



Delivering Sound Flood Management
Solutions for a Resilient Future



Solutions for Resilient Flood Risk Management

Effective flood risk management strategies begin at a local level, involving people and organizations across a strikingly diverse spectrum. We believe that collaboration is the best way forward.

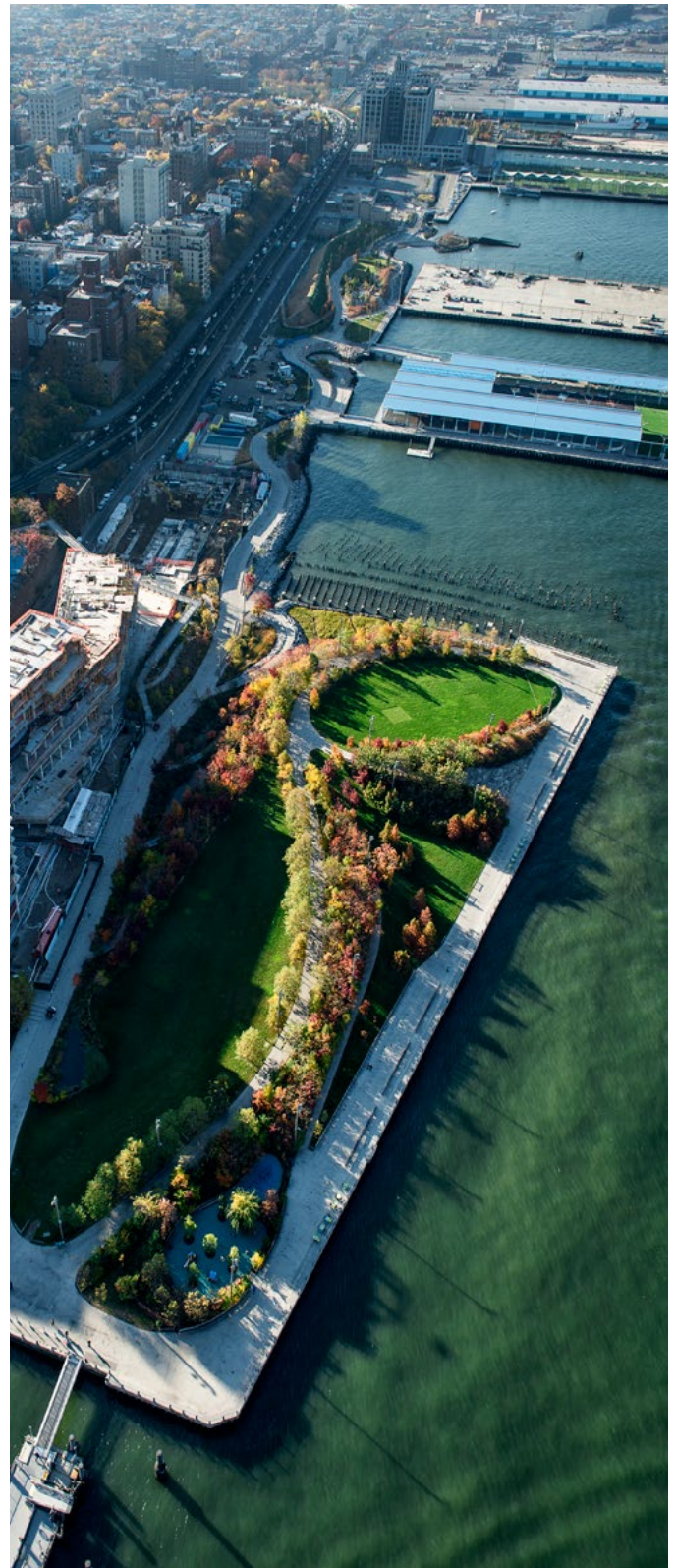
At HDR, our teams know that every flood risk management program is unique. We are knowledgeable in the methods and controls that can be used to minimize the damage and disruption to our communities from flood events. Flood risk management today requires a holistic approach that encompasses both the built and natural environments.

