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Industrial Resiliency Case Studies

New York City's industrial floodplain contains a wide range of businesses, all with unique resiliency challenges and opportunities. The following case studies are based on seven industrial businesses in the city's floodplain, most of which were damaged by Hurricane Sandy. They explore physical and operational strategies that could help reduce damage from future floods. Some case studies demonstrate best practices that have been implemented, while other case studies describe strategies that could be pursued in the future. Although each case study highlights different best practices, many of these resiliency strategies could be used more universally, and may apply across multiple different scenarios. Where strategies have fairly uniform costs across site, cost estimates are included to help businesses evaluate the tradeoffs between mitigation strategies. Ultimately, each business should consider its own physical investments, core business operations, and the risk posed by flooding and other hazards to prioritize the preparedness and mitigation actions that are most suitable to its facility.

Construction Materials Distributor

Site Characteristics

Lot size	Approximately 87,000 square feet
Shoreline length	650 feet
Shoreline conditions	Degraded bulkhead
Design Flood Elevation above grade	2-5 feet

Business Profile

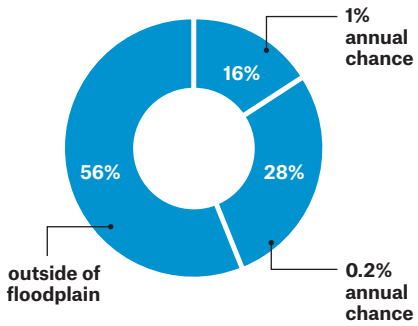
The construction industry is an important component of New York City's economy, accounting for more than 2,400 businesses and approximately 45,000 jobs, according to the Quarterly Census of Employment and Wages (2014). Employment in construction-related companies grew by almost 7 percent between 2010 and 2014 within the city's Manufacturing Districts, as defined though zoning. A healthy construction industry is vital for the maintenance of existing buildings within the city and to support new growth. Additionally, the construction industry serves an important role by allowing the city to more quickly recover from large-scale flooding and coastal storms.

A construction materials distributor was chosen as a case study to explore flood resiliency measures appropriate for large sites with unenclosed storage space. The company selected as a case study employs approximately 70 employees and operates on a site that is approximately two acres, with nearly 650 linear feet fronting the shoreline. The entire site is located within the 1% annual chance floodplain with a Design Flood Elevation ranging from two to five feet above grade. A range of buildings are located on the site, including corrugated metal warehouses, large sheds, and shipping containers used as permanent storage. In addition, lumber and other construction supplies are stacked on open-air shelving across much of the site.

Flood Risk Profile

An estimated 16 percent of businesses in the building material and supply sector in NYC are located in the 1% annual chance floodplain, and 44 percent are located within the 0.2% annual chance floodplain.

Flood risk among NYC's construction materials distributors



Construction materials distribution sites often contain a mix of unenclosed storage, enclosed warehouses, and office space. Unless properly secured, openly stored materials on these sites can become waterborne during flooding or are subject to wind damage during coastal storms, resulting in the loss of inventory and the potential for public health hazards, navigational hazards, and pollution of the city's waterways.

During Hurricane Sandy, one of the buildings on the case study site was damaged by floodwaters. More significantly, inundation of the site combined with poor soil conditions resulted in cavitation and collapse of the ground in several locations on the property. The poor condition of the bulkhead on the site contributed to this

Employment in construction-related industries grew by almost 7 percent between 2010 and 2014 within the city's Manufacturing Districts.

problem by allowing water to saturate the soil and undermine the structure above. The foundation of one building was substantially undermined, requiring a costly repair (exceeding $10,000), comprised of filling the ground with concrete to stabilize the structure.

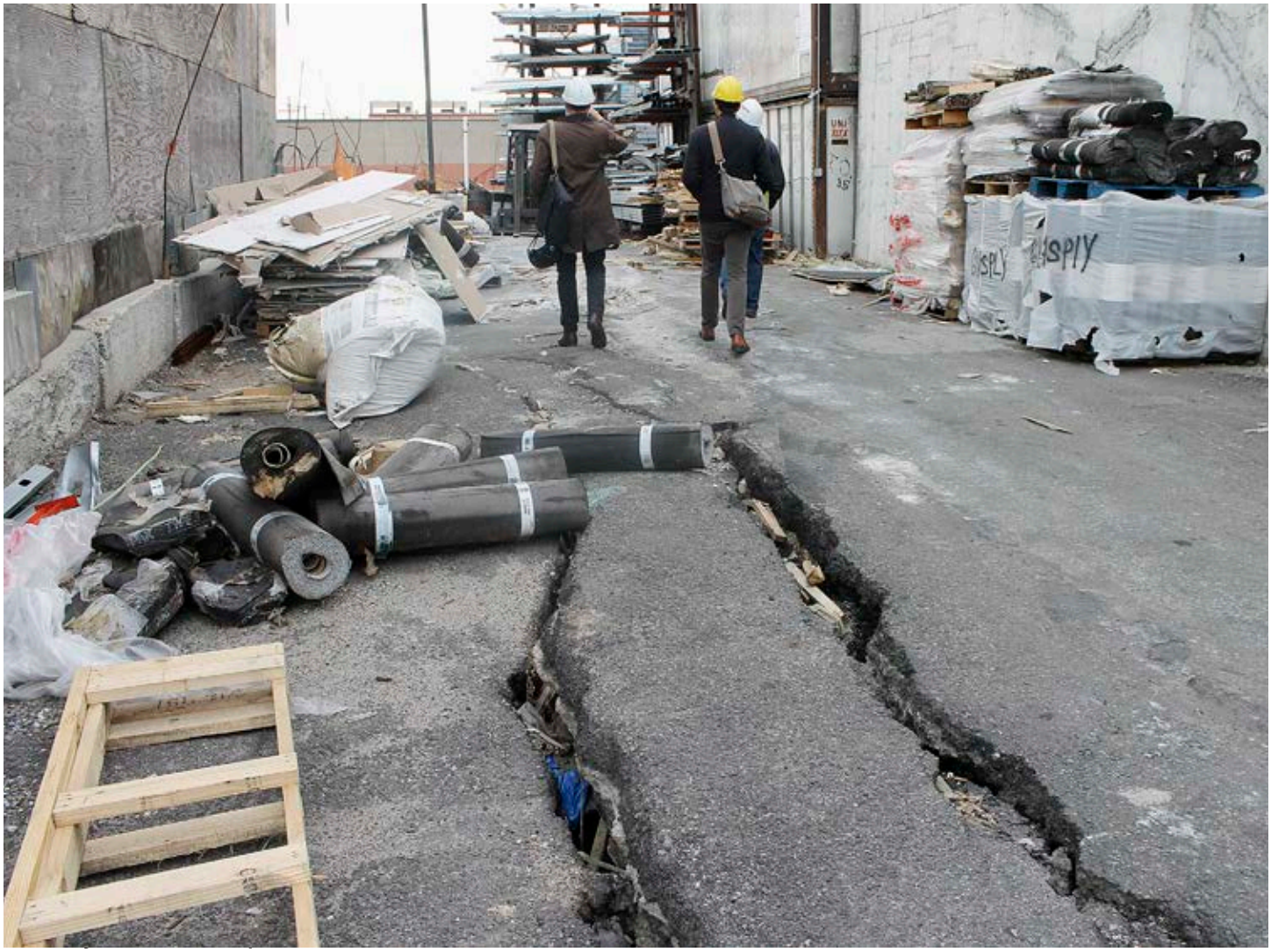
In advance of the storm, electrical equipment was connected to a backup power generator. However, because the generator was not elevated above the flood level, it was inundated and destroyed by floodwaters.

The construction materials distributor also experienced impacts from Hurricane Sandy due to disruptions beyond its site. A nearby drawbridge that was damaged during the storm caused significant delivery delays, often up to an hour. These delays, which persisted for several months following Hurricane Sandy, affected the ability of employees and customers to access the site.

Despite these various impacts to the business resulting from Hurricane Sandy, the business was able to resume operations the following day. Due to the need for construction materials as residents and businesses began the process of repairing and rebuilding across the city, the business was able to provide an important service in the wake of the storm, underscoring the extent to which the construction industry is important for the resiliency of the city as a whole.

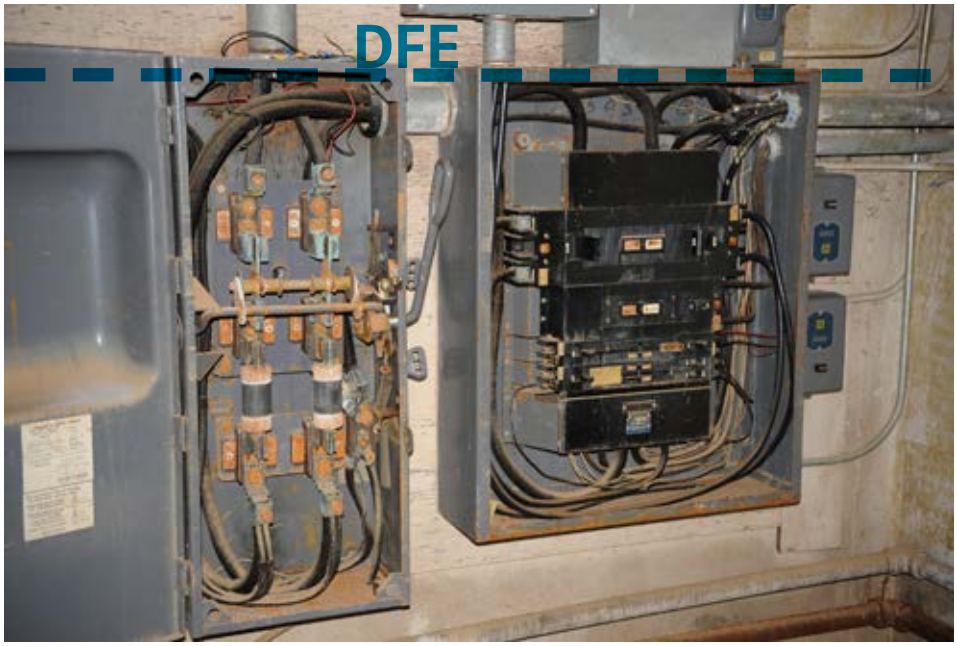
Challenges and Resiliency Measures

Construction materials distribution businesses, and many open industrial uses generally, have common characteristics that affect their exposure and vulnerability to flooding. The following resiliency challenges and best practices highlight a few strategies that similar businesses may pursue to manage the risk of flooding and coastal storms.



RESILIENCY CHALLENGE

Electrical and mechanical equipment below the DFE:
Floodwaters can cause significant damage to electrical and mechanical equipment, disrupting operations and leaving businesses prone to substantial repair or replacement costs. Construction and woodworking machinery, such as lathes and table saws, are particularly sensitive to flooding, especially by saltwater, which hastens corrosion.

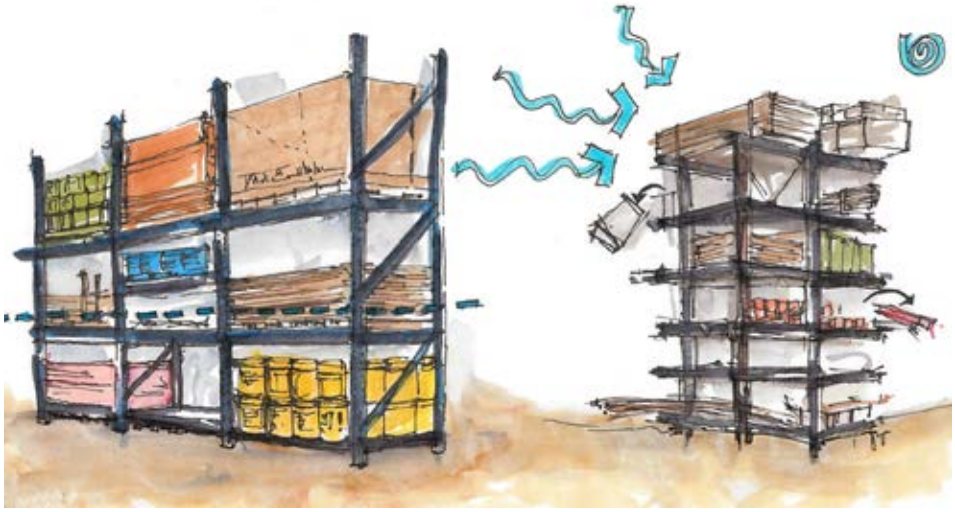


RESILIENCY MEASURE

Elevate electrical and mechanical equipment:
Elevating equipment above the DFE can reduce the likelihood of exposure and damage due to flooding. For machinery that could reasonably be temporarily relocated in advance of a storm, a facility preparedness plan should be developed that describes steps that should be taken, who is responsible, and the necessary timing to safely move equipment to higher locations on- or off-site.

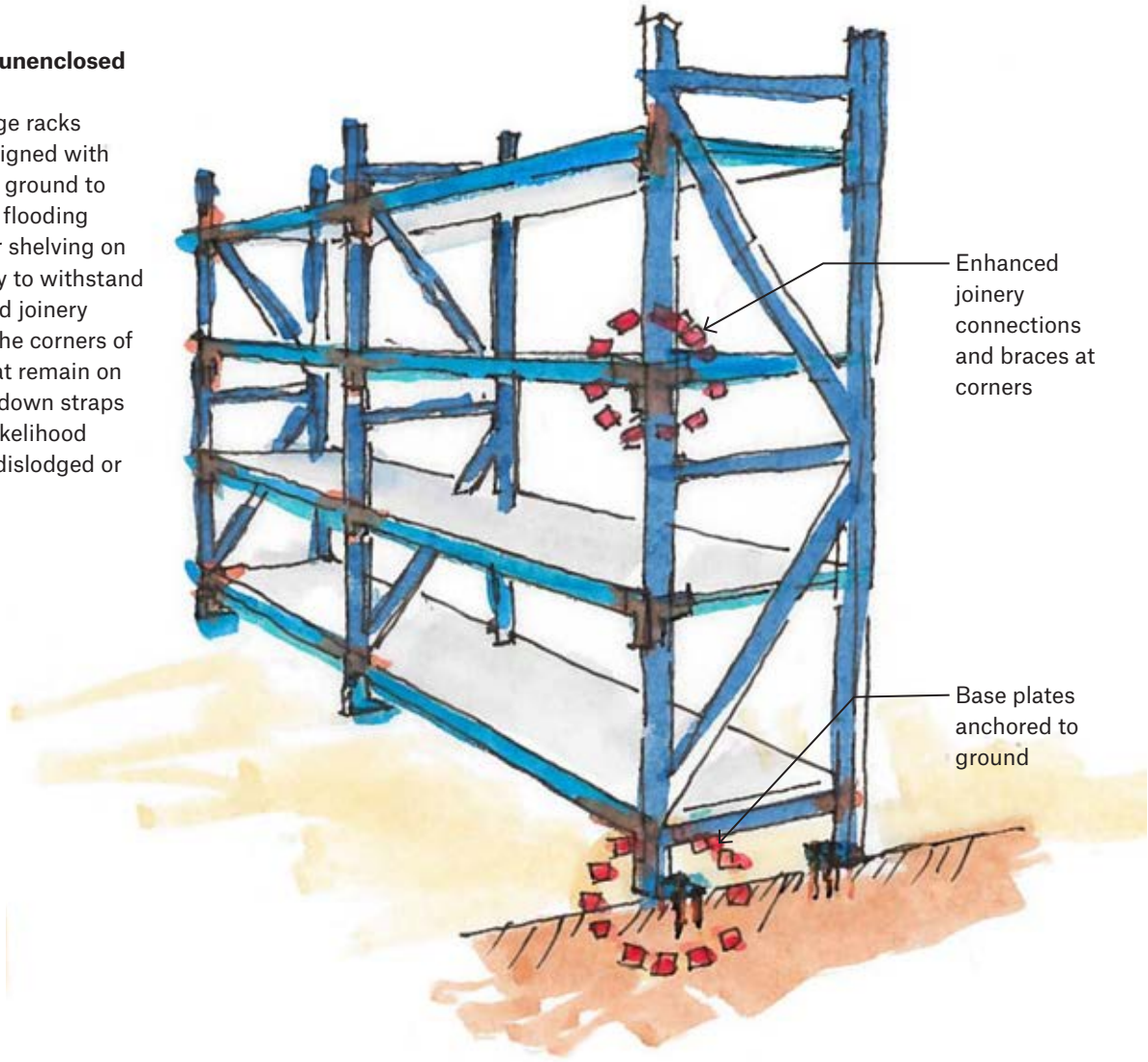
RESILIENCY CHALLENGE

Open uses and uncovered inventory exposed to wind and flooding:
If stored improperly, unenclosed construction materials may be dislodged by wind, flooding, or storm surge. In addition to damaged or destroyed inventory, the potential exists for materials such as wood, rebar, paint, and other heavy items to become debris and cause further damage on the site or on neighboring properties. Importantly, business contents stored outside of buildings are not eligible to be covered by content insurance through the NFIP, making it especially important to reduce the potential for damage to inventory stored outside.



RESILIENCY MEASURE

Properly anchor to secure unenclosed storage:
Outdoor shelving and storage racks should be appropriately designed with base plates anchored to the ground to mitigate damage from both flooding and wind. Similarly, outdoor shelving on industrial sites is more likely to withstand wind damage with enhanced joinery connections and braces at the corners of each shelf. For materials that remain on shelving during storms, tie-down straps can be used to reduce the likelihood that materials will become dislodged or airborne.



RESILIENCY CHALLENGE

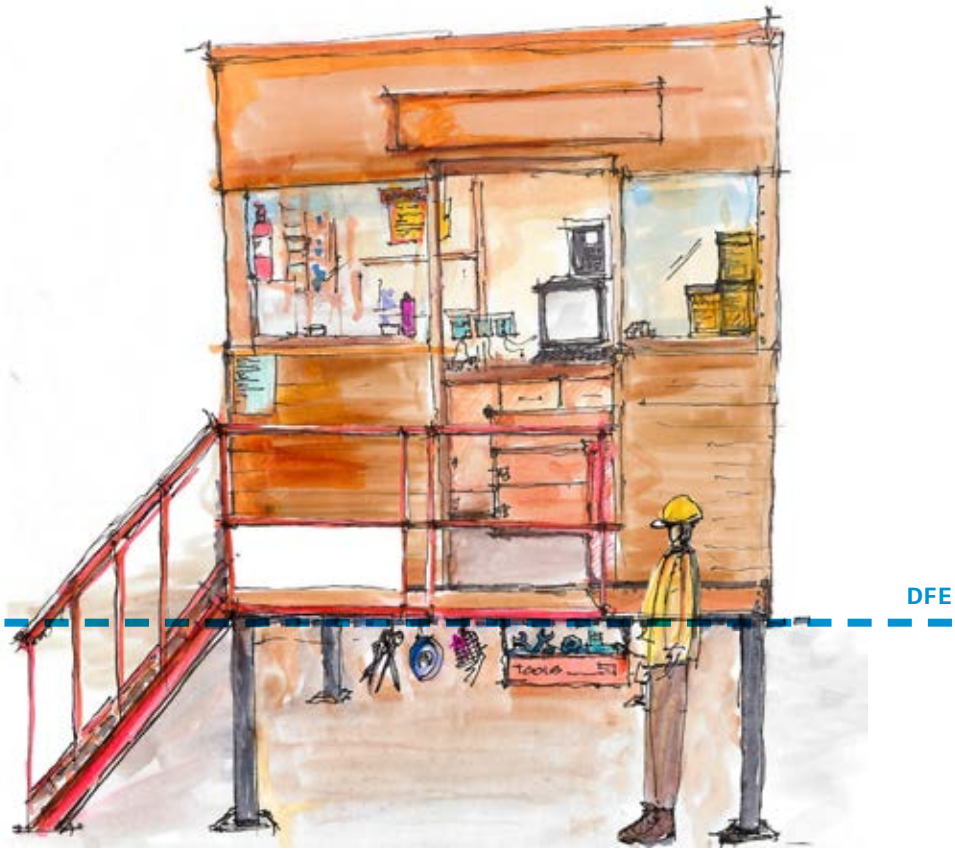
Work stations and ancillary structures not designed to withstand flooding:

Unenclosed work stations and other small structures that tend to be dispersed across larger industrial sites are particularly susceptible to damage during flooding, as these are often constructed with lightweight building materials. Without reinforcements and anchors, these structures may not be able to withstand lateral pressure from flooding and are more likely to be displaced and destroyed. Given their function in maintaining normal business operations, unprotected work stations and ancillary structures may hinder the ability for businesses to recover quickly from flooding.

