GAO Highlights

Highlights of GAO-14-741, a report to congressional requesters

September 2014

MISSOURI RIVER FLOOD AND DROUGHT

Experts Agree the Corps Took Appropriate Action, Given the Circumstances, but Should Examine New Forecasting Techniques

Why GAO Did This Study

The Missouri River stretches from western Montana to St. Louis, Missouri. The Corps manages six dams and reservoirs on the river to provide flood control and for other purposes, such as recreation and navigation. The Corps bases reservoir release decisions on the guidance in the Master Manual. In the 2011 flood, the Corps managed the highest runoff volume since 1898, resulting in record reservoir releases. Subsequently, drought occurred in the basin in 2012 and 2013.

GAO was asked to review the Corps' release decisions and communication during the flood and drought. This report examines (1) experts' views on the Corps' release decisions; (2) experts' recommendations to improve the Corps' release decisions; and (3) stakeholders' views on the Corps' communication, as well as any suggested improvements. GAO worked with the National Academy of Sciences to convene a meeting of nine experts to discuss the Corps' data, forecasts, and release decisions. GAO also interviewed 45 Missouri River basin stakeholders, including state and local agencies, among others, to discuss their views on the Corps' communication. The views of stakeholders are not generalizable.

What GAO Recommends

GAO recommends that the Corps evaluate the pros and cons of incorporating new forecasting techniques into its management of the Missouri River reservoirs. The Department of Defense concurred with the recommendation.

View GAO-14-741. For more information, contact Anne-Marie Fennell at (202) 512-3841 or fennella@gao.gov.

What GAO Found

Experts who participated in a GAO-sponsored meeting agreed that the U.S. Army Corps of Engineers (Corps) made appropriate release decisions during the 2011 flood and 2012 and 2013 drought affecting the Missouri River basin, given the severity of these events. These experts acknowledged that the flood was primarily due to extreme rain in eastern Montana in May and June 2011. The experts agreed that no existing forecasting tools could have accurately predicted these extreme rainstorms more than a week in advance. One of the experts also said that the Corps would have needed several months to release enough water from the reservoirs to have sufficient space for the runoff that occurred in 2011, and predicting an extreme runoff year that far in advance is beyond the current state of science. Moreover, the experts agreed that the Corps appropriately followed the drought conservation procedures in the Missouri River Mainstem Reservoir System Master Water Control Manual (Master Manual), which sets out policies for managing the river. The experts agreed that the Corps does not need to change the Master Manual in response to the 2011 flood or subsequent drought. However, some of the experts noted that if the Corps develops improved forecasting tools, it might be useful to evaluate whether changes to the Master Manual would help the Corps to act on information from the new tools.

The experts suggested that improving data systems and introducing new runoff forecasting techniques could improve the Corps' ability to make release decisions in less extreme events than the 2011 flood. These data systems—such as streamgages, weather radar, precipitation gauges, soil moisture monitoring, and monitoring for snow on the plains—are not managed by the Corps, but by other federal and state agencies, which creates challenges beyond the Corps' control. The experts agreed that probabilistic forecasting techniques—which correct for unknown initial conditions using statistical techniques and provide a range of potential outcomes and their likeliness—could help the Corps manage risks better than their current methods that create one forecast estimate. One of the experts said that probabilistic methods could provide greater benefits, such as higher water supply reliability, increased flood protection and hydropower production, and easier implementation of variable flows to create fish and wildlife habitats. Probabilistic techniques are currently used by New York City to support reservoir releases to manage flood risk and meet water quality goals without adding expensive new filtration equipment. Corps officials said that they have not considered using probabilistic techniques in the Missouri River basin because they are not sure the benefits would outweigh the difficulty of creating the models or explaining the new methods to their stakeholders.

During both the flood and drought, the Corps communicated with Missouri River stakeholders in a variety of ways, which most stakeholders GAO spoke with said were effective. Most stakeholders were generally satisfied with the Corps' communication, saying that the information they received from the Corps was timely and sufficient for their purposes. Most stakeholders had at least one suggestion on how the Corps could improve communication; however, there was little consensus on any one suggestion. A few stakeholders suggested that the Corps hold separate conference calls to discuss sensitive response-related issues. Corps officials said that they would consider this in the future.

Assessing Your Flood Risk

Compare Risks

Your chances of being flooded are much greater than some other risks you face daily. If you live in a 100-year floodplain, there is more than a 1 in 4 chance that you will be flooded during your 30-year mortgage. During a 30-year mortgage period you are 27 times more likely to experience a flood than having a fire.

Event	**% chance of happening during the next year**
25-year flood	4 chances in 100
Involved in a car accident	3 chances in 100
Some form of cancer	3 chances in 100
Victim of larceny	2 chances in 100
50-year flood	2 chances in 100
Victim of burglary	1 chance in 100
Injured in a car accident	1 chance in 100
100-year flood	1 chance in 100
Victim of auto theft	1 chance in 300
Victim of aggravated assault	1 chance in 500
Victim of robbery	1 chance in 1,000
Residential fire	4 chances in 10,000

Understanding the "100-year floodplain"

The first thing you need to know about the concept of a 100-year floodplain is that it is based on a statistical probability needed by the insurance industry as a standard upon which to base policies. Both the federal government and the private sector assist the insurance industry in gathering scientific measurements that are then used to generate a "*best guess" of stream flow peaks over a time. All this information goes into a formula/statistical model that generates elevations on tracts of land throughout a watershed that have "one-in-one hundred chance (1 percent) of occurrence of flooding in any given year, or a "return period" of once every 100 years."

100-year floodplains are not arbitrary but they are:
1. Limited to the "best information at the time"
2. Not a determination of where and how frequently actual flood damage will occur.
3. Subject to change

*We say "best guess" for several reasons, chiefly that streamflow data has only been collected for a maximum period of 150 years (much less in many areas) which is a small sampling in the context of regional weather patterns and actual flood events.

Read more

The "100-Year Flood" USGS Fact Sheet: http://water.usgs.gov/pubs/FS/FS-229-96/

Killed in car accident	3 chances in 10,000

Source:
Floods and Your Family brochure,
U.S. Army Corps of Engineers

- Properties can also be at higher or lower risk **within a floodplain** depending where in the floodplain they are located. For example, one house in the 25-year floodplain may flood 2 feet deep during a storm, but their neighbor deeper in the floodplain may flood 6 feet deep.
- **If** you are a typical homeowner, living in a single-story $100,000 home, without a basement, you can expect to suffer the following **damages** to your house and contents:
  1 foot of water = $14,000
  3 feet of water = $27,000
  Also add the cost of cleanup of mud and residue.

  Source: Floods and Your Family brochure, U.S. Army Corps of Engineers.

