Marsh

Navigating waterways

Climate change implications for the maritime sector

Introduction

The impact of changes in the climate on vital maritime routes are now central to assessing risks across the global supply chain.

International trade relies on critical waterways for their strategic location and reliable navigability. These include human-made waterways such as the Suez and Panama Canals, as well as the traditional arteries of trade, including the Mississippi, Danube, Yangtze, and Amazon Rivers. With extreme weather events increasing in frequency and severity, including drought and flooding, high and low water levels are increasingly impeding reliable navigation in key waterways. When these waterways become unnavigable or congested, global trade can be significantly impacted. The consequences of this can be expensive — in 2022, low water levels in the Mississippi River led to a backlog of 2,000 barges, costing around US$20 billion in supply chain disruption and economic damage.

This paper uses the Mississippi River as a case study to explore how climate-induced changes may impact inland waterways. It builds on our previous well-received investigation of the Suez Canal's fixed assets and their risk from climate change, where we showed how high winds in the region are making it more difficult for cargo vessels to steer, as highlighted by the Ever Given running aground and blocking the canal, costing US$60 billion in disruption to global trade.

This paper identifies how different stakeholders, including port authorities, local and regional governments, shipping companies, and cargo owners, can establish effective resilience measures for their operations. Their interests in and responsibilities for particular activities may vary. However, the benefits of achieving overall resilience and ensuring the smooth operation of global supply chains are common among stakeholders.

Port authorities, local and regional governments, shipping companies, and cargo owners can establish effective resilience measures for their operations.

The impact of climate change on global waterways

With 80-90% of global trade relying on water transport and maritime trade volumes set to triple by 2050, ensuring the navigability of waterways is a critical concern. Businesses must contend with external factors such as geopolitical volatility and physical factors such as extreme weather. The increasing frequency and severity of extreme weather events threaten critical trade routes and river operations, potentially resulting in delays, loss of perishable goods, and disruption to global supply chains. These trends are projected to worsen with climate-induced changes.

Despite heavy reliance on key routes for the transportation of goods, limited redundancy exists in the maritime industry. Many of the world's busiest ports rely on inland waterway navigation for accessibility, including five of the biggest seaports in Europe. Yet, inland waterways are particularly vulnerable to the effects of climate change, with the potential for trade to be significantly curtailed if there is insufficient water for the draft of a laden vessel.

If water levels are low but still navigable, vessels may be required to reduce their load factors and carry fewer goods. This means that the ratio between actual loading and total capacity decreases. During Europe's drought in 2022, low water levels in the Rhine River led to a 75% reduction in cargo capacity on some vessels. When the load factor of multiple vessels is reduced in periods of low water, the costs per ton of transported goods increases.

Furthermore, where vessels operate with a reduced cargo capacity, more trips are required to carry the same quantity of goods, likely increasing the amount of carbon emissions released. Compared with other forms of transport shipping remains one of the most sustainable ways of carrying large quantities of goods. However, growth in shipping activity is becoming greater than efficiency gains, with emissions from the sector increasing by nearly 10% between 2012 and 2018. Any efficiency gains may be eroded, and emissions will increase, if vessels can't be fully laden. A significant opportunity exists for all stakeholders to ensure that the sector remains on course for achieving its net zero ambition by 2050, while preserving world trade.

Low water levels are not the only challenge impacting navigability levels. Flooding events associated with high water levels are becoming increasingly common with climate change. Marsh McLennan analysis shows that since 1980, the number of flood disasters has increased by 181% globally. High river levels impact the ability of vessels to navigate channels because of fast moving water and over-full channels, which increase the likelihood of delays and accidents occurring in waterways.

Many waterways rely on locks to facilitate the successful passage of vessels. During high water levels, locks may face operational restrictions or closure. During extremely low water levels, there may be limited water available to fill the locks. The Panama Canal has experienced the effects of this, with some vessels reportedly paying US$2.4 million to skip queues caused by low water levels. Fewer vessels passing during these conditions can increase the cost of shipping and the price of goods.

