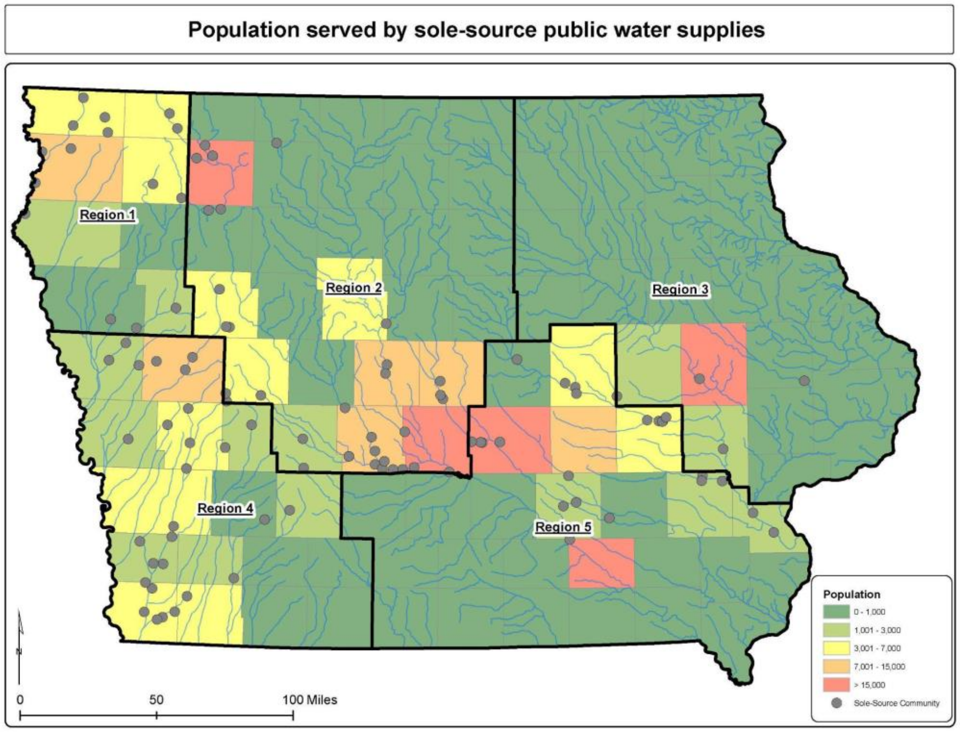


Figure 7. Community Water Supplies dependent on alluvial sand and gravel groundwater, Iowa DNR

Shortages in available water can lead to increased operating costs and/or difficulty meeting regulations for both water supply and wastewater treatment systems. In dry times, water suppliers may find that pollutants in their water sources are more concentrated (less water to dilute pollutants). This means even what water still exists in the supply might near or exceed allowable limits on pollutants in a public water supply. Similarly, wastewater treatment plants are typically restricted in how concentrated pollutants in their effluent can be, compared to the stream as a whole. At low stream flows, these limits will be lower and thus harder to avoid exceeding.

To avoid such difficulties, most water supply, distribution, and treatment systems will prepare reserve supply capacity and/or limit demand (either by not building out beyond what the system can handle at its peak, or by requesting that people restrict usage). Some systems in small towns, however, may not be able to afford the excess capacity or were built when demand better matched supply and economic capacity.

Industry

Major industries in Iowa include manufacturing (including chemical, machine/vehicle, & light manufacturing), renewable fuel and energy, insurance & banking, health and social services, food processing, warehousing & distribution, and IT & data centers.

Of these, certain industries are major water users. For instance, Iowa's industrial water users with annual usages over 500 million gallons per year (mgy) are from the following industries, from highest to lowest use: manufacturing, food processing, chemical processing, and ethanol. These industries are highly dependent on the availability of water. Loss of access to a usable water supply can lead to constraints on production. Fortunately, most of these highest water users in the state (i.e. over 500 mgy) are clustered around large rivers and/or in counties on the eastern half of the state with less drought risk (from highest to lowest use, by county: Muscatine, Wapello, Clinton, Black Hawk, Linn, Lee, Woodbury, Webster, Cherokee, Dubuque, Chickasaw), i.e. mostly Drought Regions 3 and 5.

Data from the U.S. Census Bureau show a similar pattern: over a third of employees in drought-vulnerable non-agricultural industries work in Drought Region 3 (about 212,000 employees; compared to about 160,000 in Region 2; 62,000 in Region 5; 40,000 in Region 1; and 27,000 in Region 4). (U.S. Census, 2020)

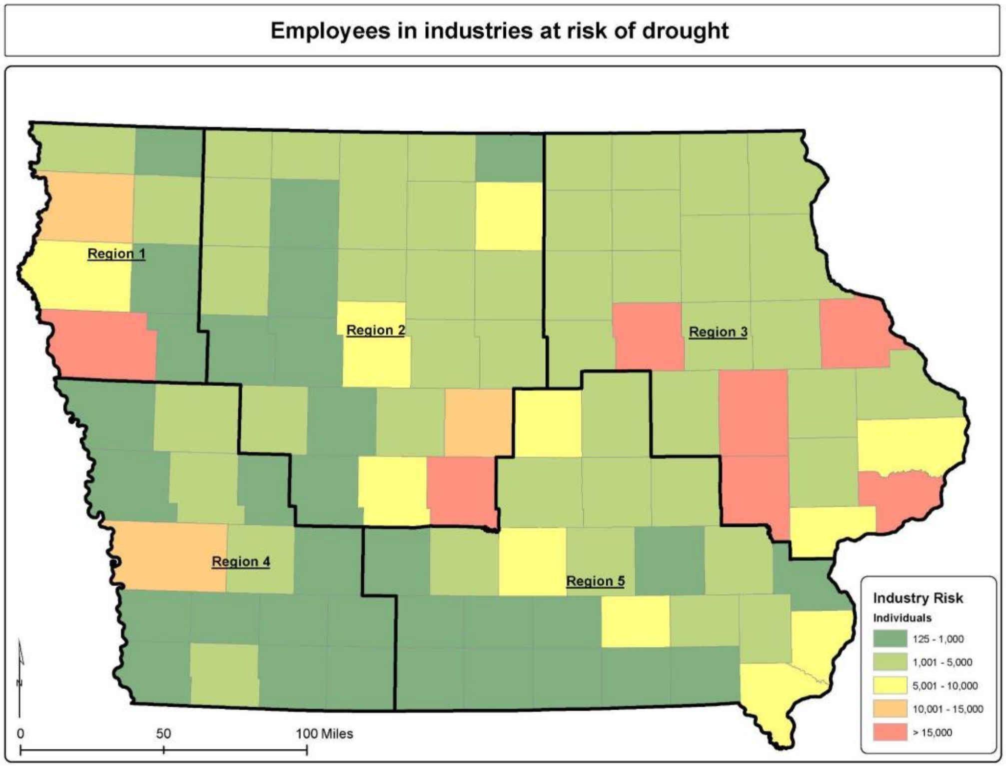


Figure 8. Employees in industries at risk of drought.

Despite the concentration of the highest water-using facilities in these relatively drought-resilient places, there is still a secondary risk from drought in the form of decreased raw materials when agriculture is affected. Ethanol production depends on growing more corn than what is produced for food. Food processing and chemical manufacturing depend on crops and livestock and their byproducts. Farm equipment manufacturing, a significant part of Iowa's manufacturing sector, is dependent on farmers and ranchers having sufficient income or credit to purchase new equipment. Finally, reduced production of food (especially if it occurs in other regions as well) can lead to higher food prices economy-wide, which restricts expendable income and hampers economic vitality.

Additional risk to industry in Iowa comes from low river levels where barges carry products along the Mississippi and Missouri rivers. The droughts from 2020 to 2022 have led to levels so low on the Mississippi that barges have been under-laden to ensure they can float on the shallow river. This makes transportation of goods, notably agricultural products, more difficult and costly. This can exacerbate the issues faced by other industries that use those goods and raise their costs, along with causing general supply chain delays.

Energy

For over a decade, Iowa has been a net producer of electricity, creating more than it uses. Iowa itself may not feel the effects of drought on electricity supply, but in an interstate market, the state may still see prices change if drought causes power shortages elsewhere. A reduction of electric power generation and water quality deterioration are potential effects of drought. Hydroelectric power accounts for only 1.9% of the state's electric generation, (U.S. Energy Information Administration, 2022) but could be diminished by low water levels in rivers and reservoirs.

Large amounts of water are also used in cooling generators in fossil fuel and nuclear power plants. The water that flows out after cooling may be too warm to safely put into a river or stream with low flow, since the higher concentration of warm or hot liquid could be detrimental to the stream's health. The energy industry's vulnerability to drought does not come necessarily from a lack of water for cooling, though that is a possibility, but rather a difficulty in disposing of that water safely and legally. Solar and wind power generation are not susceptible to drought as they do not use water for cooling. Thanks to various private, local, state, and federal initiatives, wind power accounts for over half of the electric grid mix in Iowa (56.8%). (Office of Energy Efficiency, 2022)

Environment and Recreation Sector
Along with regular precipitation, wetlands and other surface waters are vital to the survival of wildlife, including plants and animals. An ongoing drought which severely inhibits natural plant growth cycles may impact critical wildlife habitats. Drought impacts increase with the length of a drought, as carry-over supplies in reservoirs are depleted and water levels in groundwater basins decline.

Fish populations can be affected directly by water shortages or indirectly by water quality problems caused by drought. Higher nutrient concentrations due to drought (especially following precipitation that washes built-up nutrients after a dry period) can lead to bacterial or algal blooms, decreasing the oxygen available to fish. This exacerbates the already decreased amount of dissolved oxygen available to each fish when the volume of water decreases. Hunters may also have trouble finding animals when watering holes dry up.

Migratory animals are especially dependent on water being available when they pass through, but water shortages can be difficult for any plants or animals. Much of the outdoor recreation in Iowa is also tied to the presence of water, whether hunting, fishing, boating, or camping. Even non-water-adjacent recreation can become less desirable when plant and animal life is negatively affected by drought. The U.S. Department of Commerce's Bureau of Economic Analysis places the contribution of the outdoor recreation industry at about 1.8% of Iowa's GDP ($3.6 billion) in 2020. (Bureau of Economic Analysis, 2020)

Drought conditions increase the risk of wildfires, which can mean prohibitions on camping fires. During drought, public recreation areas may be closed to prevent human-caused wildfire due to desiccated hunting areas or hiking trails. Other impacts from drought include increased tree mortality due to lack of precipitation and increased vulnerability to disease due to plant water stress. Related to this is a decrease in hunting game population due to lack of forage and water.

Public Health and Safety Sector
Drought can have a number of effects on the public health and safety sector. The most obvious problem is a lack of access to water for human consumption and sanitation. These, however, are the best-protected uses of water in Iowa's water prioritization scheme (Iowa Code § 455B.266). Other sectors (e.g., irrigation or industry) will typically be restricted first. That said, when drought is severe enough to seriously affect an urban population's water supply, the consequences on human health and wellbeing are potentially significant. Furthermore, the impacts of drought on public health and safety can be seen before the state sees any actual restrictions on domestic supply.

As mentioned above, the agricultural sector is usually the first affected by drought. This cascades to the public health sector due to the potentially devastating mental health toll that crop and livestock losses can take on farmers, ranchers, and rural communities, especially those lacking insurance.

Drought can concentrate pollutants in effluent from industry and water treatment plants, further reducing clean, usable water even where it is available. Switching to alternative water sources may mean dealing with water quality issues not normally an issue for a community. One stakeholder noted that their community's backup water supply is polluted with PFAS (per- and polyfluoroalkyl substances), leading to questions of allowable PFAS limits when water supply is short.

Prolonged periods of drought can create dry landscapes that are vulnerable to wildfire hazard, but short drought periods also have the ability to increase the risk of wildfire hazards. Furthermore, depending on a community's water supply source, its ability to fight fires that do break out may be diminished by low water supply.