Through an approach that is relevant and responsible, we will work with you to understand the specific requirements of your situation based on an assessment of regional factors and our experience in solving challenging flood risk issues. We create an unshakable foundation for progress because HDR's teams include subject matter experts in geotechnical, structural, hydraulic and civil engineering. They are supported by risk specialists, consequence specialists, hydrologists, geologists, economists, meteorologists and public communication specialists.

HDR specialists are sought after for participation in consultant review boards, independent expert panel reviews, safety assurance reviews and value engineering studies. Our subject matter experts are fully capable of supporting risk cadres including facilitation, risk estimation or potential failure mode analysis. We are adept at using risk to inform the design of resilient flood infrastructure.

With our depth of expertise comes the power to help you craft bold and creative approaches that will address flood risk management, safety, cost and schedule performance. At HDR, we pull together our best minds in collaboration with our partners to uncover smart solutions to protect assets and prevent damage within your flood prone areas while responding to community needs.

Above all, we want to help you own your future, sustain your local economies, and protect your vibrant communities.



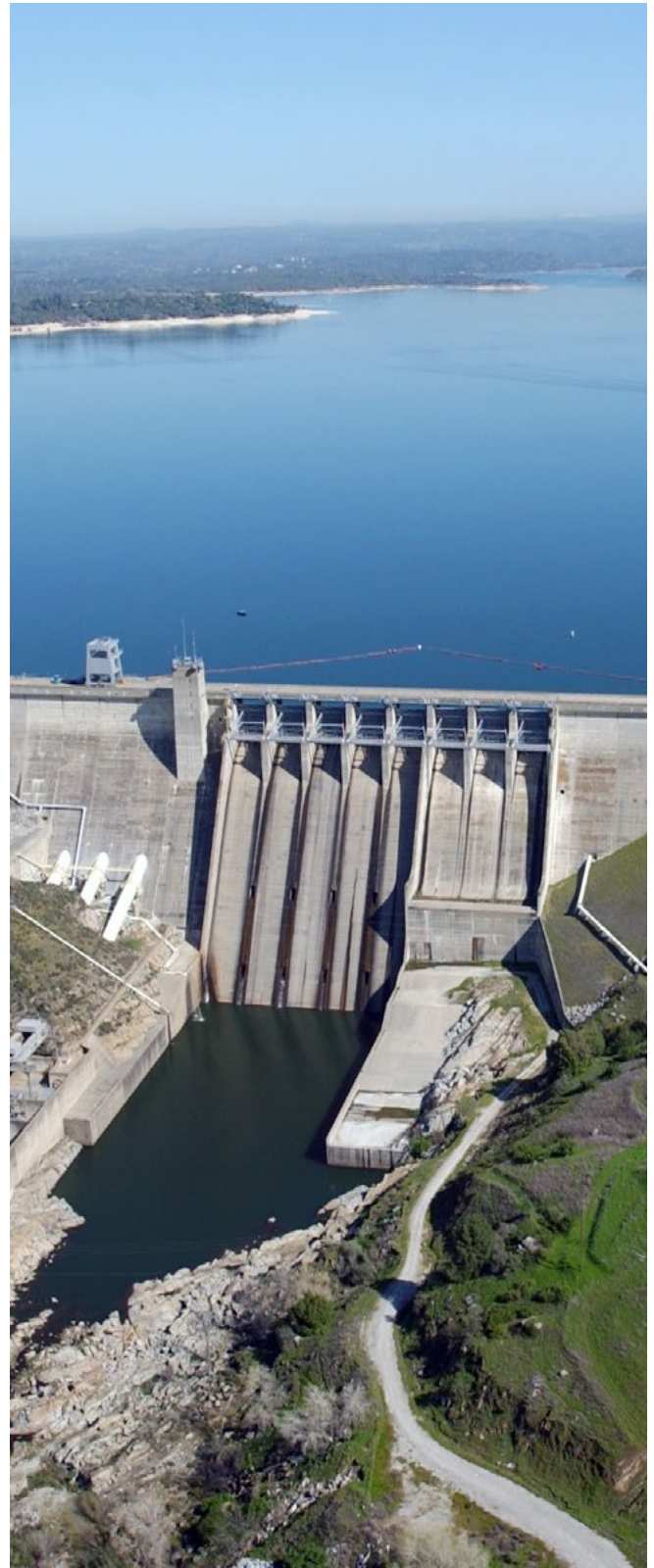


Knowing what to expect is the first step in helping your community understand their flood risk challenges.

