Chapter 16. Energy, Pipelines, and Telecommunications Infrastructure

Energy, pipelines, and telecommunications infrastructure provide vital services within the ART project area and connect it with other parts of the region, state, nation, and world. Most, if not all, of the electricity consumed in the ART project area is produced outside of the subregion. However, there are two small power plants in the ART project area as well as infrastructure that transports electricity produced elsewhere to end users within and beyond the area. Pipelines carry petroleum and fuel from refineries outside of the ART project area to major end consumers within the area – such as Oakland Airport and truck terminals – and through the area to consumers elsewhere. Telecommunications infrastructure provides telephone and Internet services to residents and businesses in the subregion, connecting them to each other and with the rest of the world.

The components of the ART project area's electricity infrastructure addressed in this report are power plants, substations, and transmission lines. There are two power plants in the ART project area: an oil-powered plant in Oakland owned by Dynegy, and a natural gas and diesel plant in Alameda owned by the Northern California Power Agency (NCPA) (Table 1). The Dynegy plant is a peaking plant, meaning it only operates during times of high demand, and it provides power to the California Independent System Operator (CAISO).[1] The NCPA plant is a peaking and reserve plant. This means that these plants are not in use all the time, but only when other sources of electricity cannot meet demand. Data on where power produced by the Alameda NCPA power plant is consumed was not available.

Electricity is carried from where it is generated via high-voltage transmission lines, which can be overhead or underground. Major overhead electrical transmission lines run parallel to the shoreline. Substations link the energy transmission system to the distribution system,

Figure 1. Energy assets evaluated include substations, which connect transmission and distribution systems and are a critical component of the electricity system.

[1] The CAISO coordinates, controls and monitors the operation of the long-distance, high-voltage electrical power system for most of the State of California.

transforming power from the high voltage at which it is generated to a lower voltage for distribution to individual homes and businesses via overhead and underground utility lines. Substations also connect lines within both the transmission and distribution systems and are a critical component of the electricity system. Substations hold expensive and potentially dangerous equipment such as transformers, which change the voltage of electrical current; capacitors, which store energy in an electric field; and voltage regulators, which maintain a constant voltage. They can be aboveground in fenced enclosures, underground, or located in special-purpose buildings. There are 15 substations situated near the shoreline in the subregion (Table 1).

Table 1. Substations and power plants in ART project area

Name	Type of Asset	Operator	Location	Service Area*
Oakland P	Substation	PG&E	Oakland, near Bay Bridge onramp	Oakland
Maritime	Substation	Port of Oakland	Port of Oakland	
Schnitzer Steel	Substation	PG&E/Schnitzer Steel	Oakland, near Inner Harbor	Schnitzer Steel
Oakland C	Substation	PG&E	Oakland, near Jack London Square	Oakland
Oakland I	Substation	PG&E	Oakland, near Jack London Square	Oakland
Naval Supply Center	Substation	PG&E	Alameda	
NCPA	Substation	NCPA	Alameda	
Cartwright	Substation	AMP	Alameda	Alameda
Jenny	Substation	PG&E	Alameda	Alameda
Owens Brockway	Substation	Owens Illinois	Oakland, South	Owens-Brockway Glass Containers
Oakland J	Substation	PG&E	Oakland, South	Oakland
EDES	Substation	PG&E	Oakland, near Airport	Oakland, San Leandro
DOMTAR	Substation	Domtar Gypsum	San Leandro	Domtar Gypsum
Grant	Substation	PG&E	Hayward	San Leandro, San Lorenzo, Hayward, Cherryland, Ashland
Eastshore	Substation	PG&E	Hayward	Hayward
Oakland	Power Plant - Peaking	Dynegy	Oakland	CAISO
Alameda	Power Plant - Peaking & Reserve	NCPA	Alameda	

* Service area information was not available for all assets.

Natural gas is transported via underground pipelines. For example, there is a major natural gas pipeline owned by PG&E that parallels I-880. Liquid petroleum jet fuel, gasoline, and diesel fuels are also transported via pipelines that cross the ART project area. A pipeline owned and operated by Kinder Morgan enters the ART project area from the north and runs parallel to the shoreline to the Oakland Airport. The pipeline is buried in a raised dike along the edge of the airport, with five to six feet between the water level and the top of the dike, before crossing the Bay to the San Francisco Airport via Brisbane. In general, these pipelines are buried at a depth of 3 to 4 feet in high-carbon steel pipelines, and many are located in railroad and Caltrans right-of-ways. Some pipelines cross natural areas such as marshes and flood control and stream channels.