Drought conditions can also cause soil to compact, decreasing its ability to absorb water, making an area more susceptible to flash flooding and erosion. Consequently, a community may simultaneously see the disastrous effects of excess water at the same time as the effects of insufficient water. A drought may also increase the speed at which dead and fallen trees dry out and become more potent fuel sources for wildfires. Drought can make trees more susceptible to insect infestations, causing more extensive damage to trees and increasing wildfire risk, at least temporarily. Trees in urban forests can also become susceptible to insects and mortality due to lack of water.

Disease
Drought has been linked to the spread of diseases, notably West Nile Virus, flavivirus, and St. Louis encephalitis. (Mora, 2022) This is due to the increased ability of mosquito populations to increase in urban drainage systems during times of decreased rainfall. (Gubler, 2001) Because once-flowing water may pool in dry conditions, there is more standing water for mosquitoes to use, located in places not normally a concern. At the same time, places where there may normally be standing water could be dry during a drought, giving mosquitoes less opportunity to reproduce. The net effect of any given drought on mosquito populations in any given area is uncertain, but has potential for benefit or harm.

Valley Fever (coccidiomycosis) can also be expected to spread to new areas, as the fungal spores that cause the disease are "increasingly aerosolized by drought conditions, making them easier to inhale." (McCann, 2011) Long drought periods followed by intense rain are also positively associated with increases in disease outbreaks due to increased rodent populations, notably the 1993 outbreak of Hantavirus in the southwestern U.S.

Drought contributes to harmful algal blooms, endangering human health both via drinking water and recreational activities. (Yusa, 2015) This has become a common hazard in Iowa, whose waters also suffer from nitrogen pollution due to runoff from livestock facilities, fertilized croplands, and lawns, which exacerbates cyanobacteria growth. Water-borne diseases such as Escherichia (E). coli, Cryptosporidium, and Giardia can also become concentrated in groundwater sources during drought, which after rainfall can contaminate water sources, especially around livestock and places where livestock manure is applied or allowed to leach into water sources. Heavy rainfall during or after an extended drought can also lead to outbreaks of Campylobacteriosis and other diseases.

Despite being located at the confluence of two rivers, the water supplier for the state's largest metropolitan area (Des Moines Water Works) has been working to employ multiple water sources and supply strategies (e.g., backup wells, flash boards, aquifer storage and recovery) due to issues with surface water quality and quantity. This insulates the Des Moines metropolitan area from some of the exacerbated water quality issues from drought, but smaller communities with less adaptive capacity have to deal with the same deteriorated water quality and quantity. Thus, even in the public health sector, larger urbanized areas that have prepared for water quality issues may be less severely impacted by drought. As regards public health and safety, the most at-risk populations will be located in rural and urban areas with less adaptive capacity.

6.2 Regional Risk
As discussed above, the general trend of regional vulnerability is a spectrum (from most vulnerable to least) going northwest to southeast, rural to urban, and shallow/surface water to deeper groundwater. The state's drought plan establishes five drought regions: northwest, central, northeast, southwest, and southeast. Within each of these regions, different jurisdictions are more vulnerable than others due to their type of water supply, their access to multiple types of water supply, their dependence on agriculture or other industries vulnerable to drought, etc. Below, the vulnerability of each Drought Region is discussed as it relates to crop insurance claims, employees in drought-vulnerable industries, state parks (as a proxy for environment and recreation[3]), climate, and populations served by vulnerable water supply systems.

Figure 9 shows counties in Iowa color-coded by how many weeks of severe drought each county has experienced from 2000 to 2022, according to the U.S. Drought Monitor. The counties with the highest number of weeks in severe drought include Carroll, Calhoun, and Sac. The northeast corner of the state shows the fewest drought weeks, while the western portion of the state shows the most, especially in the northwestern quadrant.

[3] There are 73 state parks, preserves, and forests across the state, all of which are dependent to some degree on streamflow and precipitation for the viability of the local ecosystems or the recreation opportunities. It is an imperfect proxy in that many other areas along streams serve as recreation areas, and city parks or private reserves are also not counted.

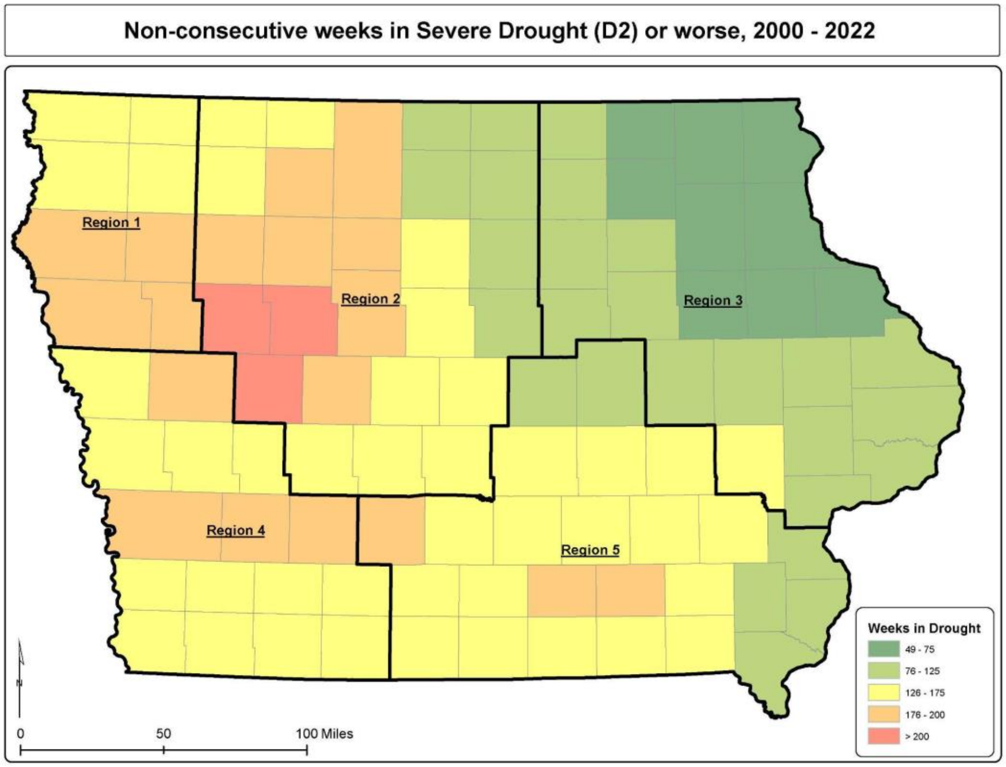


Figure 9. Non-consecutive weeks in severe drought (D2) or worse, 2000-2022.

While not specific to single regions, precipitation outside of the state of Iowa will also affect Iowa's water supplies. The entirety of Iowa's eastern and western borders are major rivers. Snowmelt and precipitation principally from Minnesota, Wisconsin, Colorado, Nebraska, North Dakota, South Dakota, Wyoming, and Montana feed the Mississippi and Missouri Rivers in Iowa. Many of these states are or could be experiencing their own droughts, meaning not only less water flowing downriver, but increased demand in those states, decreasing the flow to Iowa. With the warmer average winter temperatures anticipated, mountain snowpack may decrease, and spring snowmelt in the Rocky Mountains may come earlier in the year. With over 30% of the Missouri River's annual flow coming from the mountains, it is especially prone to decreased flow, relative to Iowa's other rivers. Regions 1 and 4 would feel this effect more than others.

Region 1: Northwest

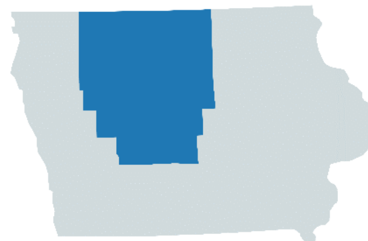
As noted in State Drought Regions, Region 1 is not only meteorologically drier than other regions, but it also relies heavily on groundwater from shallow alluvial aquifers or deeper bedrock aquifers, making it more vulnerable to water supply shortages during drought. The area is largely agricultural, but more than most regions, it is also served by farm irrigation, primarily near the Missouri River. Water supply stakeholders expressed a concern with water demand from livestock in this region. Especially on hot days, livestock can require significant amounts of water not only for consumption, but for cooling. In Region 1, there are about 28,000 people served by water supply systems dependent on alluvial sand and gravel groundwater.

The average amount of the area in Region 1 in various levels of drought or dryness over the last 23 years (2000-2022), according to the U.S. Drought Monitor, is 36.3% in D0, 20.1% in D1, 11.3% in D2, 3.9% in D3, and 0.4% in D4. Put another way, on any given week, one might expect about 12% of the region to be in severe drought or worse.[4] The region has seen D4 drought during 33 weeks since 2000 (2.8% of all weeks), with an average of 15% of the region in D4 drought during those times.

[4] This figure is somewhat skewed in that it is more common for the region to be almost entirely in severe drought or worse (100%), or for the entire region to be free of drought (0%). The 12% figure is an average of the percentage of the region in D2 across all weeks since the Drought Monitor's inception.

Notable at-risk non-agricultural industries in Region 1 include healthcare and social assistance, chemical manufacturing (including ethanol), food manufacturing, metal and machinery manufacturing, transportation, and construction. Region 1 has a higher concentration of ethanol production plants than most regions, especially relative to population. Advances in technology since the turn of the century have led to a much lower water-to-ethanol ratio in the production process (University of Illinois), so water availability, while still a concern during drought, will have less impact than it would have in decades past. However, the availability of corn, which is largely dependent on precipitation in Iowa, can still be impacted by drought. Plymouth, Woodbury, and Sioux counties were in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. (USDA RMA) Non-agricultural industry risk in Region 1 is concentrated in Woodbury, Sioux, and Plymouth counties. There is one state park in Region 1, in Woodbury County. This is the lowest ratio of parks per county in a drought region.

Region 2: Central



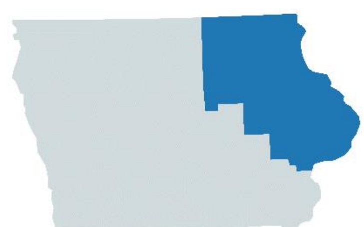
Region 2 has some of the most productive soils in the world, but the rowcrop agriculture that dominates the landscape is vulnerable to precipitation deficits, as relatively little of it is irrigated, but most of it is tiled for improved drainage. Still, the region has access to both bedrock aquifers and groundwater from alluvial sand and gravel aquifers. In Region 2, there are about 95,000 people served by water supply systems dependent on alluvial sand and gravel groundwater.

The average amount of the area in Region 2 in various levels of drought or dryness over the last 23 years (2000 to 2022), according to the U.S. Drought Monitor, is 36.0% in D0, 20.3% in D1, 10.1% in D2, 2.8% in D3, and 0% in D4. Put another way, on any given week, one might expect about 10% of the region to be in severe drought or worse.[5] D4 drought has never been seen in Region 2 since the USDM's inception in 2000.

Notable at-risk non-agricultural industries in Region 2 include healthcare and social assistance, chemical manufacturing (including ethanol), data processing and hosting (which often need water for cooling), printing and publishing, plastics and rubber manufacturing, food manufacturing, metal and machinery manufacturing, transportation, construction, utilities, waste management, and wood product manufacturing. There is a notable concentration of commercial feedlots along the I-35 corridor in Wright, Hamilton, and Hardin counties.

Carroll, Green, Calhoun, Webster, Guthrie, and Hamilton counties were in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. (USDA RMA) Non-agricultural industry risk in Region 2 is highest in Polk, Story, Cerro Gordo, Webster, Dallas, Buena Vista, Carroll, and Boone counties. There are 27 state parks in Region 2, with 10 in Dickinson county, two each in Cerro Gordo, Emmet, Polk, and Webster counties, and one each in Boone, Calhoun, Franklin, Guthrie, Hancock, Hardin, Kossuth, Sac, and Winnebago. This region has the highest ratio of state parks to counties. The high number of parks in Dickinson County is related to the presence of Iowa's "Great Lakes" region, a regional hub for water-based recreation and tourism. Saylorville Lake, a large reservoir just north of Des Moines, is also in Region 2. An exceptional drought could pose a threat to these lakes and the ecosystems and industries that depend on them.