Given the pivotal role of key waterways in global trade, it is important for stakeholders to proactively explore these risks to build resilience and mitigate potential disruptions to operations.

01| Examples of extreme weather events impacting the navigability of key waterways

Event	Cause	Impact	Intervention
Danube River, April 2006	Flooding (snow melt)	• Snow accumulation in winter 2005 and high temperatures in March 2006 resulted in the rapid melting of snow and subsequent flooding. • Estimated total cost of damages and related emergency operations exceeded €600 million.	• Emergency response operation set up that included special reservoirs, protection lines, and mobile pumps. • Emergency dikes put in place for the protection of settlement areas and placement of sandbags. • Authorities ordered the reinforcement of flood protection structures. • Authorities undertook controlled breaches of dikes and flooding of floodplain basins.
Yangtze River, 2010	Flooding	• Floods caused direct economic losses of US$14.4 billion from damage to assets and infrastructure.	• Draining of overflowing reservoirs and pile up of sandbags initiated to prevent further flooding.
Yangtze River, 2022	Drought	• Highest recorded temperature since 1961. • Precipitation dropped 40% lower compared to the 1961–2021 climatic mean. • Low water levels led to the river's closure in mid-August between Wuhan and Yueyang.	• Government-led working groups were dispatched to inspect and supervise key affected areas. • They provided technical support, implemented drought relief measures, and resolved water-use conflicts.
Mississippi River, October 2022	Drought	• Navigation restrictions in October 2022 resulted in 2,000 barges backed up. • Low water levels increased the cost of transporting grain by barge from US$11-12 per ton in the summer of 2022 to over US$71 per ton in October 2022.	• US Army Corps of Engineers dredged portions of the river to keep traffic flowing. • They also built a 1,500-foot-wide underwater levee to prevent saltwater from impacting drinking water systems.
Danube River, August 2023	Drought	• Severe drought reduced the navigable width of the channel from 180 meters to 100 meters. • Reduced water levels revealed 20 World War II wrecks containing ammunition, introducing additional blockages and dangers. • Removal of blockages cost an estimated US$30 million.	• Officials dredged along the river to salvage usable navigation lanes. • A private company was contracted for hull salvage and removal of explosives.
Panama Canal, August/September 2023	Drought	• Reduction in the number of vessels passing per day from 36 to 31. This was estimated to reduce to 18 ships per day by February 2024. • Revenue reduction of up to US$200 million was expected by February 2024. • Significant delays led to vessels paying up to US$3 million to skip queues.	• Passage restrictions were imposed to conserve water, including cutting vessel drafts and daily passage authorizations.
Amazon River, October 2023	Drought	• Low water levels required firms to use barges that could only carry 10% of ships' cargo. • This disrupted grain and agricultural exports.	• Additional "drought tax" applied by companies responsible for the pilots of approximately US$160,000. • Barge companies introduced "specific operational flexibility", providing maneuvering pushers to navigate barges at the shallowest points. • The government allocated US$27 million for emergency dredging services.

Feature: The Mississippi River

The Mississippi River, flowing 2,350 miles from Lake Itasca in Minnesota to the Gulf of Mexico, provides a case study on how climate challenges can affect global trade and create supply chain uncertainties. It is both a strategic waterway for global supply chains and fundamental for ensuring global food accessibility: Up to 60% of US grain exports and 78% of the world's exports of feed grains pass through the river.

The river basin is both getting warmer as average temperatures are rising and getting wetter. These two trends are the sources of the river's increasing susceptibility to drought and flooding, resulting in periods of limited navigability or total inaccessibility for vessels, as well as significant financial and social impacts.

Changes to river levels in the wider Mississippi Basin

Assessing historical river water levels at gauges and key sites along the Mississippi River shows how water levels have changed over time. Between 1980-2023, the Lower Mississippi River (LMR) has become more susceptible to "too high" water levels, particularly between January and July.

This is true for the Greenville and Baton Rouge gauges. It is unsurprising given that tributaries in the wider Mississippi River drain into the LMR, causing a naturally higher water flow through this channel area.