- **Myths:**
  - Floods only happen to other people.
  - It has never flooded here, so it never will.
  - There was a flood problem, but it has been fixed.
  - If flooding were a problem, someone would have told us. That's why we pay taxes.
  - It's only water. It's no big deal to be flooded.
  - The government will bail me out.
  - My homeowner's policy will cover any flood damage.
  - We just had a "100-year flood", so my family will be safe from future floods for the rest of their lives.
- **Facts:**
  - We can't predict when floods will occur, but we can usually tell where they will occur.
  - Just because it hasn't flooded in the past doesn't mean it won't in the future.
  - Just because you had a flood does not mean it won't happen again soon.
  - FLoods are caused by weather conditions and are unpredictable. If the conditions are right, floods will occur again.
  - It is almost impossible to "fix" a flood problem.
  - Real estate agents usually don't know whether flooding has ever occurred on the property.
  - Government assistance after a flood is usually limited to loans which have to be repaid. Who needs a second mortgage?
  - Figuring out how to cope with a flood is your responsibility.

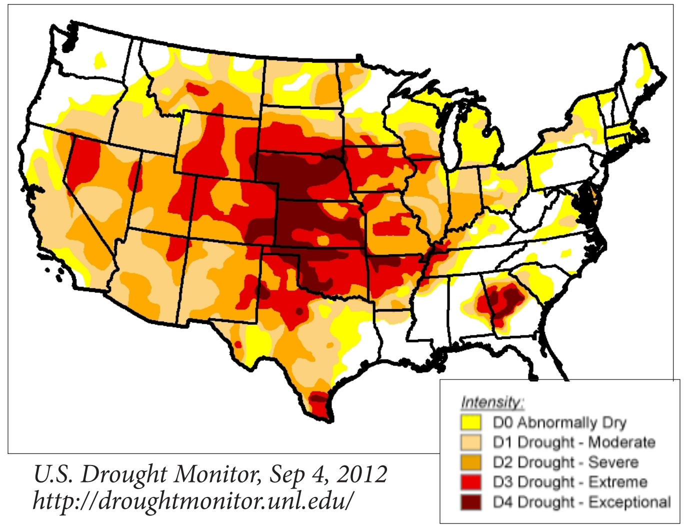
  Source: Floods and Your Family brochure, U.S. Army Corps of Engineers.

An Interpretation of the Origins of the 2012 Central Great Plains Drought

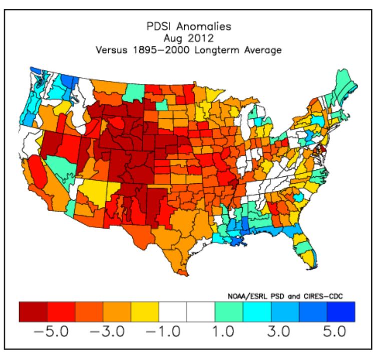
An Assessment Report of the
NOAA Drought Task Force Narrative Team

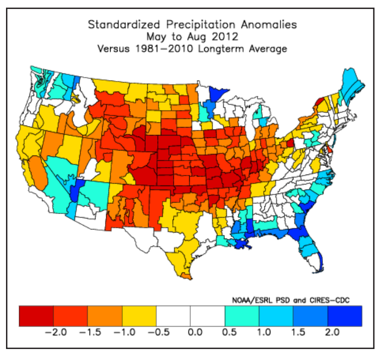
Historical Context - How do 2012 rainfall amounts and high temperatures compare to years past?

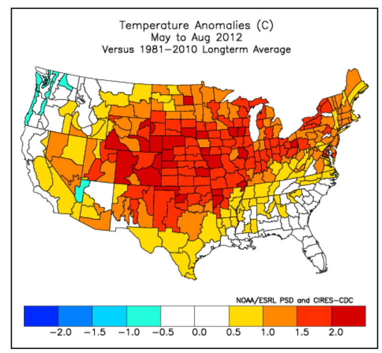
Precipitation deficits for the period May through August 2012 were the most severe since official measurements began in 1895, eclipsing the driest summers of 1934 and 1936 that occurred during the height of the Dust Bowl. This prolonged period of precipitation deficits, along with above normal temperatures, resulted in the largest area of the contiguous United States in drought since the U.S. Drought Monitor began in January 2000. By early September, over three-quarters of the contiguous U.S. was experiencing at least abnormally dry conditions with nearly half of the region (the Central Plains in particular) experiencing unprecedented severe drought.



U.S. Drought Monitor, Sep 4, 2012
http://droughtmonitor.unl.edu/







For a longer-term perspective, the Palmer Drought Severity Index (PDSI) for August 2012 is compared to a long-term PDSI average spanning from 1895 to 2000 (left) and identifies the core region of the drought to be the central Plains region, with the most extreme moisture deficits occurring over the western Plains (consistent with the Drought Monitor map). A central U.S. epicenter for the drought is also affirmed by the May-August standardized rainfall deficits (middle) with -2 standardized departures from the 1981 to 2010 long-term average being widespread from Colorado to Missouri. Much of the dry region also experienced hot temperatures (right). The combination of low rainfall and high temperatures is typically seen during summertime droughts over the central U.S.

What caused the 2012 Central Great Plains Drought?

The central Great Plains drought during May-August of 2012 resulted mostly from natural variations in weather.

- Moist Gulf of Mexico air failed to stream northward in late spring as cyclone and frontal activity were shunted unusually northward.
- Summertime thunderstorms were infrequent and when they did occur produced little rainfall.
- Neither ocean states nor human-induced climate change, factors that can provide long-lead predictability, appeared to play significant roles in causing severe rainfall deficits over the major corn producing regions of central Great Plains.

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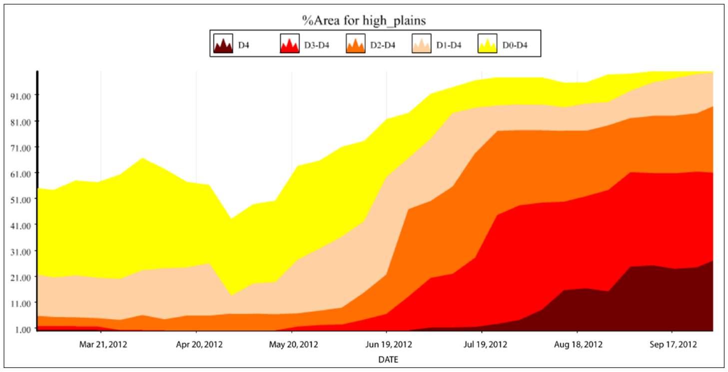
The full report can be downloaded from:
http://www.drought.gov/drought/content/resources/reports

The timing of the 2012 Central Great Plains Drought: Was it a "flash drought?"



