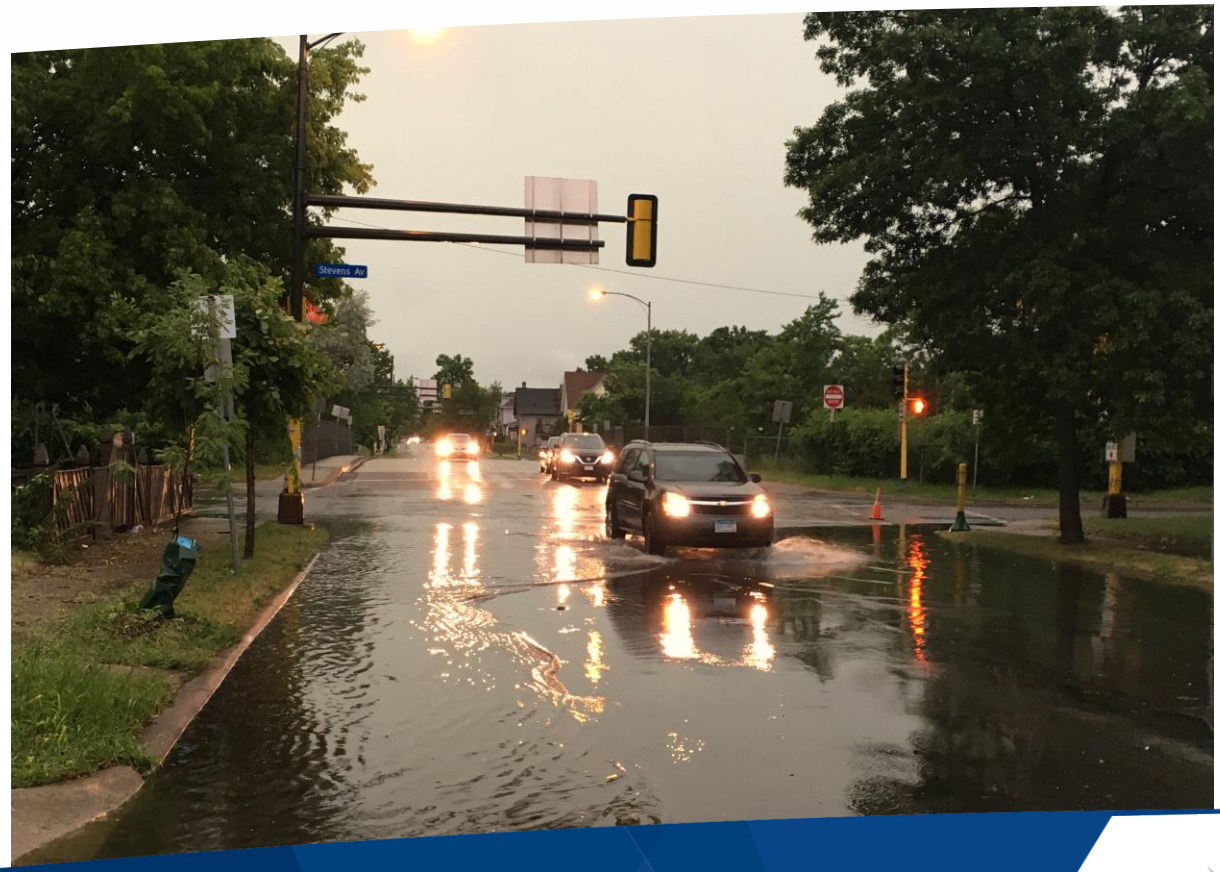
REGIONAL CLIMATE VULNERABILITY ASSESSMENT

Part 1: Localized Flood Risk
Chapter 1: Transportation & Transit



METROPOLITAN COUNCIL

August 2018

The Council's mission is to foster efficient and economic growth for a prosperous metropolitan region

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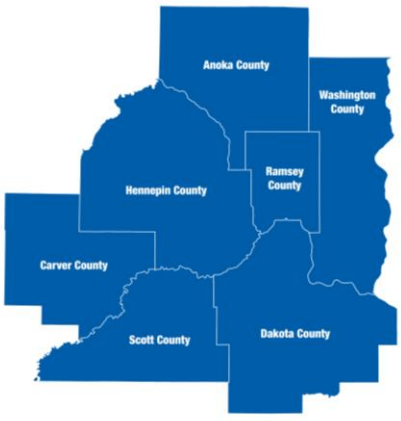

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide housing opportunities for low- and moderate-income individuals and families. The 17-member Council board is appointed by and serves at the pleasure of the governor.

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Chapter 1: Transportation & Transit

The metro area transportation and transit network consists of interconnected systems including surface roads and rails, transit services with over two hundred bus and train/LRT routes and related infrastructure, eleven airports, and region-wide dedicated bicycle routes. The network serves over 3 million regional residents and is an interstate shipping and transportation hub. Administrative authority includes multiple federal and state level agencies, tribal nations, seven counties, almost 200 local government units, and the Metropolitan Council, including Metro Transit.