Telecommunication cables are usually buried underground at a depth of 2 to 5 feet or carried by overhead telephone lines. There are access points along the underground cables that allow for periodic maintenance and replacement. Many of the telecommunication lines in the ART project area are located in railroad and Caltrans right-of-ways.

The energy, pipelines, and telecommunications industries and infrastructure addressed in this report are regulated by a number of State and Federal agencies. The Department of Transportation's (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), through the Office of Pipeline Safety (OPS), is the federal regulatory agency responsible for the oversight of pipeline safety. At the State level, the California Public Utilities Commission (CPUC) regulates electric and gas utilities, as well as some aspects of the telecommunications sector, and the State Fire Marshal acts as an agent of PHMSA with respect to pipeline safety. PHMSA regulations include safety-related requirements such as pipeline coating and burial depth, as well as periodic inspection of transmission pipelines, including surveying pipeline right-of-ways for excavation activities or population encroachment and detection of leaks and threats of corrosion. Utilities are also required to identify "High Consequence Areas" (HCA), such as areas with dense populations, and perform more rigorous inspections in these areas.

Exposure

Exposure is the extent to which an asset, such as a substation, power plant, or other infrastructure, experiences a specific climate change impact such as storm event flooding, tidal inundation, or elevated groundwater. This report analyzes the exposure of energy infrastructure in the ART project area to two sea level rise projections and three Bay water levels. The two sea level rise projections, 16 inches (40 cm) and 55 inches (140 cm), correlate approximately to mid- and end-of-century. These projections were coupled with three Bay water levels: the highest average daily high tide represented by mean higher high water (MHHW), hereafter "high tide" or "daily high tide;" the 100-year extreme water level, also known as the 100-year stillwater elevation (100-year SWEL), hereafter "100-year storm" or "storm event;" and the 100-year extreme water level coupled with wind-driven waves, hereafter "storm event with wind waves" or "wind waves." These water levels were selected because they represent a reasonable range of potential Bay conditions that will affect flooding and inundation along the shoreline. For more information about sea level rise projections and Bay water levels evaluated see Chapters 1 and 2.

Figure 2. Exposure of power plants and substations to daily high tide and storm events with 16 and 55 inches of sea level rise

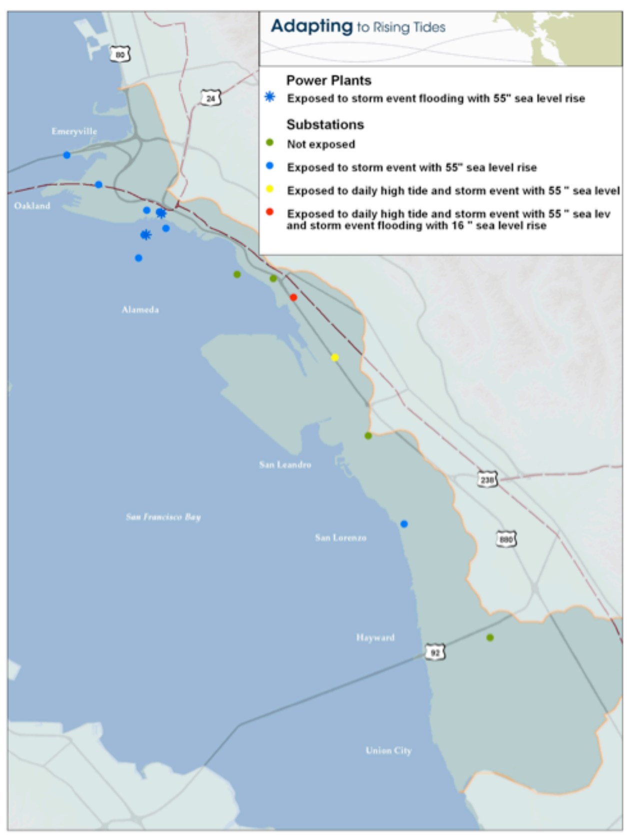

Figure 2 and Table 2 summarize the exposure of power plants and substations. Exposure analysis was not performed for transmission lines, pipelines, or telecommunications infrastructure due to data limitations. Exposure was determined within a circular 164-foot (50-meter) diameter footprint centered on the point location of each plant or station (see Appendix C). This approach was verified as being representative of the approximate footprint of most assets evaluated in this manner. The average depth of inundation was calculated for the daily high tide and storm event scenarios. Whether the asset was exposed to wind waves only, or was within a disconnected low-lying area[2], was evaluated in a binary, i.e., yes versus no, analysis.