This figure was created using the drought monitor graphic tool at http://www.drought.gov/drought/content/tools/drought-monitor-graphics

The 2012 Central Great Plains drought developed suddenly, and did not appear to be just a progression or a continuation of the prior year's record drought event that occurred over the southern Great Plains, but appeared to be a discrete extreme event that developed over the Central U.S. The figure to the left shows the rapid expansion of abnormally dry to exceptional drought conditions during June 2012 for the High Plains (Wyoming, Colorado, Kansas, Nebraska, South Dakota and North Dakota), an example of a flash drought. The x-axis extends from Mar 1, 2012 through Sep 30, 2012.

Impacts of the Central Great Plains Drought

Along with the rapid development of the drought, impacts emerged quite swiftly. Loss estimates by the end of July 2012, before drought severity peaked, were $12B. It remains to be seen if the economic effects of the 2012 drought will approach prior events, including the 1988 drought that inflicted $78 billion in losses and the 1980 event that caused $56 billion in losses (adjusted for inflation to 2012 dollars). Broad sectors were affected, and continue to be affected, by the 2012 drought. Notable for the swiftness of impacts was the reduction in crop yields caused by lack of timely rains. Also, curtailment of commerce on major river systems occurred owing to reduced water flow. It is expected that water supply reductions in the semi-arid western portions of the drought where reservoir storage was depleted by lack of rains will also have long-term impacts, as will livestock health and its long-term effect on herd stocks. Preliminary USDA estimates of farm and food impacts of the 2012 drought indicate corn yield (per acre of planted crop) was about 123 bushels. This is 26% below the 166 bushel yield expectation that the USDA had at the commencement of the growing season.

Was the extent and severity of this drought predicted?

Official seasonal forecasts issued in April 2012 did not anticipate this widespread severe drought. Above normal temperatures were, however, anticipated in climate models, though not the extreme heat wave that occurred and which was driven primarily by the absence of rain.

Report Details

An Interpretation of the Origins of the 2012 Central Great Plains Drought

Assessment Report

20 March 2013

Composed by the Narrative Team of the NOAA Drought Task Force

Lead: M. Hoerling

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The NOAA Drought Task Force is organized by the Modeling, Analysis, Predictions and Projections Program (MAPP) of OAR/Climate Program Office

http://cpo.noaa.gov/ClimatePrograms/ModelingAnalysisPredictionsandProjections/MAPPTaskForces/DroughtTaskForce.aspx

This report was produced in partnership with the National Integrated Drought Information System (NIDIS)

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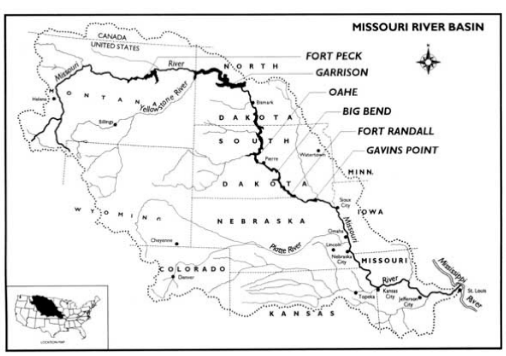
The full report can be downloaded from: http://www.drought.gov/drought/content/resources/reports

Explaining Climate Extremes

An Assessment of the 2011 Missouri River Basin Flood

In early 2011, the Missouri River Basin experienced devastating flooding, which caused significant property loss and threatened thousands of lives. January-May was the wettest recorded in the region since 1895, and the annual runoff above Sioux City, Iowa surpassed the previous record.

Researchers from the National Oceanic and Atmospheric Administration (NOAA) pursued a scientific study on the meteorological causes for the flood event with hopes to better understand its causes and assess its predictability. An assessment report has been completed, following peer review, and below are highlighted the major scientific findings.



The Missouri River Basin, the Missouri River, and the main U.S. Army Corps of Engineers reservoirs. The Upper (Lower) Basin is the region generally located in a west-east line above (below) Gavins Point near Sioux City Iowa. (Image courtesy Missouri Department of Natural Resources)

Major Findings

The factors immediately responsible for flooding were found to be a sequence of events that included:

- Pre-existing wet conditions – a particularly cold and wet 2010-2011 winter that led to unusually high snow pack, and
- Record-setting rains in late spring

The late spring rains were almost certainly the most critical in the meteorological sequence for understanding the historic proportion of Missouri Basin flooding.

The wintertime cold and wet conditions were shown to be consistent with those occurring in the upper Missouri Basin during La Niña events, and in this sense NOAA's La Niña Advisory issued on 5 August 2010 provided early warning for these types of winter conditions. However, La Niña in general, and the particular ocean conditions in 2011 specifically, were found not to materially alter the risks for a wet spring in the upper Missouri Basin.

The report suggests that neither the NOAA La Niña Alert Status nor subsequent exact knowledge of the details of the ocean conditions could have forewarned of extreme heavy spring rains.

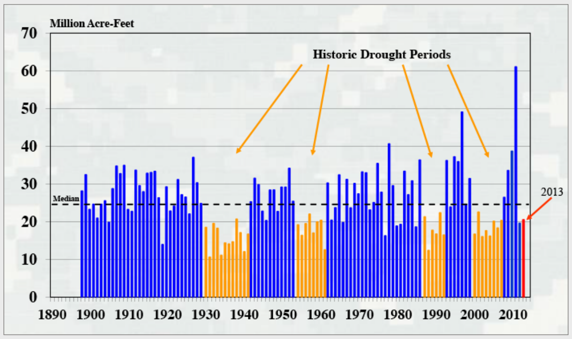
61 million acre-feet (maf) of runoff above Sioux City, Iowa beat the prior record by 12 maf

The analyses in the report indicate that the record-setting amount of water from the Upper Missouri Basin could not have been anticipated before the heavy spring rains set in, and it could almost certainly not have been anticipated at long seasonal (6-9 month) lead times.