RESILIENCY MEASURE

Elevate structures in yard:

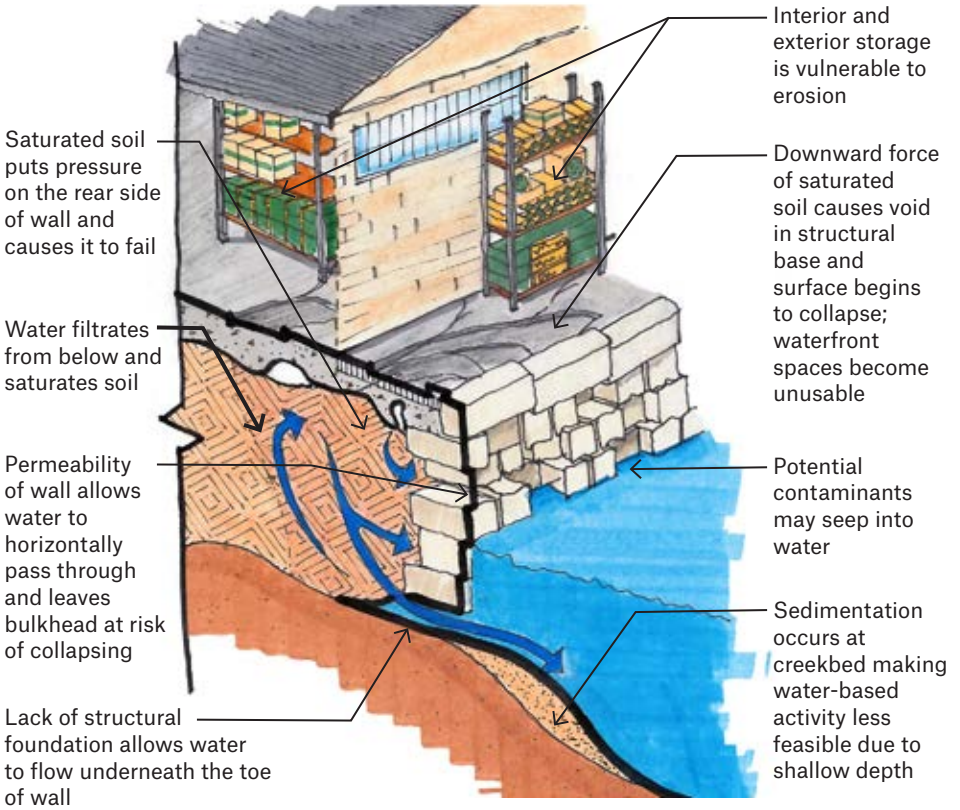
Elevating work stations and structures above flood levels can reduce the risk of flood damage and help businesses restore operations more quickly. Components of structures below the DFE should use flood resistant construction materials.



RESILIENCY CHALLENGE

Poor bulkhead conditions:

Bulkheads serve a number of functions on industrial properties along the water, including retaining land and resisting erosion in order to stabilize a site. In some cases bulkheads also provide access to vessels. In the event of a coastal storm, storm surge may overtop bulkheads, which can lead to structural failure when the soil behind the bulkhead becomes saturated and water levels recede, creating pressure between the soil water and sea water. If a bulkhead is in poor condition, the ground landward of the bulkhead may be unstable and prone to future erosion and loss of usable space.

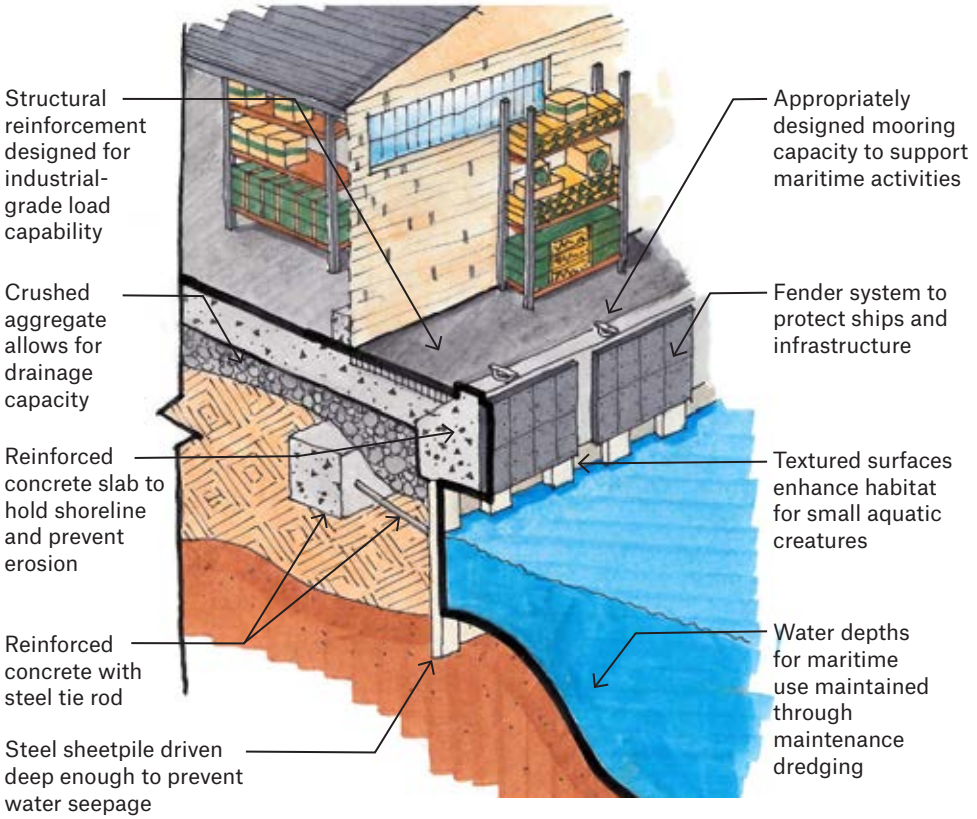


RESILIENCY MEASURE

Bulkhead repair:

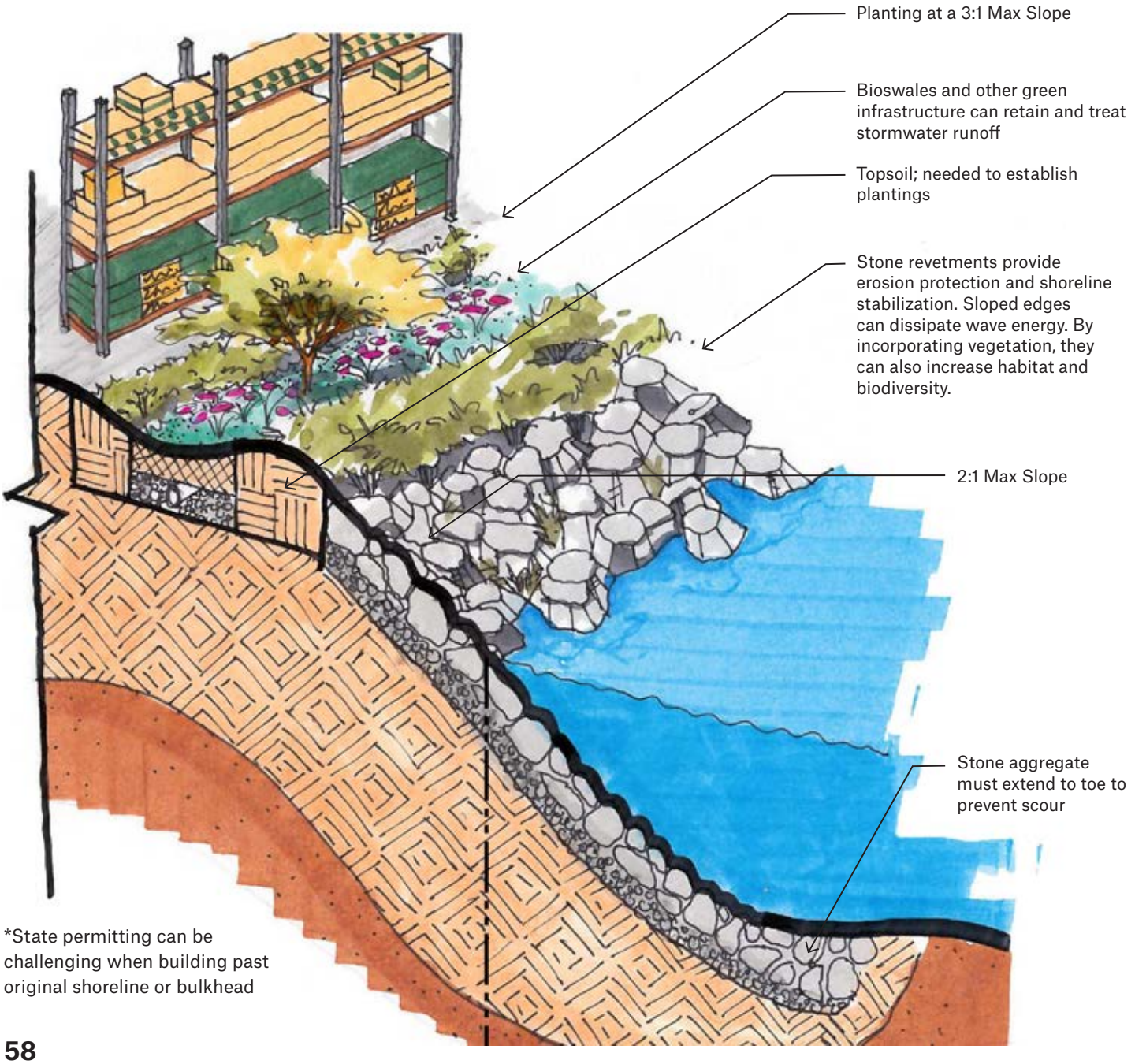
Structurally repairing bulkheads that are in poor condition or constructing new bulkheads provide for better grade load capacity, drainage capacity, and help protect against soil erosion and water seepage. In New York City, the construction of new bulkheads, or replacement and repair of existing structures, often requires permits from multiple entities, including the NYS Department of Environmental Conservation and the U.S. Army Corps of Engineers. Businesses should consult the **Waterfront Navigator: NYC's One Stop Waterfront Permit Planner** for additional information.

APPROXIMATE COST*
~$2,500 per linear foot
**See cost estimation on pg. 110 for more info*



Revetment:
Revetments are a lower cost alternative to bulkheads and provide similar protection against water filtration and soil erosion. Revetments help mitigate wave action and provide erosion protection on steeper slopes. An array of materials can be used to construct revetments, including stone or concrete blocks. Revetments can also be designed to include shoreline vegetation to help filter stormwater and improve water quality, reduce erosion, enhance habitat, and improve the aesthetic nature of the shoreline. The sloped design and rough surface of most revetments have a lesser erosion and scour impact on adjacent sites as compared to completely vertical structures such as bulkheads and seawalls. For industrial facilities that currently use their shoreline for maritime access, at least a portion of the shoreline would likely need to remain a bulkhead with water depth sufficient for barges and ships.

APPROXIMATE COST*
~$500 per linear foot
**See cost estimation on pg. 110 for more info*



*State permitting can be challenging when building past original shoreline or bulkhead

Brewery

Site Characteristics

Lot size	8,200 square feet
Building floor area	8,000 square feet
Year built	1931
Design Flood Elevation (DFE) above grade	5-7 feet

Business Profile

Food and beverage manufacturing are growing industries in New York City, and the number of breweries in particular has increased significantly in recent years. A brewery was selected to explore flood resiliency measures within this growing sector and to better understand resiliency strategies suitable for industrial sites in moderately-sized manufacturing buildings that share walls with neighboring facilities, a particularly common condition in the city's older industrial areas.

The brewery selected as a prototypical site occupied an 8,000 square foot, masonry building that was constructed in 1931. A small rear patio is used for additional seating during the warmer months and a side alley is used for loading. The company employs more than 20 full-time staff and sells approximately 8,000 barrels of beer annually. The building has a large, open area for storage and fermentation, processing, and bottling, with direct access to the loading dock for delivery. The building also contains a small tasting room with indoor seating and an office located on the second floor above the tasting room.

Flood Risk Profile

The entire brewery building is located within the 1% annual chance floodplain with a DFE of five to seven feet above grade. Despite the potential for significant flooding at this location, the company was not aware of damage to the building that occurred during Hurricane Sandy, which occurred before it occupied the space. However, the company did experience minor flooding of a few inches due to a heavy rainfall event in the winter of 2016 and is interested in taking steps to mitigate future flooding.

After moving into the space, the brewery installed a new drainage system and updated much of the building's electric and water infrastructure. The company has also invested in several large, stainless steel brewing tanks, canning lines, and other valuable equipment. Tanks are bolted into the ground and are generally undamaged by water. However, the brewing equipment does include some electrical equipment, pumps, valves, and other components that are more sensitive to the effect of water. The company also retains large inventories of raw materials and ingredients, notably barley, malt, hops, and yeast.

The brewery has a blanket insurance policy through a company that offers an insurance product specifically tailored to microbreweries, which bundles insurance coverage for risks commonly faced by businesses within a certain industry, such as product spoilage in the case of a brewery. These specialized policies are called Business Owners Policies or BOPs. This brewery's insurance policy includes flood insurance, and the insurance company requires that all policy-holders are insured-to-value.

The insurance company also conducts loss control visits intended to promote actions that minimize risk, which can compel businesses to make physical modifications to their space or embrace operational improvements such as emergency preparedness trainings.

Operational Resiliency

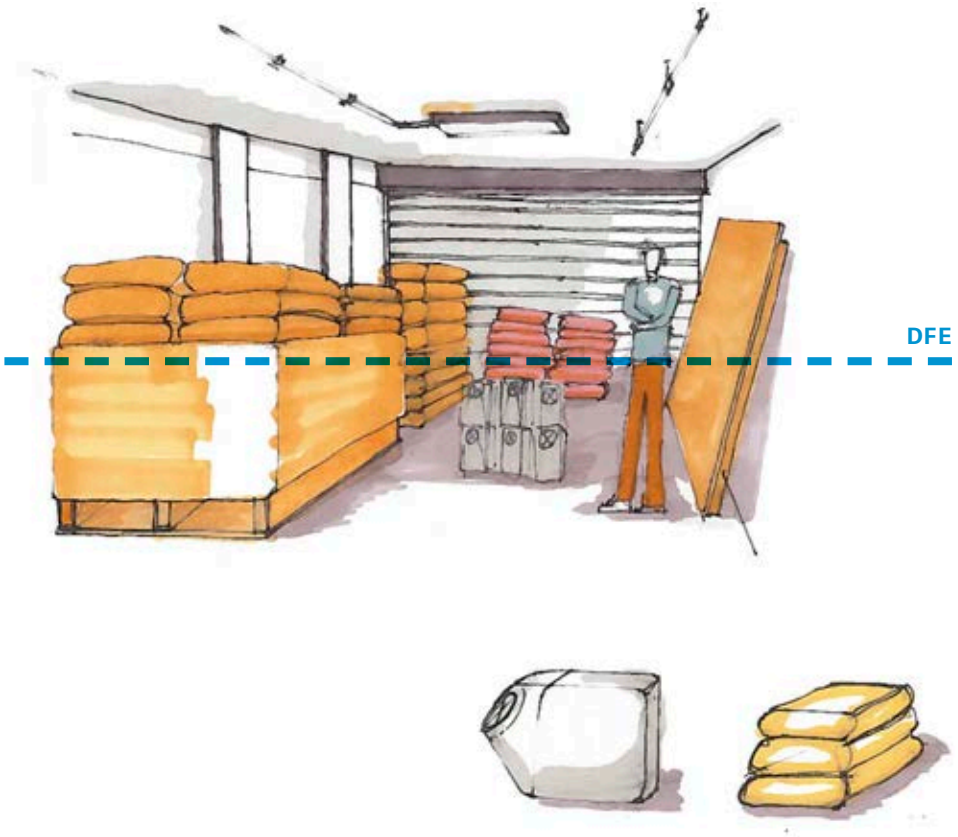
Some craft breweries establish partnerships with contract brewers, companies that have equipment to reproduce beer recipes in a different location. This is typically done to help meet demand, especially if there are surges because of popular seasonal beers, or to ensure that beer supplies remain steady if there are disruptions to supply, such as a spoiled batch or equipment malfunctions. Even if demand can typically be met with in-house brewing, working with contract brewers can be a valuable form of continuity of operations planning and can serve a dual purpose to provide resiliency to flooding and other hazards. Similarly, for other companies that produce or manufacture food or beverages, especially those that operate on a smaller scale, developing relationships with external kitchens or spaces that may be usable to maintain supply during a disruption can help reduce costs associated with lost operation and revenue.

Challenges and Resiliency Measures

Breweries and other food and beverage manufacturers have common characteristics that affect their vulnerability to flooding. The following examples demonstrate strategies to minimize damage from flooding that may apply to a range of similar industrial businesses in New York City.

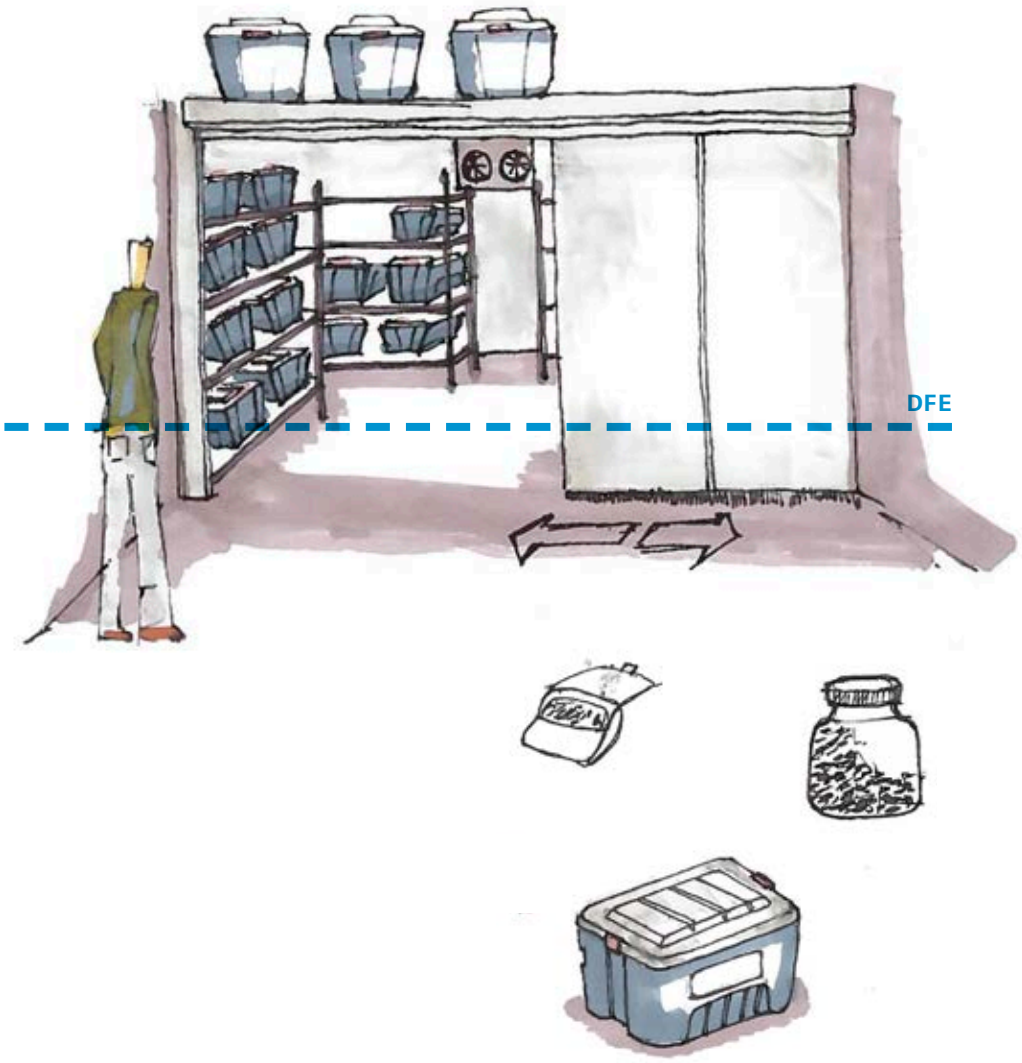
RESILIENCY CHALLENGE

Ingredients stored below the DFE may be spoiled by flooding:
When raw ingredients and perishable goods, such as barley, malt, yeast, and hops, are stored below the DFE they are likely to be compromised during floods. Many breweries store their inventory in cardboard containers on wooden pallets or on shelving. In addition to the potential cost to replace damaged inventory, the time necessary to order and replace damaged inventory may prolong the recovery time and result in a significant loss of revenue.