Table 2. Exposure of substations and power plants in the ART project area to 16 and 55 inches of sea level rise.

	16" SLR			55" SLR		
	Daily High Tide	Storm Event		Daily High Tide	Storm Event	
Asset	Average depth (ft)	Average depth (ft)	Exposed to wind waves only	Average depth (ft)	Average depth (ft)	Exposed to wind waves only
Oakland P Substation			Yes		2	
Maritime Substation			Yes		1	
Schnitzer Steel Substation			Yes		2	
Oakland C Substation			Yes		1	
Oakland I Substation			Yes		1	
Naval Supply Center Substation			Yes		2	
NCPA Substation			Yes		2	
Cartwright Substation			Yes		2	
Jenny Substation						Yes
Owens Brockway Substation						
Oakland J Substation		1	Yes	2	4	
EDES Substation			Yes	1	4	
DOMTAR Substation						
Grant Substation			Yes		3	
Eastshore Substation			Yes			Yes
Oakland Power Plant			Yes		1	
Alameda Power Plant			Yes		2	

[2] Disconnected low-lying areas are at the same elevation or are lower than an adjacent inundated area. Assets in these areas are not considered exposed because a topographic feature such as a railroad or road embankment should prevent inundation. However, they could be exposed if the protective feature fails. See Chapter 2 for a more detailed explanation.

With 16 inches of sea level rise, none of the substations or power plants evaluated are directly exposed to the new daily high tide. However, one substation, Oakland J, is in a disconnected low-lying area, and while not directly exposed, is potentially at risk of flooding depending on the type or condition of the topographic feature that prevents inundation or flooding. In addition, access to facilities located in low-lying areas could be limited if and when adjacent areas are inundated.

During a storm event with 16 inches of sea level rise, the Oakland J substation is exposed to 1 foot of flooding. The EDES and Grant substations are in disconnected low-lying areas adjacent to areas that will flood during a storm event, and are therefore are potentially at risk. All of the substations except for Jenny, Owens Brockway, and DOMTAR are exposed to wind waves during a storm event, as are both of the power plants.

With 55 inches of sea level rise, Oakland J and EDES substations are exposed to 2 feet and 1 foot of flooding, respectively, from the new daily high tide, and the Oakland power plant is in a disconnected low-lying area, and is therefore potentially at risk. Both of the power plants and all of the substations except for Jenny, Owens Brockway, DOMTAR, and Eastshore are exposed to 1 to 4 feet of flooding during a storm event, and all of the assets are exposed to wind waves except for Owens Brockway and DOMTAR substations.

Sensitivity and Adaptive Capacity

The sensitivity and adaptive capacity of energy, pipelines, and telecommunications infrastructure in the ART project area to three potential climate impacts that could occur due to sea level rise was assessed. The three climate impacts considered are:

- More frequent or longer duration flooding during storm events
- Permanent or frequent inundation by the daily high tide
- Elevated groundwater levels and saltwater intrusion

Sensitivity is the degree to which an asset or entire system (e.g., electricity generation, transmission, and distribution; fuel, oil, and natural gas conveyance; and telecommunications) would be physically or functionally impaired if exposed to a climate impact. Adaptive capacity is the ability for an asset or system to accommodate or adjust to a climate impact and maintain or quickly resume its primary function. The electricity, pipelines, and telecommunications infrastructure assessment considers various types of assets, with a correspondingly wide range of sensitivities. The sensitivity and adaptive capacity of individual assets, as well as each type of asset, as a system, is addressed below.

<u>Energy Assets – Power plants, substations, and transmission and distribution lines</u>
Power plants and substations are sensitive to flooding from storm events. They would also be sensitive to the daily high tide, but none of the assets analyzed here are exposed to this impact, although some are in disconnected low-lying areas that could be exposed. Further, it is unlikely that power plants or substations would be able to maintain function if inundated frequently or permanently, and it is assumed that they would be relocated if exposed to this impact. In the event of storm-related flooding, the equipment at power plants and substations could be damaged by water – particularly saltwater, which causes corrosion – as well as by any mud or debris that floodwaters could be carrying. If power plants were to be damaged by flooding, equipment may have to be replaced, resulting in a lengthy recovery period.