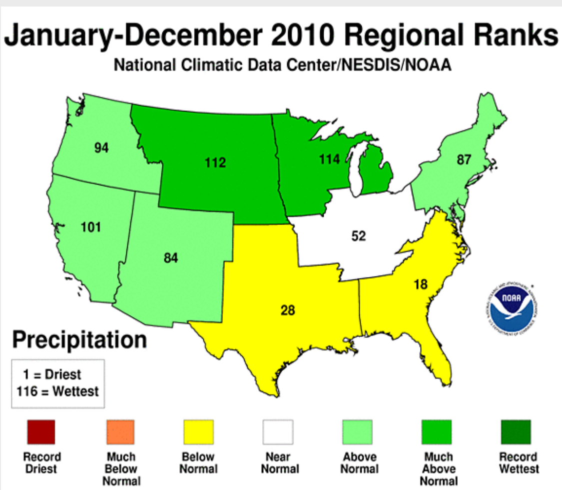
Conclusions

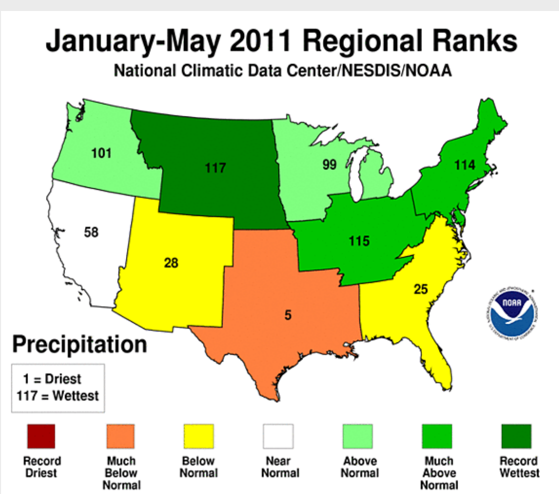
The report found that the record flooding was consistent with the physical response of basin runoff to a sequence of naturally occurring climate conditions, the majority of which resulted from random atmospheric variations, which could not have been predicted with current scientific knowledge. Due to the unusual sequence of extreme weather events, a flood of this magnitude

Annual Runoff above Sioux City, Iowa



Time series of the annual Missouri River runoff (million acre-feet) above Sioux City, Iowa for 1898-2012. The 2013 value (red bar) is a preliminary estimate. Regimes of persistent low flows, denoted by orange bars, denote hydrologic droughts within the basin. Horizontal line shows the historical median value. Data source is USACE.





The historical ranking of regional precipitation for annual 2010 conditions (top), and for the subsequent January-May 2011 conditions (bottom). Over the Missouri River Basin region, 2010 ranked 5th wettest since 1895, whereas the subsequent 5-month period January-May 2011 ranked as the historical wettest since 1895. Note the dramatic contrast between conditions in the Missouri Basin versus those immediately south. Data source is NOAA.

was a rare occurrence, and a comparable event has low probability for recurring in the immediate future.

A caveat to the conclusion that the flooding was the result of a sequence of naturally occurring climate conditions is the fact that annual flow in the Upper Missouri Basin has been more volatile in recent decades compared to prior decades dating to 1898. Specifically:

- Nine of the ten highest annual runoffs in the Missouri Basin historical record were found to have occurred after 1970, and
- Year-to-year variability of annual runoff has increased dramatically in recent decades principally due to an increase in high flow events.

The report does not address the underlying cause for post-1970 increase in the frequency of high runoffs events, but recommends further investigation of possible factors in order to better inform decision makers on the risks for future severe flooding events in the Missouri River Basin.

Given these events and the hydrology of the Missouri Basin, it was reasonable to expect that the subsequent 2012 year would also be susceptible to flooding. The previous five years had experienced above-average annual precipitation in the upper basin, resulting in progressively higher annual runoff from 2008-2011. However, the observed 2012 annual runoff in the Missouri Basin was below normal. The climate conditions themselves had not changed much between 2011 and 2012, and the concentrations of human-caused greenhouse gases were basically the same.

The fate of 2012 Missouri River runoff was apparently not set by the pre-existing conditions of 2011 anymore than pre-existing conditions determined the fate of 2011. Instead, in both 2011 and 2012 annual runoff depended primarily on meteorological factors, which abruptly returned the basin from flooding conditions in 2011 to drought conditions in 2012. The similar large-scale climate conditions of 2011 and 2012 serve as a lesson on the power of short-term variations in weather to cause contrasting impacts on the Missouri River Basin's annual runoff.

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Seasonal precipitation forecasts over the Missouri River Basin

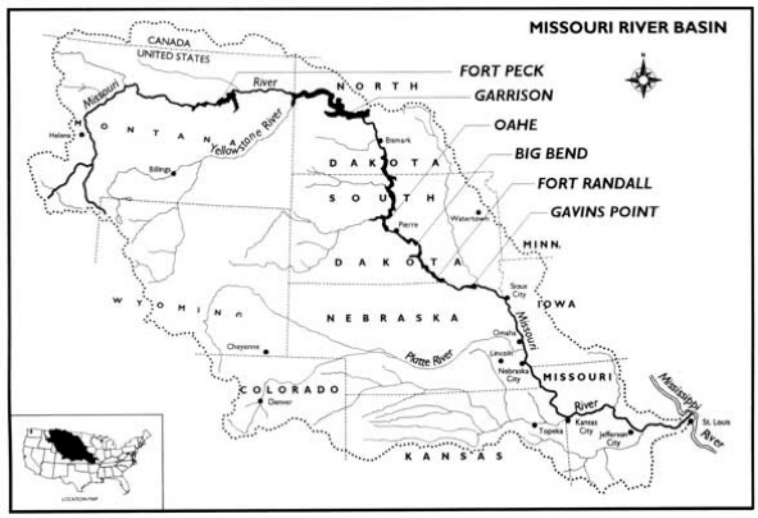
An assessment of operational and experimental forecast system skill and reliability

In 2011, the Missouri River Basin experienced devastating flooding, which caused significant property loss and disrupted thousands of lives. In 2012, the basin experienced extreme drought that impacted water supplies and downstream navigation. Historically, the climate of this region shows a general tendency for both very wet and very dry months in a given year. The ability to accurately predict seasonal flood and drought conditions between one and six months in advance was recognized to be extremely beneficial to water managers, emergency personnel, as well as the general public for planning purposes.

At the request of the Missouri River Basin Water Management office and the U.S. Army Corps of Engineers, NOAA's Earth System Research Laboratory and the University of Colorado's Cooperative Institute for Research in Environmental Sciences (CIRES) performed an assessment study to determine the skill and reliability of current state-of-the-art operational and experimental seasonal forecast systems in predicting the atmospheric conditions that led to the 2011 flood or the 2012 drought.

For the study, NOAA operational and experimental modeling systems were analyzed for December 2010 precipitation forecasts for the winter (January-February-March) and spring (April-May-June) of 2011. Likewise, December 2011 precipitation forecasts for 2012 winter and spring were analyzed. These 'retrospective' forecasts were compared to actual observations for just the Upper Missouri River Basin, for just the Lower Missouri River Basin, and for the entire Missouri River Basin.

The effects of El Niño and La Niña (together known as ENSO) on seasonal temperature and precipitation are well-known in many part of the U.S. Previous analyses have found increased forecast skill for the winter and early spring in some regions on the U.S. during El Niño and La Niña events. Thus, as an additional component of the study, data exclusively for neutral, El Niño and La Niña years were analyzed to assess if the forecast skill improved under these conditions.