Region 3: Northeast



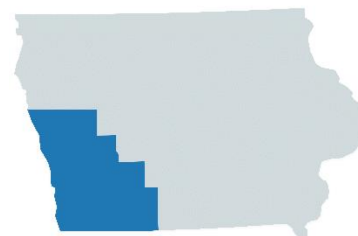
Plentiful water resources lead to Region 3 being perhaps the least drought-vulnerable region, at least on the supply side. However, the availability of water beneath the surface does not imply its accessibility. Furthermore, with most farmland in this region not being irrigated, crops are still vulnerable when drought comes. In Region 3, there are about 145,500 people served by water supply systems dependent on alluvial sand and gravel groundwater. Most of them (about 141,000) are on the Cedar Rapids municipal system.

[5] This figure is somewhat skewed in that it is more common for the region to be almost entirely in severe drought or worse (100%), or for the entire region to be free of drought (0%). The 10% figure is an average of the percentage of the region in D2 across all weeks since the Drought Monitor's inception.

The average amount of the area in Region 3 in various levels of drought or dryness over the last 23 years (2000 to 2022), according to the U.S. Drought Monitor, is 25.4% in D0, 13.0% in D1, 5.0% in D2, 1.5% in D3, and 0% in D4. Put another way, on any given week, one might expect about 5% of the region to be in severe drought or worse.[6] D4 drought has never been seen in Region 3 since the USDM's inception in 2000.

Benton and Butler counties were in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. (USDA RMA) Non-agricultural industry risk in Region 3 is highest in Linn, Scott, Johnson, Black Hawk, Dubuque, Muscatine, Clinton, Bremer, and Winneshiek counties. There are 16 state parks in Region 3, with two each in Linn and Muscatine counties, and one each in Allamakee, Black Hawk, Buchanan, Clayton, Delaware, Dubuque, Fayette, Johnson, Jones, and Winneshiek.

Region 4: Southwest

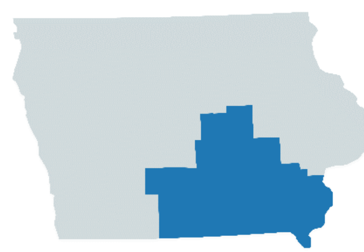


Groundwater resources in Region 4 are generally limited to shallower wells, as deeper aquifers have poor water quality. Surface water rounds out the water supply, and many water users are connected to rural water systems. In Region 4, there are about 38,500 people served by water supply systems dependent on alluvial sand and gravel groundwater.

The average amount of the area in Region 4 in various levels of drought or dryness over the last 23 years (2000 to 2022), according to the U.S. Drought Monitor, is 38.3% in D0, 21.4% in D1, 9.6% in D2, 2.0% in D3, and 0.003% in D4. Put another way, on any given week, one might expect about 12% of the region to be in severe drought or worse.[7] Region 4 has only seen 14 weeks of D4 drought since 2000.

Crawford and Pottawattamie counties were in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. (USDA RMA) Non-agricultural industry risk in Region 4 is highest in Pottawattamie, Crawford, and Page counties. There are 12 state parks in Region 4, with two each in Fremont, Monona, and Pottawattamie counties, and one each in Cass, Harrison, Montgomery, Shelby, Taylor, and Union counties.

Region 5: Southeast



Drought region 5 is similar to region 4 in that water users generally depend on shallow groundwater. However, the eastern part of the region has access to deeper water sources and the southwestern part of the region is home to the Rathbun Rural Water System, which draws water from a large reservoir (Rathbun Lake) and serves about six and a half of the 25 counties in Region 5. In Region 5, there are about 67,000 people served by water supply systems dependent on alluvial sand and gravel groundwater.
The average amount of the area in Region 5 in various levels of drought or dryness over the last 23 years (2000 to 2022), according to the U.S. Drought Monitor, is 37.3% in D0, 20.8% in D1, 9.1% in D2, 1.2% in D3, and 0% in D4. Put another way, on any given week, one might expect about 9% of the region to be in severe drought or worse.[8] D4 drought has never been seen in Region 5 since the USDM's inception in 2000.

Keokuk was the only county from Region 5 in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. (USDA RMA) Non-agricultural industry risk in Region 5 is highest in Marion, Des Moines, Marshall, Lee, Wapello, Jasper, Henry, Poweshiek, Washington, and Warren counties. There are 17 state parks in Region 5, with

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[6] This figure is somewhat skewed in that it is more common for the region to be almost entirely free of drought (0%). In fact, 80% of all weeks had 0% of the region in D2. The 5% figure is an average of the percentage of the region in D2 across all weeks since the Drought Monitor's inception.

[7] This figure is somewhat skewed in that it is more common for the region to be almost entirely in severe drought or worse (100%), or for the entire region to be free of drought (0%). The 12% figure is an average of the percentage of the region in D2 across all weeks since the Drought Monitor's inception.

[8] This figure is somewhat skewed in that it is more common for the region to be almost entirely free of drought (0%). In fact, 78% of all weeks had 0% of the region in D2. The 5% figure is an average of the percentage of the region in D2 across all weeks since the Drought Monitor's inception.

two each in Appanoose, Lucas, Van Buren, and Warren counties, and one each in Davis, Decatur, Henry, Jasper, Madison, Mahaska, Marion, Tama, and Washington counties.

6.3 Risk Summary

The following counties (listed alphabetically) have been identified as the most vulnerable to drought, based on the several factors discussed above, combined with the U.S. Centers for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI).

- Buena Vista
- Crawford
- Carroll
- O'Brien
- Osceola
- Plymouth
- Pottawattamie
- Sac
- Sioux
- Wapello
- Webster
- Woodbury

These counties are largely clustered in northwest Iowa, with the exception of Pottawattamie and Wapello. Several other counties in central and northwest Iowa also show higher vulnerability than most other counties in Iowa. These counties include Audubon, Black Hawk, Calhoun, Clay, Dallas, Greene, Hamilton, Jasper, Lyon, Marshall, Polk, Poweshiek, and Story.

Drought poses threats to Iowa that can severely impact public health and social, environmental, and economic well-being. Due to differences across the state in precipitation, geology, demographics, industry, and infrastructure, not all parts of the state are equally susceptible. Consequently, Iowa is taking a regional approach to monitoring, preparing for, and responding to drought. Iowa is expected to see droughts increase in frequency, intensity, and duration, given atmospheric trends. As an agricultural state that largely depends on rainfall rather than irrigation, this poses serious consequences for the state's environment, economy, and society. No region or sector within Iowa is entirely insulated from drought's effects, but a sensible and equitable approach to mitigating those impacts would be to prioritize jurisdictions and sectors likely to be most affected while having the least capacity to recover.

7.0 Mitigation Recommendations

Summary of Problem and Identification of Possible Actions to Mitigate Problem

Drought ultimately arises from a lack of precipitation, which is generally outside our control. Supply can still be supplemented by maintaining reserve capacity and encouraging conservation of water resources when they become scarce. Much (but not all) of the work of drought mitigation is local, whether done by households, industries, governments, or otherwise. Having information as early as possible as to when an area may be entering drought and how people can or should start preparing reserves or reducing use will help communities respond appropriately. Consequently, the state's responsibilities lie primarily in preparing local communities for drought. To that end, the following mitigation goals are proposed.

Goals

1. Improve public understanding of drought and water supply; create a culture of conservation
2. Improve data collection and analysis capabilities
3. Coordinate information and messaging from state agencies to improve public response
4. Improve infrastructure resilience against drought
5. Improve resilience and responsiveness of agriculture, industry, and natural resources
6. Build on local capacity in preparing for and responding to drought

The actions below are meant to help the state of Iowa meet the goals listed. The Action ID number corresponds to the goal. The table is a list of objectives and actions that could mitigate the impacts of drought or improve drought response. Some are borrowed from other states' drought or hazard mitigation plans, but have not been authorized or funded in Iowa, or Iowa state agencies may not currently have the capacity or priority to implement them. Consequently, it is likely not all actions listed in this table will be implemented in Iowa. Some state organizations or state agencies have been listed as potentially assisting with certain actions where they seem the most appropriate, but there is no guarantee that these parties (or anyone) will in fact take on these actions. Still, the state agencies listed will typically be well-informed on an action and may provide technical assistance or serve as a point of contact for other entities interested in drought mitigation.

The 2023 update to Iowa's State Hazard Mitigation Plan, drawing from this table, will provide a more focused list of actions the state is taking on mitigating drought.

Action ID	Action	Potentially Assisting Party(ies)	Type	Notes
1.1	Develop coordinated, prompt, reliable, and accessible information for the whole community, actionable at every level of organization (i.e., state agencies, local government, industries, NGOs, individuals), concerning current and likely drought and water supply status.	DCT	Communication & Education	
1.2	Encourage and support public education on drought vulnerability, drought-time response actions, and continuous conservation measures prior to the occurrence of drought.	DCT	Communication & Education	Work with Iowa Department of Education to promote awareness among students
1.3	Encourage and support public education on watershed health and water quality protection, which preserves the quantity of usable water during droughts.	DCT, DNR	Communication & Education	Communicate with journalists and media outlets about this plan and what can be done.
1.4	Promote a culture of conservation through public messaging and discussion with water suppliers	DCT	Communication & Education	Conservation education or outcomes could be tied to the receipt of funds for infrastructure
1.5	Encourage and support residential storm water capture and re-use infrastructure	DNR, IDALS	Infrastructure	Example: rain barrels, ponds
2.1	Characterize Iowa's surface and groundwater resource availability, quality, use, and sustainability, and share the information via a web-based data system		Monitoring & Awareness	Establish an "Iowa Drought Information System", similar to the existing Iowa Flood Information System.
2.2	Expand current network of stream gauges to improve monitoring.		Monitoring & Awareness	Focus expansion on watersheds with insufficient or non-ideal placement of gauges
2.3	Expand current network of rain gauges to improve rainfall monitoring.		Monitoring & Awareness	
2.4	Expand current soil moisture monitoring network.		Monitoring & Awareness	

Action ID	Action	Potentially Assisting Party(ies)	Type	Notes
2.5	Expand current evapo-transpiration monitoring network.		Monitoring & Awareness	
2.6	Continue to improve groundwater level monitoring (i.e., install more monitoring wells)		Monitoring & Awareness	
2.7	Encourage public use of CMOR and CoCoRaHS.	IDALS, DNR	Monitoring & Awareness	
2.8	Incentivize or require water suppliers to confidentially share supply and demand forecasts with the Drought Coordinating Team		Monitoring & Awareness	
2.9	Improve mapping of private water supply and private wastewater systems; ensuring they can be assessed during extreme weather emergencies	DNR, Local	Monitoring & Awareness	In Iowa, a Groundwater Hazard Statement is required for all property transfers involving private water/wastewater systems. Capturing the data in GIS may improve risk assessment during drought.
3.1	Develop, implement, and continually improve the IDP communication plan	DCT, IGOV	Communication & Education	
3.2	Coordinate interagency drought-related efforts and communication	DCT	Communication & Education	
3.3	Provide water suppliers with prepared materials for distribution to water users, appropriate to the drought level and region	DCT	Communication & Education	
4.1	Encourage and implement green infrastructure practices to create healthier urban environments and manage storm water in cities.	Local, IDALS, IEDA, HSEMD, DNR, DOT	Nature-Based Solutions	Practices include mechanisms that prevent soil erosion or provide improved infiltration & groundwater recharge, flood protection, habitat, and cleaner air & water
4.2	Encourage local ordinances to exempt drought-resistant native plantings from vegetation height restrictions	Local, DNR, Iowa League of Cities	Nature-Based Solutions	
4.3	Expand drought-resistant native plantings along highways and local roads	DOT, Local	Nature-Based Solutions	
4.4	Foster riparian buffers on private lands	IDALS	Nature-Based Solutions	
4.5	Restore streambanks and wetlands	DNR, IDALS, Local	Nature-Based Solutions	
4.6	Seek authorization and funding for development of new water supply sources.		Infrastructure	Focus funding on critical watersheds, vulnerable water systems, and vulnerable populations