Other aboveground electricity infrastructure consists of overhead lines. These are not sensitive to flooding, unless waves or currents are so strong that they cause poles to topple. Electricity assets are not sensitive to rising groundwater, unless they have underground components –

such as a belowground floor of a substation with sensitive equipment that could be exposed to groundwater seeping into the building. Also, higher groundwater adds to liquefaction potential, which could make poles carrying transmission and distribution lines less stable in a seismic event.

Power plants and substations have a moderate degree of adaptive capacity. Power plants and substations can be shut down to prevent major damage from floodwaters such as corrosion to transformers, capacitors, switches and other equipment. The proper shutdown of power plants takes time, however, which adds to their sensitivity. With enough advance warning, some equipment can be moved – either to another location out of the flooded area, or raised to levels above the floodwaters. On-site protection measures such as sandbagging or pumping could also keep water away from sensitive equipment. The ability of substations to transfer electricity loads to other substations outside of the floodplain contributes to adaptive capacity of the system as a whole. Data was not available on whether there is any redundancy in distribution lines within the ART project area, which would allow operators to serve customers from different substations in the event that one or more substations are forced to shut down due to flooding. Emergency plans, such as having a shutdown plan and options for the removal of equipment in advance of a flood, are another important component of adaptive capacity. Having access to temporary, mobile substations to provide service while cleaning up damaged substations would also contribute to adaptive capacity.

Fuel, petroleum, and natural gas pipelines

The pipelines in the ART project area are buried several feet beneath the ground. In the event of flooding, pipelines that are not weighted or anchored may float and become exposed, particularly during prolonged flooding and in marshy or sandy soils. Erosion during storm events could also expose and damage pipelines. For example, heavy debris could dent or puncture the pipes, or in the event of a fully exposed pipe, swiftly moving water could move, bend, or break it, causing a leak. Aside from direct damage to cables and pipes, access to underground infrastructure could be compromised in the event of flooding, which could hinder any necessary maintenance.

Underground infrastructure such as pipelines could be sensitive to rising groundwater and saltwater intrusion, and some of this infrastructure is already exposed to such impacts. For example, some pipelines along the shoreline come into contact with groundwater every day as it rises and falls with the tide. However, government regulations require pipelines to be coated and cathodically protected[3] against corrosion. Following these guidelines lowers the sensitivity of such infrastructure to rising groundwater and saltwater intrusion. Another source of sensitivity to rising groundwater is the risk of liquefaction in a seismic event. The ART project area is in an area of high seismic vulnerability and liquefaction potential – the northern portion of the area, particularly the Emeryville, Oakland, and Alameda waterfront and Oakland International Airport fill areas, has a very high liquefaction susceptibility rating, while the southern portion including San Leandro, Hayward, and Union City, have a moderate liquefaction susceptibility rating (ART, 2011). Liquefaction and lateral spreading have caused damage to buried pipelines during past earthquakes in the region and in other parts of the world (Wang and Zhang, 1992; Tajika et al., 2008). With rising groundwater, the likelihood and extent of liquefaction will increase, magnifying the potential for damage to buried assets in a seismic event.

Adaptive capacity for pipelines derives in part from adhering to regulations such as those described above, as well as regular maintenance and procedures to monitor the condition of the

[3] Cathodic protection is a technique to control the corrosion of a metal surface by making the structure work as the cathode of an electrochemical cell.

pipes. Fuel pipelines are generally well protected – buried several feet below the ground surface (or streambed in the case of water crossings) or in a railroad embankment – and are hydro-tested or internally inspected at least every five years. If any damaged areas are found, the pipeline is dug up and repaired. Likewise, if storm event flooding were to damage a pipeline, valves could be closed on either side of the damaged area to minimize the quantity of material that could escape. This would disrupt service, and if reserves are low, operators may have to transport product by truck to meet demand. If pipelines were seriously threatened by sea level rise, they could be re-located, although this would be very capital intensive.