At the same time, gauges in the Upper Mississippi River (UMR) are increasingly experiencing days of "too low" water levels, particularly at the Cairo site. This is critical because the UMR contains the dam and lock systems that guarantee navigation for the rest of the basin. In the past, when water levels have fallen, not enough water has been available to fill the locks to allow ships to navigate through the basin.

02| Mississippi River water level gauges used in analysis

Future projected climatic changes

Flooding

Changing patterns of precipitation (increased precipitation between March–May) are expected to combine with greater precipitation concentration (higher rain discharge) to cause rapid saturation of soil and high surface run off during this period (Figure 6).

As such, flooding conditions are likely to increase, impacting the ability of ships to navigate through the channel because of high water speeds and broken riverbanks. Under these conditions, waterway authorities are likely to apply operational restrictions that further limit ships' accessibility to the channel.

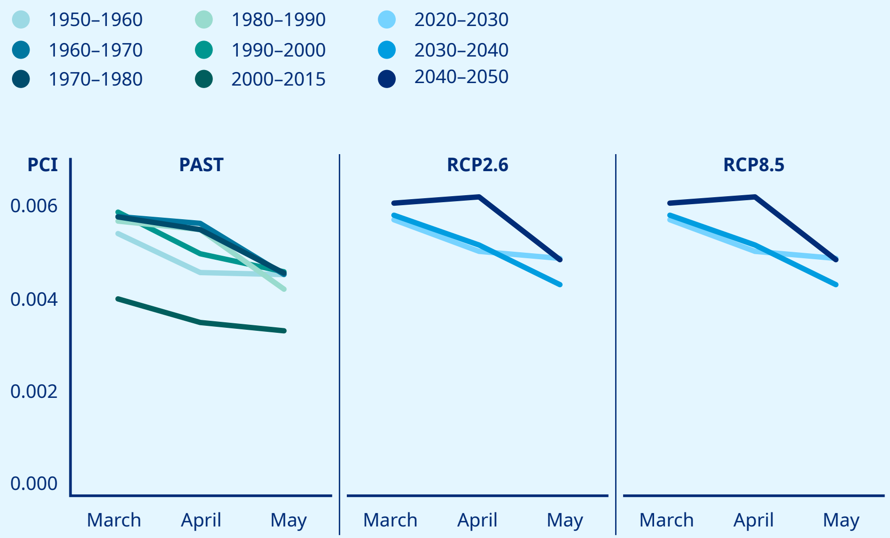
On top of this, our analysis shows that by 2050, temperatures in April are expected to be ~2.8 (°C) greater than the 1950 level (Figure 5). With the projected rise in temperature, rapid snow melt in early spring is likely. Where snow melt coincides with periods of increased precipitation and precipitation concentration, significant flooding events will become more likely.

Under these conditions, physical risks will increase, compounding the risk of disruption to the navigability of the Mississippi River as well as impacts to the surrounding communities.