RESILIENCY MEASURES

Store ingredients in waterproof containers and move above the DFE:
Storing raw ingredients and other perishable goods in waterproof containers can reduce the risk of flood damage, helping businesses to reduce the cost of replacing inventory and minimizing recovery times. Businesses with limited space for storage above the DFE should prioritize storage locations. Valuable or highly perishable inventory should be stored at higher locations, while ingredients that are easier or inexpensive to replace may be stored at lower elevations.



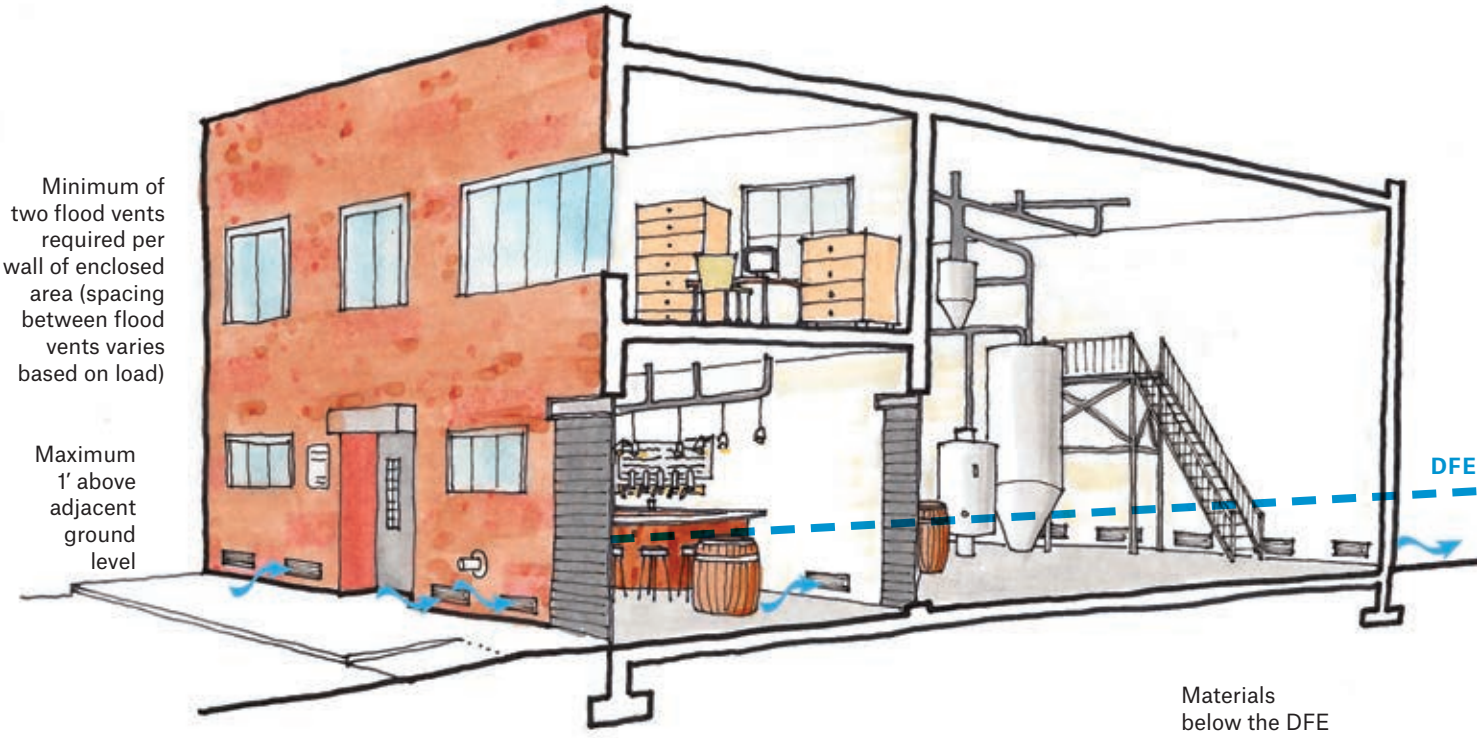
RESILIENCY CHALLENGE

Building structure, electrical components, and brewing equipment are vulnerable to flooding: The building that the brewery occupies is vulnerable to hydrostatic pressure from floodwater, since it is not designed to withstand floodwaters or allow water to enter the building without significant damage. The building's electrical components, including panels and conduits, are situated below the DFE. Damage to these devices would affect the power supply to production machinery. Additionally, brewing systems, including mills, tanks, and bottling or canning equipment, have electrical components that are vulnerable to flooding. Damage to this machinery would result in high costs for repair and replacement. Any delay in production would also result in lost operating revenue.

RESILIENCY MEASURE

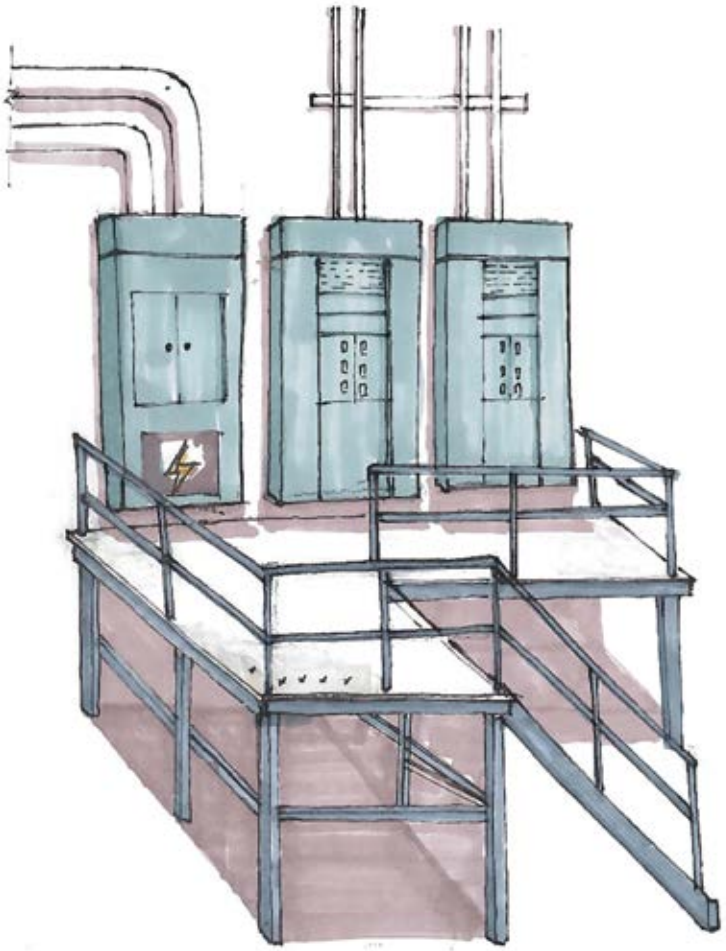
Wet floodproof: Wet floodproofing includes measures applied to a structure or its contents that prevent or provide resistance to damage from flooding while allowing floodwaters to enter the structure. This includes installing sufficient flood vents or other opening to allow floodwaters to enter, using flood-resistant construction materials below the DFE, and taking steps to protect mechanical and electrical equipment. Wet floodproofing is not an NFIP-compliant strategy for nonresidential structures and, therefore, is not recognized within the NYC Building Code as a strategy for new construction of industrial buildings or for retrofits of buildings that have been substantially damaged or substantially improved. For this reason, wet floodproofing does not result in insurance premium reductions for buildings insured through the NFIP. Nonetheless, for businesses that are not able to come into full compliance through dry floodproofing or elevating their structures, wet floodproofing may be a cost-effective strategy to reduce impacts of flooding and coastal storms.

APPROXIMATE COST*
Cost per flood vent = ~$1,750
**See cost estimation on pg. 110 for more info*



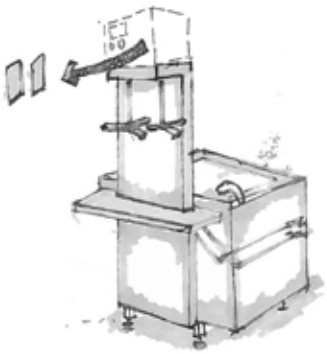
RESILIENCY MEASURE

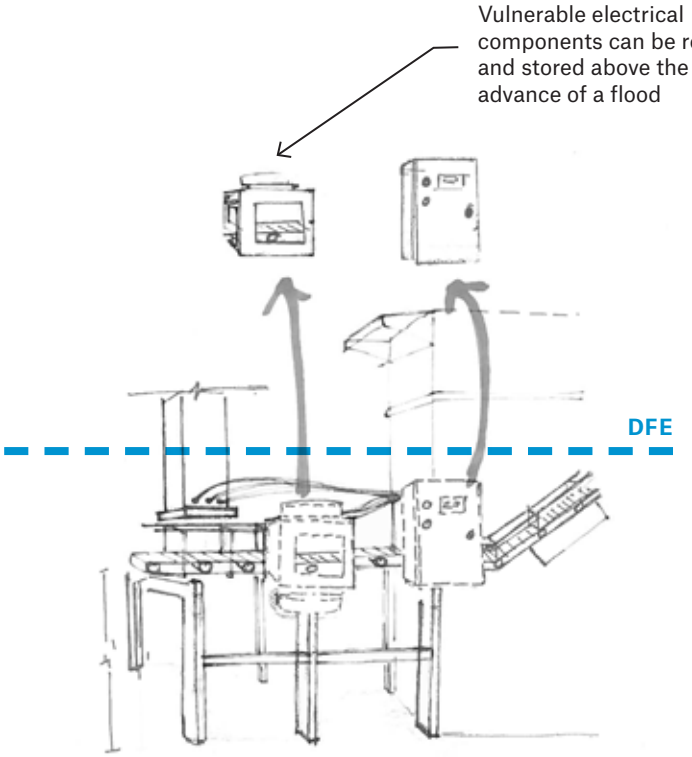
Elevate electrical panels: Locating electrical panels and other central components of the electricity supply system above the DFE may prevent damage to electrical systems and power outages. The location of electrical equipment should take into account regulations under the National Electrical Code (NEC). The NEC places limits on where electrical service equipment can be located, including clearance requirements and working space around electrical service components.



RESILIENCY MEASURE

Develop a preparedness plan to protect brewing equipment: Where possible, electrical components of machinery and other equipment may be removed and stored in safe locations when flooding is forecast. For example, circuit panels on canning lines may be quickly removed and stored on the second floor to prevent damage to the system. A facility preparedness plan should include an inventory of removable equipment or components that are below the DFE. The plan should clarify when to shut down operations and periodic staff training should include steps to safely remove vulnerable components.





Film Studio

Site Characteristics

Lot size	52,000 square feet
Building floor area	41,000 square feet
Year built	1950
Design Flood Elevation (DFE) above grade	3 feet

Business Profile

Film and television studios are one of the fastest growing industries in the city's manufacturing districts.[12] New York City and New York State have created a number of programs, including tax credits, workforce development, and use of city-owned space for production, to encourage growth within the film industry. A film studio was selected to explore flood resiliency measures applicable specifically to this sector, and generally to industrial businesses with high-value inventory and assets in industrial warehouses.

The studio is situated on three sites located adjacent to or near the water. Two of these buildings are used as stages for filming. The third building is used as an office and for equipment storage to operate a rental business for production lighting and sound equipment. For the purposes of this analysis, the focus is on the largest and primary building, which is used as a stage.

The stages occupy existing, single-story industrial warehouses that have been repurposed for use as a studio. These modifications included installing an HVAC system on the roof to minimize ambient noise during filming. The company employs approximately 30 full-time staff members, however, more than 250 people are often on-site during filming. For this reason, in addition to a building with wide column spacing and high ceilings, access to transit and parking were key considerations for the location of the studio. The company maintains a fleet of 16 vehicles, most of which are customized trucks for film equipment and power generation.

Flood Risk Profile

Film studios often contain expensive assets and equipment. In addition to cameras, lighting, and sound equipment, the sets used for film and television are a significant investment for production companies. Any delay in filming due to a damaged set could set back a filming schedule and result in costly disruptions for the studio and its client. Film sets are typically constructed a couple of feet above the floor of the warehouse, providing sufficient space beneath the set to run cables.

The studio evaluated as a case study is located in the 1% annual chance floodplain with a DFE of approximately three feet. During Hurricane Sandy, the company suffered approximately $2.8 million in equipment damage. Floodwaters inundated lighting and sound devices, causing corrosion and destroying electrical components and fixtures. While the warehouse structure was largely unaffected, mold occurred almost immediately on interior walls and fabrics that were not constructed with flood-resistant materials. Despite unplugging equipment and placing computers on top of desks prior to the hurricane, some computers were still destroyed as flood heights exceeded this level in some parts of the building. Eight trucks, valued at

During Hurricane Sandy, the company suffered approximately $2.8 million in equipment damages.

$400,000, were also flooded beyond repair during the storm

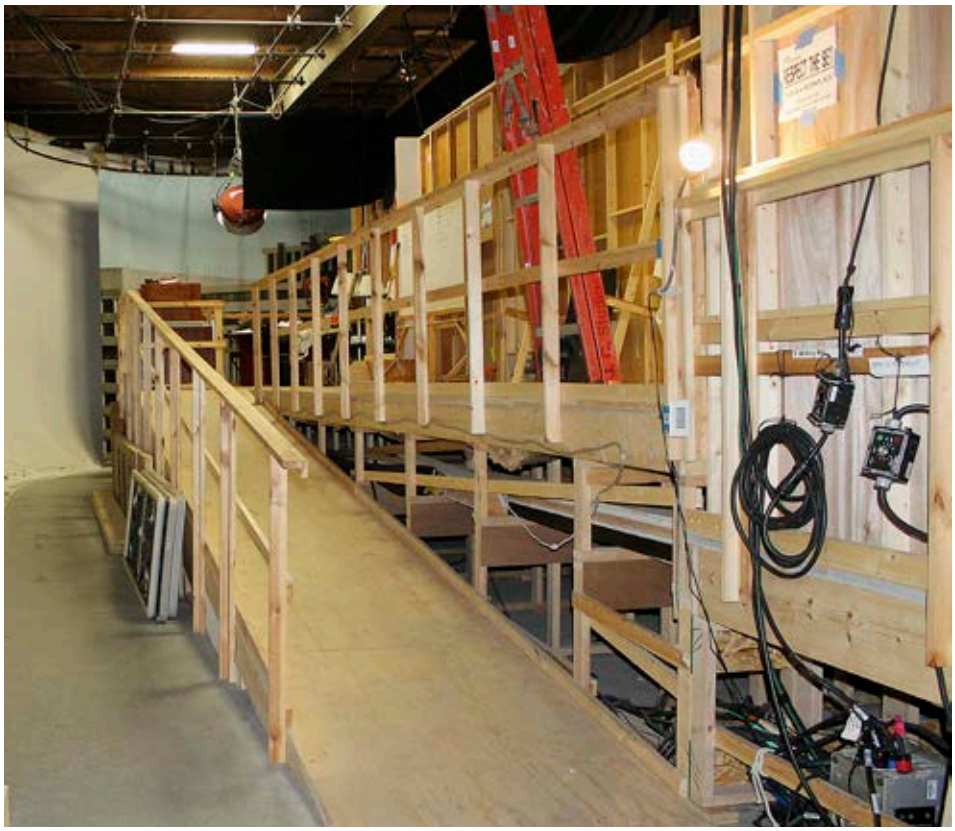
Prior to Hurricane Sandy, the studio had a private, universal coverage insurance policy, which included flood coverage. The business also maintained NFIP content coverage for all of its buildings, with the maximum coverage limit offered under the program of $500,000.

Following Hurricane Sandy, the private coverage reimbursed equipment losses, but much of the company's investment in a leased building was not covered by insurance, forcing the studio to cover repairs out-of-pocket. The FEMA reimbursement process for building contents was considered by the studio to be tedious and costly, requiring an external remediation company to attempt to fix each item or, where applicable, document that each item could not be repaired before reimbursement. New models of equipment could only be purchased with detailed justification. The company was fully paid out by FEMA after nine months. Although the company maintained vehicle insurance on all of its commercial trucks, it learned in the aftermath of Hurricane Sandy that its vehicle insurance covered only the value of the trucks prior to being customized for the film industry. In many cases, trucks that initially cost $25,000 had an additional $30,000 invested in modifications, such as shelving, lighting, generators, and storage. Since Hurricane Sandy, the company has included these types of vehicle customizations within its property coverage to avoid similar uninsured losses.

Even though insurance did eventually pay for replacement of much of the damaged equipment, the studio was forced to rent equipment from other lighting companies to maintain operations. The higher operating cost during the recovery period resulted in lost revenue due to the storm. In total, the studio felt that it took 18 months to recover from Hurricane Sandy.

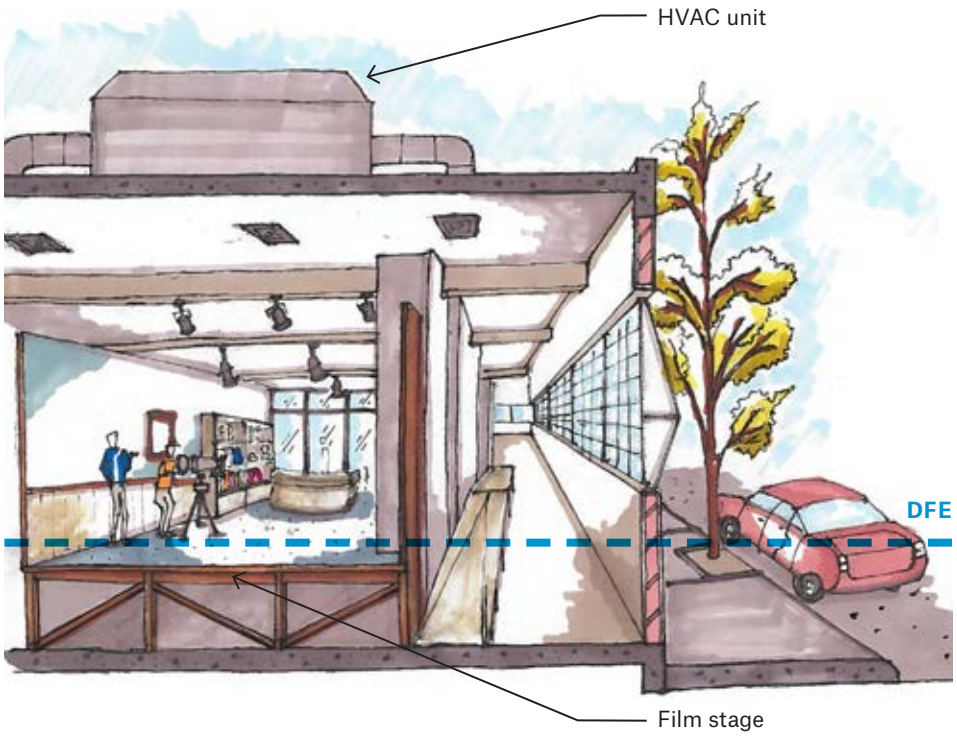
Challenges and Resiliency Measures

Film and television studios have common characteristics that affect their vulnerability to flooding. The following examples demonstrate strategies to minimize damage from flooding that may apply to a range of similar industrial businesses in New York City.



