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Resilient Ways Forward:

Vulnerability Assessment Phase I

DUTCHESS COUNTY
TRANSPORTATION COUNCIL
Better ways from here to there

Disclaimer

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Introduction

Resilient Ways Forward seeks to understand how and where our transportation system is most vulnerable to climate change. The first phase of this assessment is a system level analysis to understand the sensitivity of various components of the transportation system to specific climate hazards (see textbox for focus assets and hazards). This system-level approach will screen for priority climate risks across the transportation system to be analyzed further during the more detailed phase two asset-level analysis.

Focus Transportation Assets:

- Roads
- Bridges
- Culverts
- Rail lines/stations
- Bus system/facilities
- Sidewalks
- Rail trails
- Regional airport
- Highway garages
- Park and rides
- Transit hub
- Beacon ferry dock

Focus Climate Hazards:

- Extreme heat
- Flooding
- Drought
- Wind
- Winter conditions
- Landslides[1]

To conduct this assessment, we analyzed the sensitivity of each of these asset/hazard pairs on a low, medium, and high scale across two dimensions:

- The sensitivity of the **physical infrastructure**
- The sensitivity of **service operations and user experience**

We used the DCTC Climate Change Summary Report findings, other existing literature, professional judgement, and input from stakeholders to rate these two dimensions of sensitivity for each asset/hazard pair using the rating scales in Table 1 and Table 2.

TABLE 1. PHYSICAL INFRASTRUCTURE SENSITIVITY RATING SCALE

Low	When exposed to the hazard, the asset suffers minor to no damage and maintains functionality.
Medium	When exposed to the hazard, the asset suffers damage requiring repairs to resume full functionality.
High	When exposed to the hazard, the asset is damaged beyond repair or destroyed, and cannot resume normal function until replaced.

TABLE 2. SERVICE OPERATIONS AND USER EXPERIENCE SENSITIVITY RATING SCALE

Low	When exposed to the hazard, there is minimal to no impact to service or discomfort to users.
Medium	When exposed to the hazard, service is disrupted or suspended for up to a day. Or, hazard exposure causes discomfort for users.
High	When exposed to the hazard, service is suspended for more than 24 hours and disruptions may continue for days to weeks after the event as infrastructure repairs are made. Or, hazard poses risk of injury or death to users.

[1] Landslides are distinct from mudslides, which are driven by heavy precipitation and flooding, causing erosion. Landslides are caused by disturbances in slope stability and can occur with or without precipitation/flooding.

Phase 1 System-level Results

The sensitivity ratings for each asset/hazard pair are summarized in Table 3. Physical transportation infrastructure tends to be most sensitive to flooding and landslides, while transportation service operations and users tend to be most sensitive to flooding, winter conditions, and landslides.

TABLE 3. SUMMARY SYSTEM-LEVEL ANALYSIS RESULTS FOR DUTCHESS COUNTY

	Extreme Heat		Flooding		Drought		Wind		Winter Conditions		Landslides	
	I	S	I	S	I	S	I	S	I	S	I	S
Roads	M	L	H	H	L	L	L	H	M	H	H	H
Bridges	M	L	H	H	-	-	L	H	M	H	H	H
Culverts[2]	-	-	H	H	L	-	L	-	L	-	M	-
Rail lines/ stations	M	M	H	H	-	-	L	H	M	M	H	H
Bus system/ facilities[3]	L	M	L	M	-	L	L	M	L	H	L	L
Sidewalks	L	H	L	M	-	L	L	L	L	M	M	M
Rail trails	L	H	H	H	-	L	L	L	L	L	M	M
Regional airport	M	L	NE	NE	L	-	L	M	L	L	NE	NE
Highway garages	L	-	M	-	-	-	L	-	L	-	M	-
Park and rides	L	L	M	M	-	-	L	L	L	M	NE	NE
Transit hub	L	M	NE	NE	-	-	L	L	L	M	NE	NE
Beacon ferry dock[4]	L	L	L	M	L	-	L	M	M	M	NE	NE

I = Physical infrastructure sensitivity rating
S = Service operations and user experience sensitivity rating
NE = Asset was pre-screened and is not exposed to the hazard
(-) = Asset is unaffected by the hazard

[2] Large culverts are treated as bridges in this assessment, similar to the National Bridge Inventory (NBI). The culvert ratings are for smaller culverts. Dutchess County defines minor culverts as those with a diameter of less than 5 feet. Culverts with diameters of 5 feet or more are considered major culverts. Once the diameter reaches 20 feet it is considered a bridge.

[3] Bus system/facilities focuses on impacts to bus stops, shelters, the bus fleet, and the bus garage. Impacts to bus routes that are a result of damage or disruption to the roadway are considered under roads.

[4] The Beacon ferry dock includes consideration of the alternative bus service offered when ferry service is shut down. The bus picks up and drops off customers at the same locations as the ferry service, which reduces service disruptions and discomfort for passengers. This asset category does not include consideration of the Newburgh ferry dock as it is out-of-county infrastructure.

Recommendation for Phase 2

Phase 2 of the vulnerability assessment is an asset-level, indicator-based assessment of the exposure and criticality of high-ranking asset/hazard pairs from Phase 1. To determine which asset/hazard pairs should progress to Phase 2, we used the following criteria:

- All pairs that received a high physical infrastructure sensitivity rating
- With discretion, pairs that received a high service operational and user experience sensitivity rating (see below for explanations)

Based on the findings of Phase 1, the following asset/hazard pairs are included in the Phase 2 analysis:

- **Flooding:**
  - Roads
  - Bridges
  - Culverts
  - Rail lines/stations
  - Rail trails

- **Landslides:**
  - Roads
  - Bridges
  - Rail lines/station

Although some assets received high service operations and user experience sensitivity ratings for **extreme heat** (sidewalks and rail trails), **wind** (roads, bridges, and rail lines/stations) and **winter conditions** (roads, bridges, and bus system/facilities), there is no spatial data available for these hazards to identify specific locations or specific assets that are more prone than others to these types of impacts. In addition, these high ratings are driven by safety concerns as well as the ability to clear roads/rail lines, rather than direct infrastructure damage. Although these asset/hazards are not well suited to the geospatial analysis, adaptation options for these assets will be emphasized in the follow-on adaptation plan.

Phase 1 System-level Analysis Details

The following sections detail the evidence base for each sensitivity rating.

Extreme Heat

Extreme high temperatures will occur with greater frequency. From 1981-2010, Dutchess County saw an average of eight days each year where the high temperature reached 90°F or above. This could increase to 27-35 days per year by 2050 and 34-61 days by 2080.

No assets have high sensitivity to extreme heat. Table 4 summarizes expected impacts to physical infrastructure and users and services.