The more people know about potential flood hazards, the more likely they are to make sound decisions. Effective flood risk management is hard to quantify, because success is perhaps best measured by things that don't happen. We have helped communities in virtually every type of geography and climate understand their specific flood risks. Each system reflects the unique characteristics of both the community and associated flooding threat. Our teams have worked on global disasters and flood recovery events including tsunamis, hurricanes, large floods, and coastal emergencies.

We use some of the most advanced geographic information systems (GIS) and employ highly-skilled GIS specialists to give you relevant and consistent data that is tailored to your needs. We can overlay features on digital maps or create three-dimensional (3D) views of project areas to enhance your understanding of the geographic features in your area. Our staff also use advanced modeling software to craft mitigation strategies that reduce the severity of flood damage.

We complement our mapping services with our economists and social scientists who develop defensible risk analyses to help you make sound decisions. Our risk analysis work has been used in projects large and small, such as providing significant support for the New Orleans Hurricane Storm Damage and Risk Reduction System.



Superstorm Sandy Recovery and Restoration

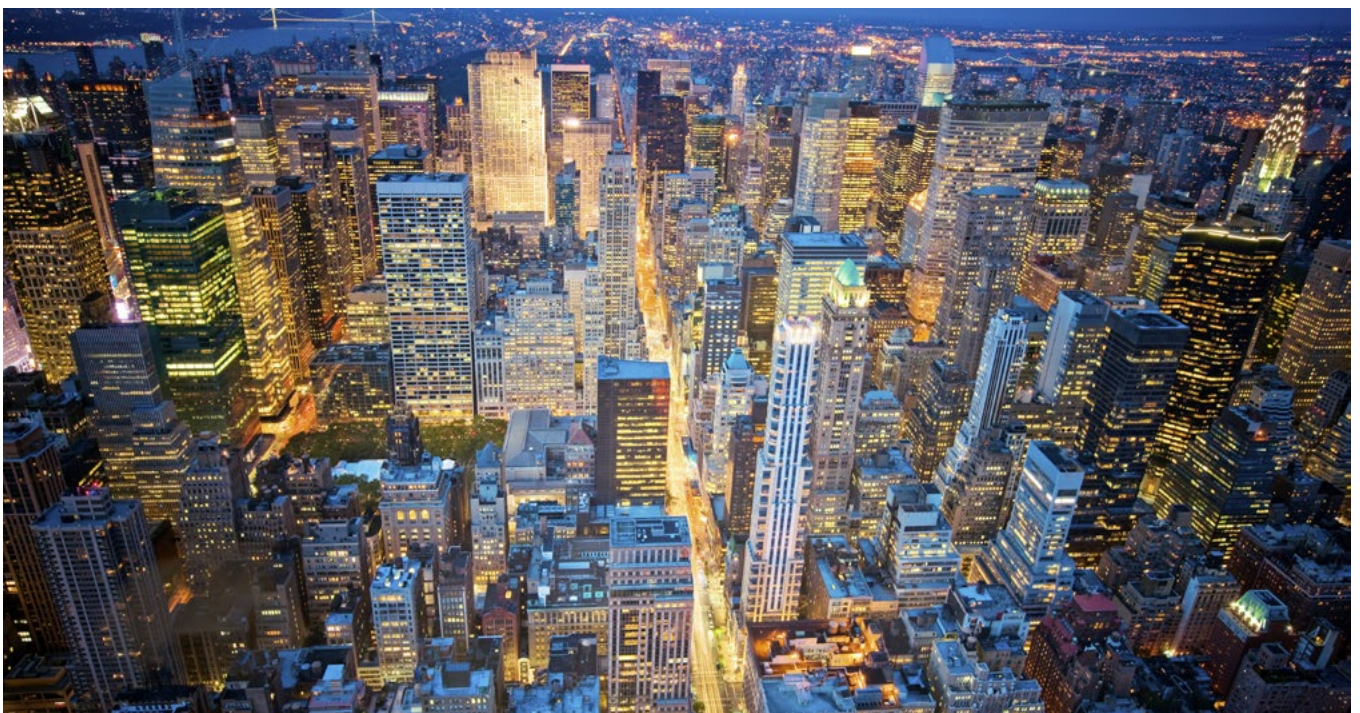
Superstorm Sandy devastated the New York and New Jersey area in late October 2012 and was the second-costliest hurricane in U.S. history. HDR supported our local clients in their recovery efforts to rebuild safer and stronger facilities and restore infrastructure to operational status quickly. We also shared our offices with clients who were displaced from their locations. A full nine-years later, HDR is continuing to support our clients in implementation of flood resilience efforts. A sampling of the completed post Sandy work includes:

Veterans Affairs Medical Center (VAMC) Flood Preparedness and Recovery

The VAMC suffered significant damage from Superstorm Sandy that dramatically reduced facility operations. HDR prepared a Flood Resiliency Study and developed a floodwall to protect from future storm events. Project elements consisted of a design to Federal Emergency Management Agency (FEMA) regulations, wave and wind analysis, establishing project design criteria for various loads including hydraulic, structural, and earthquake, and designating interior drainage systems to handle both sanitary and stormwater during the flood events. The project is now complete and functional.

NYCT 148th and 207th Street Rail Yards Flood Mitigation and Resiliency Strategies

HDR staff developed a conceptual design with alternatives for protecting two rail yards from another extreme weather event similar to Superstorm Sandy. We analyzed potential storm surge heights up to the maximum of a Category 2, including sea level rise and wave run-up. After determining the design height, we investigated different types of flood walls. Each was then evaluated based on constructibility, construction cost, and community and environmental impacts. At the portals to the underground railroad tunnels, a special material was investigated to craft a “flexgate”. It provides a system to protect the tunnel portal and minimize the effort of maintenance staff to implement prior to a storm. Because the railroad yard on 207th Street sits on piers in the Harlem River, the relieving platform and pile supports were severely damaged. The project has been constructed and is now protecting the NYC rail system.



Hurricane Harvey Recovery and Restoration

Many communities have been impacted by flooding and natural disasters in the Gulf Coast Region. Through Hurricanes Ike and Harvey, the Tax Day Flood, the Memorial Day Flood, and other extreme events, we have assisted our clients in assessment, recovery, mitigation, and construction of improvements to system resiliency. We have worked closely with staff, numerous public and private entities and have been successful in achieving their goals. Two Houston area projects are highlighted on the following pages.

Harris County Floodplain Remapping

Harris County, Texas, USA

Harris County, which includes the City of Houston, has suffered numerous catastrophic floods over the years. The public demands progress in flood risk communication and flood damage reduction. This demand was evident on 25 August 2018, when Harris County voters overwhelmingly passed a \$2.5 billion bond to fund rebuilding their community sustainably after Hurricane Harvey.

To build flood resilient homes and infrastructure, Harris County needed high-quality, detailed flood risk and hazard maps that are easily understood by the public and government officials. The maps will support decisions such as where to buy a home or the cost of flood insurance premiums. To provide this vital information, the Harris County Flood Control District and County leadership determined that updated Flood Insurance Rate Maps are needed for the County. They also worked with the Federal Emergency Management Agency to create guidance for the development of risk map products for Harris County's 22 major watersheds.

HDR was selected to provide professional engineering, project management, and quality control services to support the HCFCFD in delivering these important products. A highly qualified team of engineering firms and drainage professionals was assembled with HDR serving as the prime consultant.

Our team was responsible for floodplain modeling and mapping for selected watersheds. Hydraulic modeling involved linked 1D/2D HEC-RAS models, with hydrograph inputs developed using HEC-HMS. Multiple innovative approaches and techniques were utilized in this study, including rain-on-grid analyses aimed at identifying flood risks that traditional floodplain studies do not take into account. Floodplain mapping products include non-National Flood Insurance Program layers that contain information specific to Harris County and representative of the types of flooding experienced in this portion of the Gulf Coastal Plain.