Action ID	Action	Potentially Assisting Party(ies)	Type	Notes
4.7	Develop additional water storage, especially floodwater diversion and storage options	Local, IDALS, DNR, HSEMD	Infrastructure	Focus funding on critical watersheds, vulnerable water systems, and vulnerable populations. Use LiDAR scans to identify suitable locations for water storage, such as detention/ retention ponds
4.8	Encourage development of gray water infrastructure, recycling and reusing water at any scale whenever viable	Local, DNR, IEDA	Infrastructure	
4.9	Connect vulnerable public water systems to redundant water sources and other supply systems	HSEMD, Local	Infrastructure	Identify resilient systems to connect to nearby vulnerable systems. DNR records number of “consecutive systems” and “sole-source systems”
4.10	Monitor and review aquifer storage and recovery well analysis and permitting	DNR	Infrastructure	
4.11	Couple water supply development efforts with infrastructure assessments and improvements in agricultural and rural communities		Infrastructure	
4.12	Proactively assist well-owners with maintenance of domestic and industrial wells, including identifying potential well vulnerabilities	DNR, Local	Infrastructure	
4.13	Expand water treatment capabilities	Local, DNR	Infrastructure	Focus funding on critical watersheds, vulnerable water systems, and vulnerable populations.
4.14	Continue transitioning to energy sources that do not require water throughput for cooling	IUB, IEDA, DOC	Infrastructure	Most fossil-fuel and nuclear energy facilities use water for cooling, which has a warm water effluent that might not be permissible during low streamflow. Improved battery capacity may be required for other energy sources.
4.15	Intensify water resource planning efforts in areas where population growth, development, or future climate conditions could stress available water supply in the future.	Local, DNR, IEDA	Demand Management	
4.16	Encourage development in areas with sufficient water supply, and/or encourage the use of development fees to fund water supply systems that can reduce the community’s risk of drought.	Local, IEDA, DNR	Demand Management	Ensure plans account for future conditions (e.g. population growth, increasing temperatures, frequency of drought, etc.). Water suppliers should be an integral partner in local development planning.

Action ID	Action	Potentially Assisting Party(ies)	Type	Notes
4.17	Take a leadership role by developing and implementing a water conservation and reuse strategy for the State, local governments and public and private facilities that incorporates the use of green infrastructure, gray water systems and energy production that includes recognition programs.	DAS, DOM, Local	Demand Management	
4.18	Encourage local plumbing codes that promote water efficiency		Demand Management	
4.19	Reduce water losses through leak detection and distribution system renovation, and increase awareness of the cost-effectiveness of replacing aging infrastructure	Local, DNR	Infrastructure	The American Society of Civil Engineers ("ASCE") states that over $2 billion per year is spent in the U.S. on treating water lost to distribution system leaks. The EPA estimates two to three trillion gallons are lost per year. In some cities, it may be up to 50% of treated water.
5.1	Improve resilience to drought on agricultural land through: crop selection and management, soil conservation and soil health, cover crops, perennial groundcover, agroforestry, terraces, windbreaks, conservation cover, tree & pasture planting, grassed waterways, and other soil health and soil conservation measures to retain soil moisture	IDALS, ISU Extension	Agricultural Resilience	
5.2	Improve resilience to drought on agricultural land through: irrigation and drainage water management, retention ponds, flow-adjustment valves on field tile systems, expanded irrigation infrastructure & improved irrigation efficiency, for both row crops and specialty crops	IDALS, ISU Extension	Agricultural Resilience	Solutions should be appropriately scaled for large or small operations working with a variety of crops.
5.3	Improve livestock cooling efficiency, including non-water cooling methods	IDALS, ISU Extension	Agricultural Resilience	

Action ID	Action	Potentially Assisting Party(ies)	Type	Notes
5.4	Plan for livestock-related transportation during drought at the state level. Note regulations that may inhibit relocation of livestock to non-drought areas, and ease as appropriate when necessary. Note regulations that may inhibit bringing water or feed to drought-stricken areas, and ease as appropriate when necessary.	DOT, IGOV, IDALS, HSEMD	Agricultural Resilience	
5.5	Promote among agricultural producers an awareness of climatological trends that suggest droughts may become more common	IDALS	Agricultural Resilience	
5.6	Encourage growth of fields enrolled in the NRCS Conservation Reserve Program that can be used for haying and grazing in USDA-declared drought emergencies		Agricultural Resilience	
6.1	Continue work of Iowa Water Resources Coordination Council to facilitate water policies and mitigation funding	IDALS, WRCC	Capacity Building	
6.2	Continue work of Iowa Watershed Planning Advisory Council to protect water resources through watershed planning	IDALS, WPAC	Capacity Building	
6.3	Encourage the continued establishment of Watershed Management Authorities (WMA), including through provision of technical assistance for WMAs	IDALS, DNR, HSEMD, Local	Capacity Building	WMA is a mechanism for cities, counties, and soil and water conservation districts to cooperatively engage in watershed planning and management. A WMA may assess and reduce flood risk, assess and improve water quality, monitor federal flood-risk planning and activities, educate residents of the watershed regarding flood risks and water quality, and allocate moneys made available to the authority for purposes of water quality and flood mitigation.

Action ID	Action	Potentially Assisting Party(ies)	Type	Notes
6.4	Continue participation in the Strategic National Stockpile Program	IDPH/HHS	Capacity Building	Provides a statewide, effective plan and operational procedures to ensure Iowa is prepared to receive and distribute the assets of the Strategic National Stockpile and ensure integration into Iowa's homeland security and emergency plan
6.5	Encourage and support the development and enhancement of local and regional drought management plans	HSEMD, DNR, IDALS, Local, EMA	Capacity Building	Consider scenarios of long-term droughts and complete loss of water. Integrate drought planning with local and regional water resources planning and hazard mitigation planning. Ensure consideration of future conditions.
6.6	Partner with agricultural and industrial sectors to protect source waters	IDALS, DNR, Local	Capacity Building	
6.7	State funding for local water quality protection	DNR	Capacity Building	The Resource Enhancement and Protection program provides funding to work with soil and water conservation districts to address local water quality protection needs
6.8	Undertake water assessment and watershed planning	IDALS, DNR, HSEMD	Capacity Building	Utilize NRCS Watershed Surveys and Planning Program and NRCS Watershed Protection and Flood Prevention Program

8.0 Implementation Steps

8.1 Adoption

This plan may be officially adopted by state agencies involved, and/or endorsed by the governor of Iowa. In the event that these actions are delayed or do not occur, staff at DNR, HSEMD, and IDALS may use the plan as a template for preparing for and responding to drought.

In the event that this plan is adopted, it is critical that the Drought Coordinating Team has the flexibility to amend the plan to respond to changing conditions, changes in staffing, or errors in the plan; or to adjust drought level indicators to match the situation “on the ground.” Consequently, there is no intention to seek legislative adoption of the Iowa Drought Plan.

Parts of this plan may be included in the State Hazard Mitigation Plan update scheduled for 2023, which HSEMD will adopt by rulemaking.

8.2 Plan Revision and Update Schedule

- First update: within 2 years of initial plan (by January 2025)
    - Within the first year of implementation, HSEMD will lead tabletop exercises to test the plan and find areas for improvement.

- Feedback may also be gathered from actual drought occurring from 2020 to 2022. The Drought Coordinating Team will consider the real-world application of the included drought level indicators and adjust as necessary.
- Second update and continuing: 5 years after initial plan (January 2028) and every 5 years thereafter, to coincide with State Hazard Mitigation Plan updates

8.3 Data and Information Needs

The next steps in providing timely and accurate drought information to Iowans are the development of an Iowa Drought Information System (IDIS) and the completion of the statewide hydrologic monitoring station network.

8.3.1 Iowa Drought Information System (IDIS)

Drought-related data are currently scattered across various databases, websites, and models at a variety of online or inaccessible server platforms, making it difficult for Iowans to access comprehensive and easily accessible drought information. The Iowa Drought Information System would display a collection of drought-related monitoring and climate data on a web-based visualization platform freely accessible to the public.

The IDIS platform would be modeled after the highly successful Iowa Flood Information System (IFIS) that was developed by the Iowa Flood Center in 2011. IFIS provides an easy way for local governments and citizens to access a wide range of flood data and information from one web location, and IDIS would do the same thing with drought data and information. IDIS would integrate and disseminate relevant drought information in a one-stop shop web platform in order to improve the public's and decision-makers' understanding and management of drought risk. Improved understanding and mapping of drought conditions are critical for Iowa's agricultural industry, water utilities, and all other water users. The threat of a variable climate and long periods of dry conditions make this information valuable to all Iowans. Improving the ability to quantify the emergence and severity of drought in agricultural regions will lead to improved resilience for food production systems.

There are many existing sources of drought-related data that could be included for visualization and analysis in IDIS. At a minimum, IDIS would provide access to the following:

1. Rainfall data at some 70 real-time rain-gauge stations deployed by the Iowa Flood Center and the Iowa State University, the National Weather Service (NWS) daily coop gauging network (~200 stations), radar-based rainfall estimates from NOAA and the IFC, as well as the Community Collaborative Rain, Hail and Snow (CoCoRaHS) civilian rain gauge network.
2. Streamflow and baseflow data from 150 USGS, 300 IFC "bridge sensors" with synthetic rating curves and statewide continuous hydrologic model for low streamflow;
3. Soil moisture sensors including from UI hydrostation (20) measurements at different depths and ISU soil moisture stations;
4. Soil moisture modeling output from the IFC hydrologic model (available statewide);
5. NASA satellite data including, among others, the Soil Moisture Active Passive (SMAP) and Gravity Recovery and Climate Experiment (GRACE) satellites.
6. Groundwater levels including UI hydrostation wells (see Hydrologic Monitoring Stations), Iowa Geological Survey water level monitoring network, water level monitoring data reported by water supply operators, USGS water table monitoring stations, and long-term project monitoring wells;
7. Evapotranspiration (ET) data from the IFC statewide model reported at hourly and daily scales;
8. U.S. Drought Monitor (USDM) maps produced weekly
9. Intelligent data analytics products including drought impact assessment, watershed level drought score, and real-time data exploration and visualization products.
10. Other information requested specifically by IDIS users that could be incorporated into the system.

IDIS would use a Google map-based web interface to bring this wide variety of drought-related monitoring data together in a single platform. Public demand for drought information can be estimated from interest in the highly successful IFIS. Usage of IDIS would be expected to be similar to IFC's first-in- the-nation on-line flood-information system, IFIS, which has since been visited more than 4 million times.

The IDIS will be automated to assess drought conditions in the state at a frequency of once per day. This drought frequency exceeds the weekly frequency of the USDM and will serve to monitor the expansion and contraction of drought conditions based on daily inputs. The IDIS will be built to be customizable in the future to incorporate new drought inputs and related derivative products. Improved communication and the prediction of droughts will improve the resiliency of the Iowa communities by assisting them in preparing for and recovering from natural disasters and by facilitating the sharing of information among users. The concept of IDIS was shared with citizen and agency stakeholders during the development of this IDP and was widely supported and recommended. It should be noted that those supporting and recommending the implementation of IDIS are the likely users of the system, which indicates that such a system would be accepted and used just as consistently as the current IFIS system.