TABLE 4. TRANSPORTATION SENSITIVITIES TO EXTREME HEAT[5, 6, 7, 8, 9, 10]

	Impacts to Physical Infrastructure	Impacts to Users and Services
Roads	Sensitivity: Medium	Sensitivity: Low
	• Sustained high temperatures can result in softening of the asphalt binder, leading to rutting and bulging of the pavement surface. • High temperatures can cause heaving of concrete joints as concrete contracts and expands. • Sustained periods of high heat preceded by cooler temperatures can cause concrete roadways to buckle as pavement expands. • Higher temperatures can reduce the operational lifespan of pavement leading to more frequent surface treatments and material/labor costs.	• Road repairs can cause lane closures and delays. • Extreme heat can increase the risk of tire blow-outs, especially on heavy vehicles. • Extreme heat can heighten the risk of heat stress for passengers in vehicles without air conditioning, especially populations that are highly vulnerable to heat-related health risks like the young and the elderly. • Pavement and concrete absorb and retain heat, contributing to the urban heat island effect, which

[5] FHWA. 2019. HIF-18-025 Strategies for Concrete Pavement Preservation. https://www.fhwa.dot.gov/pavement/pubs/hif18025.pdf.
[6] Climate change could hasten deterioration of U.S. bridge infrastructure (2019), https://engr.source.colostate.edu/climate-change-could-hasten-deterioration-of-u-s-bridge-infrastructure/.
[7] Jacobs, J.M., et al., 2018. Transportation. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, pp. 479-511. doi: 10.7930/NCA4.2018.CH12.
[8] NIDIS, 2023. Navigation and Transportation. Drought.gov. https://www.drought.gov/sectors/navigation-and-transportation.
[9] FHWA. 2014. Transportation Climate Change Sensitivity Matrix. https://www.fhwa.dot.gov/environment/sustainability/resilience/tools/sensitivity_matrix.xlsm.
[10] NYSERDA. 2011. Climate Change in New York State. Chapter 9: Transportation. https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/EMEP/climaid/ClimAID-Transportation.pdf.

	Expected future conditions would cause moderate damage that may impact functionality.	can disproportionately affect populations vulnerable to heat-related health conditions. *Expected future conditions would cause minimal impact to service and users.*
Bridges	Sensitivity: Medium	Sensitivity: Low
	• High temperatures increase stress on the bridge structure. This stress can be compounded by heavy congestion on bridges crossing the Hudson River. • Sustained high temperatures can result in softening of the asphalt binder, leading to rutting and bulging of the pavement surface in bridge decks. • High temperatures can cause heaving of concrete joints as concrete contracts and expands. *Expected future conditions would cause moderate damage that may impact functionality.*	• Bridge repairs can cause lane closures and delays. • Extreme heat can increase the risk of tire blow-outs, especially on heavy vehicles. • Extreme heat can heighten the risk of heat stress for passengers in vehicles without air conditioning, especially populations that are more vulnerable to heat-related health risks like the young and the elderly. *Expected future conditions would cause minimal impact to service and users.*
Culverts	Sensitivity: N/A	Sensitivity: N/A
	• No major infrastructure impacts.	• No service impacts.
Rail lines/ stations	Sensitivity: Medium	Sensitivity: Medium
	• Expanding, weakening, and bending/kinking of rail can cause tracks to expand and get longer. This places more stress on the ties, ballasts, and rail anchors keeping the track in place, damaging tracks and even leading to derailment. Multiple days of extreme heat can also cause tracks to expand into wavelike shapes or heat kinks, which may require replacement of a section of the rail. However, this is more of a concern during extremely high temperatures (close to 105°F), which are unlikely to occur in Dutchess County.	• Passengers waiting on train platforms in high temperatures are at higher risk of heat stress, especially populations that are highly vulnerable to heat-related health risks like the young and the elderly. • Service delays or closure can result from buckled tracks. • Power outages during extreme heat events can affect service.

	• Extreme heat can cause mechanical failures in railroad locomotives and equipment, especially when temperatures are above 110°F. • Exposure to heat can also reduce the operational lifespan of rail assets, leading to more frequent maintenance and material/labor costs. • Increased demand for cooling will put stress on air conditioning and energy supply in addition to raising operating costs. *Expected future conditions would cause moderate damage that may impact functionality.*	• Reducing operating speeds to limit potential for damage or derailments increases passenger travel time and causes delays. ○ Amtrak regularly reduces its operating speed during heatwaves. • Derailments can cause injury and death to passengers and train operators. *Expected future conditions would cause moderate service disruptions and discomfort for passengers.*
Bus system/ facilities	Sensitivity: Low	Sensitivity: Medium
	• Extreme heat can contribute to overheated bus engines and result in engine failures. • Increased demand for cooling will put stress on air conditioning and energy supply in addition to raising operating costs. Lack of sufficient air conditioning on buses is already a concern for Dutchess County. • Heat stress can increase the frequency of tire shredding. • Electric buses may be more sensitive to extreme heat impacts. In particular, heat (and the need for cooling) can affect battery life and reliability, reducing the mileage buses are able to travel. *Expected future conditions would cause minor damage with minimal impact functionality.*	• Passengers waiting at bus stops in high temperatures are at higher risk of heat stress, especially populations that are highly vulnerable to heat-related health risks like the young and the elderly. ○ While many passengers may choose alternate modes of transportation, low-income passengers may not have other transportation options. • Bus engine failure or reduced electric battery reliability can cause travel delays for passengers. • Sustained high temperatures can result in the softening of roads' asphalt binder, leading to rutting and bulging of the pavement surface on bus routes, especially at stops. Road delays and closures for repairs may lead to service delays for passengers. *Expected future conditions would cause moderate service disruptions and discomfort for passengers.*

Sidewalks	Sensitivity: Low	Sensitivity: High
	• Sustained extreme heat could cause concrete to expand and eventually buckle, leading to cracks and lifts on sidewalks. *Expected future conditions would cause minor damage with minimal impact to functionality.*	• Only some segments of sidewalk have street trees or other shading features that help mitigate heat impact for people using sidewalks. • Pedestrians experience discomfort during extreme heat events and consequently walk less. Heat waves may cause a disruption for more than one day and can increase the risk of heat stress for pedestrians, especially the young and elderly. • If exposed to extreme heat, concrete buckling can pose safety risks for pedestrians and create trip hazards or render the sidewalk unusable for those with physical disabilities. *Expected future conditions would cause significant disruptions and may pose risks to pedestrians.*
Rail trails	Sensitivity: Low	Sensitivity: High
	• Sustained extreme heat can cause pavement to buckle, leading to cracks and lifts on rail trails . *Expected future conditions would cause minor damage with minimal impact to functionality.*	• Only some segments of rail trails have trees or other shading features that help mitigate heat impact for rail trail users. • Users experience discomfort during extreme heat events and consequently limit rail trail use. Heat waves may cause a disruption for more than one day and can increase the risk of heat stress for users, especially the young and elderly. • If exposed to extreme heat, pavement buckling can pose safety risks for users, especially if they are traveling on bikes or scooters at higher speeds. *Expected future conditions would cause significant disruptions and may pose risks to users.*