The Missouri River Basin, the Missouri River, and the main U.S. Army Corps of Engineers reservoirs (Image courtesy Missouri Department of Natural Resources).

Major Findings

Monthly and seasonal precipitation in the Upper Basin, in the Lower Basin, and entire Missouri River Basin is highly variable with standard deviations averaging close to 30 percent of the long term average.

The upper Missouri River Basin received approximately 70% more precipitation in May 2011 than would be considered normal based on the monthly climatology. In contrast, during September 2012, rainfall in the upper Missouri River Basin was more than 80% below normal for the month, as part of a prolonged dry period lasting from June-September 2012.

The lower Missouri River Basin experienced similar wet (2011) and dry (2012) periods to those observed for the Upper Basin, but the precipitation values were not as extreme relative to the monthly long term averages.

Comparisons of model versus observed precipitation showed similar patterns of wet and dry conditions. However, the forecasts did not provide consistently skillful and reliable predictions of the amplitude and duration of conditions leading to the 2011 flooding and 2012 drought.

The only potentially useful forecast skill was for short lead predictions in the Lower Basin during El Niño events.

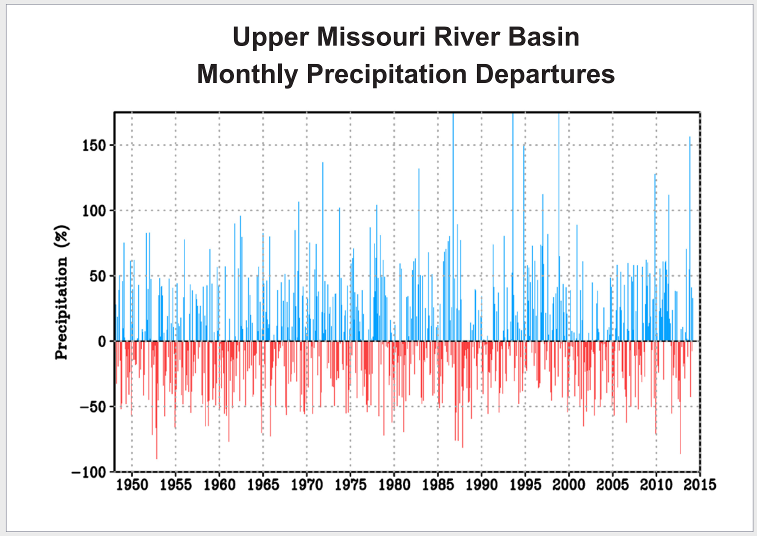
Conclusions

The meteorological factors leading to the 2011 flood or the 2012 drought are not accurately predicted at seasonal lead times by current state-of-the-art, operational and experimental forecast systems.

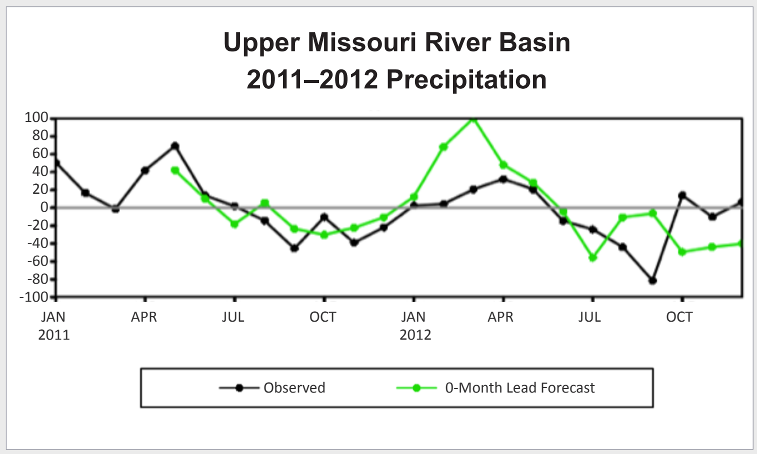
For the lead times and for the times of year of interest, in separate analyses made using all years, only ENSO neutral years, or only La Niña years, the three metrics used to quantify forecast skill in the Missouri River Basin indicate no useful skill in precipitation forecasts for the Upper Basin, for the Lower Basin, or for the entire Missouri River Basin.

While perhaps not useful to manage basin-wide flood and water supply risks, there is potential skill for predictions of precipitation at short lead times during El Niño events in the unregulated lower part of the basin below the mainstem dams.

The link between El Niño and precipitation in the Lower Basin may potentially be of value in the Lower Basin to inform a broad range of regional to local regulatory and management practices.



Monthly precipitation departures from the long term monthly averages for 1948 to present illustrating high month-to-month variability within the Upper Basin.



Comparison of precipitation observations (black), and 0-month lead time precipitation forecast (green). Units are percentage of above or below observed monthly climatology from 1982 - 2009.

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Funding for this project was provided by U.S. Army Corps of Engineers

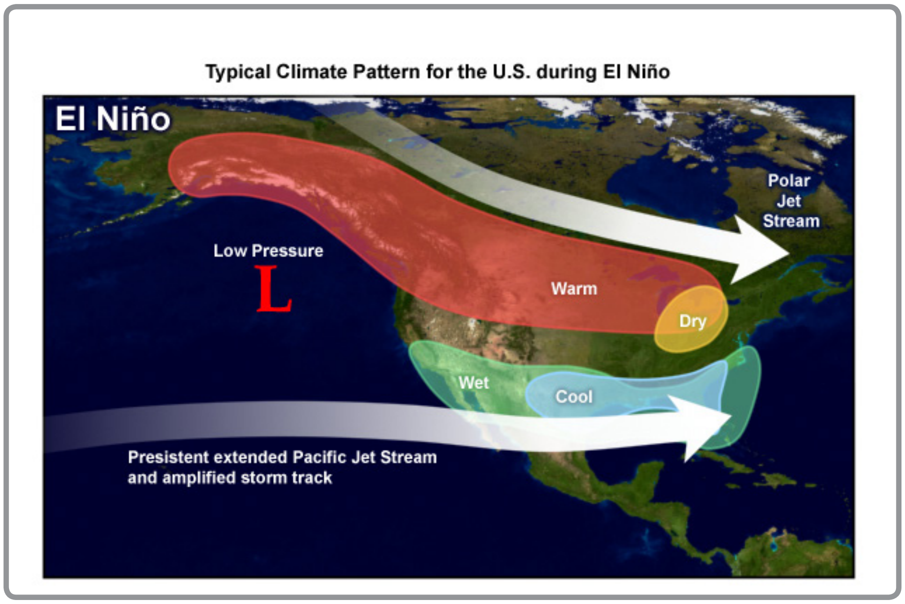
Cover photo: Missouri River, by Aimee Castenell

El Niño Impacts and Outlook

Missouri Basin Region

September 2014

Typical El Niño Winter Pattern



Typical El Niño jet stream patterns across the U.S. include a stronger than usual storm track across the southern U.S., leaving the northern U.S. removed from the average storm track. Image courtesy of NOAA.