As with power plants and substations, a well-coordinated emergency response plan also contributes to adaptive capacity. If fuel or gas pipelines are compromised, responders need to know where infrastructure is located; have a plan to isolate the problem, for example by closing valves and removing product; be ready to counteract any consequences such as leaking fuel or escaping gas and associated fire hazards; and have a plan to restore service. Further, the sensitivity and adaptive capacity of the entire system – of electricity transmission and distribution, and of pipelines – depends on the ability of operators and emergency responders to handle any impacts that might occur. A flooded substation, for example, would be the responsibility of the owner/operator; therefore, areas in which many assets owned by the same company are exposed to the same impact may be particularly sensitive, since that company could be stretched thin in the event of flooding. If a pipeline carrying fuel is compromised, it will involve the owner, as well as emergency responders and a number of agencies responsible for environmental protection, public health, and other elements of the community that would be affected by an accidental release.

Adaptive capacity is also built through awareness and planning ahead. PG&E, for example, formed a cross-departmental Climate Change Operational Impact Team in 2008, which conducts bi-annual reviews of scientific literature on sea level rise and other climate impacts. These reviews are intended to identify climate risks to facilities and inform the development of adaptation strategies (PG&E, 2011). While sea level rise is currently considered a "low-medium" risk, the company states that they are aware of potential risks and will address them over time.[4]

Telecommunications infrastructure

Telecommunications cables and wires run both overhead and underground. Overhead telecommunications lines, like electricity transmission and distribution lines, have low sensitivity to flooding and rising groundwater. Underground cables, however, could be sensitive to severe flooding if erosion occurs – in Queensland, Australia, for example, cables buried 1.5 meters deep were severed during an extreme storm in 2011 (Braue, 2011). Cables that are buried above the current water table could be sensitive to rising groundwater and saltwater intrusion if they were not designed to withstand such conditions, and liquefaction in an earthquake could cause them to shift and break. Flooding could also impair access to underground infrastructure, which could prevent or delay repairs. Power is required for many cellular telecommunication facilities to operate, and on-site backup power is generally not required, linking cellular functionality to the vulnerability of the electrical grid.

As is the case with electricity substations, adaptive capacity in telecommunications comes in part from the ability to shift loads to unimpaired infrastructure. Adaptive capacity of the system is enhanced by replication – that is, the multiple channels available for communication – through mobile phones, landlines, and through the Internet, for those with access. Given the rapidly changing nature of the telecommunications sector, it is difficult to predict what types of

[4] PG&E has not had access to elevation data that is sufficiently accurate for the company to assess the risk to its infrastructure from sea level rise flooding; more accurate data should be made available to the company to facilitate the evaluation of risk to exposure.

technology will be in use over the time scale considered in this report, but the basic principles of flexibility and overlap should still contribute to adaptive capacity.

Consequences

The potential consequences of the climate impacts on the energy, pipelines, and telecommunications infrastructure are considered for the ART project area. Consequences are the magnitude of the economic, social, environmental, and governance effects if an impact occurs. Factors that inform the magnitude of the potential consequences include the severity of the impact on operations and maintenance or capital improvement costs, the size and demographics of the population affected, and the types of natural resources affected.

<u>Economy</u>

Energy, pipelines, and telecommunications infrastructure provide vital services within the ART project area, as well as linking it to regions outside the area. The disruption of this infrastructure could therefore have serious economic consequences. If substations or power plants are threatened with flooding, they will be shut down, and if equipment is damaged they could be out of service for some time. Repair or replacement of damaged equipment could be quite expensive. As discussed above, managers may be able to shift electricity loads to other substations. If not, however, the areas served by flooded substations would lose power until any damaged or moved equipment is repaired or replaced. Loss of power can range from an inconvenience, if only for a short duration, to a serious problem if power is out for a long time, as it could result in a loss of productivity due to workplaces and schools being closed.

If fuel, petroleum, or natural gas pipelines are disrupted and alternate forms of transportation are unavailable or too costly, end users – such as the Oakland Airport – could be forced to suspend operations, which could have serious economic consequences. Managers try to ensure that there is a reserve available, and fuel can be trucked if the pipelines are out of service, but trucking fuel is more expensive than transporting it via pipeline. Further economic consequences in the form of operations and maintenance and capital improvement costs could occur if any pipelines are damaged and have to be repaired, or, as a last resort, re-located. In the event that a climate impact actually results in a release of fuel or natural gas, cleanup costs could also be quite high.

If telecommunications infrastructure such as telephone lines and Internet cables were to be impaired by flooding, it could seriously disrupt business operations, with corresponding economic consequences. Repairing any damaged infrastructure would also incur costs.