Regional airport	Sensitivity: Medium	Sensitivity: Low
	• Concrete cracking or buckling on taxiways can decrease pavement performance. • Sustained high temperatures can result in softening of the asphalt binder, leading to rutting and bulging of the pavement surface and decreased performance of asphalt runways. • Higher temperatures can reduce the operational lifespan of pavement leading to more frequent surface treatments and material/labor costs. • Longer runways or weight restrictions may be needed for airplanes to generate lift in hotter temperatures. • Increased demand for cooling within airports will put stress on air conditioning and energy supply. *Expected future conditions would cause moderate damage and may impact functionality.*	• Outdoor workers can experience heat stress and become ill. • Insufficient cooling within the airport may cause discomfort for users. *Expected future conditions would have minimal impact to service and users.*
Highway garages	Sensitivity: Low	Sensitivity: N/A
	• When exposed to extreme heat, pavement surrounding the highway garage can crack or buckle. • No direct impact on the highway garage. *Expected future conditions would cause minor damage with no impact to functionality.*	• No service impacts. Highway garages do not provide a transportation service.
Park and rides	Sensitivity: Low	Sensitivity: Low
	• Sustained high temperatures can soften the asphalt binder, leading to rutting and bulging of the pavement surface.	• Maintenance operations to address the impacts of rutting and cracking can close off portions of the park and ride and decrease available vehicle parking spaces.

	• Extreme heat damage can decrease the useful life of park and rides and lead to more frequent repairs and maintenance needs. *Expected future conditions would cause minor damage with no impact to functionality.*	*Expected future conditions would have minimal impact to service and users.*
Transit hub	Sensitivity: Low	Sensitivity: Medium
	• Extreme heat could cause pavement buckling at and around the transit hub. *Expected future conditions would cause minor damage with no impact to functionality.*	• Passengers are at risk of discomfort and heat related illness, especially young and elderly populations. *Expected future conditions would cause user discomfort.*
Beacon ferry dock	Sensitivity: Low	Sensitivity: Low
	• Extreme heat could cause pavement buckling around the dock. *Expected future conditions would cause minor damage with no impact to functionality.*	• Passengers are at risk of heat related illness, especially young and elderly populations. However, the ferry service is timed with the arrival of the trains at Beacon station, therefore passengers are not waiting outside for long periods of time. There is also a temporary awning/tent to provide shade at the dock. *Expected future conditions would cause minor user discomfort.*

Flooding

Precipitation is expected to become more variable each year, with some years receiving much more precipitation than other years. Heavy rain events are also expected to become more frequent and intense, leading to flooding.[11] Along the Hudson River, areas could also experience greater storm surge depth and extent during a coastal storm due to sea level rise.[12]

Roads, bridges, culverts, rail lines/stations, and rail trails have high sensitivity to flooding. Table 5 summarizes expected impacts to physical infrastructure and users and services.

TABLE 5. TRANSPORTATION SENSITIVITIES TO FLOODING[13, 14, 15, 16, 17, 18, 19]

	Impacts to Physical Infrastructure	Impacts to Users and Services
Roads	Sensitivity: High	Sensitivity: High
	• Flooding can cause erosion of paved surfaces, worsening of existing pavement damage, and structural integrity degradation. • Pavement and embankment failure can result from overtopping and erosion when roadways parallel streams and rivers. • Higher groundwater tables from sea level rise can weaken roadway base materials.	• Pavement drainage and stormwater systems may be undersized for future storms. Insufficient drainage capacity or blockage may worsen local flooding and cause standing water on driving surfaces. • Flooding can lead to severe and long-lasting road closures, delays, and detours. ○ Tropical Storm Irene washed out several roads that required significant repairs to operate.

[11] U.S. Federal Government. NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Days with more than one inch of precipitation in Dutchess County, NY. https://crt-climate-explorer.nemac.org/ Accessed February 2023.
[12] Hudson River Flood Impact Decision Support System. 2018. www.ciesin.columbia.edu/huson-river-flood-map/
[13] Jacobs, J.M., et al., 2018. Transportation. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, pp. 479-511. doi: 10.7930/NCA4.2018.CH12.
[14] Klaus, Jaboc., et al., 2011. Transportation. Responding to Climate Change in New York State. https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Environmental/EMEP/climaid/ClimAID-Transportation.pdf
[15] FHWA. 2014. Transportation Climate Change Sensitivity Matrix.
[16] FHWA. 2017. Post Hurricane Sandy Transportation Resilience Study in NY, NJ, and CT. https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/hurricane_sandy/page00.cfm.
[17] NYSERDA. 2011. Climate Change in New York State. Chapter 9: Transportation.
[18] University of Minnesota. 2018. Design Techniques Protect Roadway Embankments, Reduce Damage during Flooding. https://www.cts.umn.edu/publications/catalyst/2018/february/flooding
[19] Kaufman et al. 2012. Transportation During and After Hurricane Sandy. Rudin Center for Transportation, NYU. https://wagner.nyu.edu/files/rudincenter/sandytransportation.pdf.

	• The pavement subgrade can take a very long time to dry out after a flooding event, making the pavement weaker. This can lead to additional damage to the pavement subgrade as vehicles travel over the road. *Expected future conditions would cause significant damage and impact functionality.*	○ During Hurricane Ida, more than 30 roads closed, and many were damaged from severe flooding. • Heavy rain events can reduce visibility (difficulty seeing street signs and other vehicles) and heighten safety risks (slippery roads, moving or standing water over roads). *Expected future conditions would cause significant disruptions to service and may pose risks for users.*
Bridges	Sensitivity: High	Sensitivity: High
	• Heavier water flows may increase scour and erosion around bridge foundation areas, making them more susceptible to damage. • Insufficient drainage capacity or blockage may cause standing water on driving surfaces. • Debris flows during flood events can damage bridge foundations. • Flood sensitivity is less of a concern for newer bridges in Dutchess County. Following extreme weather events like Hurricanes Sandy and Irene, Dutchess County began using the design flood elevation standards recommended by the American Society of Civil Engineers (ASCE). These measures ensure that bridges and culverts are elevated out of floodplains. *Expected future conditions would cause significant damage that impact functionality.*	• Flooding can lead to more severe and longer lasting service disruptions. For example, unsafe conditions and/or failure can cause bridge closures, delays, and detours. ○ Tropical Storm Irene caused some bridges to be washed out, requiring significant repairs. • Heavy rain events can reduce visibility and heighten safety risks. *Expected future conditions would cause severe disruptions to service and may pose risks to users.*
Culverts	Sensitivity: High	Sensitivity: High