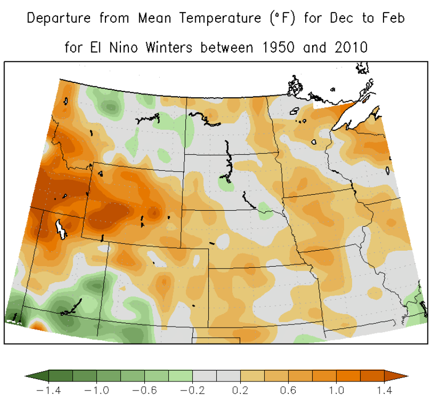
El Niño Winter Tendencies

El Niño is a particular pattern in the Pacific Ocean that affects weather downstream to the United States. It has its most notable impacts in the winter, when wind patterns in the atmosphere are strongest. When El Niño is present, it provides some predictable effects to weather patterns. While no two El Niño events are alike, the typical winter weather pattern (left) brings the polar jet stream farther north than usual, across Canada, while the Pacific jet stream remains in the southern U.S. As a result, the upper Missouri River basin can be warmer than normal, with the potential for less frequent heavy snow than usual. Confidence in these patterns is higher with stronger El Niño events.

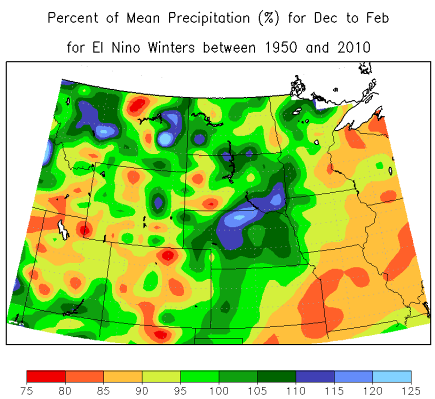
El Niño Outlook and Climate Connections

Winter Temperature and Precipitation

Departure from Average Temperature (°F) in Winter During Past El Niños



Percent of Average Precipitation (%) in Winter During Past El Niños



Departures from average temperature (left) and percent of average precipitation (right) in December through February during past El Niño years. Image courtesy of the Midwest Regional Climate Center.

The winter outlook from the NOAA/NWS Climate Prediction Center mainly is consistent with typical El Niño patterns across the central U.S., shown above, with a slightly increased chance for above-normal temperatures from the upper Missouri River basin. There also is a slightly increased chance for below-normal precipitation in Montana and Wyoming. During past El Niños, wet conditions have been observed across parts of the Central Plains and into the upper Missouri River basin.

El Niño Likely

Highest Potential for Weak to Moderate El Niño

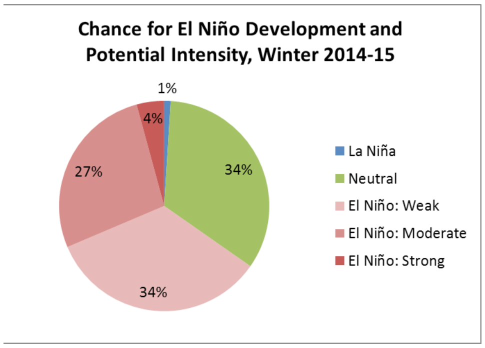


Chart based on summaries and forecast model data from the NOAA/NWS Climate Prediction Center and the International Research Institute for Climate and Society.

Odds still favor an El Niño forming by mid to late fall, with a 60-70% chance of development. There is a 30-40% chance for neutral conditions to continue through this winter, with a near-zero chance for La Niña to develop.

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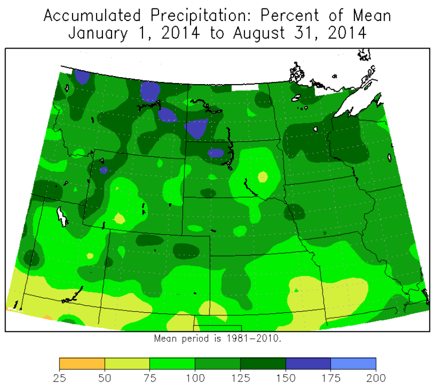
Ongoing Conditions and Possible Impacts

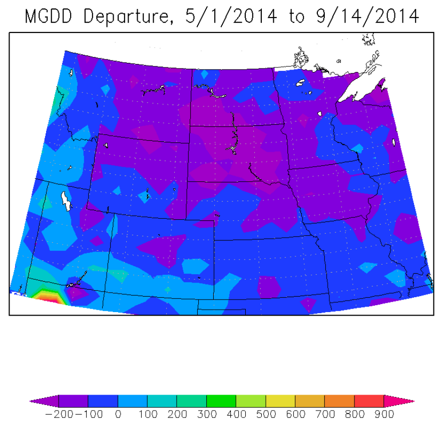
Precedent Conditions



Precipitation percent of normal for January 1 through August 31, courtesy of High Plains Regional Climate Center.

Moisture conditions through the summer of 2014 have been near to above average across the upper Missouri River Basin, alleviating drought conditions in the mid to lower Missouri River valley. Areas of near to below average precipitation linger in eastern South Dakota and in Kansas and Missouri.

Growing Season Lagging



Growing degree day departure from average for May 1 through September 14, courtesy of Midwestern Regional Climate Center.

The 2014 growing season had a late start due to a cold spring, and it continues to lag in the Missouri Basin region. Even average conditions through the rest of the growing season would hamper some crops from reaching maturity. El Niño is not associated with the potential for early or late first freeze in the fall.

Missouri River Levels

Gavins Point Dam. Image courtesy of the U.S. Army Corps of Engineers.

Due to a wet summer, the Missouri River is running higher than usual for the time of year. Navigation season will be extended into the fall to move water out of the reservoirs and make space. Some indicators suggest a tilt toward lower than usual mountain snowpack in the Fort Peck drainage area during El Niño, but the signals are weak.