The project is being completed in two phases. Phase I involved studies of 11 watersheds in the northern and western portions of Harris County. Phase II involved studies of the remaining 11 watersheds located in the southern and eastern portions of the county. The modeling and mapping will take approximately three years, with an additional one to two years allocated for developing and refining the new floodplain maps.





North Canal High Flow Diversion Channel Hazard Mitigation Grant Program

City of Houston, Texas, USA

The North Canal High Flow Diversion Channel Project is located in downtown Houston at the confluence of White Oak and Buffalo Bayous. The full project includes three primary components that would be constructed to reduce flooding adjacent to those locations, as well as upstream. These components are the North Canal channel diversion, South Canal channel diversion/detention, and bridge improvements/associated channel improvements at Yale Street and Heights Boulevard.

Construction of the diversion channels requires property acquisition and a railroad relocation. The North Canal diversion channel creates a high-flow diversion channel upstream of the confluence of White Oak and Buffalo Bayous, thus allowing stormwater runoff to divert around a natural meander in the bayous in downtown Houston. The South Canal component will be constructed in conjunction with the Texas Department of Transportation's I-45 realignment project. The South Canal component comprises a sloped gradient inline detention area adjacent to the existing Buffalo Bayou overflow bank, a portion of a 9.1 meter maintenance berm between the inline detention and secondary detention basin to be constructed by TxDOT, and pedestrian improvements that connect to the existing Buffalo Bayou Hike and Bike Trail.

The third component of the project includes upstream improvements to widen the openings for both the Yale Street and Heights Boulevard bridges. The proposed structure changes align with the downstream work of conveying water through the bayous. During construction of the bridges, channel improvements within White Oak Bayou will be completed in order to improve conveyance. In addition, an existing abandoned railroad bridge will be demolished to improve flow through the bayou.

The Project is being funded through the Federal Emergency Management Agency's Hazard Mitigation Grant Program (HMGP). The Texas Department of Emergency Management is the recipient of HMGP funding, and the City is the sub-recipient. The City is partnering with multiple state and county agencies to implement the project.



Additional Projects

The Haughton River Floodplain Upgrade Project

North Queensland, Australia

Floods are a fact of life in North Queensland, Australia. Community safety and connectivity during floods is paramount, and so is the upgrade to reliable, yet cost-effective infrastructure. The Haughton River Floodplain Upgrade Project improved flood resilience of a vital Bruce Highway link in North Queensland, midway between Ayr and Townsville, improving community safety with minimal disruptions, best value for money, and enhancing sustainable development goals for the region.

The key driver was a desire to achieve a substantial reduction in the frequency and duration of disruptive flooding closures of the Bruce Highway at Giru from multi-peak floods. Haughton River closures of the national highway cause debilitating disruption to locals, tourists, emergency services, transport operators and other motorists; and effectively cuts off the North and Far North Queensland road transport system. Existing bridges

and culverts over the waterways within the project area currently have a flood immunity of less than 63.2% Annual Exceedance Probability (AEP) or more than 1 exceedance per year. On average, this section of highway is closed for over 6.5 days per year due to flooding.

Arup and HDR Joint Venture (AHJV) delivered the designs for the Haughton River Floodplain Upgrade project with construction time and cost savings, whilst reducing impact upon the environment and meeting the flooding challenge of this 13.5 km complex floodplain. The design solutions introduced replacement of a series of substandard crossings to effectively remove the flood vulnerability of the Bruce Highway across the Haughton River floodplain. Once the project is complete, the severity and frequency of closures will be greatly reduced, from an annual average submergence of 160 hours to just one hour – a massive improvement.