	• Debris and sediment accumulation due to flooding can block some culverts, which can worsen flood impacts by bringing more floodwater to other culverts. • Floodwater can overwhelm culverts, causing them to washout and fail. • Culverts can collapse due to flood damage of surrounding soil and vegetation. *Expected future conditions would cause significant damage that impact functionality.*	• Culverts can get clogged or backed up with debris, causing flooding. • In severe cases, a washed out culvert can leave roads impassable. *Expected future conditions would cause severe disruptions to service.*
Rail lines/ stations	Sensitivity: High	Sensitivity: High
	• Floodwater and moving debris can damage stations, rails, and trains. • Inundation of equipment can lead to electrical damage, which would close the line. • Floodwater can threaten track stability by weakening wooden ties and eroding the supporting system. • Floodwater can inundate or wash out rail yards, signals, and switches. • Metro-North track and many key equipment providing power and communications are located below, at, or slightly above ground level and are particularly vulnerable to flooding.[20] *Expected future conditions would cause significant damage and impact functionality.*	• Flooding can lead to severe and long-lasting service disruptions. ○ After Superstorm Sandy, half of Metro North's Hudson River railroad line was underwater, and service was suspended for three days. • Since trains are not designed to run on tracks that are flooded, passengers may experience travel delays or cancellations during flood events. • Reduced train speeds during high precipitation events may cause service delays. *Expected future conditions would cause significant disruptions to service and may cause risks for users.*
Bus system/	Sensitivity: Low	Sensitivity: Medium

[20] MTA/Metro-North. December 20, 2022. Email exchange between DCTC and MTA/Metro-North contact.

facilities	• Floodwater and moving debris can damage buses and bus stop shelters.
	• Flooding could be of greater concern to the bus garage because it is located in a flood-prone area. This should be considered in potential adaptation planning efforts.
	
	Expected future conditions would cause minor damage and may impact functionality.
		• Flooding can lead to long-lasting service disruptions. Buses can temporarily re-route or move a stop during a flood scenario but are unlikely to stop service entirely.
		• Heavy rain events can cause moderate service disruptions or delays for up to a day. For example, buses may be rerouted to avoid flooded or blocked roads, leading to service delays and longer travel times.
		  ○ Storm events can also result in reduced visibility (difficulty seeing street signs and other vehicles) and slippery roads.
		  ○ Insufficient drainage capacity or blockage may cause standing water on driving surfaces.
		
		Expected future conditions would cause moderate disruptions and may pose risks to pedestrians.

Sidewalks	Sensitivity: Low	Sensitivity: Medium
	• Flooding events may cause damage to sidewalks through erosion and possible embankment failure, especially if there is existing damage. • Sidewalks along the river or near streams may experience washouts during significant flooding events, causing damage to sidewalks. • Insufficient drainage system capacity may lead to standing or flowing water on sidewalks. *Expected future conditions would cause minor damage that may impact functionality.*	• Flooding events can cause sections of sidewalks to become flooded, rendering them unpassable and dangerous for pedestrians (though sidewalks usually don't require significant clean up to resume functionality once flood waters recede). *Expected future conditions would cause moderate disruptions and may pose risks to pedestrians.*
Rail trails	Sensitivity: High	Sensitivity: High

	• Extreme flooding can cause washouts of portions of the rail trail over stream crossings.
	  ○ A heavy rain event in July 2023 caused significant flooding and completely devastated some sections of the rail trail. Additionally, some trail segments are located in wetlands, making them more sensitive to flooding.
	• Insufficient drainage system capacity may lead to standing or flowing water, or debris accumulation.
	• Erosion, worsening of existing damage, and embankment failure may occur.
	
	Expected future conditions would cause significant damage and impact to functionality
		• During a flood event, rail trails can become unpassable and dangerous for users.
		  ○ Heavy rain events can wash out entire sections of the rail trails, making them unpassable for multiple days.
		• Heavy rain events can reduce visibility and heighten safety risks for users.
		
		Expected future conditions would cause significant disruptions and may pose risks to users.

Regional airport	Sensitivity: N/A	Sensitivity: N/A
	• Not exposed. The Hudson Valley Regional Airport is not located in the FEMA 100-year or 500-year floodplain. It is also not exposed to sea level rise or storm surge.	• Not exposed. The Hudson Valley Regional Airport is not located in the FEMA 100-year or 500-year floodplain. It is also not exposed to sea level rise or storm surge.
Highway garages	Sensitivity: Medium	Sensitivity: N/A
	• Flooding events can cause damage to equipment in highway garages, requiring replacement or repairs. • Flooding events can cause damage to the highway garage structure and compromise its' structural integrity. • Although some highway garages are sensitive to flooding, municipalities have moved most garages out of floodplains.	• No service impacts. Highway garages do not provide a transportation service.

	Expected future conditions would cause moderate damage and may impact functionality	
Park and rides	Sensitivity: Medium	Sensitivity: Medium
	• Flooding can cause erosion of paved surfaces, worsening of existing pavement damage, and damage to pavement subgrade. • Insufficient drainage capacity or blockage may cause standing water on driving and parking surfaces. *Expected future conditions would cause moderate damage that may impact functionality.*	• Some park and rides may become inaccessible and disrupt travel plans for commuters. *Expected future conditions would cause moderate disruptions to service and may pose a risk to users.*
Transit hub	Sensitivity: N/A	Sensitivity: N/A
	• Not exposed. The Poughkeepsie Transit Hub is not located in the FEMA 100-year or 500-year floodplain. It is also not exposed to sea level rise or storm surge.	• Not exposed. The Poughkeepsie Transit Hub is not located in the FEMA 100-year or 500-year floodplain. It is also not exposed to sea level rise or storm surge.
Beacon ferry dock	Sensitivity: Low	Sensitivity: Medium
	• Debris from flooding can damage the dock. However, because the dock floats, it is largely unaffected by flooding. *Expected future conditions would cause minor damage and minimal impact to functionality.*	• Service could be suspended during flooding events due to equipment or structural damage or risk of travel. However, there is an alternate bus service when ferry service is suspended, which reduces service disruptions and discomfort for passengers. ○ The Newburgh-Beacon ferry suspended operations in preparation for Superstorm Sandy in 2012. *Expected future conditions would cause moderate disruptions to service and may pose risks to users.*

Drought

Dutchess County is expected to experience longer periods without precipitation, increasing the risk of drought. However, the specific timing or duration of future droughts remains difficult to predict.[21]

No assets have high sensitivity to drought. Table 6 summarizes expected impacts to physical infrastructure and users and services.