The Council has analyzed its wastewater infrastructure using its *Localized Flood Map for Climate Vulnerability Screening.* To learn about the methods employed in creating the localized flooding data layer, please refer to the document entitled *Localized Flood Risk – Introduction* on the CVA webpage: *https://metrocouncil.org/CVA*. For the transportation and transit analysis, sensitivity throughout the network was assessed, primarily, in terms of the number of people affected by any potential disruption. Specific attributes were identified for many transportation and transit components that provided either a direct or proxy measure of affected users. For some components, the Flood Impact Zone (FIZ) itself provides the measure of vulnerability either because of a very low impact threshold (rails, runways) or a lack of other distinguishing attributes (bike routes).

Table 1. Sensitivity & Exposure by Transportation &Transit Asset

Transportation-Transit Asset	Low	Medium	High
Bus Routes by Type	*Express*	*Local*	*Hi Frequency*
Bus Routes by Number Affected	*1 route*	*2-3 routes*	*≥ 4 routes*
Bus & Transit Stops*, by Routes Served	*1 route*	*2-3 routes*	*≥ 4 routes*
Roadways, by Functional Class	*Local & Collector*	*All other Arterials*	*Principal Arterials*
Rail Lines, Airport Runways, Bicycle Network	*- Sensitivity/Exposure defined by Flood Impact Zone only. Primary, and in some cases Shallow/Primary, represent the highest vulnerability.*		

**Transit stops include Rail Stations, bus stops within 1/8 mi. of rail stations, park and ride facilities, and Transit Center facilities.*

Each asset's sensitivity/exposure was compared against the Flood Impact Zone to create a composite ranking of vulnerability using the Vulnerability Matrix shown in Table 2. This matrix combines the level of sensitivity/exposure from Table 1 with the Flood Hazard to determine an overall vulnerability for a specific asset at a given location.

Table 2. Vulnerability Matrix for Transportation &Transit Assets*

Flood Hazard		Vulnerability		
		Low*	**Medium***	**High***
Flood Impact Zone	Shallow	*Very Low*	*Low*	*Medium*
	Primary	*Medium*	*High*	*Very High*
	Secondary	*Low*	*Medium*	*High*
	Tertiary	*Very Low*	*Low*	*Medium*

**This extra step is performed for Bus Routes, Transit Stops, and Roadways. The Low, Medium, or High ranking from Table 1 is inputted into this matrix to determine vulnerability when intersected with the Flood Hazards.*

Overview of Regional System Assessment

Riverine flooding areas are generally known and regulated by relevant stakeholders, be it local floodplain managers or state agency staff. It is advisable that riverine flooding be considered with the latest modelling data and Atlas 14 precipitation estimates to ensure that all floodplain mapping is up to date and as accurate as possible.

Figure 1. Comparison of Localized Flooding and FEMA Floodplains

Localized flooding helps expand understanding of flooding dangers, which have traditionally relied upon rigorously studied and closely managed 100- and 500-year floodplains. Much of the built environment, including roads and rails, has intentionally been located outside the floodplain, or has been built to withstand flooding, whether as a matter of best practice or regulation.

When examining potential impact of flooding events on infrastructure, the floodplain should be considered alongside localized hazards for analysis of built assets, existing emergency management, and for potential compounding of hazards where both types of flood impact could occur.