8.3.2 Hydrologic Monitoring Stations

To better understand and monitor drought conditions, it is critical to have a uniform network of hydrologic monitoring sensors placed across the state to gather consistent and reliable hydrologic data. While climate data are widely available from a variety of sources, there is a notable lack of subsurface hydrologic data available on statewide drought conditions. Currently subsurface data on soil moisture conditions and groundwater levels are only available from sparsely located research stations or leftover from various projects. A dedicated hydrologic monitoring network is recommended for gathering reliable and systematic information on drought conditions in the state.

Expansion of hydrologic monitoring to include one station per county would provide systematic, drought-related information to all Iowans. Currently, through the Iowa Watershed Approach (IWA), the Iowa Flood Center has already deployed 20 hydrologic stations in several counties in Iowa. Each hydrologic station measures rainfall, wind speed and direction, soil moisture and temperature at four soil depths, and water levels in a shallow groundwater well. These stations have been used to inform drought and flood forecast models and provide critical publicly available data to local landowners, researchers, and agencies. As demonstrated so far in the IWA project, the hydrologic stations are low cost, low maintenance, last for many years, and collect and transmit data every few minutes. The data gathered would be immediately useful to local agencies and community members who will have access to the data through the Iowa Drought Information System.

Since several county stations were already installed as part of other projects, expansion of the Iowa Flood Center's network of hydrologic stations is needed to provide county-level coverage across the state. In addition to the IWA deployments, in 2023, the Iowa Flood Center anticipates federal funding from Representative Miller-Meeks and Representative Hinson through Community Planning Grants to expand the hydrologic network to Iowa Congressional Districts 1 and 2 in eastern Iowa (30 counties). Thus, it is imperative to finish the county network in western Iowa (50 counties) without a hydrologic station (~50). With a fully operational hydrologic monitoring network that includes one station per county, a systematic analysis of drought conditions across the state can be conducted, including the development of a statewide assessment of soil moisture conditions, soil water deficits and drought severity. This detailed information will be used to better inform the National Drought Center on drought conditions in Iowa. Better hydrologic data given to the National Drought Center will mean improved drought designations in Iowa that reflect actual, boots-on-the-ground conditions.

In summary, the development of the Iowa Drought Information System and expansion of the hydrologic network will improve communication and prediction of droughts and the resiliency of Iowa communities by helping them prepare for and recover from natural disasters. Although data are available from many different sources, the information is not widely distributed nor easily accessible. The IDIS will facilitate the sharing of information among users and improve the quality of life for both agricultural and urban residents.

8.4 Informational Material to Develop

The following are concepts for materials that the DCT could develop or contribute to that would help the public understand drought risk and preparedness. Development of these materials should include input from all relevant state agencies.

- Conservation tips and infographics
- Water resources information. (e.g., "Where does my water come from?")
- Response to drought

    - Public Health resources
        - Mental health & drought
        - Possible effects of drought

- What is a drought watch/warning/emergency and what do we do about it?
    - Local Government
    - Industry
    - Individuals

- What can we do to mitigate drought?
    - Local Government
    - Industry
    - Individuals

- Guidance for public water systems:
    - Performing drought vulnerability assessments?
    - Example rate structures

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Appendices

A. Prior Planning: 1985 State Water Plan and Prioritization

The most recent drought planning document for the state of Iowa is the State Water Plan which was published in January 1985 by the Iowa Water, Air and Waste Management Commission. The document includes sections on the approach to the planning efforts, historic background, a review of issues and alternatives that were examined, as recommendations and proposed implementation. From the executive summary of that plan:

> The State Water Plan was mandated by the 1982 Legislature. Chapter 455B of the Iowa Code requires the Water, Air and Waste Management Commission, "to assess the water needs of all water users… and prepare a general plan of water allocation in this state considering the quantity and quality of water resources available in this state designed to meet the specific needs of water users."
>
> Several objectives are to be met by the Water Plan.
> 1. Describe the availability and quality of water in Iowa.
> 2. Estimate present and future water use.
> 3. Prepare an allocation plan.
> 4. Propose a means of implementation. (1985 Iowa Water Plan page i)

Recommendations are included later in the Executive Summary:

> A primary objective of the Water Plan has been to examine how the state's water shall continue to be used by both large regulated and non-regulated users on a daily basis, as well as during times of shortage. The key question to be answered has been "How do we share the water during a shortage, or who should have priority?" In answering this question, the Commission has examined the state's waters as having certain economic, social and aesthetic values necessary for the continued well-being of the state. The results of this analysis are several recommendations, including a priority allocation scheme. (1985 Iowa Water Plan page ii)

The executive summary goes on to discuss the need for conservation measures:

> One of the main points to come out of the planning effort was the idea that before users are restricted from water use due to an allocation scheme, water conservation should be required. Simply stated, there are two options: We can share a shortage, or someone will go without. The approach being proposed is that we embrace the former action through conservation in an attempt to avoid the latter. (1985 Iowa Water Plan page ii)

Much attention has been paid during recent drought occurrences in Iowa to the <u>Priority Allocation System</u>. This system has its origins in the 1985 Iowa Water Plan. The plan states:

> It is recommended that a structured priority allocation system be adopted that would only be implemented during severe droughts (such as Iowa experienced in the 1930's, 1950's, and 1970's), or in local areas due to shortage. Such a structured system would only be applied as warranted under those conditions defined in the next section would serve as a triggering mechanism.
>
> The allocation structure, from highest to lowest priority, is as follows.
> 1. Self-supplied domestic.
> 2. Domestic fraction of municipal and rural systems.
> 3. Livestock production.
> 4. Power Generation.
> 5. Industrial.
> 6. Non-traditional irrigation.
> 7. Other irrigation.
> 8. Recreation and leisure.
> 9. Out of state export.

…Specific conditions that would trigger the investigation and possible implementation include:

1. Local petition
   - 25 of more individuals
   - County or municipality
2. Drought
   - Governor's declaration
   - Drought index
3. Disaster
   - Governor's declaration
   - Agency emergency response (1985 Iowa Water Plan page iii)

The 1985 Iowa Water Plan has a small section related to drought planning. That section is:

Drought Contingency Planning
The state's most serious and widespread water problems occur during periodic severe droughts. In an effort to either plan for or attempt to mitigate the effects of these droughts several options were presented.

1. Maintain the status quo.
2. Prepare statewide emergency response for severe droughts.
3. Prepare a state-coordinated emergency response for local droughts or loss of supply.
4. Adopt a regulatory framework for allocating water during droughts.
5. Long-term planning and prevention measures.
6. Financial assistance to communities and others plagued by problems. (1985 Iowa Water Plan p. 19)

Later in the Water Plan is included section 5.0 Recommendations and Proposed Implementation. In that section of the report is section 5.2.3. Definitions of Shortages and Triggering Mechanism. Section 2 of that portion of the plan is titled Drought, and it includes this information on triggers:

a. Governor's Declaration. The Governor can declare by Executive Order a state of emergency (such as during a severe drought) implementing the priority allocation scheme on a temporary basis. This could be applied statewide (as in 1977) or within a region of the state severely affected by a drought. Such a declaration may not require an initial investigation by the Department as to the applicability of implementing the priority allocation scheme.
b. Drought Index. Even in the absence of, or prior to a Governor's declaration, the Department could implement the priority allocation scheme based on a drought index. The drought severity indices (crop and hydrological) developed by NOAA and computed weekly by NOAA during the crop season, and the crop moisture availability computed in the top five feet of soil (developed at Iowa State University) or the Palmer index, could be used by the Department in deciding whether or not to implement (or recommend implementation) of the priority system. (Note: these indices could also be used as a means for encouraging or requiring either daily or emergency conservation, respectively, by irrigation. Such irrigation scheduling is routinely done in Nebraska and other states.) (1985 Iowa Water Plan pp. 28-29)

B. Planning Process

In December 2021 representatives from the Iowa Department of Agriculture and Land Stewardship (IDALS), the Iowa Department of Homeland Security and Emergency Management (HSEMD), and the Iowa Department of Natural Resources (DNR) met to discuss the need for a drought plan for Iowa. This need was also reinforced by the drought emergency meetings that were held at the State Emergency Operations Center (SEOC) during the spring and summer of 2021.

At this initial drought planning meeting it was confirmed that the three principal agencies (IDALS, HSEMD, and DNR) would lead an effort during 2022 to develop a plan. The National Drought Mitigation Center (NDMC) in Lincoln was contacted with a request for guidance and assistance. The NDMC helps people, organizations and institutions build resilience to drought through monitoring and planning, and they are the academic partner and web host of the U.S. Drought Monitor. Their staff are skilled in climatology, social science and public engagement. The NDMC works at all scales, from individual ranches to local, state and tribal governments, and countries around the world. NDMC staff are responsible for creating the weekly US Drought Monitor map.

In April 2022, the three principal agencies involved in the plan began meeting biweekly to prepare a drought plan, along with stakeholders and partners from the NDMC and USDA Climate Hub in Ames. It was determined that the plan should be completed by the end of the year to align with the State Hazard Mitigation Plan update and to avoid a long, drawn-out planning period. Stakeholder meetings were scheduled for July and August, with an initial draft of the plan due to be released in October for comment from partners and participating stakeholders.

The stakeholder meetings took place in Sioux City (July 20, 2022), Cedar Rapids (July 21, 2022), and Creston (July 22, 2022), as well as virtually using Zoom on August 3, 2022. Attendees participated in a series of five breakout sessions that asked the following questions:

- When previous droughts occurred, how was your community affected? How were your day-to-day operations affected?
- Given drought trends and future projections, what impacts and challenges are your communities and/or organizations likely to face?
- What information is needed before a drought to help you make informed decisions? WHEN do you need to have that information? Are there any sector-specific triggers?
- Where do you get data/information about drought? What data/information did you have in 2012 / what data/information do you wish you had?
- At what point would you change daily operations (if at all) to adjust for drought conditions?
- What does your community or organization need to be more resilient to drought?
- What can you do ahead of time to prepare for drought?
- Do you have a plan in place that addresses potential drought impacts/challenges? If so, how does it address these impacts? If not, what does your ideal plan look like (who needs to be involved, what information do you need, etc.)?
- Do you have a communication plan in place that addresses these impacts? If so, how does it address the impacts? If not, what would a communication plan look like (how do you get it out to the community, what information should you supply, etc.)?
- What are the pros and cons of a regional approach to drought response?
- What drought mitigation actions are most effective from your perspective? Least effective?
- During the recovery period from a drought, what are some actions or resources that may be needed to assist your community and/or organization to bounce back?
- What are we missing?

The discussion that was prompted by these questions was documented and consulted to draft the drought plan. Stakeholder concerns and ideas have been incorporated throughout the document.

In addition to stakeholder meetings, the initial draft of this plan was released for stakeholder comment on October 28, 2022, with comments due by November 15, 2022. Comments were received from emergency management personnel, environmental advocates, rural affairs advocates, drought experts, climatologists, and more. Some partners continued providing input as late as mid-December 2022. Each comment received was a valuable contribution to the plan and informed the planning team's work.

C. Iowa - Climate and Physical Setting

1. Climatological Summary

Iowa's climate is characterized by marked seasonal variations due to the state's latitude and interior continental location. During the six warmer months of the year the prevailing moist southerly flow from the Gulf of Mexico produces a summer rainfall maximum. The prevailing northwesterly flow of dry Canadian air in the winter causes this season to be cold and relatively dry. At intervals throughout the year air masses from the Pacific Ocean moving across the western United States reach Iowa producing comparatively mild and dry weather. The autumnal heat waves are a result of the dominance of these modified Pacific air masses. Hot and dry winds, originating in the desert southwest, occasionally reach into Iowa during the summer, producing unusually high temperatures and desiccating crops.