TABLE 6. TRANSPORTATION SENSITIVITIES TO DROUGHT[22, 23, 24, 25, 26, 27]

	Impacts to Physical Infrastructure	Impacts to Users and Services
Roads	Sensitivity: Low	Sensitivity: Low
	• Contraction of dry soil can reduce pavement integrity and cause cracking, especially in roads near trees because trees soak up ground moisture. However, this region is not underlain by soils with high swelling potential. • Drought conditions can make unpaved roads harder and drier, which can increase runoff if drought periods are followed by heavy rain events. *Expected future conditions would cause minor damage and minimal impact on functionality.*	• Increased dust production from unpaved roads can be a potential health hazard to travelers. • Increased dust production can reduce visibility, creating safety hazards. *Expected future conditions would cause minimal disruptions to service.*
Bridges	Sensitivity: N/A	Sensitivity: N/A
	• No infrastructure impacts.	• No service impacts.
Culverts	Sensitivity: Low	Sensitivity: N/A

[21] Krakauer, Nir, et al. 2019. Trends in Drought over the Northeast United States. MDPI. https://www.mdpi.com/2073-4441/11/9/1834
[22] Federal Highway Administration, 2017. Sensitivity Matrix. U.S. Department of Transportation. https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/gulf_coast_study/phase2_task2/sensitivity_matrix/matrix08.cfm
[23] National Integrated Drought Information System, 2023. Navigation and Transportation. Drought.gov. https://www.drought.gov/sectors/navigation-and-transportation
[24] Hill, C. 2016. Drought, soil contraction causing highway pavements to crumble in Mississippi. Preliminary findings.
[25] FHWA. 2014. Transportation Climate Change Sensitivity Matrix.
[26] NYSERDA. 2011. Climate Change in New York State. Chapter 9: Transportation.
[27] Geoscience News and Information. 2005. Expansive Soil: The hidden force behind basement and foundation problems. https://geology.com/articles/soil/

	• Periods of low flow can cause sedimentation build-up in culverts, which reduces their capacity during later storms and may require increased maintenance to clear them out. *Expected future conditions would cause minor damage and minimal impact on functionality.*	• No service impacts.
Rail lines/ stations	Sensitivity: N/A	Sensitivity: N/A
	• No infrastructure impacts.	• No service impacts.
Bus system/ facilities	Sensitivity: N/A	Sensitivity: Low
	• No infrastructure impacts.	• Contraction of dry soil can reduce pavement integrity and cause cracking, especially in roads near trees because trees soak up ground moisture. Road repairs may cause service delays for passengers. However, this region is not underlain by soils with high swelling potential. *Expected future conditions would cause minimal disruptions to service.*
Sidewalks	Sensitivity: N/A	Sensitivity: Low
	• No infrastructure impacts.	• Street trees may be under stress and decline or die during a drought, leading to less shade and hotter conditions on sidewalks for pedestrians. *Expected future conditions would cause minimal impact to users.*
Rail trails	Sensitivity: N/A	Sensitivity: Low
	• No infrastructure impacts.	• Street trees may be under stress and decline or die during a drought, leading to less shade and hotter conditions on rail trails for users.

		Expected future conditions would cause minimal impact to users.
Regional airport	Sensitivity: Low	Sensitivity: N/A
	• Drought can cause pavement cracking in airport runways; however, this region is not underlain by soils with high swelling potential. *Expected future conditions would cause minor damage and would have minimal impact on functionality.*	• No service impacts.
Highway garages	Sensitivity: N/A	Sensitivity: N/A
	• No infrastructure impacts.	• No service impacts. Highway garages do not provide a transportation service.
Park and rides	Sensitivity: N/A	Sensitivity: N/A
	• No infrastructure impacts.	• No service impacts.
Transit hub	Sensitivity: N/A	Sensitivity: N/A
	• No infrastructure impacts.	• No service impacts.
Beacon ferry dock	Sensitivity: Low	Sensitivity: Low
	• During a severe drought, the Hudson River water level could drop, putting stress on dock infrastructure. *Expected future conditions would cause minor damage and would have minimal impact on functionality.*	• During a severe drought, the Hudson River could experience a low flow of water, causing the ferry to suspend operations. However, there is an alternate bus service when ferry service is suspended, which reduces service disruptions and discomfort for passengers. *Expected future conditions would cause minimal disruptions to service.*

Wind

Dutchess County could experience higher winds as the intensity of hurricanes, tropical storms, tropical depressions, and other extreme weather events (e.g., thunderstorms) increase.

Roads, bridges, and rail lines have high sensitivity to wind. Table 7 summarizes expected impacts to physical infrastructure and users and services.

TABLE 7. TRANSPORTATION SENSITIVITIES TO WIND [28, 29, 30]

	Impacts to Physical Infrastructure	Impacts to Users and Services
Roads	Sensitivity: Low	Sensitivity: High

	• Heavy winds can create and move debris, and down power lines, potentially damaging or blocking roads.
	• Strong winds can blow over highway, street, and road signs, and damage traffic signals.
	
	Expected future conditions would cause minor damage and would have minimal impact on functionality.
		• Road closures or delays may occur due to downed power lines and trees, and debris blocking roadways following heavy winds.
		  ○ It can take more than 24 hours to clear trees and wires from roadways depending on the extent of utility damage and the utility company's responsiveness.
		  ○ The combination of strong winds and flooded land from Tropical Storm Irene in 2011 caused many downed trees and power lines in the area, resulting in road closures. [31]
		  ○ During Tropical Storm Isaias in 2020, damage occurred to many trees and utility poles and caused more than 50,000 reported outages throughout the county. [32] A portion of I-84

[28] Klaus, Jaboc., et al., 2011. Transportation. Responding to Climate Change in New York State. https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Environmental/EMEP/climaid/ClimAID-Transportation.pdf

[29] FHWA. 2014. Transportation Climate Change Sensitivity Matrix.

[30] NYSERDA. 2011. Climate Change in New York State. Chapter 9: Transportation.

[31] National Oceanic and Atmospheric Administration. 2022. Storm Events Database. https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=339972

[32] Daily Freeman. 2011. About 2500 Central Hudson User without Power.

		was also closed due to a downed tree that blocked two lanes of the highway.[33] ○ In May 2018, a severe thunderstorm with strong winds led to travel restrictions along the I-84 corridor in southern Dutchess County, due to fallen trees and malfunctioning traffic lights from severe wind. • Power outages from downed power lines impact traffic lights. • High winds can reduce visibility and cause safety risks. *Expected future conditions would cause significant disruptions to service and may cause risks for users.*
Bridges	Sensitivity: Low	Sensitivity: High
	• Wind can cause additional stress on bridge superstructure and substructure, leading to increased degradation. • High wind speeds can lead to stronger water force, which can cause bridges to scour. *Expected future conditions would cause minor damage and may impact functionality.*	• Bridge closures or delays may occur due to downed power lines and trees, and debris blocking bridges following heavy winds. ○ It can take more than 24 hours to clear trees and wires from bridges depending on the extent of utility damage and the utility company's responsiveness. • Travel restrictions may be put in place on bridges exposed to high winds. For example, vehicle traffic is typically restricted at sustained wind speeds around 30-40 mph. Once wind speeds reach 40-50 mph, the bridge may be closed.