RESILIENCY CHALLENGE

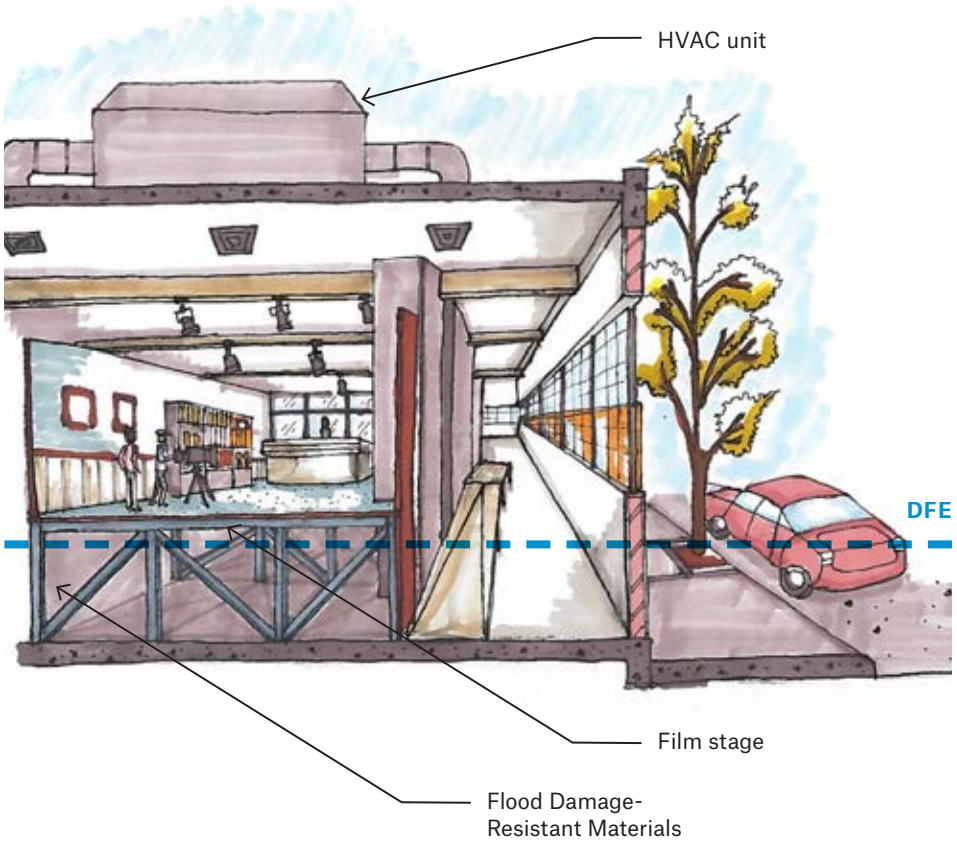
Film sets are immovable and highly vulnerable to flood damage: Film sets are significant investments for film studios and, once constructed, cannot be easily moved or relocated. If situated below the DFE, sets and large props may be susceptible to flood damage. Film sets and props are particularly vulnerable to floodwater, as they are often designed and constructed with more temporary, less resilient materials. A disruption in a production schedule to repair or replace an active set could result in significant costs for the studio and tarnish the company's reputation.



RESILIENCY MEASURES

Add freeboard to the set floor within the building: If the building has sufficient ceiling heights, film studios should consider increasing the elevation of stages and sets to meet or exceed the DFE. Even if floodwaters enter a building, a set that is elevated above the DFE may be able to reduce damage and resume operation quickly. In addition, the area below the set should utilize flood-resistant construction materials.

Install the HVAC system on the building roof: Locating the HVAC system on the roof of a building as opposed to installing it at-grade reduces the likelihood of exposure to floodwaters. For film and televisions studios that tend to modify buildings to reduce ambient noise caused by mechanical systems, installation on the roof can also help meet these goals. Due to the potential for high winds during coastal storms, HVAC systems and other mechanical equipment installed on the roof should be properly anchored and secured.

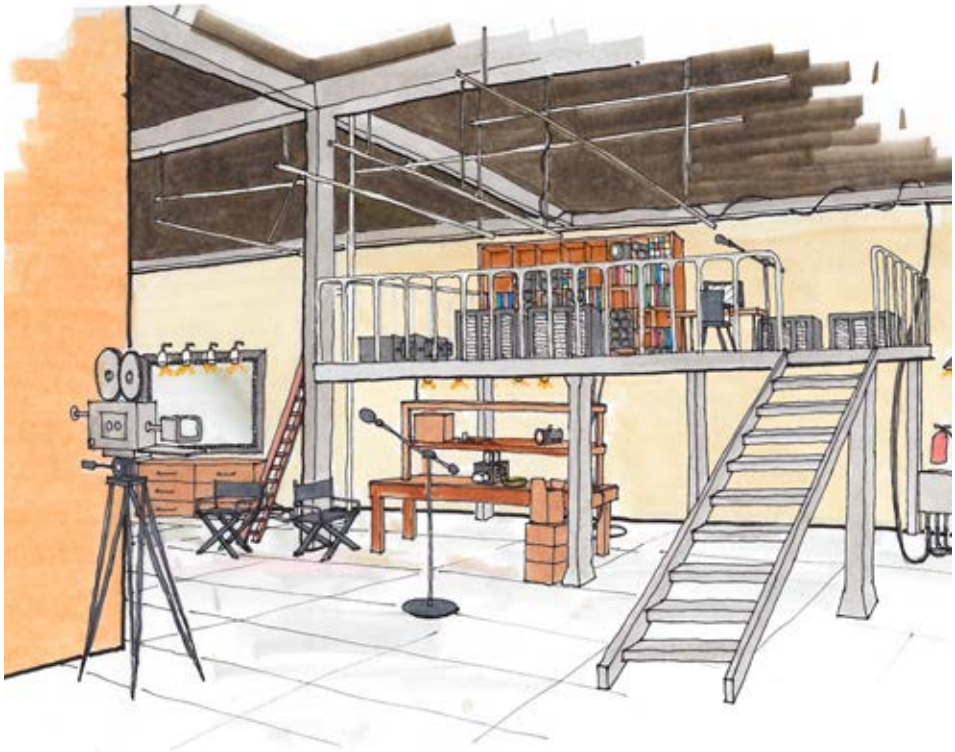


RESILIENCY CHALLENGE

Film-making equipment highly vulnerable to flood damage: Cameras, microphones, lights, stands, cables, and other equipment are often stored at grade within production studios so they can be easily accessed and used. Without storage space above the DFE, this equipment is likely to be inundated during flood events. Damage to these assets not only results in high replacement or repair costs, but can also hinder operations and delay production.

RESILIENCY MEASURES

Construct a mezzanine for protected storage and office space: Many industrial spaces have sufficient floor-to-ceiling height to construct mezzanines to create office or storage space. The availability of space above the DFE allows for permanent storage or temporary relocation of valuable equipment during floods, significantly reducing risk for businesses that have major investments in assets and equipment. Mezzanines can double as offices where business records can be safely stored and protected from flooding. A facility emergency preparedness plan should also be developed to clarify which equipment should be stored above grade, when it should be relocated, and who is responsible for taking these steps.



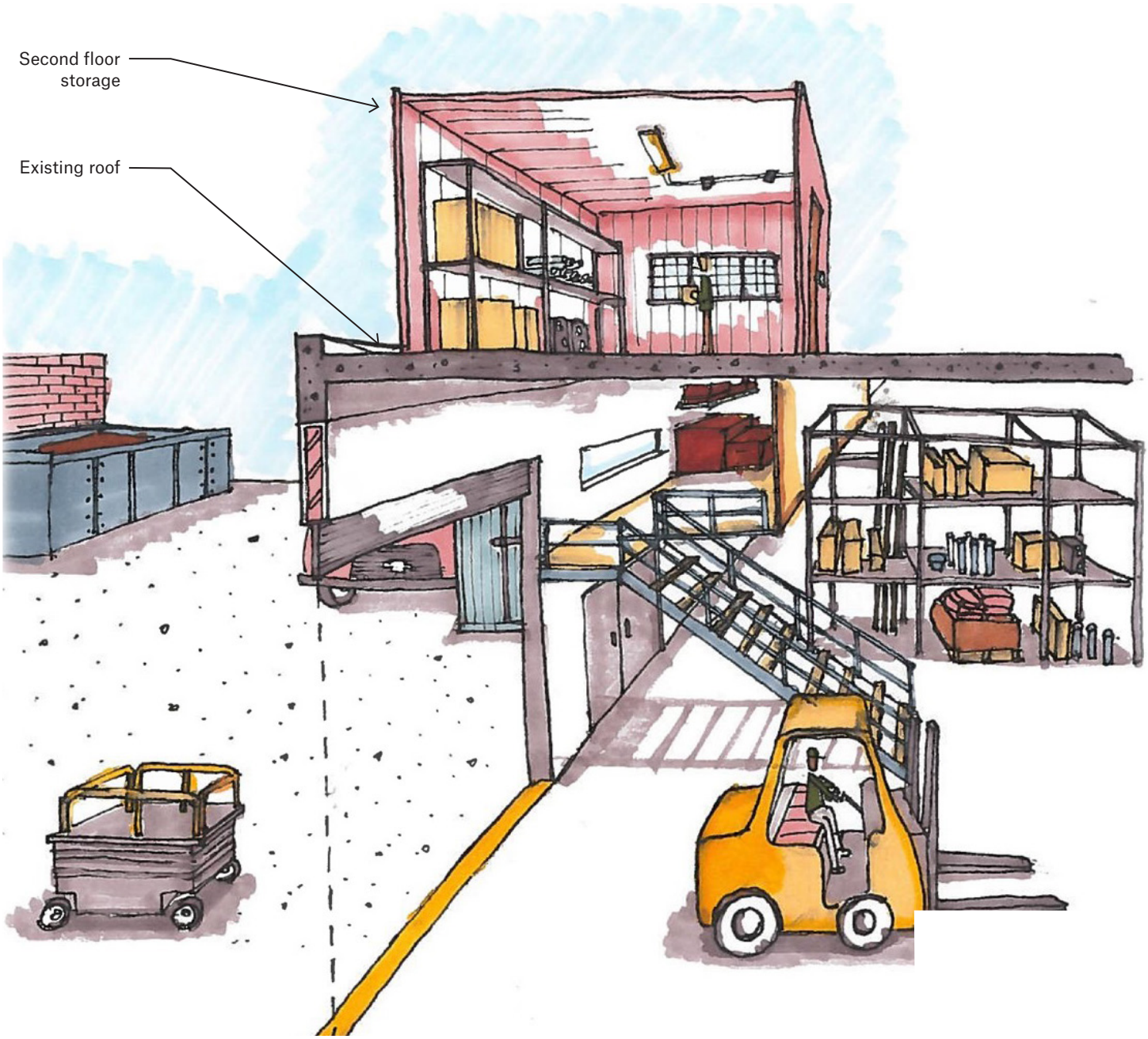
APPROXIMATE COST*
500 sf mezzanine = ~$112,000
**See cost estimation on pg. 110 for more info*

RESILIENCY MEASURES

Construct a second floor storage space on roof deck: The availability of storage spaces above the DFE allows for permanent storage or temporary relocation of valuable equipment during floods, significantly reducing risk for businesses that have major investments in assets and equipment. These spaces can also double as offices where business records can be safely stored and protected from flooding. Additionally, insurance availability can be enhanced and premiums can be reduced by having storage space above the floodplain. A facility emergency preparedness plan should also be developed to clarify which equipment should be stored above grade, when it should be relocated, and who is responsible for taking these steps.

In some zoning districts, floor area or height restrictions may limit the ability to construct second floor additions. A more detailed discussion of these zoning considerations can be found on page 102.

APPROXIMATE COST*
500 sf rooftop addition = ~$214,000.
**See cost estimation on pg. 110 for more info*

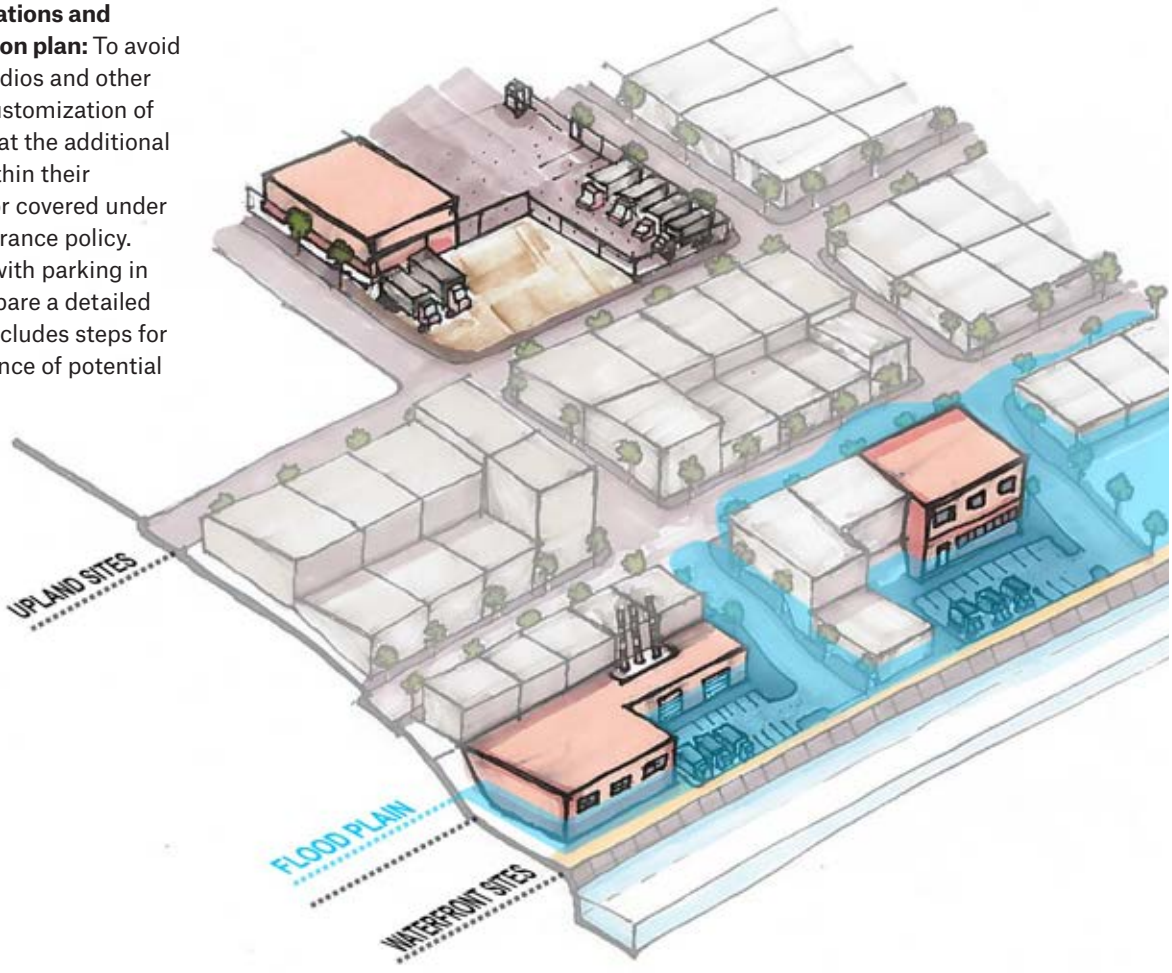


RESILIENCY CHALLENGE

Commercial vehicles parked in the floodplain may be damaged during storms: For many industrial companies, vehicle fleets that are parked in the floodplain are a significant liability. Trucks used in the film industry also tend to be customized with additional storage, lighting, and generators, increasing their value and making these vehicles more difficult to replace. Vehicle insurance policies often cover only the cost of the vehicle before modification.

RESILIENCY MEASURES

Insure vehicle customizations and prepare parking relocation plan: To avoid uninsured losses, film studios and other companies that rely on customization of vehicles should ensure that the additional cost is either included within their vehicle insurance policy or covered under the general business insurance policy. Additionally, companies with parking in the floodplain should prepare a detailed preparedness plan that includes steps for vehicle relocation in advance of potential flood events.



Food Distributor

Site Characteristics

Lot size	200,000 square feet
Building floor area	180,000 square feet
Year built	1960
Design Flood Elevation (DFE) above grade	3-7 feet

Business Profile

A large food distribution business located in the city's industrial floodplain was selected as a prototypical site, representing a major industry in the city that continues to grow as the population expands. In 2014, more than 750 food distribution facilities were located in manufacturing districts, employing more than 15,000 employees. These businesses are concentrated in Hunts Point, Maspeth, and East Williamsburg, many of them located in areas vulnerable to flooding.[13]

Ensuring that the city's food distribution network is resilient to disruptions is critical to the city's overall resilience. The 2016 New York City Food Distribution & Resiliency Study, conducted by the Mayor's Office of Recovery and Resiliency and the Economic Development Corporation, found that the city's point-of-sale outlets typically keep between four and five days of food in stock, making it imperative that food distribution businesses have the ability to maintain or quickly resume operation following a flood, coastal storm, or other disruption.[14]

The company evaluated as a prototype of large food distributors employs more than 3,000 people in New York City and operates out of approximately 350,000 square feet of warehouse space that is spread across three separate buildings. All deliveries to and from the site are conducted by the company's fleet of 250 commercial trucks.

Flood Risk Profile

Two of the three buildings occupied by the food distributor prototype are located in the 1% annual chance floodplain. The largest building, which has a footprint of more than 180,000 square feet, has a DFE that ranges from three to seven feet above grade.