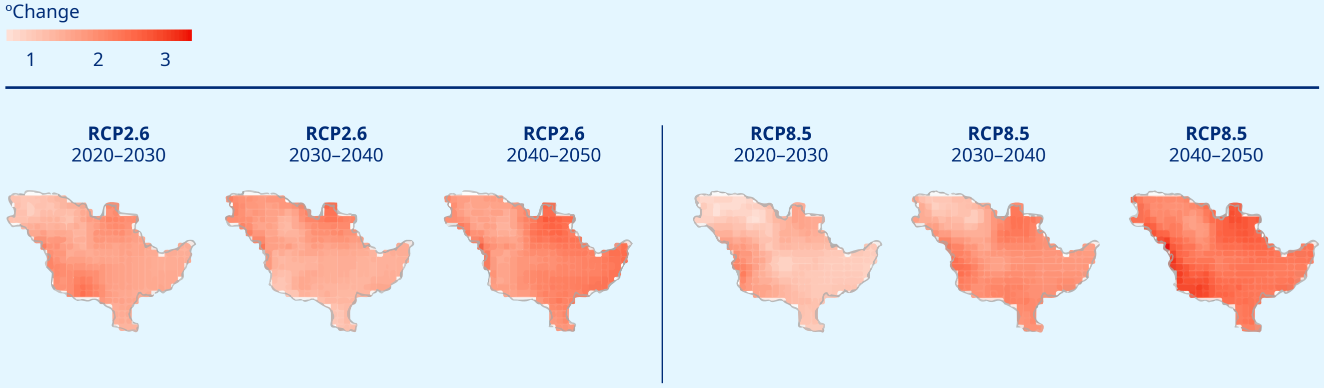
Drought

Increased temperatures and decreased rainfall in summer months have already led to notable drought events in the Mississippi River, including in June 2022, where the river fell by 20 feet over 11 weeks. Droughts severely disrupt inland navigation services by reducing water levels, making the channel become completely non-navigable or forcing vessel loads to be significantly reduced. As portrayed in Figure 6, climate models suggest that average temperatures will rise in the Basin by around 3°C, increasing the likelihood of similar events affecting the operation of the Mississippi River. This could cause considerable disruption in the maritime industry, financial losses, higher container costs across the global supply chain, and threaten to grind trade of grains, fertilizer, metals, and petroleum to a halt.

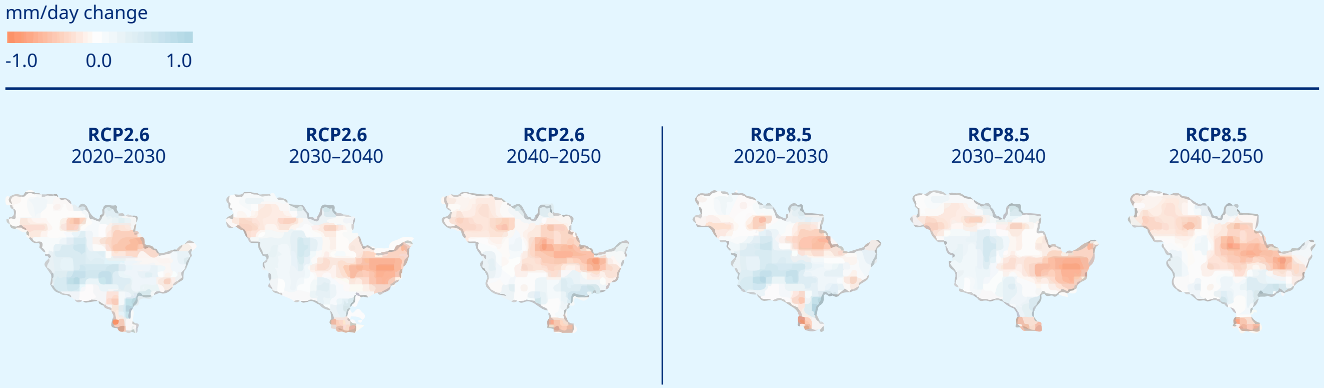
03| Changes in the concentration of historical and projected precipitation from March to May in the Mississippi Basin measured by the average precipitation concentration index (PCI), which analyzes the structure of daily precipitation amounts



04| Changes in projected average temperature from March to May in the Mississippi Basin, using 2015 as a baseline



05| Changes in projected average precipitation from August to October in the Mississippi Basin, using 2015 as a baseline



RCP = Representative Concentration Pathway

Sources: *GFDL-ESM4 (USA) Model, Copernicus Climate Data Store*

Building resilience

Increasing the resilience of the Mississippi River and other key waterways can take the form of several measures, with cross-stakeholder engagement essential for effective implementation (Figure 6).

Waterway engineering

- Short- and long-term resilience to physical climate risk can be encouraged through waterway engineering. Port authorities, and local and regional governments may rather increase resources and funding to support dredging, channel surveying, and salvage capabilities within large and extensive waterways.
- Conducting a review of where low water levels and high siltation have historically been an issue will allow authorities to concentrate resources where most required. Local and regional governments are usually responsible for implementing proactive upgrades to dam and lock facilities, but other stakeholders, including port authorities, shipping companies, and cargo owners have a vested interest in ensuring that appropriate upgrades are implemented.
- Given the potential negative impacts on the environment, each case should be assessed individually to understand the effectiveness, sustainability, environmental impact, and economic viability that waterway engineering methods will provide.