Ho Chi Minh City Master Plan Resiliency Study

Ho Chi Minh City, Vietnam

Vietnam is rapidly urbanizing with an urban population growth rate of almost 3% in 2018. Nearly 38% of its population currently lives in urban areas; by 2050, this number will rise to 57%. Vietnam's location makes it especially vulnerable to typhoons, floods and drought. With climate change, the frequency and intensity of these weather-related events will intensify. Its coastal cities and low-lying areas are most vulnerable as they accommodate a high concentration of the population. The rate of urbanization in Vietnam is expected to exacerbate the economic costs related to such weather events. Rising air and water pollution, inadequate solid waste management and wastewater treatment, urban sprawl, and loss of green space threatening urban livability are some of the outcomes of urbanization.

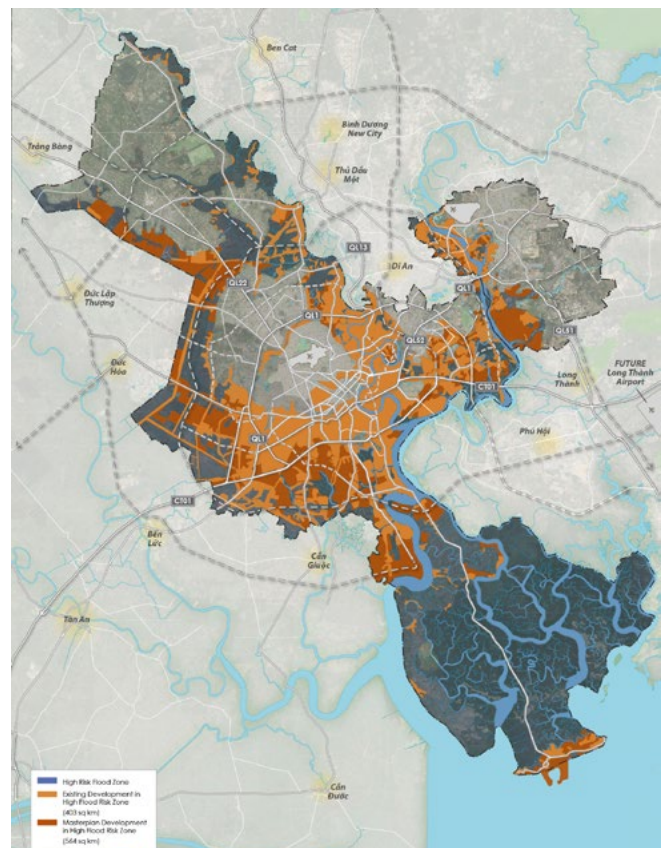
It is evident that the country is at a critical point in its urbanization process. Consideration of sustainability and resilience as a core part of urban development, namely "sustainable urbanization", is vital if Vietnam is to meet its Nationally Determined Contributions, Sustainable Development Goals and reap the benefit of its urbanization process.

HDR is conducting a study on behalf of the World Bank to develop a master plan to enhance climate smart urbanization, integrate flood resilience and low carbon growth options in urban planning to steer sustainable development and policy in Vietnam. With Ho Chi Minh City in the process of updating its Master Plan, this study will also inform its climate smart urban strategies.

The study is an innovative and important step toward coordinating urban growth, land use and transportation with climate resiliency and sustainability strategies in Vietnam. The historic transformation from a predominantly rural to an urban pattern is having significant implications for the organization of society, economy and the environment. Urban growth patterns have a lasting effect on resource consumption, environmental quality, carbon emissions and ultimately our climate, as is evident in Vietnam's sprawling cities.

Ho Chi Minh City is facing significant growth challenges from urban migration and has become a matrix for flood risk, traffic crisis, economic segregation, and environmental pollution. Though unique in scale, population, and economic wealth as is evident in its current and planned infrastructure investments, the challenge of growing sustainably in the face of climate change and sea level rise is staggering.

The study integrates riverine, coastal and urban flood planning with growth strategies that foster low carbon emissions and a more resilient urbanization pattern.



Cedar Rapids Flood Control System

City of Cedar Rapids, Iowa, USA

The City of Cedar Rapids, Iowa experienced record-setting catastrophic flooding on 13 June 2008. The Cedar River crested to its highest level in Cedar Rapids history at 9.5 meters, which was more than 3.35 meters higher than the previous record. It was the sixth largest FEMA emergency declaration in U.S. history. This historic inundation was caused by a flood that was estimated to have exceeded the 800-year event.