During Hurricane Sandy, one building flooded with two feet of water and another had approximately six inches of floodwater. Despite flooding in these buildings, physical damage to the building was relatively minimal, requiring the business to replace carpet, drywall, and flooring in some parts of the buildings—primarily in spaces used for offices. Removing debris during the recovery period was a significant financial burden, as the company was compelled to rent approximately 30 dumpsters per day

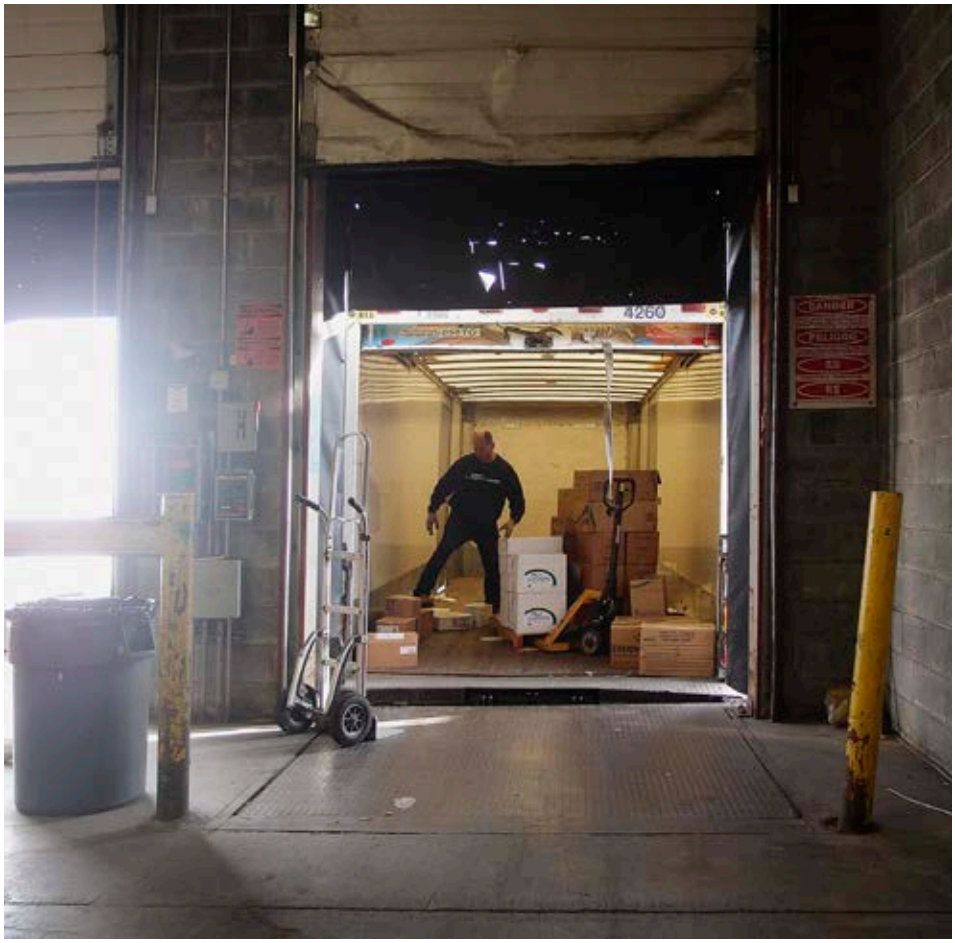
for several days during the clean-up. More significantly, the company's entire fleet of trucks was parked within the floodplain during Hurricane Sandy. One hundred and sixty of their 250 trucks were flooded beyond repair, forcing the company to quickly find suitable replacements or short-term rentals before it could resume operations.

A significant concern for the company is the need to maintain refrigeration for large quantities of perishable foods. During Hurricane Sandy, electricity was uninterrupted for the duration of the storm. The business had a 500 KW generator that was installed six inches above grade and was inundated by floodwaters. Had the business lost power, the damage to their backup generator would have resulted to additional losses and delays in restoring operations.

The company maintains a large, private insurance policy from a major reinsurance company, which includes continuity of operations coverage. This policy covered most physical damages from Hurricane Sandy and reimbursed roughly half of lost sales. The company does not have coverage through the NFIP. Most of the trucks were leased and insured. Of the $10 million in losses due to vehicle damage, the company was reimbursed approximately $8 million by insurance. In the aftermath of Hurricane Sandy, the company's premium increased and its insurer required a detailed plan describing preparedness strategies for future events.

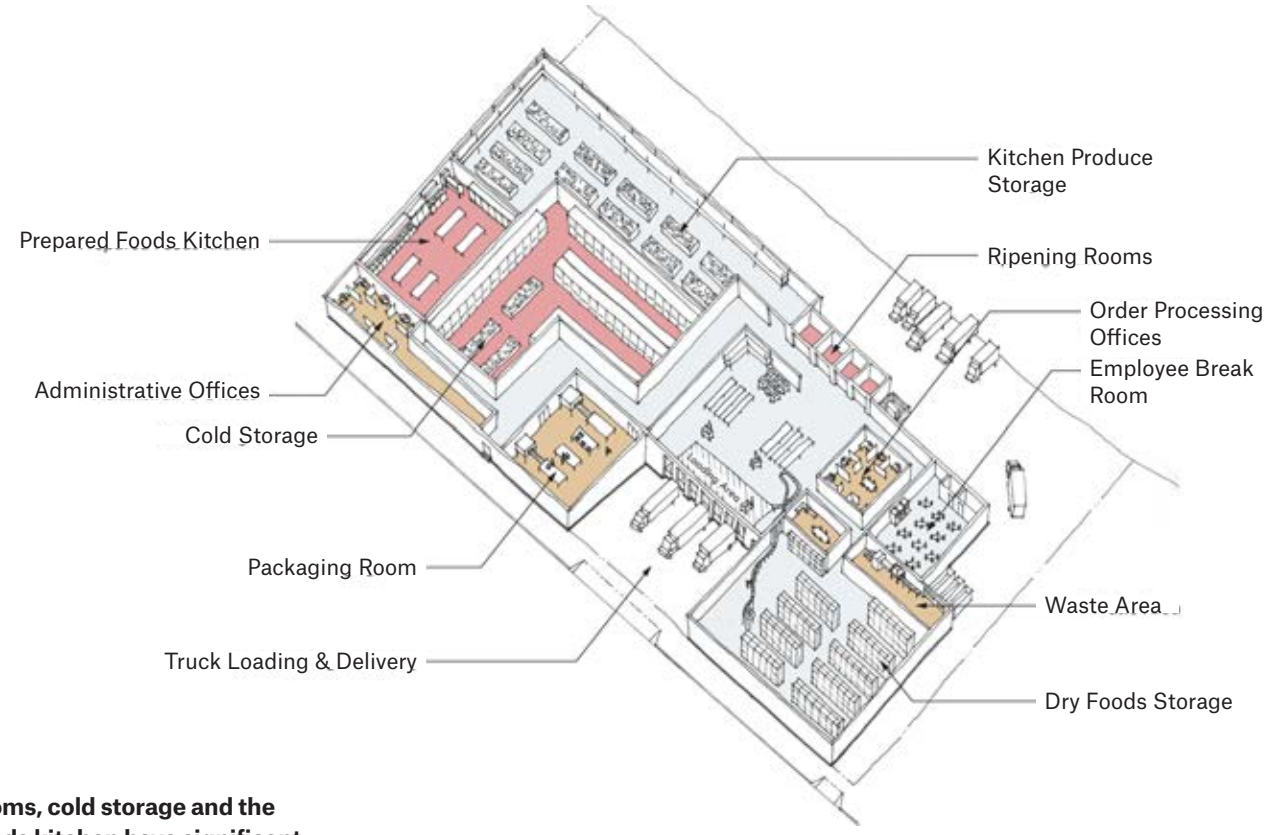
Challenges and Resiliency Measures

Food distribution sites and other transportation and warehousing facilities have common characteristics that affect their vulnerability to flooding. The following examples demonstrate strategies to minimize damage from flooding that may apply to a range of similar industrial businesses in New York City.

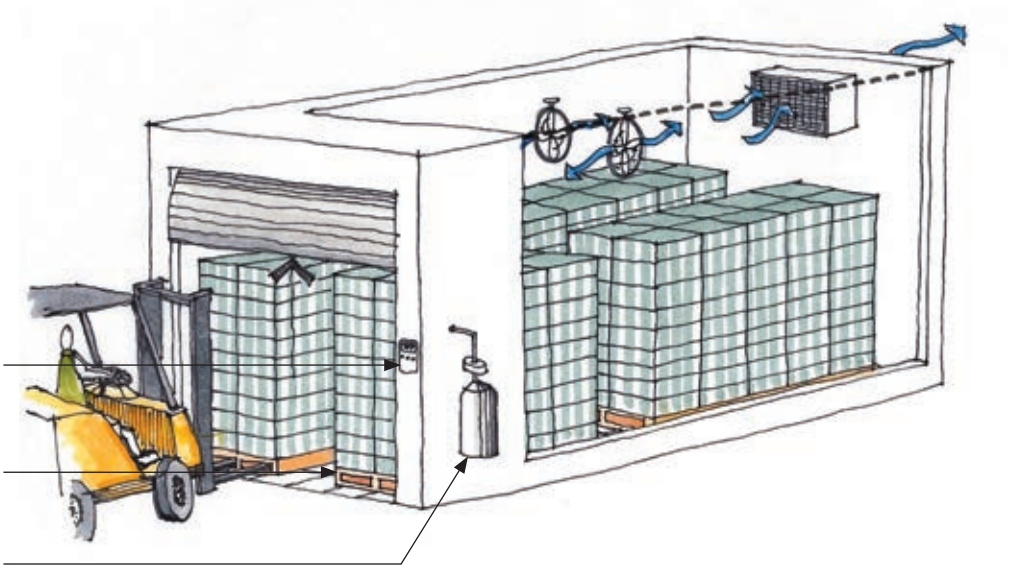


RESILIENCY CHALLENGE

Critical rooms within the facility are particularly vulnerable to flooding: Certain spaces within the facility contain significant investments in equipment and inventory, while other spaces are less vulnerable to flooding. For example, rooms colored in red, such as cold storage or ripening rooms, are disproportionately vulnerable to flooding due to high-value equipment. Rooms in yellow, such as packaging rooms, are slightly less vulnerable. The rooms in gray are the least vulnerable. Due to the large size of the facility, fully protecting the entire building from flooding would be prohibitively costly.



Ripening rooms, cold storage and the prepared foods kitchen have significant investments in equipment: Ripening rooms are key components of the distributor's operation and tend to contain more investments in equipment that could be damaged by floodwaters. While it may not be cost-effective for the business to fully protect the entire facility, the potential for flooding within key areas of the building that contain more sophisticated equipment is a significant risk.

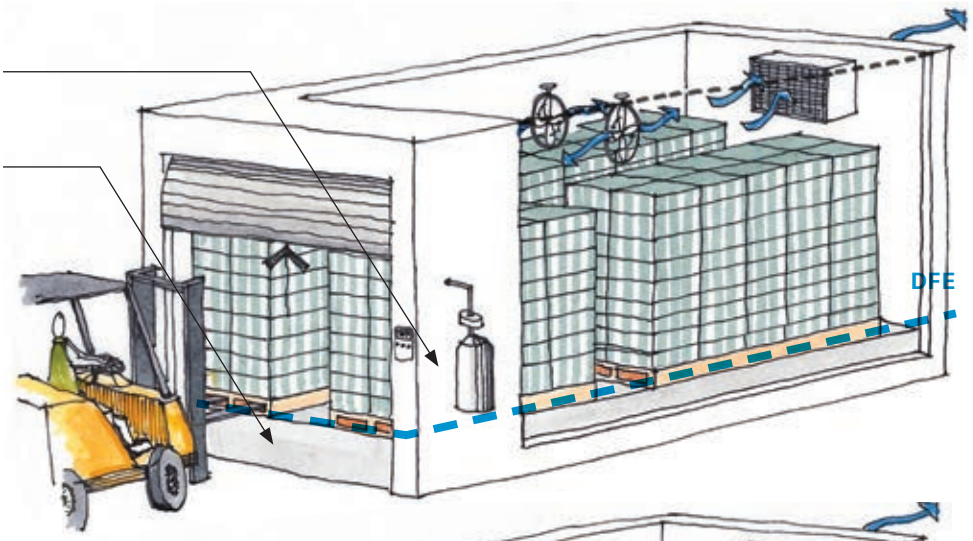


RESILIENCY MEASURES

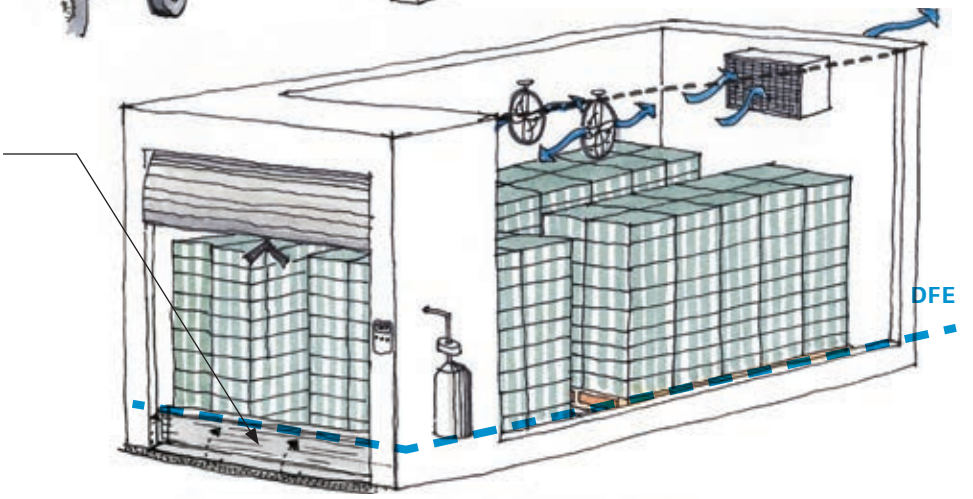
Floodproof critical warehouse spaces: Although it may not be feasible or cost-effective to dry floodproof the entire warehouse space for many large distribution businesses, some businesses may choose to floodproof critical spaces within the structure to ensure that protected space exists for valuable inventory or equipment. This strategy, known as partial floodproofing, can involve a combination of elevating floors within the structure, dry floodproofing, or wet floodproofing.

The first example illustrates elevating the floor within a specific room. Elevating floors provide space that is permanently protected from floods up to the elevation of the floor. This strategy is only feasible if there are sufficient ceiling heights within the building. The second option illustrates dry floodproofing with a deployable flood barrier. This strategy requires that walls are sufficiently reinforced to manage hydrostratic pressure during floods.

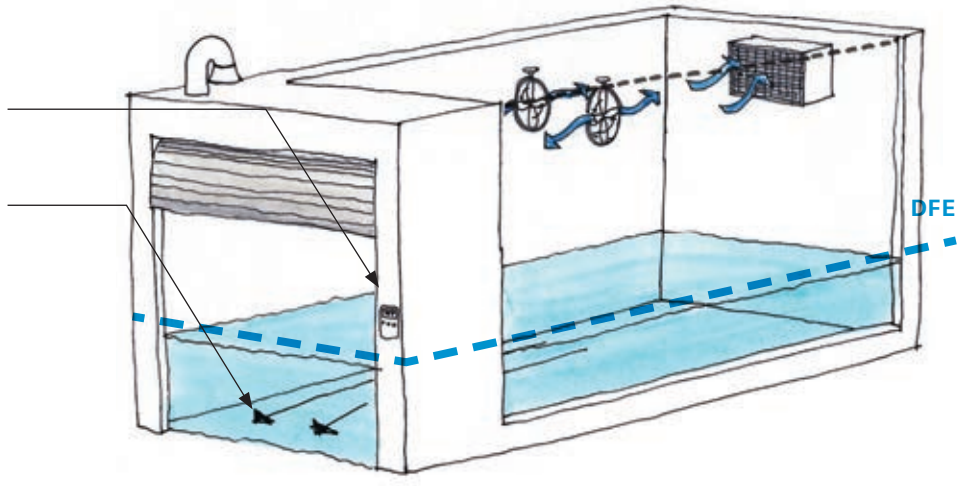
Additionally, space is needed within the building to store flood barriers, and staff must be trained to successfully install barriers in advance of flooding. The third option describes wet floodproofing, which involves raising electrical and mechanical devices above the DFE and installing flood resistant materials. Because inventory could not be protected with this method, a preparedness plan should describe steps to reduce inventory in advance of potential floods.



APPROXIMATE COST*
Elevated floor (24") = ~$4,800
**See cost estimation on pg. 110 for more info*



APPROXIMATE COST*
Deployable flood barrier = ~$1,200
**See cost estimation on pg. 110 for more info*



RESILIENCY CHALLENGE

Office space is particularly vulnerable to flooding: Offices are typically constructed with fewer flood-resistant construction materials than warehouse spaces, yet they pose additional risk to companies that rely heavily on logistics. In particular, damage to computers or other business records could result in a major disruption to long-term operations.

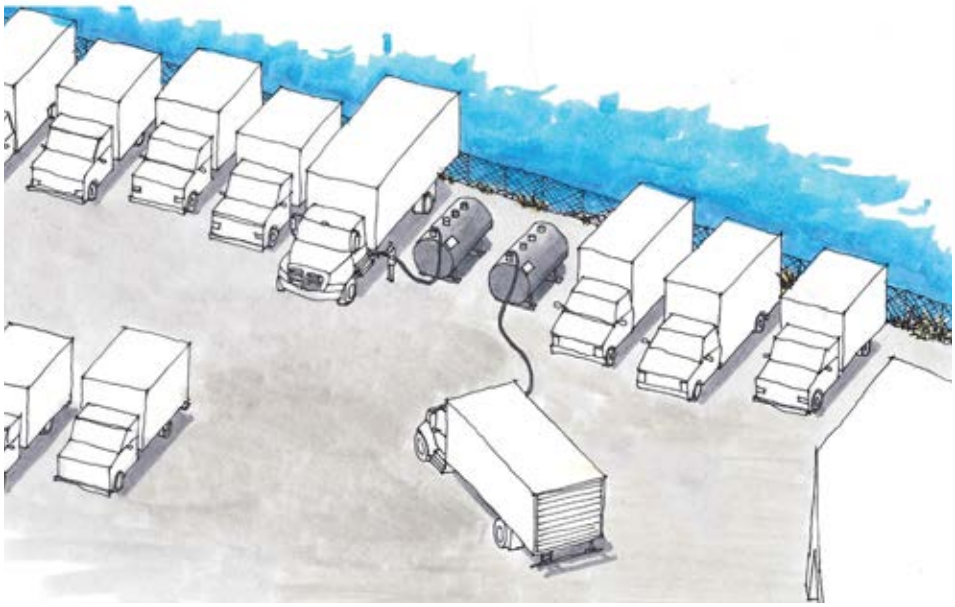
RESILIENCY MEASURES

Wet floodproof office space: Wet floodproofing tends to be a less expensive alternative than dry floodproofing. Rather than preventing flood water from entering the area, wet floodproofing involves installing flood-resistant construction materials below the DFE and flood vents that allow water to enter the structure. Creating systems that allow floodwater to enter more freely causes forces on either side of the structure's walls to equalize, minimizing the chance of more significant structural damage. A list of flood-resistant construction materials is provided in FEMA Technical Bulletin 2-08, Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the NFIP.

APPROXIMATE COST*
Cost per flood vent = ~$1,750
**See cost estimation on pg. 110 for more info*

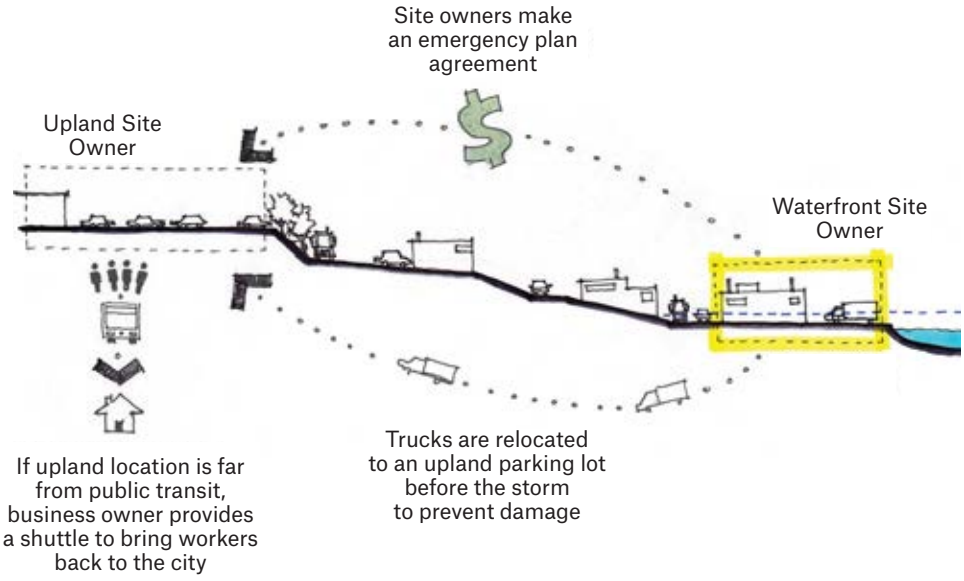
RESILIENCY CHALLENGE

Truck fleets parked within the flood zone: Delivery trucks and other vehicles such as fueling tankers are regularly parked within the floodplain. Without sufficient planning to relocate fleets of trucks in advance of coastal storms and potential flooding events, the potential damage to vehicles may cause a significant financial burden and an impediment to resuming operations. The fuel, oil, and other hazardous substances within commercial trucks also pose an environmental risk, as flooding can result in spills and leaks.