The average annual temperature ranges from 46°F in the extreme north to 51°F in the southeastern corner of the state. In July, the hottest month, daily temperatures range from morning lows of around 57F and afternoon highs of 83°F in the northeast corner of the state up to lows of 66°F and highs of 86°F in the southwest. In January, the coldest month, temperatures range from morning lows of 6°F and afternoon highs of 25°F in the northwest corner of Iowa up to lows of 15°F and highs of 33°F in the southeast. Extreme temperatures have varied from 117°F at Atlantic and Logan on July 25, 1936, to -47°F at Washta on January 12, 1912 and Elkader on February 3, 1996. The average number of days with maximum temperatures 90°F or higher ranges from under ten days in extreme northeast Iowa up to over 30 days in the southwest corner of the state. The number of days with 0F or lower minimum temperatures ranges from around 25 days along the Minnesota border to around 10 days along the Missouri border.

Precipitation averages 35.55 inches per year for the state, ranging from 30.74 inches in the extreme northwest to as much as 37.85 inches in the southeast. However, annual totals vary widely from year to year and locality to locality. Annual totals have varied from as little as 12.11 inches at Clear Lake in 1910 and Cherokee in 1958 to as much as 74.50 inches at Muscatine in 1851. For Iowa during the period of reliable statewide records (since 1873) the year 1993 was the wettest (48.22 inches) and 1910 the driest (19.93 inches). The idea that ‘rain makes grain’, while generally true, is not an absolute. Persistent cloudiness, late planting owing to excessive wetness, flooding and cool temperatures made 1993 one of the worst crop years of recent decades. Meanwhile, 1910, though easily recording the least rain in the historical record, brought record high corn yields for that era as rains were timely and summer temperatures were mild. Nearly three-fourths of the annual precipitation is received during the April through September growing season. Measurable precipitation occurs on around 100 days per year. The heaviest official one day rainfall of record is 13.18 inches at Atlantic on June 14, 1998.

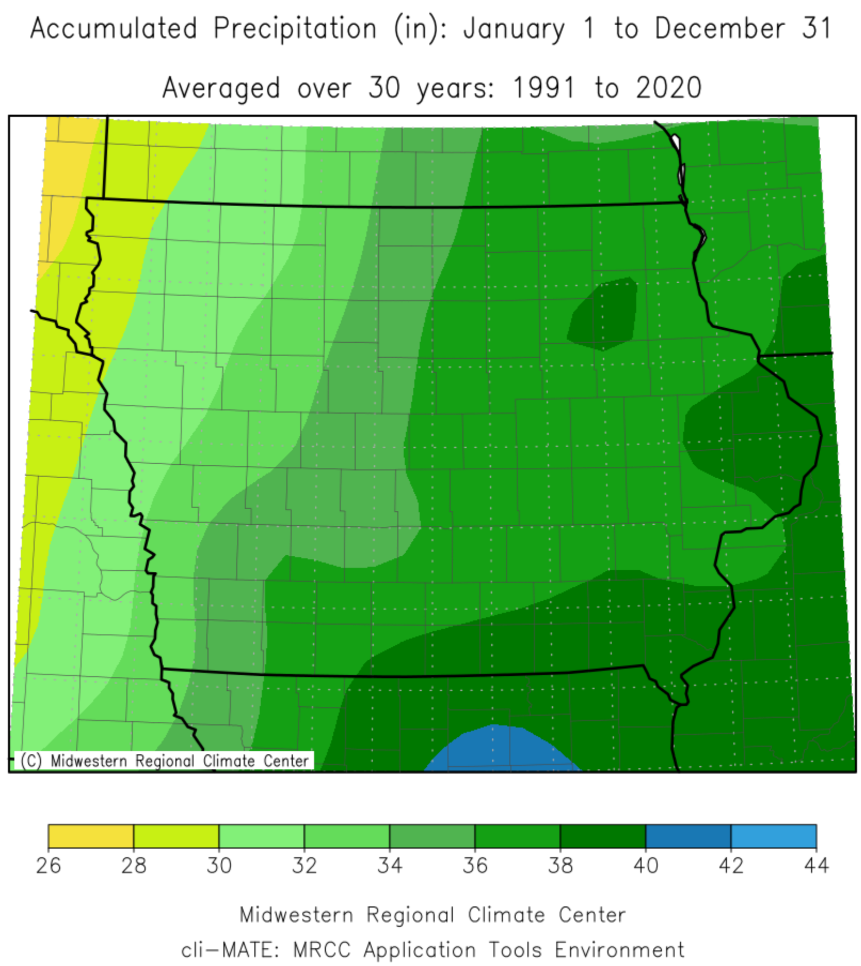

Figure 10. Accumulated precipitation (in inches), averaged over 30 years (1991-2020).

Seasonal snowfall averages 32 inches across Iowa and varies from around 37 inches in northeast Iowa to about 26 inches in the extreme southeast corner of the state. The snow season normally extends from late October through mid-April but significant snows have fallen as early as September 16 (1881) to as late as May 28 (1947). The average number of days per season with snow cover one inch or deeper varies from about 40 days along the Missouri border to around 85 days along the Minnesota border. December, January and February are normally the snowiest months, averaging about seven to eight inches each. However, late winter storms in March and April have produced as much as 27 inches of snow in a single storm and 24-hour amounts have reached 24 inches. The snowiest winter on record (since 1887-1888) was in 1961-1962 with a statewide average of 59.0 inches while the lowest state average with only 11.9 inches was recorded in the winter of 1965-1966. Seasonal snowfall totals have varied from 2.4 inches at Keokuk in 1965-1966 up to 93.1 inches at Elkader in the winter of 1950-1951.

Around 85 percent of the 45 to 65 thunderstorms per year occur from April through September with the peak frequency coming in June. At times, these thunderstorms become severe producing hail, high winds, torrential rains and an occasional tornado. Tornado occurrences average about 46 per year spread over 16 days with May and June being the peak months of tornado occurrence. Hail occurs most frequently in May, however, nearly half of the crop-hail damage comes in July when crops are more susceptible to yield-reducing damage. Historically, hail losses are greatest in the northwest, where hailstorms are typically more severe and also somewhat more frequent than in the southeast.

Floods are most frequent in June, as the month has the highest average rainfall of any month (5.26 inches). Mid-March through early April is another favored time for flood occurrence when snowmelt, combined with rain and frozen soils, can produce significant flooding on the major rivers. Ice jams, caused when river ice begins to break up in the spring, can also contribute to flooding. Flash flooding from heavy thunderstorm rainfall is most frequent in the overnight hours from June through September. Flooding in mid-winter is very rare as the cold-season months experience low precipitation totals; January averages only 0.97 inch and a high percentage of precipitation falling as snow.

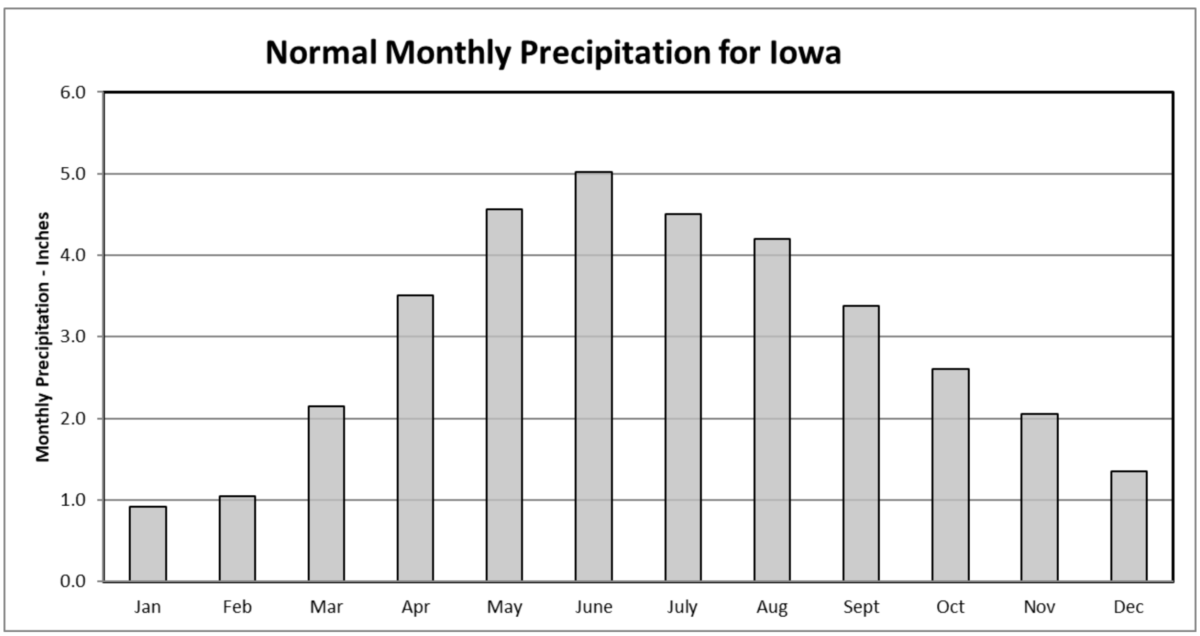

Figure 11. Normal monthly precipitation for Iowa.

Drought occurs periodically in Iowa with the most severe in historical times occurring in the 1930s. Other major droughts, usually characterized by deficient rainfall combined with unusually high summer temperatures, occurred in 1886, 1893-94, 1901, 1954-56, 1976-77, 2011-13 and 2020-22. Although droughts are not the spectacular weather events that floods, blizzards or tornadoes can be, historically they produce more economic damage to the state than all other weather events combined.

Overall, Iowa’s climate, combined with its rich soils, is nearly ideal for the production of grain crops such as corn and soybeans. Rainfall is greatest during the growing season when it is needed most. Summer temperatures are high enough for optimal corn and soybean growth, but yet not usually so high as to cause severe crop stress. Much of the summer rains come in the form of fairly brief thunderstorms, which are most frequent at night, thus allowing ample sunshine during the daylight hours. Finally, the fall months are normally relatively dry thus allowing optimal dry-down of the crops and ready access to the fields for harvesting. However, trends over the last several decades have indicated that spring and fall are becoming wetter. The cold winters usually result in the soils being frozen from early December through late March. The freezing of the soils also benefits annual crops in that the freeze-thaw process acts to 'stir' the soil and reduce soil compaction; warmer winters have caused an increase in freeze-thaw cycles.

2. Drought History

The most widespread and pervasive drought in United State history occurred in the 1930s and was known as the "Dust Bowl." During this decade, drought covered all but a small portion of the Great Plains. The devastation created by the drought also coincided with the economic hardships of the Great Depression. While the Dust Bowl is often considered one drought event, there were four individual drought periods covering 1930-1931, 1934, 1936 and 1939-1940. With these events occurring in rapid succession, the region was unable to recover as the next drought set in.

As the National Drought Mitigation Center's Dust Bowl history outlines:

Several actions in the 1920s also increased the region's vulnerability to drought. Low crop prices and high machinery costs (discussed in the previous section) meant that farmers needed to cultivate more land to produce enough to meet their required payments. Since most of the best farming areas were already being used, poorer farmlands were increasingly used. Farming submarginal lands often had negative results, such as soil erosion and nutrient leaching. By using these areas, farmers were increasing the likelihood of crop failures, which increased their vulnerability to drought.

These economic conditions also created pressure on farmers to abandon soil conservation practices to reduce expenditures. Furthermore, during the 1920s, many farmers switched from the lister to the more efficient one-way disc plow, which also greatly increased the risk of blowing soil. Basically, reductions in soil conservation measures and the encroachment onto poorer lands made the farming community more vulnerable to wind erosion, soil moisture depletion, depleted soil nutrients, and drought.

The Dust Bowl had catastrophic implications on agriculture as enormous precipitation deficits, hot temperatures and windy conditions were pervasive. As such, the conditions were the key ingredients for widespread dust storms, but also infestation of insects. Taken together, crop damage and catastrophic losses were widespread over much of the decade. Lack of precipitation also produces hardships in terms of water shortages for livestock and humans alike.

The Dust Bowl era finally began to abate during the spring of 1938, and by 1941, most impacted areas were receiving climatologically expected precipitation. The national economic atmosphere also began to improve with the onset of World War II, which produced an economic boom not seen in the 19th and 20th centuries.