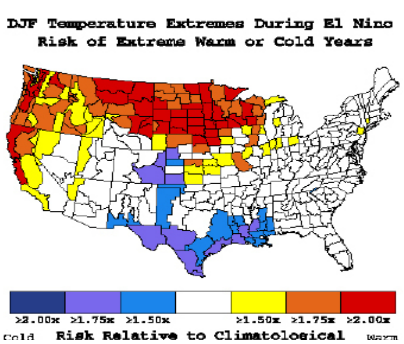
El Niño Limitations and Myths

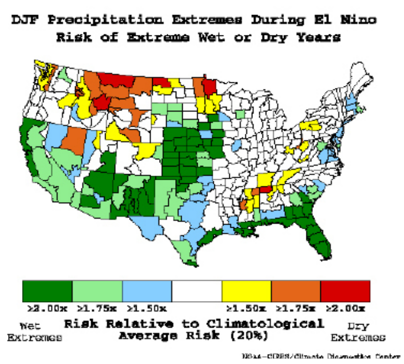
El Niño impacts can be limited by many factors, including:

- It may not develop.
- It may be weak, with little or no discernible influence on weather patterns.
- It may be masked by other weather and climate signals.
- Single extreme events can "buck the trend" of the averages for the rest of the season, with one or two high-impact events overshadowing the average conditions.

El Niño can affect some temperature and precipitation signals in the region, but it is not known to affect:

- First freeze date in the fall (either early or late).
- Last freeze date in the spring (either early or late).
- Potential for ice storms or blizzards.
- Track or intensity of any single weather system.





Risks of extreme temperatures and precipitation during moderate to strong El Niño events. Images courtesy of NOAA Earth Systems Research Laboratory.

Partners and Links

Great Lakes Environmental Research Laboratory
www.glerl.noaa.gov
Great Lakes Integrated Sciences + Assessments
glisa.umich.edu
High Plains Regional Climate Center
www.hprcc.unl.edu
Int'l Research Institute for Climate and Society
iri.columbia/edu/our-expertise/climate/forecasts/enso
Midwestern Regional Climate Center
mrcc.isws.illinois.edu
National Drought Mitigation Center
www.drought.unl.edu
National Integrated Drought Information System (NIDIS)
www.drought.gov
National Oceanic and Atmospheric Administration
www.noaa.gov
- **National Weather Service - Central Region**
  www.crh.noaa.gov/crh
- **National Climatic Data Center**
  www.ncdc.noaa.gov
- **Climate Prediction Center**
  www.cpc.ncep.noaa.gov
- **National Operational Hydrologic Remote Sensing Center**
  www.nohrsc.noaa.gov

State Climatologists
www.stateclimate.org
South Dakota State University Extension
igrow.org
U.S. Department of Agriculture
www.usda.gov
- **NRCS National Water & Climate Center**
  www.wcc.nrcs.usda.gov
- **Regional Climate Hubs**
  www.usda.gov/oce/climate_change/regional_hubs.htm

Useful to Usable (U2U)
https://drinet.hubzero.org/groups/u2u
Western Water Association
wwa.colorado.edu

NOAA: Another warm winter likely for western U.S., South may see colder weather

noaanews.noaa.gov/stories2014/20141016_winteroutlook.html

Repeat of last year's extremely cold, snowy winter east of Rockies unlikely

October 16, 2014

(Credit: NOAA)

Below average temperatures are favored in parts of the south-central and southeastern United States, while above-average temperatures are most likely in the western U.S., Alaska, Hawaii and New England, according to the U.S. Winter Outlook, issued today by NOAA's Climate Prediction Center.

While drought may improve in some portions of the U.S. this winter, California's record-setting drought will likely persist or intensify in large parts of the state. Nearly 60 percent of California is suffering from exceptional drought – the worst category – with 2013 being the driest year on record. Also, 2012 and 2013 rank in the top 10 of California's warmest years on record, and 2014 is shaping up to be California's warmest year on record. Winter is the wet season in California, so mountainous snowfall will prove crucial for drought recovery. Drought is expected to improve in California's southern and northwestern regions, but improvement is not expected until December or January.

"Complete drought recovery in California this winter is highly unlikely. While we're predicting at least a 2 in 3 chance that winter precipitation will be near or above normal throughout the state, with such widespread, extreme deficits, recovery will be slow," said Mike Halpert, acting director of NOAA's Climate Prediction Center. "This outlook gives the public valuable information, allowing them to make informed decisions and plans for the season. It's an important tool as we build a Weather-Ready Nation."

El Niño, an ocean-atmospheric phenomenon in the Tropical Pacific that affects global weather patterns, may still develop this winter. Climate Prediction Center forecasters announced on Oct. 9 that the ocean and atmospheric coupling necessary to declare an El Niño has not yet happened, so they continued the El Niño Watch with a 67 percent chance of development by the end of the year. While strong El Niño episodes often pull more moisture into California over the winter months, this El Niño is expected to be weak, offering little help.

(Credit: NOAA)

The Precipitation Outlook favors above-average precipitation across the southern tier, from the southern half of California, across the Southwest, South-central, and Gulf Coast states, Florida, and along the eastern seaboard to Maine. Above-average precipitation also is favored in southern Alaska and the Alaskan panhandle. Below-average precipitation is favored in Hawaii, the Pacific Northwest and the Midwest.

Last year's winter was exceptionally cold and snowy across most of the United States, east of the Rockies. A repeat of this extreme pattern is unlikely this year, although the Outlook does favor below-average temperatures in the south-central and southeastern states.

In addition, the Temperature Outlook favors warmer-than-average temperatures in the Western U.S., extending from the west coast through most of the inter-mountain west and across the U.S.-Canadian border through New York and New England, as well as Alaska and Hawaii.

Video: Winter Outlook 2014-2015. (Credit: NOAA)

The rest of the country falls into the "equal chance" category, meaning that there is not a strong enough climate signal for these areas to make a prediction, so they have an equal chance for above-, near-, or below-normal temperatures and/or precipitation.

The U.S. Seasonal Drought Outlook, updated today and valid through January, predicts drought removal or improvement in portions of California, the Central and Southern Plains, the desert Southwest, and portions of New York, Connecticut, Rhode Island and Massachusetts. Drought is likely to persist or intensify in portions of California, Nevada, Utah, Idaho, Oregon and Washington state. New drought development is likely in northeast Oregon, eastern Washington state, and small portions of Idaho and western Montana.

This seasonal outlook does not project where and when snowstorms may hit or provide total seasonal snowfall accumulations. Snow forecasts are dependent upon the strength and track of winter storms, which are generally not predictable more than a week in advance.

NOAA's mission is to understand and predict changes in the Earth's environment, from the depths of the ocean to the surface of the sun, and to conserve and manage our coastal and marine resources. Join us on Twitter, Facebook, Instagram and our other social media channels.

Upper Missouri Basin: Proposal for Enhanced Monitoring for Floods and Drought

February 2013 – Prepared by an inter-agency team of monitoring, forecasting and water management experts.

Summary: This proposal identifies critical investments in soil moisture and snowpack monitoring in the Upper Missouri River Basin and plains, in order to reduce flood risk and improve river and water resource management in the Basin. This enhanced monitoring network will require a $6.25 million capital investment and approximately $1.5 million in annual operations. Decision makers will take the next step by determining funding sources and implementation priorities for the enhanced monitoring network.