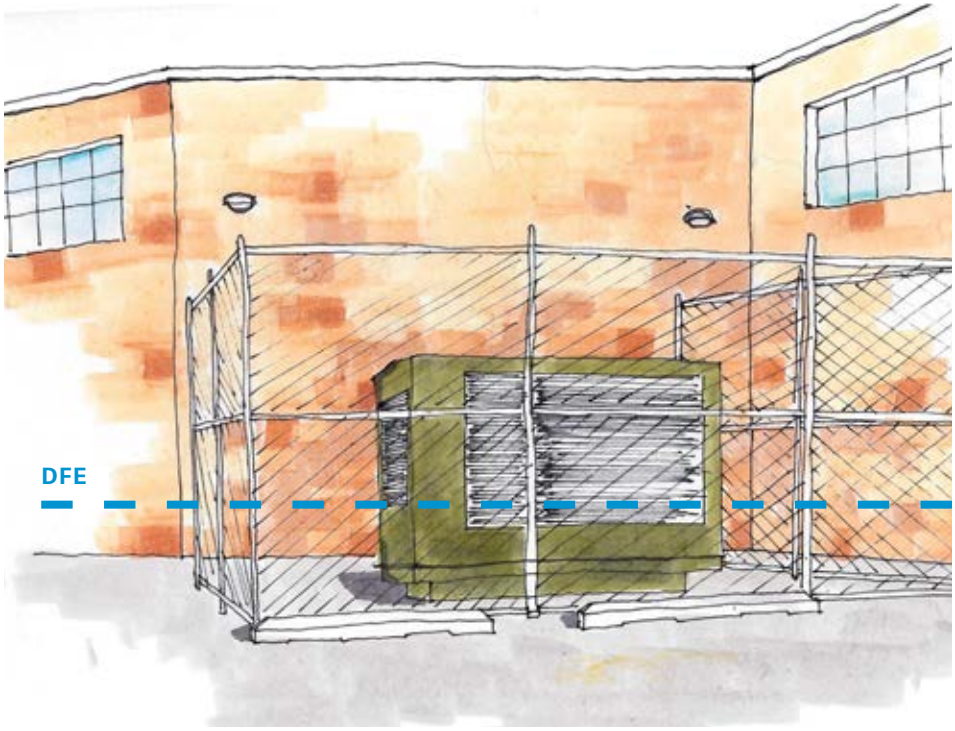
RESILIENCY MEASURES

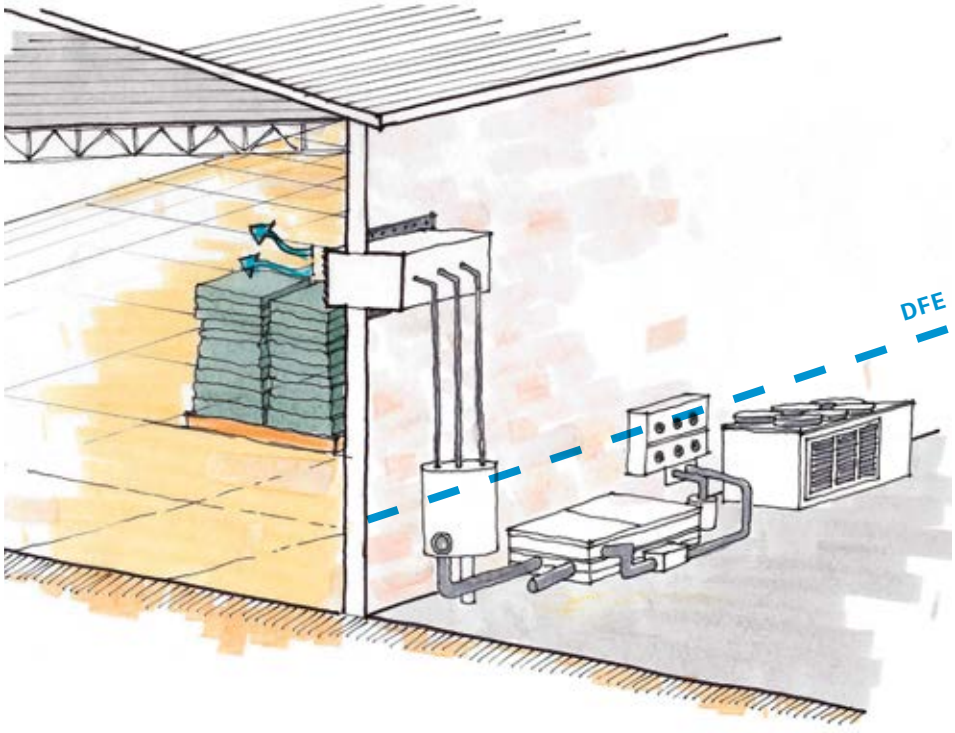
Preparedness plan to relocate trucks: Facility preparedness plans should include steps to relocate vehicles to higher ground before a potential flood. Specifically, the plan should identify areas where trucks and other vehicles may be relocated, the timing of relocation as a storm approaches, how the trucks will be relocated, and by whom. The food distributor evaluated as a case study has prearranged with a company outside of New York City to rent excess parking space for future storms. At the end of the final shift before the company ceases operations for the storm, staff members would drive all 250 trucks to the designated parking area and several prearranged buses would shuttle drivers back to the food distributor's facility.



RESILIENCY CHALLENGE

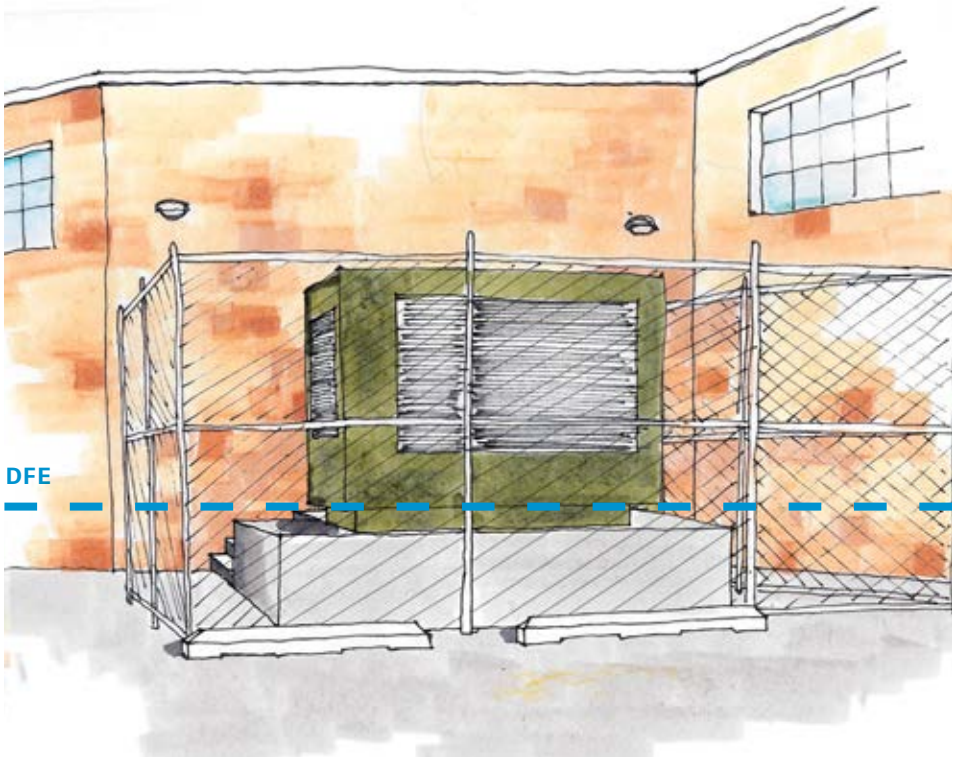
Backup generators located below the Design Flood Elevation: Backup power generators can play an important role in ensuring continuity of operations for industrial businesses. For food distributors that rely on refrigeration, reducing interruptions in power supply can prevent spoiled inventory. Generators installed at or near grade in the floodplain are often damaged and unable to serve their intended purpose in the event of flooding.



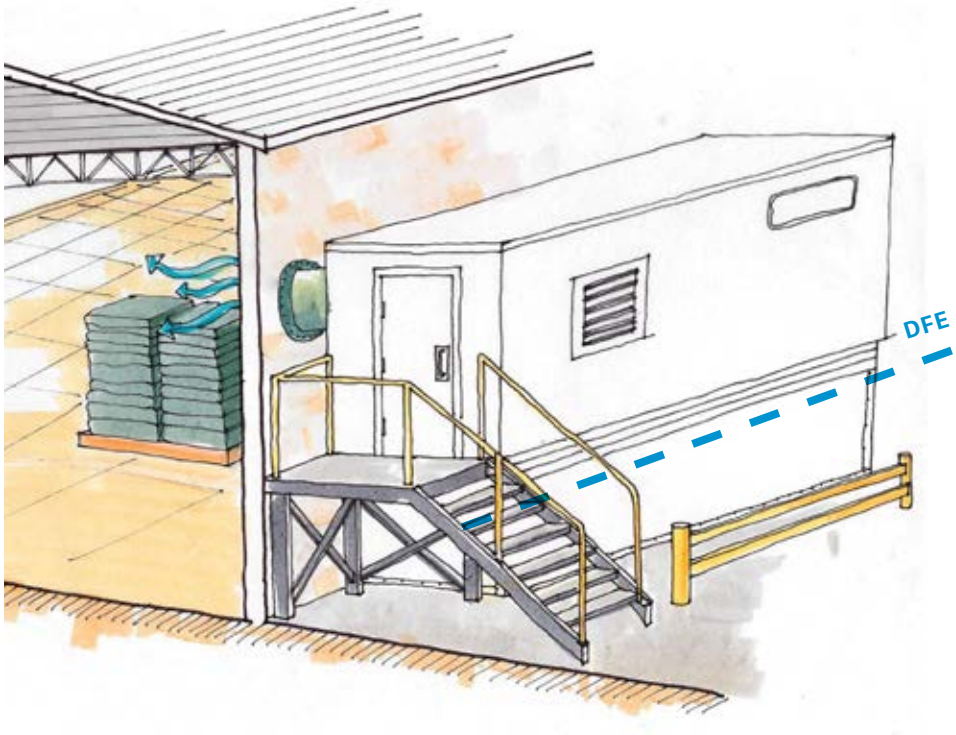


RESILIENCY MEASURES

Elevate generators above the DFE: Power generators within the floodplain should be located above the DFE or adequately enclosed in a dry floodproofed space. Generators can be raised on concrete pads or steel platforms. All components of the emergency power system, such as transfer switches or pumps, should also be elevated. Where backup power systems are incapable of meeting the full operational demand of the facility, distribution systems should be directed toward key areas of the site to minimize losses and ensure that critical operations may continue or resume quickly. Companies that rely on refrigeration but do not have a generator on-site at all times should consider establishing a lease contract for an emergency generator and ensure that a transfer switch is installed in the building.



APPROXIMATE COST*
Concrete platform to raise generator = ~$41,800
**See cost estimation on pg. 110 for more info*



Ship Maintenance and Repair Facility

Site Characteristics

Shoreline length	3,600 feet
Floating dry docks	7
Design Flood Elevation (DFE) above grade	3-11 feet

Business Profile

A ship maintenance and repair facility was selected as a case study to explore flood resiliency measures for large industrial sites that provide maritime-support services. Many businesses within the maritime-support services sector facilitate operations of the Port of New York and New Jersey, the largest port on the East Coast. These are particularly prevalent along the north shore of Staten Island, as well as Sunset Park and Red Hook in southwest Brooklyn.

The business selected for the study is one of the largest ship maintenance and repair facilities in the region, with seven floating dry docks and several piers and floating barges used for pier-side repair work. More than 300 small to medium sized vessels are serviced at this site annually. The business employs more than 200 full-time employees.

Flood Risk Profile

The majority of the property is located within the 1% annual chance floodplain, with small parts of the upland site located in the 0.2% annual chance floodplain. Beginning several days in advance of the storm, the business began taking steps to prepare the site and minimize damage. Staff unbolted and removed heavy machinery from piers, secured and anchored other immovable equipment, and relocated the business' fleet of more than 50 vehicles to higher elevations.

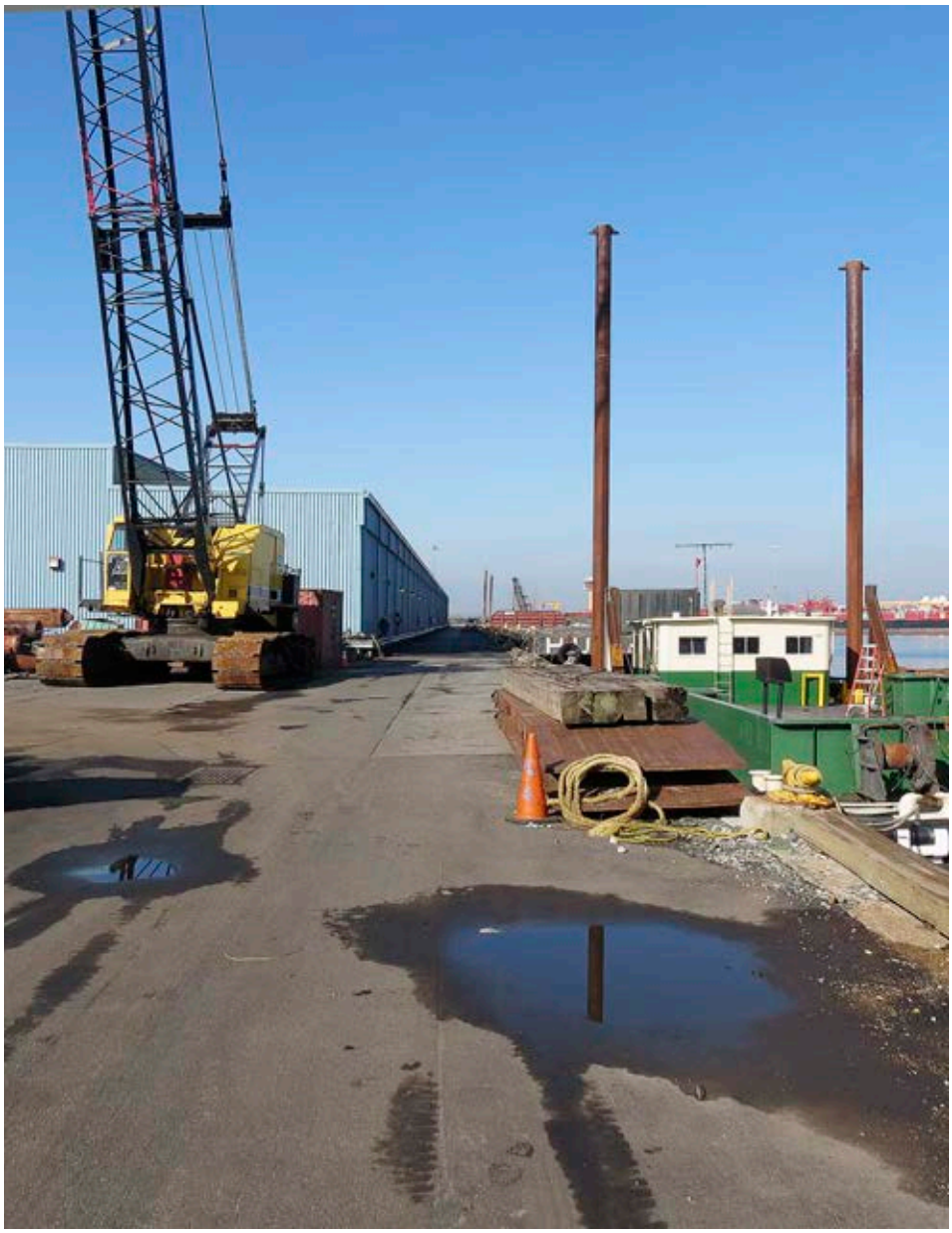
Despite these preparedness steps, the business experienced significant flooding and damage during Hurricane Sandy that resulted in more than $3 million in losses. While the business does carry property insurance, it has decided not to maintain a flood insurance policy, choosing instead to self-insure. Therefore, all of the Hurricane Sandy recovery costs were absorbed by the business.

Major electrical systems, including several 500 KW and 1,000 KW substations, were severely damaged or destroyed. Similarly sized backup generators that were located on piers were also flooded.

Fortunately, there was no significant damage to dry docks or floating piers. Unlike floating piers, which were able to safely rise with storm surge, stationary piers were overtopped and several were damaged during Hurricane Sandy.

Since most dry docks were installed with 500 KW generators, the facility was able to resume operating the following day by running power from these generators landward to power the site. The facility also has a modern oil barge on-site, which was undamaged during Hurricane Sandy. The fuel on-hand in this barge was critical for powering generators and equipment, despite regional fuel distribution shortages and power outages.

Challenges and Resiliency Measures
Ship repair and other maritime support services such as tug and barge operations have common characteristics that affect their vulnerability to flooding. The following examples demonstrate strategies to minimize damage from flooding that may apply to a range of similar industrial businesses in New York City.



RESILIENCY CHALLENGE

Electrical substations below the DFE: Many industrial sites install and maintain one or more electrical substations on-site for electrical distribution. When operating below expected flood levels, critical components of substations, including switching, protection and control equipment, and transformers, may be exposed to floodwater and permanently damaged. In addition to repair or replacements costs, which can be extremely high, loss of high-capacity electrical supply for industrial activities can hinder operations.

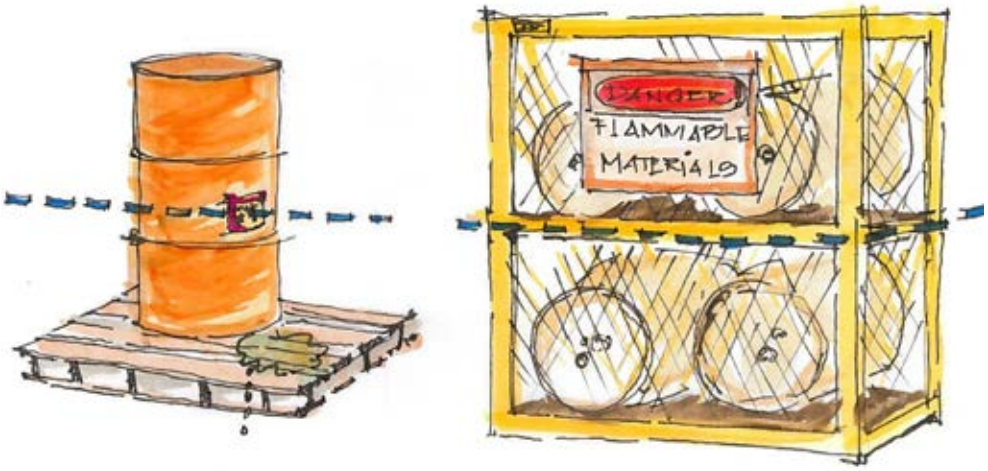
RESILIENCY MEASURES

Elevate electrical substations: Substations and other permanent electrical equipment can be elevated above the DFE, either on elevated platforms or on concrete pads where flood elevations are lower. Substations can be elevated most cost-effectively during the initial installation or when electrical equipment is replaced over time. However, this can also be accomplished as a retrofit for existing equipment to mitigate flood damage.