Demand management

- Waterway and port authorities are already using and developing strategies for prioritizing vessels during climate stress. This includes dynamic charging for transit and perishability-based prioritization, which can limit the impact on supply chains and food accessibility.
- Emissions-based prioritization is another possibility, given the increased focus on climate in the maritime industry. Ports and local authorities can determine accessibility according to the vessel's energy efficiency rating. These stakeholders, in line with international standard setters, as well as governmental authorities, are central to the effective application of these climate adaptation measures.
- Port authorities and governments should undertake research to understand the nature of transportation within their waterways.

Process redesign

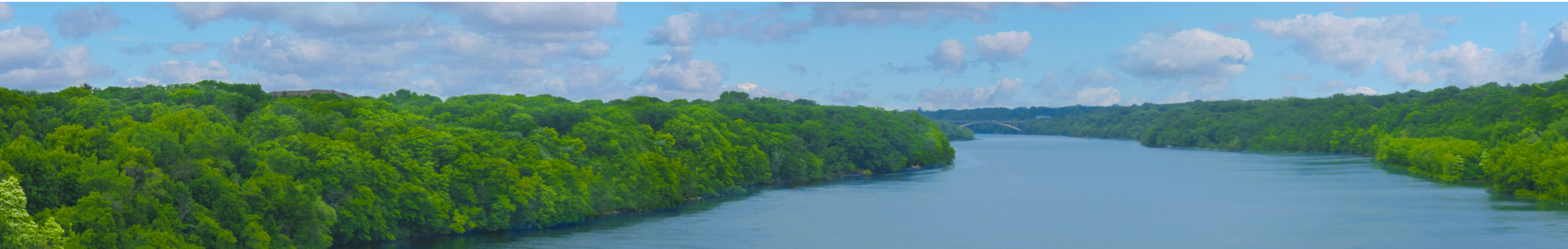
- All stakeholders should consider process redesign measures to protect their individual and collective interests. In the longer term, government agencies and port authorities should review alternative port locations where conditions are likely to worsen.

Resilience adaptation

- Funding or capital for resilience adaptation investment can be secured through government (co)sponsorship or institutional investors, such as pension funds.
- Guidance from frameworks such as the UN's Principles for Resilient Infrastructure, which ensures that resilience is embedded into the planning and implementation of infrastructure projects, can support countries and communities to mitigate risk.
- The maritime industry should continue to adapt to new trade routes and manage utilization where possible, such as avoiding certain passages during hotter, drier months.

Insurance solutions

- Trade disruption insurance (TDI) solutions can address the financial impact of supply chain disruption for all stakeholders as well as manufacturers, suppliers, and others impacted by supply chain volatility. Other solutions include consequential loss and cargo and stock throughput (STP) insurance.
- Parametric solutions can provide financial coverage for property damage and business interruption when a river is above or below a certain water level. Parametrics respond to movements of an independent index (such as a river's water levels) rather than the occurrence of an event or a specific loss of value.
- Sentrisk™ is an AI-powered platform that can provide intelligence on supply chain vulnerabilities, thereby transforming supply chain risk exposure into business opportunities by reducing volatility and avoiding losses.