2012 and 1988 Droughts

A common question received during the development of the 2012 drought was how does this compare to previous droughts? And when was it last this dry? Given the multitude of factors that combine to create drought conditions it is never easy to accurately place a drought in historical perspective. This is compounded by the fact that when the drought is occurring, we do not know what the ultimate course it will take. Will this be a long-lasting drought or is relief perhaps just around the corner? In Iowa there were continual comparisons made between the 2012 drought and that of 1988, which was the last time Iowa experienced a combination of prolonged excessive summer heat and substantial precipitation shortfalls (frequent drought in the 1999-2003 period largely took place without unusual heat). The 1988 drought began with very dry conditions in the spring while that of 2012 was initially characterized by a very dry second one-half of 2011 and a warm spring in 2012. July 2012 went on to be much hotter, and drier than July 1988, thus more frequent comparisons began to be made with earlier droughts, such as the mid 1950's and the 1930's. However, the worst of the heat in 1988 came in August while in 2012 the worst of the heat was over by the end of July. Overall, the two years compare somewhat similarly.

In 1988 Iowa recorded its fourth hottest and 14th driest summer while in 2012 it was the fifth driest and 14th hottest summer. Precipitation for the calendar year of 1988 averaged about five inches less than in 2012, mainly thanks to a drier spring. Precipitation was also much more variable in 1988 with a few extremely dry locations (only 14.02 inches for the year at Blockton along the Missouri border in southwest Iowa) while parts of northwest Iowa received near- normal precipitation. In 2011-2012 the geographic center of the drought impacts seemed to be constantly on the move. In the beginning it was southeast Iowa with the greatest impacts in late summer 2011. By the end of 2011 it was far northwest Iowa. By the beginning of the summer of 2012 the worst conditions seemed to be over east central Iowa but by mid-summer practically no rain was falling over parts of west central and southwest Iowa (which had been the wettest area of the state early-on).

The 2012 drought was not a particularly long-lasting drought; in terms of water supply issues, drought was not persistent enough to result in the types of water supply issues seen in droughts such as the 1930s and 1950s (and in fact the overall precipitation totals of the 2012 drought were not even as low as much more recent droughts in 1988 and 1976). In short, the 2012 drought was intense, with the particular misfortune of a very hot and dry July (fourth hottest and fifth driest among 140 years of data), but comparatively brief. Also, an important factor that limited hydrological impacts from the intense drought of 2012 is that Iowa experienced an exceptionally wet, and often unusually cool, period from December 2006 through June 2011. This was the wettest extended period in Iowa since at least 1860 (some indication of similarly wet weather in the mid Nineteenth Century). Among 140 years of statewide average statistics, 2007 ranked as Iowa's 6th wettest calendar year, 2008 was 5th wettest, 2009 was 12th wettest and 2010 was 2nd wettest. This, combined with a cool and wet spring season in 2011 meant that all of Iowa's aquifers were at or near historically high levels and soil moisture reserves were abundant at the onset of the drought.

Another difference between 2012 and earlier droughts is that following the 1988 drought a major effort was made to develop regional rural water associations. The rural water systems greatly mitigated the local water supply issues that were frequent in 1988 and 1989 when many municipalities and hundreds of rural farm families had no alternative to shallow wells for their water. However, the nature of water use also had changed greatly between 1988 and 2012. Large livestock confinement operations were few and far between in 1988 and were commonplace in 2012. Thus, there were hundreds of relatively large rural water users in 2012 that had a critical need for water. In some cases, there were parts of western Iowa where even the rural water systems were very close to not having enough water to meet the minimum daily water needs.

Additionally, the recent development of the renewable fuel industry also created much greater water demand in those areas where they were located, a water need that simply did not exist in 1988. In most cases the ethanol production facilities developed their own sources of water, independent of municipal or regional water systems. Production of ethanol also declined in 2012 owing to a drought-induced spike in corn prices, thus simultaneously decreasing the demand for water needed for that purpose. As the drought intensified the Iowa DNR worked to identify water systems most at risk of being unable to meet water demand. Potential breakdowns in water treatment, or losses of water owing to water main breaks, became very important as many systems were just barely meeting water demand with 24-hour per day operations. Thus, a sudden loss of storage or treatment capability would have immediate impacts. Water systems were strongly encouraged to be sure their water allocation priorities were set and that the public was made aware of potential rationing policies prior to their having to be implemented.

3. Iowa Geologic and Groundwater Overview

Iowa's groundwater resources are broadly categorized as being either surficial aquifers or bedrock aquifers. Surficial aquifers occur in the relatively loose granular sediments that lie between the land surface and deeper solid bedrock.

Bedrock aquifers, on the other hand, lie beneath the state's surficial materials and consist of solid rock layers such as limestone, dolomite, and sandstone. This sedimentary bedrock foundation originated in tropical marine environments that submerged Iowa in the distant geologic past. The bedrock aquifers are further defined by less permeable strata, such as shale, that separate and isolate individual aquifers.

ALLUVIAL AQUIFERS

River valleys are one of Iowa's major landscape features. Along and beneath these valleys are shallow sand and gravel deposits containing alluvial aquifers. The alluvium itself was deposited during a river's past history. Such sediment may be as young as a sand bar from last year's flood or as old as a deep 10,000-year-old gravel deposit left by the last glacier's meltwater flow. Alluvial aquifers are important sources of moderate-to-large water supplies across the state, but their lateral extent is restricted to river valley corridors. Rising river levels will cause a simultaneous rise in the water table of an adjacent alluvial aquifer, sometimes to visible heights in nearby fields. Similarly, falling river stages will produce a falling water table, and shallow lakes may disappear.

Most of the early Euro-American exploration of Iowa took place along its rivers, and many of Iowa's first settlements were nestled along river banks. Today many of Iowa's major metropolitan centers are along rivers. Consequently, Iowa has numerous municipal wells tapping the alluvial deposits beneath valley landscapes. These provide valuable, as well as vulnerable, water supplies for large numbers of urban-dwelling Iowans. Wells along the Mississippi and Missouri valleys are known to produce 1,000 to 2,000 gallons per minute (gpm) on a sustained basis for municipal, industrial, and irrigation uses. Alluvial aquifers along Iowa's interior streams commonly produce several hundred gallons per minute, with larger yields possible in some localities.

Buried-valley aquifers

A second type of surficial aquifer occurs along ancient river valleys once carved into the underlying bedrock surface across Iowa. Like alluvial aquifers, these deeper sources are composed of sand and gravel, but they are buried now by younger impermeable glacial tills, thus confining the aquifers and creating artesian pressures. These old valleys were partially filled with outwash sand and gravel prior to or between glacial episodes. The presence of these steep-sided valleys is easily recognized on topographic maps of the bedrock surface, but they usually show no visible expression on the modern landscape because they are blanketed by glacial drift. It is worth noting, however, that in places they do influence the routes taken by modern drainage. A number of Iowa rivers have segments that follow the course of one of these deeper buried valleys.

Glacial drift aquifers

A third type of surficial aquifer occurs widely beneath the broad upland landscapes that separate most of Iowa's river valleys. These are known as glacial drift aquifers. The term "drift" refers to the glacial deposits that mantle Iowa's deeper bedrock foundation. Though ranging from nearly zero to over 600 feet thick, glacial drift averages about 200 feet in thickness over the state. Drift includes not only pebbly clays known as glacial till, but also occasional sand and gravel deposits sandwiched within or at the bottom of these glacial clays. These porous sands and gravels, resulting from episodes of meltwater flow during glacial advances and retreats, tend to be thin, discontinuous, and quite unpredictable in their occurrence.

The suitability of drift aquifers as a source of groundwater varies considerably across the state. Some productive aquifers occur in north-central Iowa, where geologically youthful glacial materials lie at the land surface and contain abundant sand. Wells in this area report yields from less than 10 to over 90 gpm. In contrast, glacial drift is generally absent in the far northeastern Iowa counties. In eastern Iowa, the drift deposits are often bypassed in favor of deeper, more productive bedrock aquifers. In parts of southern and western Iowa, however, where alluvial aquifers may not be available and bedrock aquifers are deep, unproductive, or produce water of poor quality, a good glacial drift aquifer can be a life-saver. Such wells typically range from 50 to 200 feet deep but occasionally reach depths of 400 feet or more. They normally yield only a few gallons per minute, but a respectable 10 to 20 gpm may be obtained from some under favorable conditions. Though water production is low, their widespread potential in the abundant glacial deposits across the state make these aquifers valuable resources, especially for rural homeowners and especially in the western half of Iowa. In terms of natural water quality, shallow drift aquifers are consistently less mineralized than water from either deeper glacial drift aquifers or from the buried valley aquifers.

BEDROCK AQUIFERS

Bedrock aquifers are another basic class of Iowa's groundwater resources. Bedrock consists of sedimentary rock layers, primarily limestone and dolomite (carbonate rocks), as well as shale, siltstone, and sandstone. These rocks originated as sediment deposited in ancient seas, rivers, and deltas that occupied Iowa between 75 million years ago (Cretaceous age) and 550 million years ago (Cambrian age). The total thickness of these formations ranges from 5,200 feet in southwest Iowa to about 800 feet in the northeast. This sequence of sedimentary rocks varies widely in its ability to store and transmit water.

Of the state's sedimentary rocks, sandstones and carbonates make the best aquifers. Sandstones often have abundant pore spaces between their grains, so groundwater moves easily following the interconnected openings. Problems with water yields from these aquifers occur when there is an increase in mineral cements, which can clog the intergranular pore space. In contrast, carbonate rocks - limestone and dolomite - are finer grained, and groundwater actually follows vertical fractures, crevices, caves and other solutional openings as well as horizontal bedding planes (thin partings that separate sedimentary rock layers). Groundwater movement along these permeable pathways is especially noticeable at roadcuts in winter, when emerging groundwater forms frozen waterfalls.

Solutional openings are peculiar to lime-rich carbonate rocks and result from the chemical dissolving action of circulating groundwater. Such subterranean drainage accounts for sinkholes at the land surface, streams that disappear, caverns underground, and springs on hillsides - landscape features known as karst topography. Other types of porosity in Iowa's carbonate rocks occur where fossiliferous zones have been dissolved out, or where the rock has been broken in the geologic past, or even between mineral crystals, particularly in the Silurian dolomites. Because these openings in limestone and dolomite are so irregular in occurrence, size, and orientation, yields to wells can be highly variable, even over very short distances.

Dakota Aquifer (Cretaceous age)
The Dakota aquifer is composed of sandstone deposits 200 to 300 feet in thickness, and provides water for many rural and public water supplies in northwest and west-central Iowa. This aquifer is composed of the Woodbury and underlying Nishnabotna sandstones, which formed in riverine environments 100 million years ago. The sandstones range in grain-size from very coarse to fine, and they are poorly cemented, providing abundant pore space for groundwater storage. Over 80 percent of the Nishnabotna alone is composed of medium- to coarse-grained quartz sandstone. The sandstones are confined over most of their area by 200 to 400 feet of clay-rich glacial till as well as by thick shale, siltstone, thin chalky limestone, and lignite (low-grade coal).

Wells drilled into the Dakota range from 100 to 600 feet deep and yield 100 to 500 gpm. Some wells can produce as much as 800 to 1,500 gpm. Water quality tends to be fair to poor. The areas of poorer water quality result from high concentrations of dissolved solids (between 500 and 3,000 mg/L), particularly sulfate and calcium carbonate, which are common minerals picked up by groundwater in contact with the confining layers above. Areas of better water quality are found where confining layers are thin and some porous pathways allow for more rapid recharge by unmineralized surface waters. This occurs most notably in the southern area of the aquifer's extent.

The Dakota aquifer in Iowa is recharged by downward percolation through its confining units. Regional groundwater flow is from north to south, and natural discharge from the aquifer occurs into the lower reaches of major rivers in the region.