Since 2014, HDR has worked with the City of Cedar Rapids in coordination with the US Army Corps of Engineers (Rock Island District and St. Paul District), and along with partners Stanley Consultants and Anderson-Bogert, to provide the City with a comprehensive and certified flood risk reduction system. This new system, slated to be complete in 2024, will provide flood protection equivalent to the 2008 flood level along approximately 6.5 kilometers of riverbank, on the east and west sides of the river (for a total system length of nearly 13 kilometers). HDR's work on this system, along with our partners, has included providing planning and design services for the portion of the system on east bank of the Cedar River, from north of Cedar Lake to the Otis Road Cargill plant. Designs on the east side have been

completed by USACE Rock Island District, Stanley, HDR, CDG Engineers, and Bergmann. In full cooperation with the City, the Corps of Engineers, and project partners, HDR has been executing a successful flood risk management plan built around a strong public process component, and a vision for public spaces and amenities, urban planning, and economic development. Throughout planning and design, we have collaborated with Cedar Rapids to balance functionality for flood risk mitigation with long-term public use and economic growth benefits.



Oroville Dam Emergency Response

Butte County, California, USA

On 7 February 2017, the California Department of Water Resources (DWR) had a failure at its main spillway at Oroville Dam. At 235 meters high, Oroville Dam is the tallest dam in the United States and serves mainly for water supply (431 ha-m of water), hydroelectricity generation and flood control.

In just over three days, HDR mobilized 50 staff working around the clock, seven days a week to support the DWR mission at the dam. Our role focused on monitoring and reporting various elements of the Oroville Dam Spillway Emergency Response project as an extension of DWR's Dam Safety Branch, reporting up to them and the Incident Command structure.

The primary objective of our monitoring activities was to provide data and information regarding the condition of the spillway structures and erosion areas as input for emergency response decision-making by DWR. During the monitoring effort, we managed staffing, scheduling, resourcing, and safety for 150 staff, including 26 rotating positions (52 staff per day). Our staff included engineers, construction experts, and safety advisors who covered all aspects of geology, geotechnical, structural, civil and scour elements.

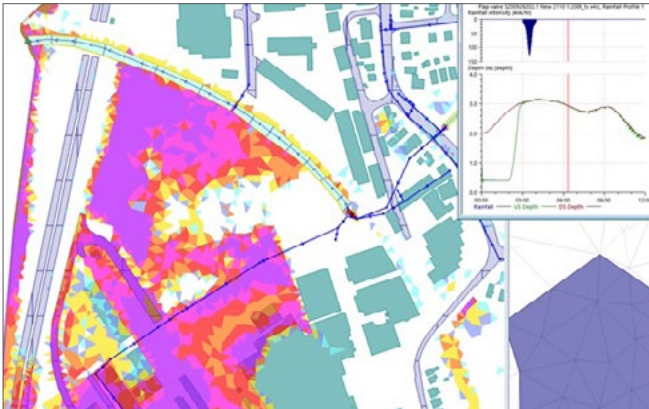
Subsequent to this effort, HDR facilitated a Congressionally-mandated independent risk assessment of the repaired spillways, including preparation of hydrologic hazard and consequence assessments. We also assembled a team of experts to provide a needs assessment to DWR on how to mitigate the risk at Oroville Dam Complex.



Flood Resiliency Project

United Kingdom

HDR has a detailed understanding of a developer's commercial priorities to resolve environmental constraints including those posed by flood risk. Our team have extensive experience in producing site specific flood risk assessment and flood mitigation measures necessary to negotiate with relevant authorities to enable previously restricted sites to be reclassified as suitable for development.



Our engineers understand the need to produce pragmatic and commercial viable yet environmentally and sustainably sensitive solutions to enable not only authority approval to proceed but also to assist in ensuring that the developers returns remain reasonable.