06| Stakeholder-based resilience recommendations

	Resilience measure		Stakeholders					
Type	Details	Time horizon	Cargo owners	Shipping companies	Port authorities	Local and regional governments	International standard setters	Comments
Waterway engineering	Dredging, channel surveying	Short term	—	—	●	●	—	Ongoing maintenance commitments may be required as channels revert to their natural shape. Dredging can also have serious and long-lasting negative environmental impacts that must be considered.
	Upgrades to dam and lock facilities	Short/long term	—	—	●	●	—	Cargo and shipping companies can engage with port authorities and governments to provide feedback and lobby for upgrades.
Demand management	Dynamic charging for transit	Short term	—	—	●	●	—	This may raise questions about how to prioritize cargo, such as by essential needs, ability to pay, carbon intensity, or other metrics.
	Perishability-based prioritization	Short term	—	—	●	—	●	Engagement from cargo owners and shipping companies would benefit from effective prioritization.
	Emissions-based prioritization	Medium term	—	—	●	●	●	The International Maritime Organization (IMO) and other international standard setters are working with stakeholders to establish an understanding that emissions reduction is a priority for the maritime sector's future.
Process redesign	Barge and rail transfer	Short term	●	●	●	●	—	Engagement and support from all stakeholders is required. The resilience measure is likely to be driven by port authorities and local government.
	Identification of alternative ports and port relocation	Short/long term	●	●	●	●	—	All stakeholders should consider additional locations to build redundancy.
Resilience adaptation	Securing capital for investment	Short/medium term	—	—	●	●	—	Funding resilience is traditionally complex as it does not generate a stream of new cashflows, but rather seeks to preserve existing cashflows.
Insurance solutions	Insurance products, including for physical infrastructure and goods	Short/long term	●	●	●	●	—	Suitable products vary by stakeholder but can all bolster existing insurance to ensure robust coverage against climate-related events.

Conclusion

Maritime and global trade rely on critical routes and infrastructure. As these vital routes come under strain from increased physical climate risk exposure, the reliability and criticality of the mechanisms underpinning international trade are threatened.

Addressing these risks will require a range of interventions by many stakeholders to build resilience throughout the supply chain and reduce vulnerability to disruption. The nature of interventions will differ across geographies and stakeholders, but their collective implementation is crucial. Without significant investment and cooperation in waterway engineering, demand management, process redesign, and resilience adaptation, the unnavigability of key waterways will pose a growing risk to global trade.

The waterways of the future may look radically more engineered and managed compared to where they are today. By spearheading breakthroughs and by way of strategic investment, all stakeholders can drive improvements and build resilience in key waterways worldwide, while mitigating potentially catastrophic outcomes. With waterborne freight still one of the most sustainable transport methods, stakeholders attuned to the emerging and growing threat of climate-related risks will be best placed to respond and capture future opportunities.

The waterways of the future may look radically more engineered and managed compared to where they are today.

Methodology

- Daily historical data was analyzed regarding the depth in the gauges in the Mississippi River from 1980 to 2023 focusing on (Cairo, Memphis, Greenville, and Baton Rouge). This data was retrieved from the US Army Corps of Engineers´ platform RiverGages.com Water Levels of Rivers and Lakes.
- The evolution of climatic conditions was assessed, including precipitation and temperature levels in the Mississippi Basin to determine whether and how they have changed since 1950. This was achieved by analyzing the daily grid level data gathered by the Copernicus Climate Change Service from the European Commission.
- Climate daily grid level climate projections for two RCP scenarios (Representative Concentration Pathways 2.6, limited climate change and 8.5, severe climate change) were analyzed to understand how climatic conditions are expected to evolve in the Basin and whether climatic conditions that in the past have coincided with floods and droughts are expected to recur and worsen in the future. This was achieved through the analysis of the daily grid level data of the GFDL-ESM4 (USA) model gathered by the Copernicus Climate Change Service from the European Commission.

Precipitation and temperature data

- Source: Copernicus Climate Change Service from the European Commission
- Granularity: Daily grid level data
- Past data: 1950-2015, historical observations
- Projections: 2015-2050. Model: CESM2 (USA)
  - RCP 2.6
  - RCP 8.5

River level data (gauge depths)

- Source: US Army Corps of Engineers
- Granularity: Daily gauge level data
- Past data: 1980 (or origin of the gauge data) - 2023.

Waterways Action Plan (WAP) data

- Source: Mississippi River and Tributaries Waterways Action Plan: Upper Mississippi River Annex (2021), Illinois Waterway Annex (2021), and MSU Baton Rouge Annex (2023).

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