Mississippian Aquifer
Productive wells from the Mississippian aquifer supply private and public water supplies for much of the north-central part of the state. The water quality is generally good. In contrast, the same aquifer produces much smaller yields of poorer quality water in central and southeastern Iowa. Throughout its range the aquifer consists of a thick sequence of limestone and dolomite, with thinner deposits of sandstone, shale, the silica-rich mineral chert (flint), and gypsum.

The most productive wells from the Mississippian aquifer are concentrated in north-central Iowa where excellent yields of 500 to 900 gpm are known from municipal wells in Marshall, Story, Hardin, and Wright counties. These high yields coincide with an area of well-developed karst, where the limestone is highly dissolved. In central and southeast Iowa, however, yields are as low as 2 to gpm, owing to the scarcity of crevices in the rock formations. Well depths here extend about 100 to 400 feet below land surface.

Regional flow in the Mississippian aquifer is in a southerly direction, and it discharges into the Des Moines and Skunk rivers and their tributaries.

Silurian-Devonian Aquifer
This aquifer is composed of bedrock units from two major systems of geologic time, the Silurian and the Devonian. They are usually described as a single aquifer package because, regionally, they are composed of similar carbonate rocks that are hydraulically connected and yield similar water quality. Locally, however, there are differences in terms of rock types and water quality, and thus these two units are sometimes considered independently. For example, in eastern Iowa they are two discrete aquifers. In some places, there is no underlying Silurian, and in other places there is no overlying Devonian. And locally, shale and clayey dolomites act as aquicludes, further separating parts of the aquifer system.

This aquifer underlies the entire state except for the northwest and northeast corners. It is an important source of water primarily in eastern and northern Iowa, serving rural, public, and industrial users. The aquifer is composed mainly of porous dolomites of Silurian age, and limestone and thick shales of Devonian age. As is typical of carbonate rocks, porosity and permeability are dependent on such natural openings as fractures, zones, bedding planes, and solution caverns. These features vary in size, extent, and frequency of occurrence. This aquifer's porosity and permeability are best developed in a road and about 65 to 70 miles wide and about 200 miles long across the northeastern part of the state.

The regional flow of groundwater in the Silurian-Devonian aquifer is to the southeast. Natural discharge from the aquifer toward valleys contributes significantly to the amount of water flowing in the Iowa, Winnebago, Shell Rock, Cedar, and Maquoketa rivers. The aquifer thus serves as an important source of baseflow to these streams.

Cambrian-Ordovician Aquifer
This is the only aquifer in Iowa that is widely used even where it is covered by younger bedrock units. The Cambrian-Ordovician aquifer is a widespread and dependable source of water for high- capacity wells, and it is used extensively by municipalities and industries in the eastern half of the state. The aquifer is composed of three separate formations - the Jordan Sandstone (Cambrian age) at the bottom, dolomite and sandstone of the Prairie du Chien Group in the middle (Ordovician age), and the St. Peter Sandstone at the top. All these bedrock units are water-bearing, so they usually are treated as a single aquifer. Wells that require large amounts of water typically tap the full range of the Prairie du Chien and Jordan units, while other wells may tap only the St. Peter or a combination of the St. Peter and upper Prairie du Chien. While often called the "Jordan aquifer," much groundwater also comes from the Prairie du Chien. Thus "Cambrian-Ordovician aquifer" is a more accurate term for this water-producing zone.

Typical well depths in this aquifer range from 300 to 2,000 feet, with some over 3,000 feet deep. As noted earlier, bedrock aquifers are inclined in a southwesterly direction toward Kansas and Oklahoma; thus, the deepest wells are in southwest Iowa.

IOWA'S GROUNDWATER PROVINCES
Iowa's groundwater resources consist of five principal aquifers - four bedrock aquifers and an assortment of shallower sand and gravel deposits that overlie the bedrock and collectively are called surficial aquifers. Widespread confining beds retard movement of groundwater between the bedrock aquifers in particular.

The major bedrock aquifers extend over large geographic areas, well beyond Iowa's orders. These regional aquifers are the Dakota (Cretaceous), the Mississippian, the Silurian-Devonian, and the Cambrian-Ordovician ("Jordan") aquifers. Each aquifer system includes several stratigraphic formations and water-bearing zones. Most of the groundwater flow in these aquifers can be described as deep, confined, and relatively unaffected by recharge from the surface. Because of the downward slope of the state's bedrock sequence toward the southwest, however, these aquifers do have areas of local flow where their upper edges lie closer to the land surface and where recharge occurs.

Each of these four bedrock aquifer systems serves as a primary groundwater source over some part of the state, or as a second option in other areas. As already noted, the smaller area of primary aquifer use coincides closely with its area of shallower depth and better natural water quality.

Northeast Iowa Groundwater Province
The Northeast Iowa Groundwater Province is rich in water resources and thus can be described as “good”. This region has several options for groundwater sources. Depending on location within the province, these options include the Mississippian aquifer, the Silurian-Devonian aquifer, and the Cambrian- Ordovician aquifer. Locally, the more restricted Galena and Dresbach (Mt. Simon) aquifers are also available.

Both glacial drift and river valley alluvium are often bypassed in favor of the relatively shallow and more productive underlying bedrock aquifers. Deposits of glacial drift are thin or absent in far northeast Iowa, but thicken to about 300 feet in the southern or western parts of the province. Alluvial aquifers are utilized along the larger rivers that cross the province in a northwest-to-southeast direction, especially the Iowa, Cedar, and Wapsipinicon.

The Mississippian aquifer is used primarily along its narrow outcrop belt that stretches from north-central to southeast Iowa. Where the Mississippian is absent, the Silurian-Devonian aquifer provides abundant water. Water quality in both these regional bedrock aquifers is generally good, but is typically hard because of dissolved minerals from the carbonate rocks and is occasionally prone to taste and odor problems. These naturally occurring quality problems increase in a westerly direction across the province.

In extreme northeast Iowa, both the Mississippian and Silurian-Devonian rocks are absent, having been removed by erosion in the geologic past. Here, the Cambrian-Ordovician aquifer is the most reliable groundwater source. A few counties in northeastern Iowa also use the Galena aquifer, a shallower Ordovician water-bearing formation. Use of the deep Dresbach aquifer is confined to a few Mississippi River counties, specifically eastern Allamakee, Clayton, Winneshiek, Dubuque, Jackson, Clinton, and Scott.

In parts of northeastern Iowa, the bedrock aquifers are highly susceptible to contamination, especially where they lie at or near the land surface and where the karst conditions described earlier are present. Newer wells frequently are drilled to greater depths to avoid these known contamination problems. Aquifers in the central and east-central portions of the province have a thicker cover of glacial drift, making them less susceptible to contamination problems from surface sources. Major aquitards in this region include the clay-rich glacial drift and the Maquoketa Shale.

Northwest Iowa Groundwater Province
Northwest Iowa can be characterized as “fair” in terms of groundwater availability, quantity, and quality. This area has fewer options for groundwater than northeast Iowa. The Dakota Sandstone, or Cretaceous aquifer, is the primary groundwater source because of the relatively shallow depth, generally good yields, and fair water quality of its sandstone units (except for local areas of exceptionally high sulfate). Regional bedrock aquifers lying below the Dakota Sandstone are very high in total dissolved solids and are unsuited for human or livestock use. Alluvial aquifers, on the other hand, are extensively used along major valleys, especially those of the Floyd, Rock, Little Sioux, Big Sioux, and Missouri rivers.

Buried valley aquifers are quite productive in certain locales of northwest Iowa. Glacial drift aquifers, while not as productive, are sufficient for many private and small public water supplies. The “salt and pepper” sands also occur within or at the base of the glacial tills in western Iowa, and locally these sand deposits produce moderate amounts of water.

Northwest Iowa has substantial amounts of loess and glacial drift (an aquitard) covering the bedrock aquifers, thus protecting them from surface contamination. The major contamination issue in this province is the vulnerability of the widely used alluvial aquifers.

Southern Iowa Groundwater Province
The search for groundwater in southern Iowa can be challenging. Consequently, this province is generally classified as a “poor” or difficult area in terms of finding water of sufficient quantity and quality. Pennsylvanian strata are the uppermost bedrock across large expanses of southern Iowa. These rock units, generally regarded as an aquitard, can sometimes be pressed into service if local occurrences of limestone and sandstone are favorable.

Three major bedrock aquifers are used in southern Iowa, the Mississippian carbonate as well as the Dakota and Cambrian- Ordovician sandstone aquifers. The Mississippian carbonate aquifer is used in areas where the Pennsylvanian bedrock is relatively thin or absent. The Dakota sandstone aquifer extends from northwest Iowa into several southwestern Iowa counties. The Cambrian-Ordovician aquifer has been relied on for decades in central and southeast Iowa as the only source of an adequate and reliable volume of water for towns and industries in particular. The introduction of Rural Water Districts has reduced or eliminated that reliance. Elsewhere, water in the deep regional bedrock aquifers is generally unusable because of very high levels of total dissolved solids.

For these reasons, both glacial drift aquifers and buried valley aquifers assume a more important role in providing water in southern Iowa. Alluvial aquifers also are valuable here, especially along the Skunk, Des Moines, and Nishnabotna rivers. These shallow sources are vulnerable to contamination problems from the land surface and present the most serious contamination issues in the province. The steeply rolling, well-drained topography across much of southern Iowa is well-suited to the installation of ponds and reservoirs, many of which are used to augment water supplies for both people and livestock.

Most areas of southern Iowa have a thick covering of glacial materials that keep surface contaminants from entering bedrock aquifers. The main exception is an outcrop area of the Mississippian aquifer in far southeastern Iowa, especially Des Moines County, where limestone is exposed near the land surface and local karst conditions are present.
Water use in Iowa includes both groundwater and surface water resources for a variety of purposes, including agriculture, commercial, domestic, industrial, irrigation, mining, power generation, and public water supplies. In these so-called “off-stream” uses, water is actually withdrawn or diverted from a groundwater or surface water source. This does not include such water uses as barge transportation, recreation, or fish hatcheries.

Information about water use usually is separated into water withdrawn and water consumed. Consumptive use is that part of water withdrawal that is removed from the environment by people or livestock, by incorporation into manufactured products, by evaporation, or transpiration by crops and other vegetation. This water is no longer available for future use. Estimates indicate, for example, that less than 1 percent of the water used for power plant cooling is lost through evaporation, while nearly 100 percent of water used by agriculture and irrigation is consumed. Overall, only about 13 percent of the water withdrawn for use in Iowa is considered to be consumed. Note that groundwater accounts for about two-thirds of the water consumed in Iowa.

The largest amount of water used in Iowa is for power generation. A little over two-thirds of the state’s total water withdrawn is for production of steam and for cooling of equipment in thermoelectric power plants. Almost 99 percent of this cooling water comes from surface sources such as the Mississippi and Missouri rivers, as well as larger interior streams such as the Des Moines and Cedar rivers.

Public water supplies account for the second largest amount of water withdrawn in Iowa. These include cities, towns, mobile home parks, housing developments, and rural water associations. On average, Iowans use about 1,100 gallons of water every day if indirect sources such as manufactured products, food production, and energy generation are included. Individually, however, we actually use about 100 gallons per day for drinking, food preparation, laundry, washing, and wastewater. Nearly 70 percent of the water used by public water supplies in Iowa comes from groundwater. When the rural population on privately owned wells is added in, nearly 80 percent of Iowans depend on groundwater for their drinking water supplies.

Other major uses of groundwater in Iowa include irrigation, with over 90 percent of needed water coming from groundwater sources, and livestock and poultry production, with 75 percent of their total withdrawals being from groundwater.

Sand and gravel production and limestone quarrying dominate mining activities in Iowa, and are one of the smaller categories of water use with less than 2 percent of the total. Most of the water withdrawn is for dewatering quarries and for washing aggregate products. The water consumed by these processes is negligible.