[33] Hudson Valley Post. 2022. Downed tree on I-84 in Hudson Valley closes down part of highway. https://hudsonvalleypost.com/downed-tree-on-i-84-in-hudson-valley-closes-down-parts-of-highway/?utm_source=tsmclip&utm_medium=referral&fbclid=IwAR2TisirfxewNLrA8eeNp4GYw8rUF91K4jf6m4hm3QNLmBxQS8Z9ta45ti8

		○ Truck restrictions have occurred on Hudson River bridges due to the severity of wind speeds during high wind events.[34] *Expected future conditions would cause significant disruptions to service and may cause risks for users.*
Culverts	Sensitivity: Low • Wind damage can cause debris to build up. If extreme wind events are followed by flood events, this debris build-up can clog culverts and other stormwater management infrastructure. *Expected future conditions would cause minor damage and may impact functionality.*	Sensitivity: N/A • No service impacts.
Rail lines/ stations	Sensitivity: Low • High winds can create and move debris, potentially damaging or blocking rail lines. • High winds can damage platforms, stations, and other structures. *Expected future conditions would cause minor damage and may impact functionality.*	Sensitivity: High • High winds can cause trees to fall on tracks, which can cause service delays until trees are removed. This is a costly operation, with Metro-North spending about $1 million each year on tree removal. • Power outages due to downed power lines can affect rail service. ○ Following a severe thunderstorm with high winds in May 2018, Amtrak and Metro North suspended their service in the county.[35] • High winds can knock over rail signals, which can lead to additional service disruptions.

[34] Moving Dutchess Forward. 2020. Climate Change Trends. https://movingdutchessforward.com/introduction-learn/climate-change-trends/
[35] Daily Freeman. 2011. About 2500 Central Hudson Users without Power.

		Expected future conditions would cause significant disruptions to service.
Bus system/ facilities	Sensitivity: Low	Sensitivity: Medium
	• High winds can create and move debris. • High winds can damage bus stop infrastructure. *Expected future conditions would cause minor damage and may impact functionality.*	• Road closures or delays due to downed power lines and debris blocking roadways can lead to service delays. • Power outages from downed power lines impact traffic lights, increasing congestion and causing safety hazards. *Expected future conditions would cause moderate disruptions to service.*
Sidewalks	Sensitivity: Low	Sensitivity: Low
	• Wind can cause overhead structures (utility lines, trees, etc.) to fall onto sidewalks, potentially causing damage. *Expected future conditions would cause minor damage that may impact functionality.*	• Portions of the sidewalk may be closed if trees or structures topple over and restrict pedestrians from using the sidewalk. *Expected future conditions would cause minimal disruptions and may pose risks to pedestrians.*
Rail trails	Sensitivity: Low	Sensitivity: Low
	• Wind can cause overhead structures (utility lines, trees, etc.) to fall onto rail trails, potentially causing damage. *Expected future conditions would cause minor damage that may impact functionality.*	• Portions of the rail trail may be restricted if trees or structures topple over and restrict people from using the rail trail. *Expected future conditions would cause minimal disruptions and may pose risks to users.*
Regional airport	Sensitivity: Low	Sensitivity: Medium
	• Wind-blown debris can cause damage to airport terminals, buildings, and equipment. *Expected future conditions would cause minor damage that may impact functionality.*	• Flight departures and landings may be delayed in cases of strong crosswinds and wind-blown debris. *Expected future conditions would cause moderate disruptions to service and may pose a risk for users.*

Highway garages	Sensitivity: Low	Sensitivity: N/A
	• High winds could cause damage to highway garages. *Expected future conditions would cause minor damage with minimal impact to functionality.*	• No service impacts. Highway garages do not provide a transportation service.
Park and rides	Sensitivity: Low	Sensitivity: Low
	• High winds could cause light fixtures or nearby trees to fall and make areas of the park and ride temporarily unusable until debris is removed. *Expected future conditions would cause minor damage with minimal impact to functionality.*	• Wind-blown debris could limit access in the park and ride. *Expected future conditions would cause minimal disruptions to service.*
Transit hub	Sensitivity: Low	Sensitivity: Low
	• High winds could move debris and cause damage to transit hub benches and waiting areas. *Expected future conditions would cause minor damage with minimal impact to functionality.*	• During high winds, delays could occur from physical damage, unsafe conditions, or power outages. *Expected future conditions would cause minimal disruptions to service.*
Beacon ferry dock	Sensitivity: Low	Sensitivity: Medium
	• High winds can move debris and cause damage to the ferry dock and equipment. • If wind speeds are strong enough, coastal storm surge could damage the dock. *Expected future conditions would cause minor damage with minimal impact to functionality.*	• High winds can stall ferry operations and impact commuters, especially if wave conditions are unsafe. However, there is an alternate bus service when ferry service is suspended, which reduces service disruptions and discomfort for passengers. *Expected future conditions would cause moderate disruptions to service.*

Winter conditions

Dutchess County will experience fewer days each year below freezing (32°F) which will cause precipitation to fall more often in the form of rain rather than snow. However, when winter storms do occur, they are projected to be more severe and include greater snowfall.[36,37] Additionally, winter is expected to be shorter in Dutchess County, with the first fall freeze occurring later and the last spring freeze occurring earlier in the year. During the winter, Dutchess County is expected to see temperatures fluctuating around freezing more often, which is likely to result in increased icing (instead of snow, which is caused by very cold temperatures).

Roads, bridges, and bus system/facilities have high sensitivity to winter conditions. Table 8 summarizes expected impacts to physical infrastructure and users and services.

TABLE 8. TRANSPORTATION SENSITIVITIES TO WINTER CONDITIONS[38, 39, 40, 41, 42]

	Impacts to Physical Infrastructure	Impacts to Users and Services
Roads	Sensitivity: Medium	Sensitivity: High
	• Ice formation and snow removal can deteriorate pavement, causing potholes and cracking. More frequent ice conditions (due to temperatures fluctuating around freezing more often) may lead to increased salt application, which can further deteriorate roads.	• Snow or ice can pose a safety risk to drivers. ○ In March 2017, the Pi Day Blizzard caused travel bans on all county roads, tractor-trailers were banned on most interstates, and schools were closed for two days.[43,44]

[36] U.S. Federal Government. NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Days each year with minimum daily temperatures below 32 degrees Fahrenheit in Dutchess County, NY. https://crt-climate-explorer.nemac.org/.

[37] Dupigny-Giroux, L.A., et al. 2018. Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18

[38] Airport Cooperative Research Program (ACRP), 2018. Using Existing Airport Management Systems to Manage Climate Risk. National Academies. https://www.trb.org/Main/Blurbs/178312.aspx

[39] FHWA. 2014. Transportation Climate Change Sensitivity Matrix.

[40] Siddique, Z., Hossain, M., Meggers, D. 2005. Temperature and Curling Measurements on Concrete Pavement. Research Gate.https://www.researchgate.net/publication/228678490_Temperature_and_Curling_Measurements_on_Concrete_Pavement

[41] Randall, Mike. 2022. Ferry services resumes from Newburgh to Metro-North's Beacon train station. Recordonline.com. https://www.recordonline.com/story/news/local/2022/03/11/hudson-river-ferry-service-resumes-between-newburgh-beacon/6992686001/

[42] DCTC. 2021. Moving Dutchess Forward – Sidewalks are public infrastructure – let's treat them that way! https://movingdutchessforward.com/wp-content/uploads/2021/04/DCTC_MovingDutchessForward_Advocate_Local-Actions_Sidewalk-Sidebar.pdf

[43] National Weather Service. 2020. Major Winter Storms.