APPROXIMATE COST*
100 sf steel platform = ~$27,700
**See cost estimation on pg. 110 for more info*

RESILIENCY CHALLENGE

Unprotected hazardous substances: Most industrial processes require storage and use of hazardous substances to facilitate daily operation. Improper storage of hazardous substances can result in leaks or spills that can degrade the environment and put workers or neighboring communities at risk. If not properly secured, tanks, barrels, or other containers of hazardous substances may be undermined or displaced by flooding. In addition to the potential for leaks due to ruptured containers or inadequate seals, unexpected harmful consequences such as explosions resulting from the accumulation of gases from ruptured tanks can pose a significant risk.

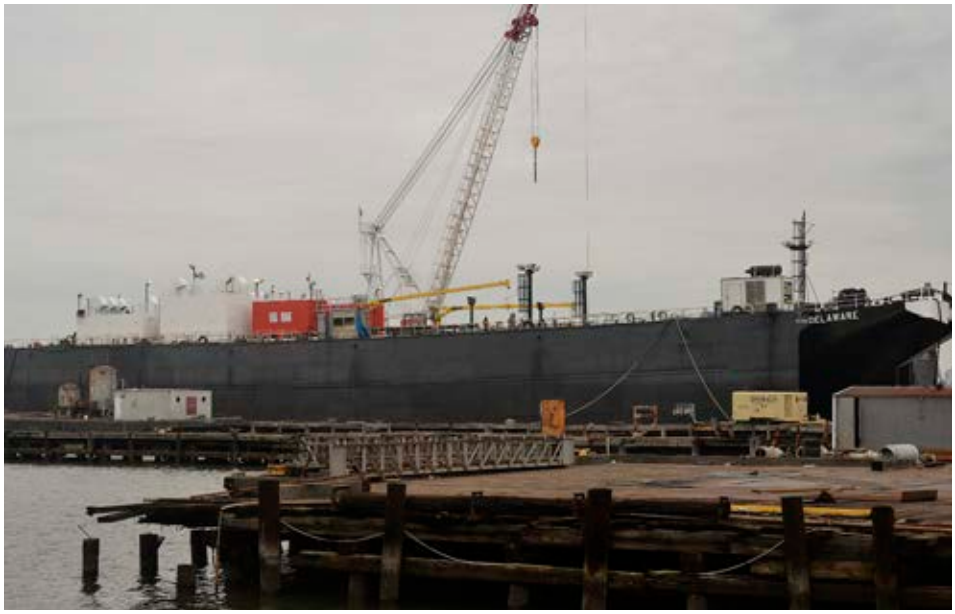


RESILIENCY MEASURES

Safely store hazardous substances to reduce leaks or spills: Where possible, hazardous substances should be permanently stored in areas outside of the floodplain. To prevent leaks during everyday operations, containment bunds can be purchased to place beneath barrels or other containers with hazardous substances. Storage containers should be watertight, sheltered from rain, isolated from stormwater runoff, and stored using overpacks to prevent spills. For smaller containers, flammable and acid cabinets can help secure and contain hazardous substances. Where infeasible to relocate outside of the floodplain, containers and tanks that contain hazardous substances should be elevated, safely secured, and anchored to prevent spills and leaks. Appendix G of the NYC Building Code requires that above-ground tanks be elevated to the DFE and designed to prevent flotation, collapse, and lateral movement. Petrochemical fuel tanks may also be installed on trailers, making it easier to relocate to higher locations on-site, or to safe locations off-site, in advance of a potential flood or coastal storm.

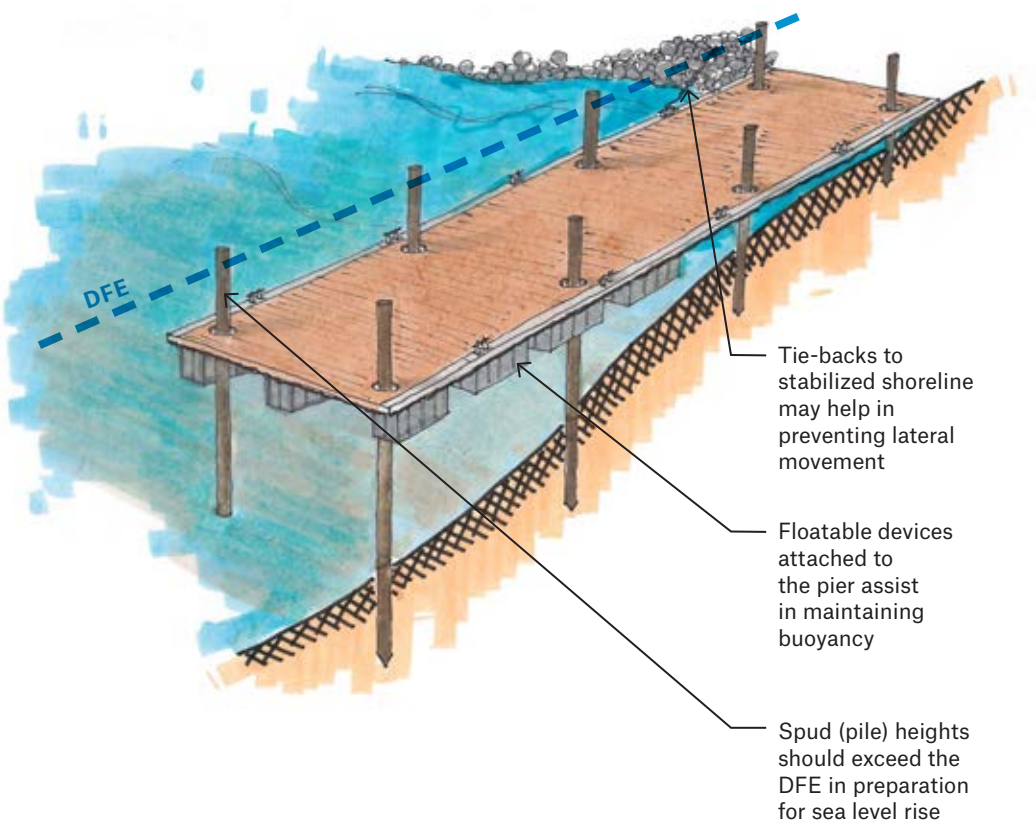
RESILIENCY CHALLENGE

Stationary piers vulnerable to flood damage: Piers are an essential asset to many maritime businesses, including tug and barge operations and ship maintenance and repair. Stationary piers are situated above the water line and mounted on pilings driven in the ground. During coastal storms with storm surge, stationary piers may be overtopped or damaged by wave action. As sea levels rise, existing stationary piers are likely to be inundated by floodwaters more frequently. Damage to piers, or damage to equipment and machinery located on these structures, can hinder operations of the city's port and maritime industry.



RESILIENCY MEASURES

Replace stationary piers with flexible piers on spuds: When stationary piers are damaged or need to be replaced, mechanisms that allow piers to safely rise and fall with water levels can be an effective form of flood mitigation and sea level rise adaptation. The ship repair and maintenance facility used as a case study has chosen to replace several stationary piers with rail barges that are mounted on spuds through the deck. Flexible piers or barges on spuds are more resilient to flooding by allowing for tidal fluctuations, storm surge, and sea level rise.



Automobile Dismantler

Site Description

Lot size	5 acres
Design Flood Elevation (DFE) above grade	1-7 feet
Shoreline conditions	Rip-rap revetment

Business Profile

An automobile dismantler was selected as a prototypical site to explore flood resiliency challenges and mitigation measures for large, unenclosed industrial sites that contain immovable machinery and equipment. The selected business occupies a site that is approximately five acres and located entirely within the 1% annual chance floodplain. The business purchases inoperative cars from auto shops and private individuals. The cars are then dismantled and used auto parts and scrap metal (copper, lead, aluminum, etc.) are sorted, stored, and resold. Prior to Hurricane Sandy, the business employed approximately ten workers. In large part because of damage caused by Hurricane Sandy, the business has downsized to approximately three full-time staff.

Flood Risk Profile

The DFE on the automobile dismantler's site is very high, ranging from approximately one to seven feet above grade. Due to the nature of the business, the size of the site, and the number of cars and heavy parts, it is very difficult to protect the business's inventory from flooding. In addition to the potential for damage during floods, the presence of hazardous substances, such as oils, gasoline, and transmission fluid, pose an environmental and public health risk. The business does not carry a flood insurance policy.

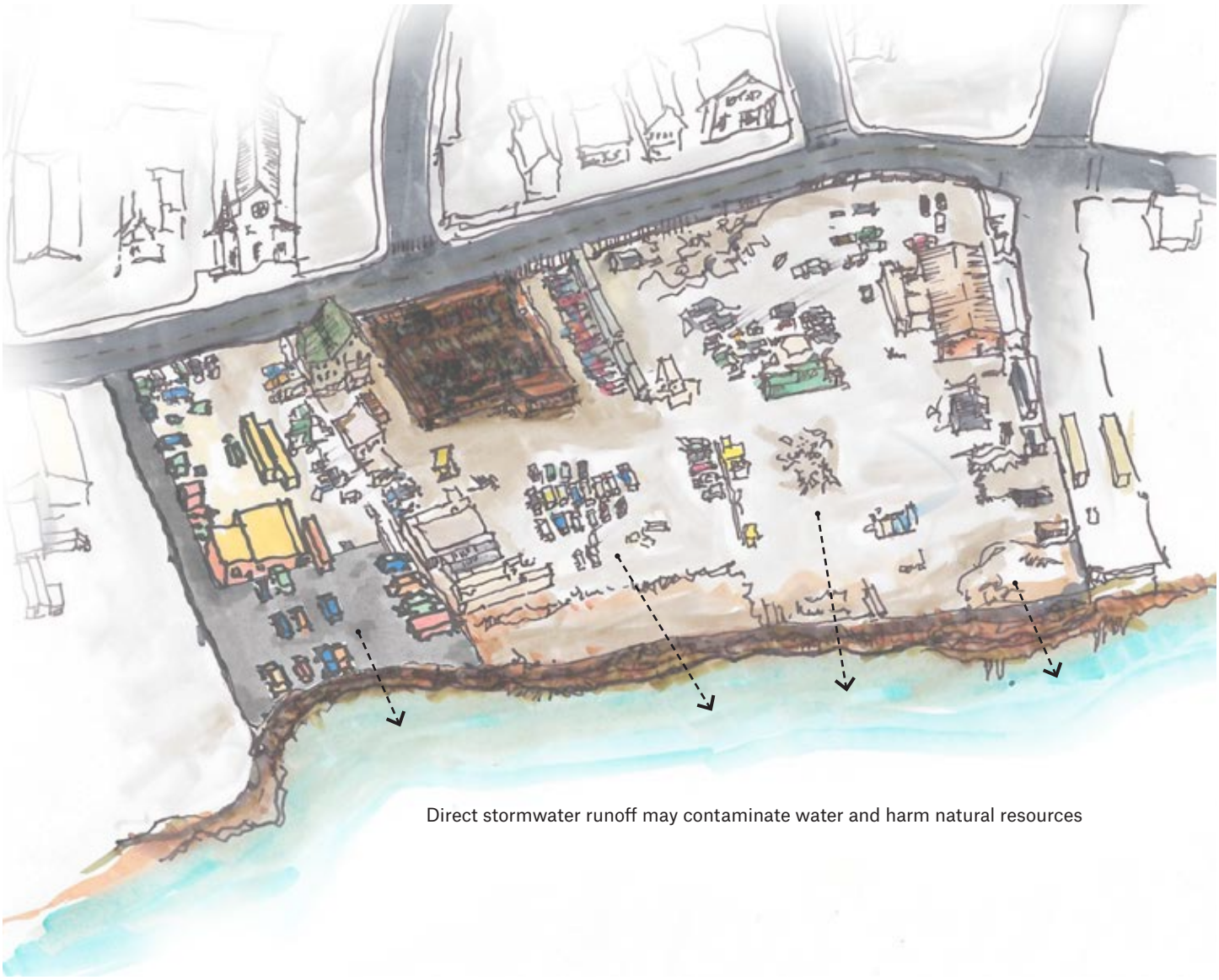
During Hurricane Sandy, the automobile dismantler's property was inundated by five to eight feet of water. The majority of the business's inventory of cars and auto parts was destroyed. The flooding also damaged several pieces of equipment, including a car crusher and a forklift. A small office on the property was also destroyed by Hurricane Sandy and subsequently replaced by a temporary trailer. In total, the business estimated that the storm damage totaled $500,000. While it is possible that hazardous substances leaked out of some cars that were inundated by flooding from Hurricane Sandy, the company did take steps in advance of the storm to have its tanks of used oils and automotive fluids emptied, which amount to several hundred gallons of hazardous substances that were removed from the facility before the storm.

Challenges and Resiliency Measures

Auto dismantlers, scrap metal recycling facilities, and other large, unenclosed industrial sites have common characteristics that affect their vulnerability to flooding. The following examples demonstrate strategies to minimize damage from flooding that may apply to a range of similar industrial businesses in New York City.

RESILIENCY CHALLENGE

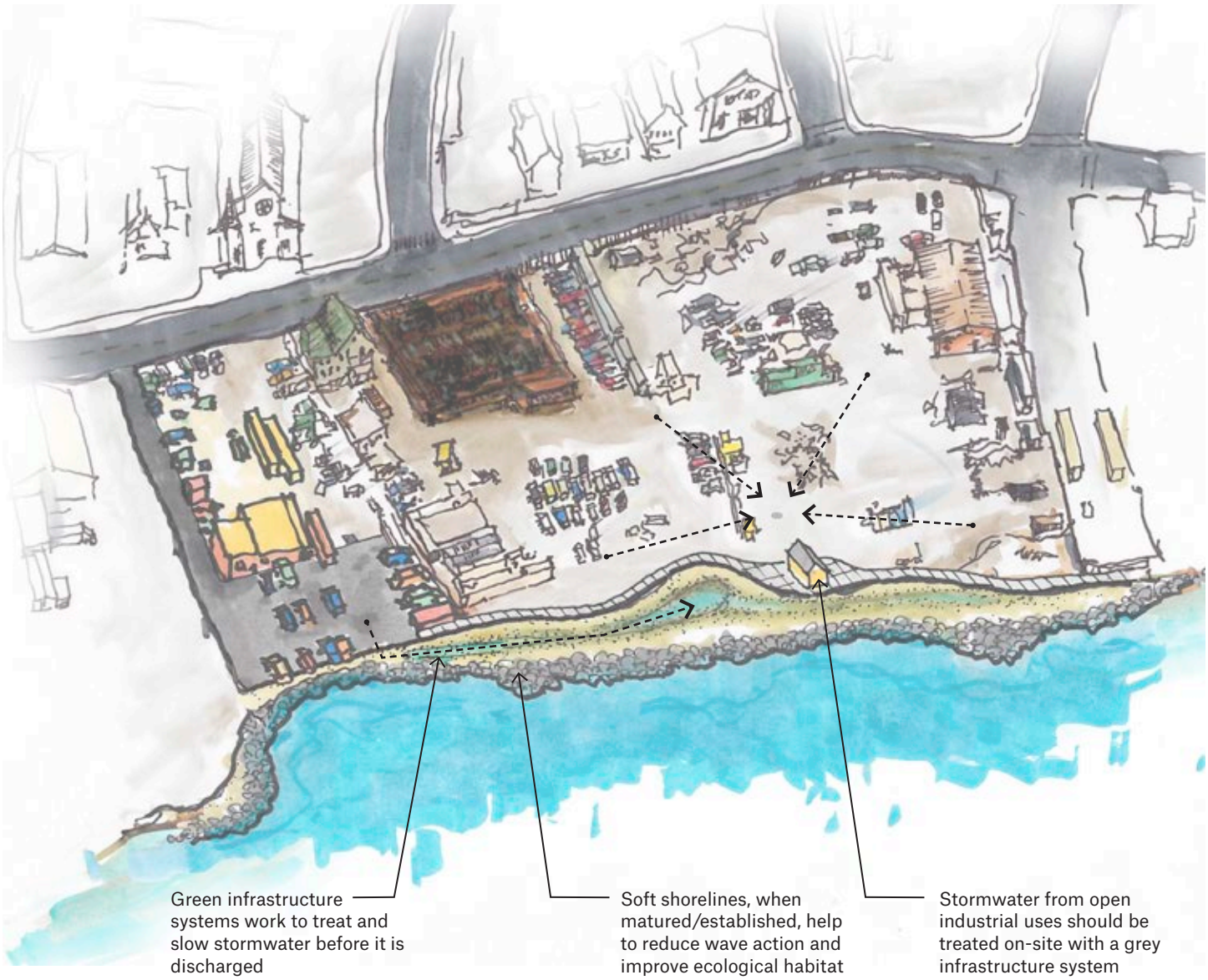
Stormwater runoff:
Open industrial facilities can contribute to water contamination when stormwater runoff is exposed to unenclosed materials. The absence of appropriately installed stormwater treatment systems can create a wide range of impacts. Stormwater runoff can pick up oils, grease, sediment, bacteria, debris, litter, and other contaminants and convey them into a storm sewer, a combined storm and sanitary sewer, or directly into coastal or riverine waters, depending on the location of the site. Hazardous materials carried by stormwater can also leach into the soil or ground water, contaminating the soil and underground aquifers. Leaching of chemicals and other pollutants often occurs when dismantled cars and discarded appliances are stockpiled in open yards. Open industrial sites that drain directly into the city's municipal sewer infrastructure can create costly maintenance problems. For example, concrete dust and other particulate matter can block city drains, triggering a system backup and flooding in the streets or on private property. Without proper controls, open industrial uses located adjacent to waterways or in the floodplains can pose further threats to coastal waters and tributaries during a severe storm or flood as a result of strong winds or elevated waters that can disperse unsecured materials off-site.



Direct stormwater runoff may contaminate water and harm natural resources

RESILIENCY MEASURES

Green infrastructure to manage stormwater runoff: Green infrastructure can be a valuable solution for absorbing or storing stormwater runoff. However, it should be carefully sited to avoid accidentally infiltrating pollutants into the surrounding soil, ground water, and surface waters. Green infrastructure should not be placed in areas with the potential for high concentrations of pollutants, such as heavy metals, oil and grease, chemicals, or other hazardous materials. Generally, this means placing green infastructure up-gradient of process and storage areas on industrial sites and redirecting contaminated stormwater away from green infrastructure. In the example below, green infrastructure may be effective for managing stormwater resulting from an employee parking area. Green infrastructure, such as native vegetation, bioswales, and green space can increase permeability of the infiltration system, absorb rainfall, and prevent water from overwhelming the stormwater system. The intention of green infrastructure for stormwater management is to decrease the volume of water that enters waterways as direct runoff through a combination of practices that infiltrate, evapotranspire, or store runoff for beneficial use. In areas affected by coastal flooding, green infrastructure and open space preservation can complement gray infrastructure approaches to further reduce damage to infrastructure and property.



RESILIENCY CHALLENGE

Unenclosed and unsecured inventory vulnerable to flooding: Auto parts and valuable salvaged materials that are submerged due to flooding, especially with saltwater, are likely to develop rust or be destroyed, eliminating their resale value. In addition to damaged inventory, unsecured auto parts and scrap metal that are dislodged by flooding can severely harm structures or equipment on the property and create similar hazards for nearby properties.