Background: In the spring and summer of 2011, unprecedented flooding in the Upper Missouri River Basin caused over $2 billion in direct damages and led to FEMA disaster declarations in all states along the river. The events of 2011 continued a pattern of significant flooding that has emerged over the past two decades, including The Great Flood of 1993 and another significant plains snow flood events in 1995 and 1997. In addition, the basin endured an 8-year drought ending in 2007 and is currently in the midst of another drought.

In September 2011, the Corps commissioned an independent expert review panel to examine the causes and response to the flooding. As one of its six primary recommendations, the panel identified the need for better monitoring information across the Great Plains, particularly regarding snow water equivalent (SWE) and soil moisture.

Technical Review: Pursuant to the independent review, from September to December of 2012, a team of monitoring experts from across the region developed a technical report titled *Snow Sampling and Instrumentation Recommendations*.[1] The report is built around three components:

1) *Inventory:* The team conducted an inventory of existing federal, state, and volunteer networks to measure weather, snowpack and soil moisture (Figure 1);
2) *Gap Assessment:* The team identified gaps in monitoring, including gaps in geographic coverage and monitoring capabilities for key parameters; and
3) *Monitoring Recommendations:* The team sought to identify what will be needed to meet forecasting and monitoring goals for the Upper Missouri River Basin. They considered how to maximize the use of existing resources to develop the pragmatic solution described here.

Monitoring Proposal: The proposal endorses three approaches to enhance data collection: 1) automated measurements; 2) manual snow sampling; and 3) aerial snow surveys. The proposed network would consist of both new and retrofitted weather stations managed by a combination of state and federal entities.

- Automated Measurements: Existing automated monitoring networks include the NRCS Soil Climate Analysis Network (SCAN), the NRCS Snowpack Telemetry (SNOTEL) Network, and the states' Automated Weather Data Network (AWDN) sites. The proposal includes upgrades to 92 existing network sites as well as the addition of 29 new AWDN sites across South Dakota, Montana, and Wyoming. (See Figure 1.)
- Aerial Water Resource Surveys: The National Weather Service runs the Airborne Snow Survey Program, which can cover large regions and sample remote areas. Currently, the program runs just over 60 flight lines in the Upper

[1] Released February 1, 2013. The full proposal, including descriptions of the various existing and proposed monitoring platforms as well as detailed budgets, is available for review.

Photo: Missouri River Flood, 2011, Bismarck-Mandan.

Missouri Basin; the proposal would increase the total number of flight lines to approximately 300.

- Manual Snow Sampling: The proposal would use on-the-ground volunteer data collection to complement automated and remote sensing.

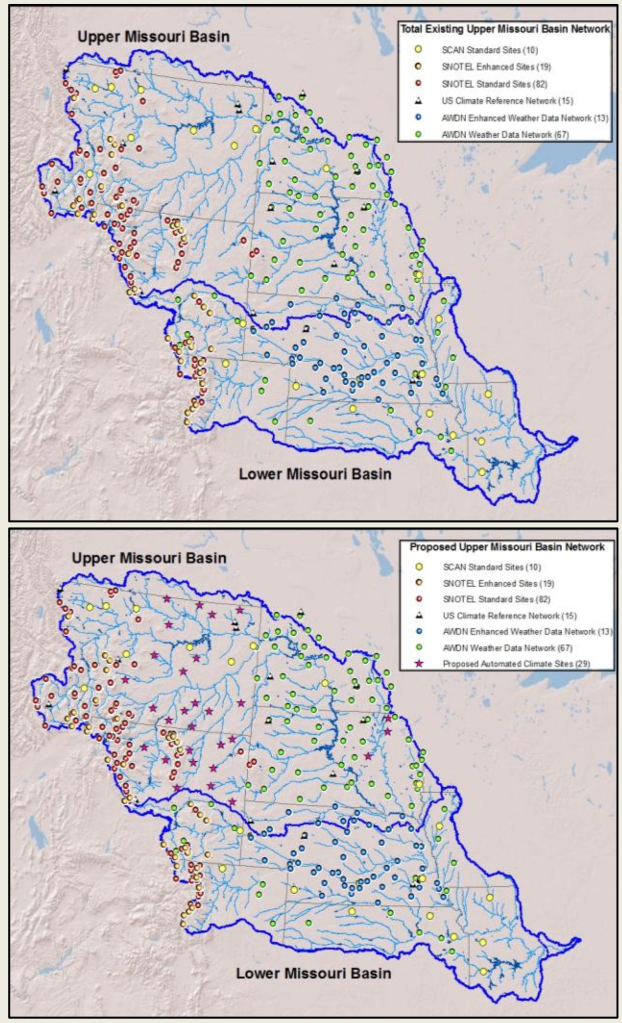


Figure 1: Top, Total Existing Upper Missouri Basin Network. Bottom, Proposed Network.

Budget: The technical committee developed a budget for this proposal including capital investment, personnel, and O&M costs. Based on this assessment, the Year 1 investment would be approximately $6.25M and ongoing operational costs would be $1.5M.

Benefits: The enhanced monitoring network will help to inform our understanding of flood and drought conditions, including annual runoff forecasts and the National Drought Monitor. The Army Corps of Engineers has indicated that the monitoring framework established by this proposal could have been essential to mitigating damages from flooding in 2011. A USACE water manager stated, "… more accurate early-season runoff forecasts based on verifiable field measurements and modeling … system service level would have been raised earlier and more aggressively … would have had more flood control storage space available in May, June and July."

Next Steps: This proposal represents the first step towards enhanced monitoring capacity in the Missouri River Basin. Next steps will focus on briefing decision-makers, including the Governors of the Basin states, tribes, and the Regional Executives for the federal agencies.

Partners recognize the need for a strong, coordinated federal-state partnership to secure the funding and staffing resources needed to build and sustain this proposed network. The technical committee will be available to work with decision-makers to evaluate priorities or sequencing associated with this proposal.

BUDGET	Capital (Yr 1)	Annual/O&M (Yr 2 +)
Automated Monitoring		
Enhanced (92)	$1,715,000	$390,000
New (29)	$1,060,000	$105,000
Aerial Water Surveys	2,550,000	$150,000
Manual Snow Sampling	920,000	$810,000
TOTAL	**6,245,000**	**$1,455,000**

Authorship: The proposal was developed by an interagency team of monitoring, forecasting and water management experts, including the National Oceanic and Atmospheric Administration, the Corps of Engineers, the Natural Resources Conservation Service, Bureau of Indian Affairs, Western Governors' Association, and state water resource managers and state climatologists.
Lead Contacts: Lead contacts are Doug Kluck, NOAA, and Kevin Grode, USACE.