[44] DutchessNY.gov. 2017. Dutchess County Storm Update – March 14th 5pm. https://www.dutchessny.gov/Departments/County-Executive/34410.htm

	• More frequent fluctuations in temperatures during winter months can cause more frequent icing, deteriorating roadways. This is especially true for gravel and dirt roads, which can turn to mud and become impassable due to more frequent freezing and melting of the road base layer. *Expected future conditions would cause moderate damage and may impact functionality.*	• Winter storms can reduce visibility, creating additional safety hazards. ○ In March 2018, winter storms caused portions of I-84 to close after several vehicle crashes.[45,46] The Taconic State Parkway reported low hanging trees due to the heavy weight of the snow, creating difficult driving conditions and limited visibility.[47] • Permitted vehicle weight may be reduced on thawing icy roads. • Winter storms and temperatures fluctuating around freezing may require more road maintenance and repair, which could cause road delays or closures. Gravel and dirt roads are particularly susceptible to impacts from icing and require more maintenance. *Expected future conditions would cause significant disruptions to service and may cause discomfort/risk for users.*
Bridges	Sensitivity: Medium	Sensitivity: High
	• Rain or snow during winter storms can cause higher levels of soil saturation, making bridges more susceptible to movement. • Ice formation and snow removal can deteriorate pavement, causing potholes and cracking. More	• Bridges freeze faster than roads, and ice formation on bridges can pose a safety risk to passengers. ○ In December 2021, freezing rain caused icy road conditions, vehicle crashes and spin outs, and school closures.[48]

[45] Daily Freeman. 2018. Updated Snow Totals, Accumulation topped 20 inches in parts of Ulster, Dutchess, Columbia counties. https://www.dailyfreeman.com/2018/03/08/updated-snow-totals-accumulation-topped-20-inches-in-parts-of-ulster-dutchess-columbia-counties/

[46] Lewison, Dave. 2018. Interstate 84 shutdown, heavy snow and accidents. Hopewell, NY, Storm Chasing Video. https://www.stormchasingvideo.com/2018/03/07/interstate-84-shutdown-heavy-snow-accidents-hopewell-ny-3-7-2018/

[47] Lewison, Dave. 2018. Interstate 84 shutdown, heavy snow and accidents. Hopewell, NY, Storm Chasing Video.

[48] National Oceanic and Atmospheric Administration. 2022. Storm Events Database. https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=996888

	frequent ice conditions may lead to increased salt application, which can further deteriorate bridge structures and pavement. • More frequent fluctuations in temperatures during winter months can cause more icing, deteriorating bridge pavement. *Expected future conditions would cause moderate damage and may impact functionality.*	• Winter storms can reduce visibility, creating additional safety hazards. • Winter storms and more frequent icing may require maintenance and repair, which could cause delays or closures. *Expected future conditions would cause significant disruptions to service and may cause discomfort/risk for users.*
Culverts	Sensitivity: Low	Sensitivity: N/A
	• Snowmelt runoff after heavy snowfall can overwhelm culverts and other stormwater infrastructure. *Expected future conditions would cause minor damage and would have minimal impact on functionality.*	• No service impacts.
Rail lines/ stations	Sensitivity: Medium	Sensitivity: Medium
	• Tracks can ice over during severe storms. • Snow and ice conditions can make rail stations impassable. • Cold temperatures can make tracks more brittle, increasing the risk of track breakage and separation. • Equipment can be damaged by increased icing. *Expected future conditions would cause moderate damage and may impact functionality.*	• Train service delays or shutdowns may occur due to snow build-up on rail lines or ice formation on above-ground rails. However, Metro-North has installed electric snow melters on most of their switches, so this is not a significant concern. • Severe cold and icy conditions can present safety and health risks to transit passengers waiting on exposed platforms. • Severe winter storms can cause wind damage and electricity outages, leading to service disruptions. However, Metro-North has buried and insulated most of their signals, therefore wind and snow disruptions to signals are not a significant concern.

		Expected future conditions would cause moderate disruptions to service and may cause discomfort/risk for users.

Bus system/ facilities	Sensitivity: Low
	• Bus engines may have difficulty starting in cold temperatures.
	• Extreme cold reduces the effectiveness and efficiency of vehicle batteries, potentially reducing the service life of electric buses.
	Expected future conditions would cause minor damage and would have minimal impact on functionality.
		Sensitivity: High
		• Bus service delays and rerouting may occur, especially for bus lines that run on steep slopes or unplowed roads.
		  ○ Past snow events have led to average service suspensions of 1 day per year since 2015.
		  ○ In December 2020, a winter storm caused Dutchess County to suspend the County's Public Transit service until the storm concluded the following day.[49]
		  ○ In March 2023, a Nor'easter suspended all transit service for the following day and travel and parking restrictions were in place for drivers.[50]
		• Extreme cold impacts on buses, particularly electric buses, may cause service delays.
		• During severe snow events, buses may only run on major streets, reducing access to buses in other locations.
		• Severe cold and icy conditions can present safety and health risks to transit passengers waiting at stops and traveling to and from transit stops.
		• Snow pile-up from plowing can make it more difficult for users to access bus stops.

[49] DutchessNY.Gov. 2020. Winter Storm Update. https://www.dutchessny.gov/Departments/County-Executive/Winter-Storm-Update-Thursday-December-17th-2020.htm
[50] Mid Hudson. 2023. State of Emergencies being declared in advance of storm. https://midhudsonnews.com/2023/03/13/state-of-emergencies-being-declared-in-advance-of-storm/

		• Severe winter storms can cause wind damage and electricity outages, leading to service disruptions. • Road delays or closures caused by snow or ice may cause service delays for passengers. *Expected future conditions would cause significant disruptions to service and may cause discomfort/risk for users.*
Sidewalks	Sensitivity: Low	Sensitivity: Medium
	• Cracking can occur if snow melt is absorbed by concrete and then refrozen when temperatures drop. • Clearing sidewalks of snow and ice may require additional resources and staff. In most communities in Dutchess County, property owners are required to clear sidewalks. *Expected future conditions would cause minor damage and would have minimal impact on functionality.*	• Heavy snow can make it difficult to walk on sidewalks. • Ice can cause dangerous conditions for pedestrians. *Expected future conditions would cause moderate disruptions and may pose risk to pedestrians.*
Rail trails	Sensitivity: Low	Sensitivity: Low
	• Ice formation and snow removal can deteriorate asphalt pavement, causing potholes and cracking. *Expected future conditions would cause minor damage and would have minimal impact on functionality.*	• Snow and ice conditions can cause dangerous conditions for some rail trail users if not properly equipped for the conditions (e.g., walkers, bikers). Other users may benefit from these conditions (e.g., snow shoeing, cross country skiing) *Expected future conditions would cause minimal disruptions and may pose a risk for some users.*
Regional airport	Sensitivity: Low	Sensitivity: Low
	• Damage to navigational aids and other equipment may occur during snow and ice storms.	• Delays can occur if snow and ice need to be cleared from runways or if de-icing aircraft is necessary.