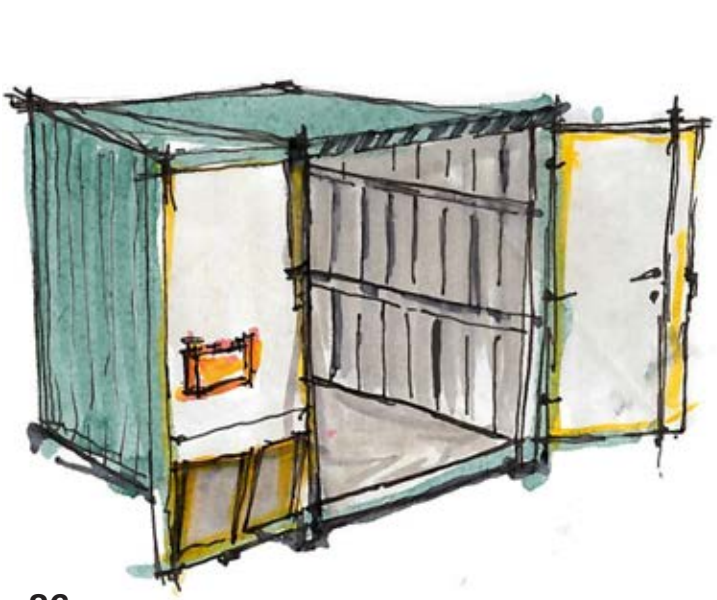
RESILIENCY MEASURES

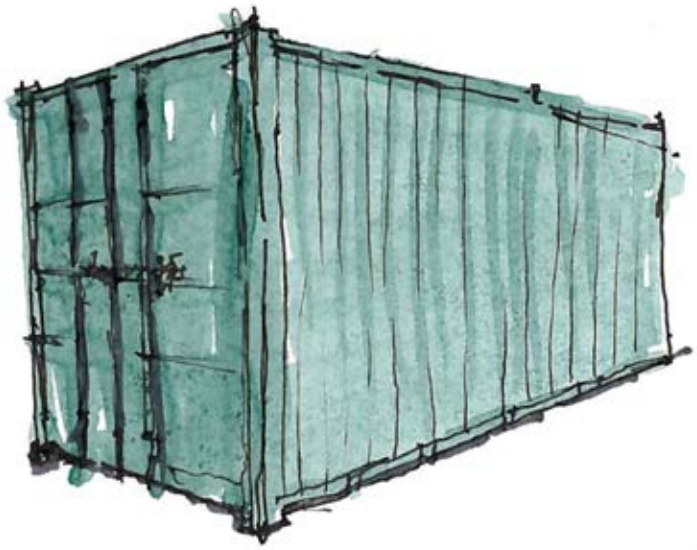
Store inventory in anchored shipping containers: Because of their low cost and durability, many industrial companies use shipping containers as makeshift storage structures. Shipping containers with water-tight doors can be purchased for approximately $2,500. The automobile dismantler case study installed shelving within the container and uses upper shelving to store more valuable equipment, such as salvaged catalytic converters or transmissions. Enclosed storage also protects valuable inventory from being displaced by wind. It is important to note that shipping containers used for permanent storage are required to comply with Appendix G of the NYC Building Code and should be secured to the ground.

APPROXIMATE COST

Shipping containers = ~$2,500

Elevate and anchor shipping container on 2' foundation = ~$11,200





RESILIENCY MEASURES

Install outdoor shelving to organize and secure inventory off the ground: Securing auto parts above grade with anchored shelving can help minimize damage from flooding. Higher value auto parts or other inventory that are most sensitive to flooding or saltwater should be prioritized and stored at higher elevations or moved to enclosed storage in advance of expected flooding.

Industrial Dry Cleaner

Site Description

Building floor area	3,900 square feet
Year built	1898
Design Flood Elevation (DFE) above grade	3-5 feet

Business Profile

Many dry cleaners and wet garment cleaners are located in industrial areas of New York City. The industry is trending toward larger, consolidated cleaning facilities with separate retail storefronts or pick-up and delivery service. Industrial scale cleaners provide an important service that supports other thriving sectors of the city's economy, including restaurants, hotels, and airports.

A dry cleaner was selected to better understand flood resiliency measures applicable to modestly sized industrial facilities with high-value, immovable equipment. The selected site has two retail storefronts located within the city, and also provides pick-up and delivery service to retailers and individual clients with a fleet of three large vans. The dry cleaning space operates out of a two-story, masonry building constructed in the 1890s. Cleaning equipment is all located on the ground floor, while finishing (e.g., ironing and bagging) occurs on the second floor. A modified shipping container is attached to the rear of the building and contains the boiler, air compressors, and additional supplies. Nearly 20 people are employed on-site, with additional employees located at the retail locations.

Flood Risk Profile

The dry cleaner used as a case study is located entirely in the 1% annual chance floodplain, with a DFE of approximately three to five feet above grade. During Hurricane Sandy, floodwaters rose nearly five feet within the building, inundating both dry cleaning machines and wet cleaning machines located on the first floor. Some electrical components and motors of dry cleaning machines were damaged. Because of the high risk associated with perchloroethylene (PERC), these machines are bolted to the ground and operate on a sealed, closed-loop system. Therefore, floodwaters did not enter the dry cleaning machines, which left them mostly undamaged. Several wet cleaning machines were destroyed by flooding, which cost approximately $25,000 each to replace.

Within the shipping container attached to the rear of the building, air compressors were destroyed and a boiler became buoyant and was destroyed during Hurricane Sandy. Water soluble solvents and detergents were uncontained and spilled during the flood. All three vans owned by the company were parked outside the business and were totaled by the storm. These were covered and replaced by individual vehicle insurance policies. In total, the business estimated damages to be approximately $575,000.

The business did not have flood insurance prior to Hurricane Sandy, which the owner was unaware of until after the storm. However, the business has since decided not to carry a flood insurance policy because the quoted premium of $100,000 annually seemed too high relative to potential damages from future storms. Instead the business is interested in minimizing losses by improving preparedness planning and investing in flood mitigation.

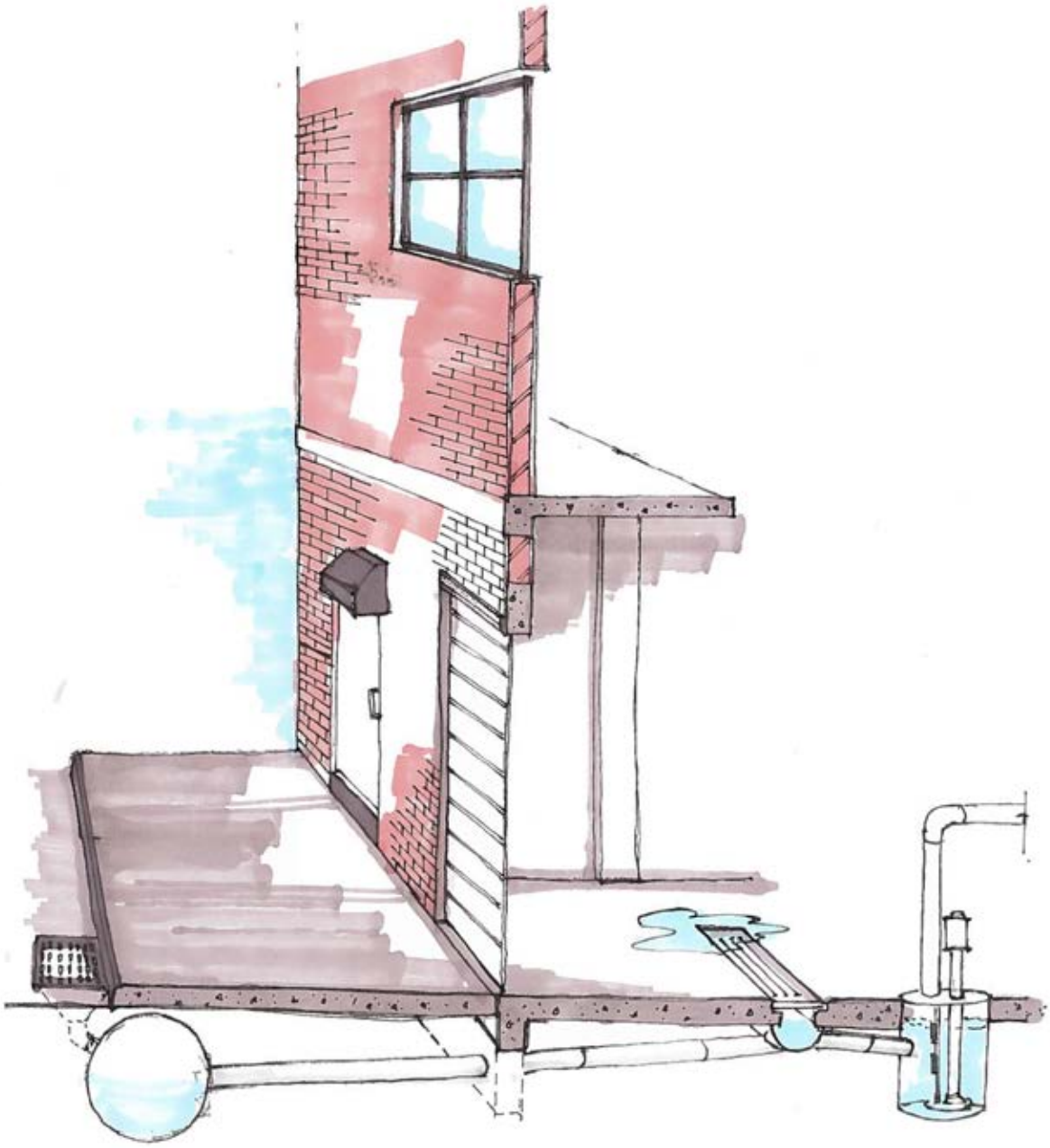
Operational Resiliency

Based on its experience during Hurricane Sandy, the dry cleaner has developed a preparedness plan to reduce damages during future predicted flooding events and ensure continuity of operations. The plan specifies that, in advance of a storm, electrical components such as pumps and controls will be removed from dry and wet cleaning equipment and stored on the second floor or in another location outside of the floodplain. Staff receive regular training to safely remove these components.

In addition, the dry cleaner has created an agreement with another dry cleaning business located outside of the floodplain to be able to temporarily use its facility in the event of future flooding or another type of disruption. The preparedness plan describes staffing arrangements to operate at night while the temporary facility is not in use.

Challenges and Resiliency Measures

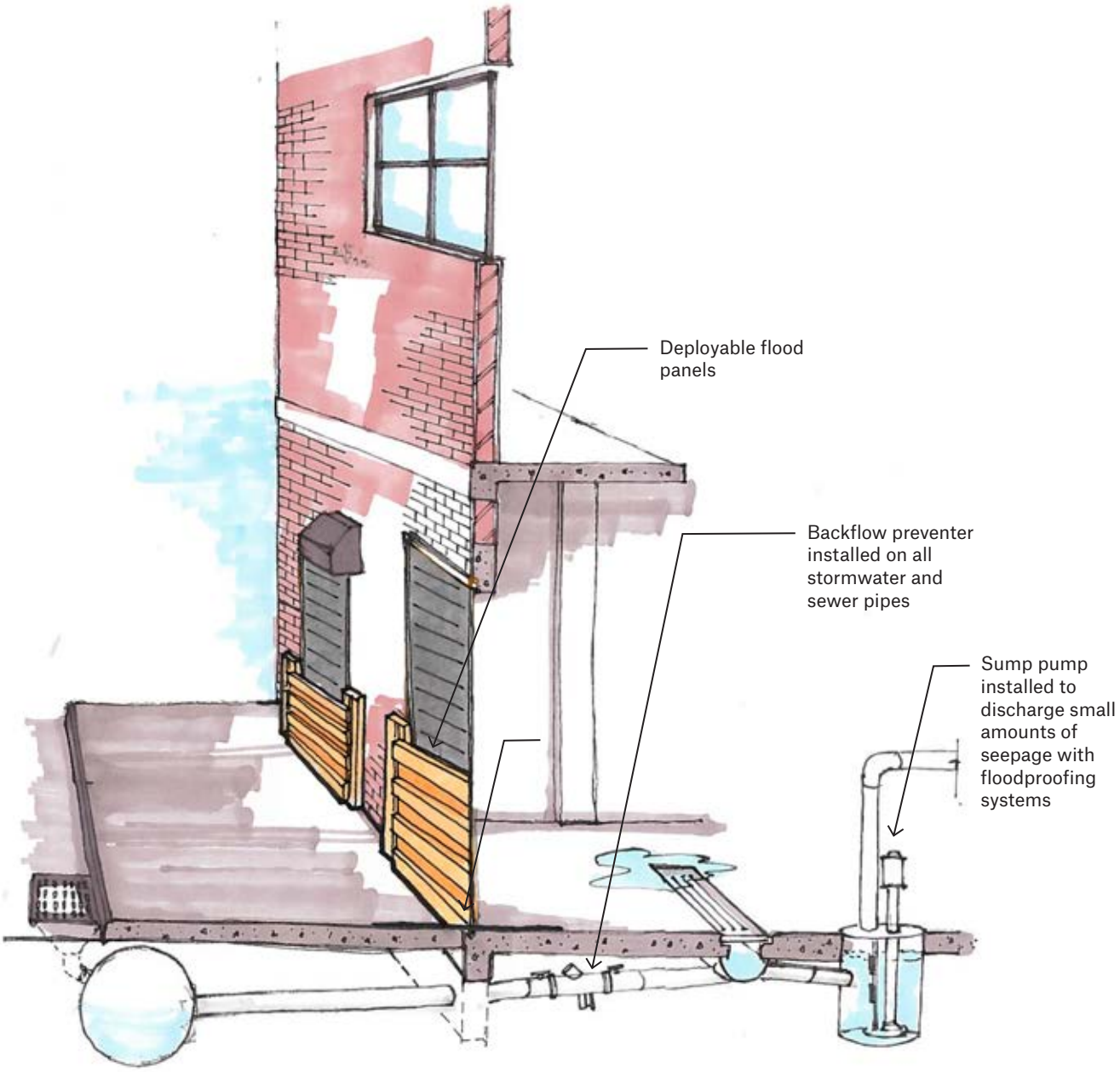
Industrial dry cleaners and other smaller industrial spaces containing high-value equipment have common characteristics that affect their vulnerability to flooding. The following examples demonstrate strategies to minimize damage from flooding that may apply to a range of similar industrial businesses in New York City.



RESILIENCY CHALLENGES

Valuable and immovable dry cleaning equipment unprotected from flooding: The dry cleaning and wet cleaning machines are the most valuable physical assets of the case study business. These are unprotected and uninsured from flooding. Damage to this equipment poses a significant financial risk for the business and has the potential to delay recovery time following storms. The use of hazardous materials for dry cleaning operations increases the risk of this equipment being located below the DFE.

Stormwater backflow can result in interior flooding despite dry floodproofing: Even if buildings are dry floodproofed to prevent floodwater from entering, coastal storms and flooding can overwhelm drainage systems, resulting in stormwater backflow that causes flooding from within the structure.



RESILIENCY MEASURES

Dry floodproof exterior of building: The relatively small footprint of the dry cleaner and the high potential cost for flooding makes dry floodproofing an option that should be considered to improve flood resilience. Dry floodproofing typically involves sealing a building's exterior and openings to prevent water from infiltrating in the event of a flood. Many different products exist for dry floodproofing, including flood panels, waterproof membranes for walls, and waterproof doors and gates. If dry floodproofing systems must be manually deployed in advance of a flood, regular training of staff and maintenance of equipment should be conducted to ensure systems remain effective.

Install sump pumps to remove excess water: Sump pumps are able to remove small amounts of water that leak into a building and are an important component of dry floodproofing systems. Sump pumps are installed below the ground floor and consist of drainage pumps that automatically remove water from sump pits through discharge pipes.

Install backflow preventer on stormwater pipes: Backflow preventers, also called backflow valves, ensure that stormwater is only able to flow in one direction, away from the building's stormwater drain.

APPROXIMATE COST*

Flood panels at door openings = ~$15,000 each

Flood panels at roll-up gates = ~$21,000 each

Install backflow preventer = ~$15,800

Install sump pump = ~$24,500

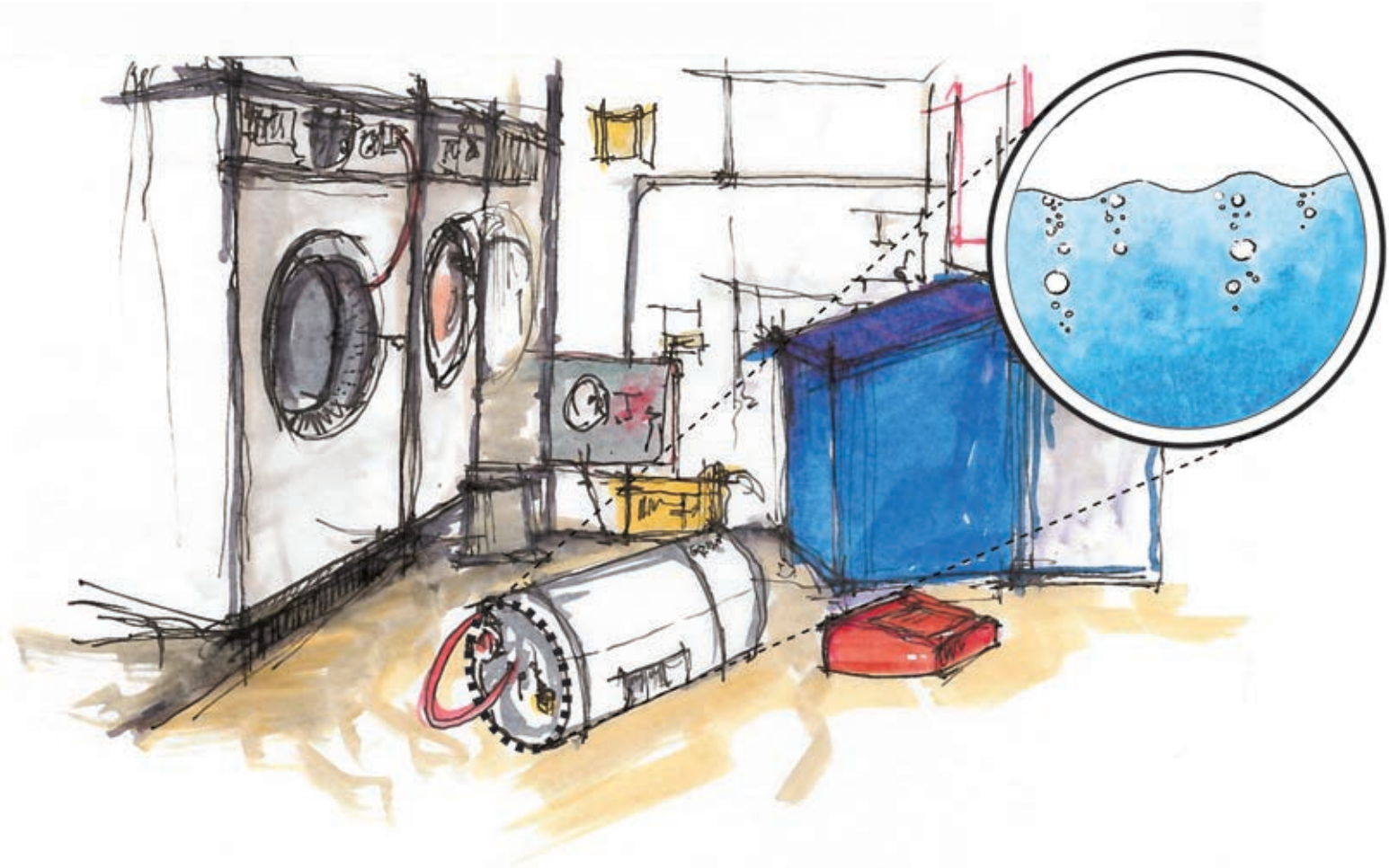
**See cost estimation on pg. 110 for more info*

RESILIENCY CHALLENGE

Debris impact load resulting from equipment dislodged by floodwater: Dislodged equipment during floods can become debris, which can cause further structural damage to the property. Unfilled water tanks and boilers may be removed from their locations by hydrodynamic forces and become buoyant. Depending on the weight of the object and water velocity, this can create additional damage to other equipment and structures on site.

RESILIENCY MEASURE

Fill water tank to prevent buoyancy: To reduce the likelihood of water tanks being dislodged by floodwater and minimize risk of additional debris load, water storage tanks, particularly elevated tanks, should be filled in advance of storm events. This serves to maintain fully pressurized water mains during the storm, provide backup water supply in the event of power outages, and weigh down elevated tanks that may be affected by heavy winds and flooding.

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New York Container
Terminal in Staten Island