<u>Society</u>

Since the power plants in the ART project area are peaking and reserve plants, there would only be consequences in the form of a power shortage if a sea level rise impact occurred during a time of peak demand or if base plants were disabled at the same time. Further, because the Oakland power plant provides power to the CAISO rather than directly to the region, the ART project area may not be affected if it is shut down. If power is disrupted, either due to power plants or substations being affected by a climate impact, the consequences for society could be fairly serious – in addition to lost productivity from the closure of schools and workplaces, many other important services rely on power being available. For example, telecommunications and pumps, which are vital during an emergency, could be forced out of service unless backup power is available. Power outages also pose health risks for residents who rely on home medical equipment such as ventilators and oxygen concentrators, which require electricity to function. A prolonged power outage could also make it difficult for residents to heat and light their homes or cook if they rely solely on electricity for these services.

The societal consequences of a climate change impact on pipelines are likely to be minimal to moderate, depending on the severity of disruption to the transportation of fuel and natural gas. However, if a fuel or natural gas pipeline were to leak or explode, due for example to liquefaction in a seismic event, there could be serious consequences for the life and health of those in proximity to such an incident.

If telecommunications infrastructure is directly affected by a climate impact, it could hamper emergency response as well as everyday communication needs. Cellular networks could enable basic communication to carry on, although if electricity services are impaired, people will be unable to charge their mobile phones and cellular facilities that rely on power to operate may go out of service. Residents who rely on landline services and do not have access to cellular or Internet services would be particularly affected by the effects of a climate impact on electricity and / or telecommunications, as they would have fewer options to communicate with emergency responders and family members. This could have equity implications, as such individuals are often among the elderly or low-income populations.

Environment

There could be environmental consequences of a climate impact on power plants and substations if fuels such as oil or diesel, or other materials used in these facilities were to be moved offsite by floodwaters. As noted above, if liquefaction in a seismic event caused a pipeline to leak or explode, the environmental consequences could be significant, especially where pipelines run through sensitive areas such as marshes and wetlands.

Governance

Most of the assets covered in this section are privately owned but regulated by a number of state and federal agencies. Governance consequences depend on the type of impact – for example, releases of materials from power plants or pipelines could involve PHMSA and the CPUC, not to mention emergency responders and environmental agencies. A coordinated response can be challenging to implement, especially if multiple facilities are affected at once, which could overwhelm asset owners, emergency responders, and regulatory agencies.

Key Findings

The energy, pipelines, and telecommunications infrastructure assessed for the ART project area includes power plants, substations, transmission lines, natural gas and liquid petroleum pipelines, telephone poles, and underground cables. Geo-referenced data was only available for power plants and substations, and these were the only assets for which an exposure analysis was conducted. Of the 15 substations and two power plants in the ART project area, none are exposed to the daily high tide with 16 or 55 inches of sea level rise, but almost all are exposed to wind waves with either amount of sea level rise. All but four of the assets evaluated are exposed to storm event flooding with 55 inches of sea level rise.

Aboveground energy infrastructure such as substations and power plants are very sensitive to water. These assets would need to be shut down to prevent damage if exposed, and even so, damage to sensitive equipment could still occur. Underground assets such as pipelines and cables are less sensitive than aboveground infrastructure, but the consequences if they are affected can be very high. For example, if a liquid fuel pipeline were to break during a seismic event due to increased liquefaction caused by elevated groundwater levels, surrounding natural resources and wildlife could be seriously affected.

The adaptive capacity varies depending on the type of asset considered. Telecommunication systems have fairly high redundancy, which contributes to this asset's fairly high adaptive capacity. For example, there are multiple options for communication such as Internet, landline, and mobile phones. Pipelines regulations mandating protection against corrosion and the placement of shutoff valves contribute to adaptive capacity for this system of assets, while flexibility in load shifting would increase the adaptive capacity of energy infrastructure.

There is a general lack of information for these systems of assets, which increases vulnerability. For example, the location of telecommunications infrastructure was not available, and such information may be lost as older technologies are abandoned and new ones are implemented. Information about plans for shutting down power plants and substations and moving sensitive equipment above flood levels was not available, nor was information available about redundancy among electricity substations.

Given the lack of exposure data and overall information about the type and location of the different assets, the overall vulnerability of this asset category cannot be determined at this point. It would be worthwhile to conduct further analysis, not only because there are fairly high potential consequences if these assets were to be compromised, but also because of the role they play in the event of an emergency. For example, telecommunications and electricity are critical during a flood in order to coordinate response, pump floodwater away from people and vital infrastructure, assist with rescue, and initiate recovery actions.

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