	• Clearing snow and ice from runways may require additional resources and staff. • During ice storms, planes may require de-icing before takeoff. *Expected future conditions would cause minor damage and minimal impact to functionality.*	*Expected future conditions would cause minimal disruptions to service and may pose a risk to users.*
Highway garages	Sensitivity: Low	Sensitivity: N/A
	• Unprotected equipment may be damaged during an ice or heavy snowstorm. • Cleanup of tree branches and trees surrounding the highway garage and its equipment may be required after a snowstorm. *Expected future conditions would cause minor damage and would have minimal impact on functionality.*	• No service impacts. Highway garages do not provide a transportation service.
Park and rides	Sensitivity: Low	Sensitivity: Medium
	• Ice formation and snow removal can deteriorate pavement, causing potholes and cracking. • During a snow event, clearing park and rides of snow and ice may require additional resources and staff. *Expected future conditions would cause minor damage and would have minimal impact on functionality.*	• Heavy snow and ice causes park and rides to become unusable until cleared or melted. *Expected future conditions would cause moderate disruptions to service and may pose a risk to users.*
Transit hub	Sensitivity: Low	Sensitivity: Medium
	• During a snow event, clearing entrances and parking areas may require additional resources and staff. *Expected future conditions would cause minor damage and would have minimal impact on functionality.*	• Heavy snow and ice can cause the transit hub to become unusable until snow is cleared or melted. Service would be moved to the street or sidewalk in this case. • Snow and ice can cover benches and make them unusable for users, causing discomfort.

		• Past snow events have led to average service suspensions of 1 day per year since 2015. *Expected future conditions would cause moderate disruptions to service and may pose a risk to users.*
Beacon ferry dock	Sensitivity: Medium	Sensitivity: Medium
	• Ice cracking and moving along the Hudson River can cause structural damage to the ferry dock. • During a snow event, clearing entrances, parking lots, and the dock may require additional resources and staff. *Expected future conditions would cause moderate damage that may impact functionality.*	• Icy conditions on the Hudson River can cause service suspensions and travel delays. However, there is an alternate bus service when ferry service is suspended, which reduces service disruptions and discomfort for passengers. ○ In March 2022, the Newburgh-Beacon ferry suspended its service due to icy conditions on the river. • Heavy snow and ice fall can create dangerous conditions for people accessing the ferry and delay commuter travel. *Expected future conditions would cause moderate disruptions to service and may pose a risk to users.*

Landslides

The southwest and eastern parts of Dutchess County have steep slopes where landslides or rockfalls are more likely to occur.

Roads, bridges, and rail lines/stations have high sensitivity to landslides. Table 9 summarizes expected impacts to physical infrastructure and users and services.

TABLE 9. TRANSPORTATION SENSITIVITIES TO LANDSLIDES[51]

	Impacts to Physical Infrastructure	Impacts to Users and Services
Roads	Sensitivity: High	Sensitivity: High
	• Landslides can cause physical damage to road surfaces. *Expected future conditions would cause significant damage and impact functionality.*	• Landslides can block roads, leading to traffic delays, detours, and road closures. • In extreme cases, landslides can cause injury and death to travelers. *Expected future conditions would cause significant disruptions to service.*
Bridges	Sensitivity: High	Sensitivity: High
	• Landslides can cause physical damage to bridges. • Landslides around bridge support structures can make bridges unstable. *Expected future conditions would cause significant damage and impact functionality.*	• Landslides can block bridges, leading to traffic delays, detours, and road closures. • In extreme cases, landslides can cause injury and death to travelers. *Expected future conditions would cause significant disruptions to service.*
Culverts	Sensitivity: Medium	Sensitivity: N/A
	• Landslides can completely bury or block culverts, making them non-functional. However, historic and anecdotal evidence indicates that there are only a	• No service impacts.

[51] Arun Kristian Das. 2021. Yonkers landslides knock out Metro-North Hudson Service. Fox5 NY. https://www.fox5ny.com/news/yonkers-landslides-knock-out-metro-north-hudson-service.

	small number of locations in Dutchess County where landslide risk is a concern. *Expected future conditions would cause moderate damage and may impact to functionality.*	
Rail lines/ stations	Sensitivity: High • Landslides can block rail lines and cause physical damage to stations, trains, and other rail infrastructure. *Expected future conditions would cause significant damage and impact functionality.*	Sensitivity: High • Landslides can cause service disruptions if tracks are blocked by debris. *Expected future conditions would cause significant disruptions to service.*
Bus system/ facilities	Sensitivity: Low • Landslides can cause physical damage to buses and bus stop infrastructure. However, buses can be temporarily rerouted or move a stop if part of a road or stop is damaged. *Expected future conditions would cause minor damage and minimal impact to functionality.*	Sensitivity: Low • Landslides can disrupt bus service if roads are blocked. However, buses can be temporarily rerouted or move a stop if part of a road or stop is damaged. *Expected future conditions would cause minor disruptions to service.*
Sidewalks	Sensitivity: Medium • Landslides can block portions of the sidewalk. • Landslides can cause physical damage to portions of the sidewalk and require debris removal or repairs. *Expected future conditions would cause moderate damage and may impact functionality.*	Sensitivity: Medium • Sidewalks may require clean up or repairs to become accessible for pedestrians. *Expected future conditions would cause moderate disruptions and may pose risks to pedestrians.*
Rail trails	Sensitivity: Medium • Landslides can block portions of a rail trail and cause physical damage to rail trails. *Expected future conditions would cause moderate damage and may impact functionality.*	Sensitivity: Medium • Rail trails may require clean up or repairs to become accessible for users. *Expected future conditions would cause moderate disruptions and may pose risks to user.*

Regional airport	Sensitivity: N/A	Sensitivity: N/A
	• Not exposed. The Hudson Valley Regional Airport is in an area of low landslide susceptibility.	• Not exposed. The Hudson Valley Regional Airport is in an area of low landslide susceptibility.
Highway garages	Sensitivity: Medium	Sensitivity: N/A
	• Landslides can cause physical damage or block access to highway garages. *Expected future conditions would cause moderate damage and may impact functionality.*	• No service impacts. Highway garages do not provide a transportation service.
Park and rides	Sensitivity: N/A	Sensitivity: N/A
	• Not exposed. All park and rides are in areas of low landslide susceptibility.	• Not exposed. All park and rides are in areas of low landslide susceptibility.
Transit hub	Sensitivity: N/A	Sensitivity: N/A
	• Not exposed. The Poughkeepsie transit hub is in an area of low landslide susceptibility.	• Not exposed. The Poughkeepsie transit hub is in an area of low landslide susceptibility.
Beacon ferry dock	Sensitivity: N/A	Sensitivity: N/A
	• Not exposed. The Beacon ferry dock is in an area of low landslide susceptibility.	• Not exposed. The Beacon ferry dock is in an area of low landslide susceptibility.