An example of a specific recently delivered development in the United Kingdom - located at an area of historical mudflats previously reclaimed by dumping inert waste. The site was at low elevation and at risk of pluvial flooding due to tidal levels and significant runoff from the catchment of an adjacent large town centre. The proposed solution provided a combination of ground improvement works (including a 500mm piling mat) to raise the site above flood level/tide level, and also allowing surface water to discharge via gravity during high tide therefore minimising on site attenuation requirements.

Central Valley Flood Protection Plan

Sacramento and San Joaquin River Valleys, California, USA

According to the California Department of Water Resources (DWR), more than 1 million Californians live and work in the floodplains of the Sacramento and San Joaquin River Valleys (the Central Valley). The Central Valley Flood Protection Plan is a comprehensive flood management planning effort that addresses flood risks in an integrated manner while concurrently improving ecosystem functions, operations and maintenance practices, and institutional support for flood management. The area is protected by more than 70 flood control reservoirs and an extensive network of rivers, bypasses, canals, and levees.



As part of the plan, we:

- Developed hydrologic inputs for hydraulic models, including hydrology that reflects current and future conditions with consideration of climate change
- Developed HEC-ResSim reservoir operation models to analyze alternative storage scenarios, also in consideration of climate change
- Assisted with modification, review, and execution of system-wide HEC-RAS hydraulic models to determine channel and floodplain stages
- Developed HEC-LifeSim consequence models to quantify the life safety risk considering the impact of evacuation timing in the event of a levee breach
- Developed HEC-FDA models to assess changes in flood risk associated with structural and non-structural alternatives. In consideration of both economic and life risk.

Our input and findings assisted DWR in developing a Statewide investment approach.

Meet Our Experts

Our multidisciplinary teams are custom-fit to each project, taking it from small detail to great achievement, and building strong relationships along the way.

Together, we will work with you to minimize flood impacts through appropriate design, planning and analysis. Our staff's broad skill sets ensure careful and comprehensive consideration of technical, social, economic, and environmental aspects of every project we undertake. You can rest assured that we will provide relevant and responsible solutions—you can count on us for sustainable planning and design of flood mitigation infrastructure. Contact our team of experts to discuss your flood risk management needs.



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Our Story

We specialize in engineering, architecture, environmental and construction services. While we are most well-known for adding beauty and structure to communities through high-performance buildings and smart infrastructure, we provide much more than that. We create an unshakable foundation for progress because our multidisciplinary teams also include scientists, economists, builders, analysts and artists.

Our employees, working in more than 200 locations around the world, push open the doors to what's possible each and every day.

Our areas of expertise	Civic & Culture Arts Sports & Recreation	Industrial Food & Beverage Mining Oil & Gas	Transportation Aviation Freight Rail Highways & Roads Ports & Maritime Transit
	Defense & Intelligence Civilian Agencies Installations Mission Critical & Security	Justice	Urban & Community Development Community Design Mixed-Use & Retail Parks, Plazas & Streetscapes Transit Oriented Development Urban Redevelopment
	Education Higher Education K-12 Schools	Power & Energy Hydropower Power Generation Renewable Energy Transmission & Distribution	Waste Hazardous Waste & Remediation Solid Waste
	Finance	Science Containment Interdisciplinary Life Sciences Physical Sciences Public Health Vivaria	Water Conveyance Drinking Water Fisheries Wastewater Water Resource Management
	Health Acute Care Ambulatory Care Behavioural & Mental Health Translational Health Sciences	Tech/Media/Telecom & Data Data Centres Microelectronic & Nanotechnology	Workplace
	Hospitality		

We celebrate these achievements

#2 Top Architecture/Engineering Firms
Building Design+Construction, Giants 300

#4 Top 100 Global Design Firms
*Building Design Magazine's
"World Architecture Survey"*

#6 Top 500 Design Firms
Engineering News-Record

#10 Largest Employee-Owned Companies
*National Center for Employee Ownership
(S-CORP)*

100+ years

We've partnered with our clients to push boundaries and shape communities.

10,000+

Professionals in more than 225 offices around the world.

50 States and 60 Countries
Completed projects



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We practice increased use of sustainable materials and reduction of material use.

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