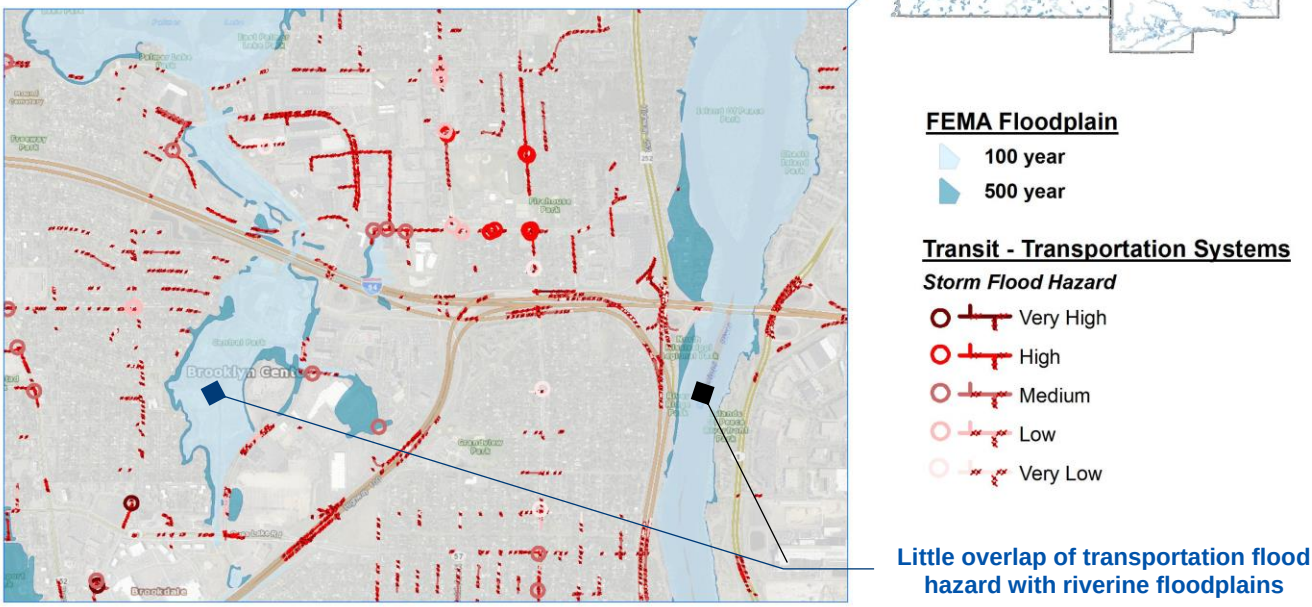


Figure 1 shows that transportation and transit assets are generally designed with riverine flooding in mind and located outside of the regulatory floodplain. Therefore, The Transportation and Transit Chapter of the CVA does not include analysis of riverine flooding. Other chapters of the CVA do include consideration of the FEMA floodplain.

The localized flooding data layer does not replace the FEMA flood information. It allows for a localized screening of areas that could be prone to surface water flooding that can occur outside the influence of streams and rivers. In recent years, cities have seen much more surface or localized flooding from short, intense rain events. While communities plan for such occurrences, in some instances stormwater infrastructure can become overwhelmed or blocked. The localized flooding data shows potential flood risks in the transportation and transit network in the event of stormwater infrastructure failure.

To analyze the potential localized flood impacts to the transportation and transit systems, the Council has produced an overview of systemwide exposure to localized flooding hazards. It should be emphasized that this analysis was conducted in 2017, so as assets change (for example, bus routes), an analysis can be updated as required.

Table 3 provides a systemwide overview of potential localized flooding impacts to transportation and transit assets. Due to the extensive nature of the transportation and transit network, these system assets are subject to some potential localized flooding impacts. However, the percentage of total assets within a Flood Impact Zone across all indicators is relatively low, with 82.6% of all assets located outside areas of potential risk. For assets located within hazard areas, more than one-third of all assets fall within the Primary flood hazard, considered the highest category of flood hazard, with nearly half of all transit stops and nearly half of all LRT/commuter miles located within the Primary flood hazard area.

Table 3. Transportation &Transit Potential Localized Flood Vulnerability by Flood Impact Zone

			Flood Impact Zone % for Assets in a FIZ				
Asset	Total	Total Assets in FIZ*	Primary	Secondary	Tertiary	FIZ Average Max. Depth**	Shallow
Bus Routes	5,976 mi.	17.4%	36.3%	27.3%	25.3%	4.76ft	11.1%
LRT/Commuter Lines	111 mi.	9.6%	47.5%	25.2%	18.4%	3.75ft	8.9%
All Transit Stops	19,422 stops	12.8%	46.6%	12.4%	12.9%	3.39ft	28.1%
All Roadways	44,266 mi.	12.8%	38.1%	25.2%	24.2%	3.87ft	12.5%
Regional Highways	24,584 mi.	16.2%	34.9%	26.4%	27.1%	4.28ft	11.6%
Bicycle Routes	6,773 mi.	15.5%	34.2%	26.6%	27.5%	4.02ft	11.6%

**Refer to Total Asset in FIZ column to determine total exposure to potential localized flooding for each asset. More than 80% of all Council assets are outside of a FIZ.*
***FIZ Average Maximum Depth refers to Primary, Secondary, and Tertiary FIZ. It does not include Shallow.*

Table 3 also shows the average maximum depth for flood hazard areas for each asset. In other words, where an asset intersects a Flood Impact Zone (FIZ), there is an average depth of flood potential for that asset where it intersects a FIZ. The risk for each asset depends on the importance assigned to different flood hazard depths. For instance, for LRT and commuter rail lines, both Shallow and Primary flood levels represent a higher vulnerability, given the fact that even a little bit of standing water over the rail can affect this form of transit. For bus routes, the Shallow FIZ is of a much lower concern because buses can traverse Shallow areas of localized flooding without safety or operational issues.

It is important to note that Table 3 shows systemwide percentages and averages. Asset-based and site-specific analysis (assessment of a certain bus route, for example) should be conducted to clearly identify and prioritize areas of vulnerability and subsequent site-specific strategies to increase resilience of Metropolitan Council systems.

The sections that follow will describe the vulnerability of each component of the regional transportation and transit network, including the methodology for assessing vulnerability by asset, analysis, considerations for planning and response, and strategies for addressing the system vulnerabilities.

Regional Highway Network

Rationale

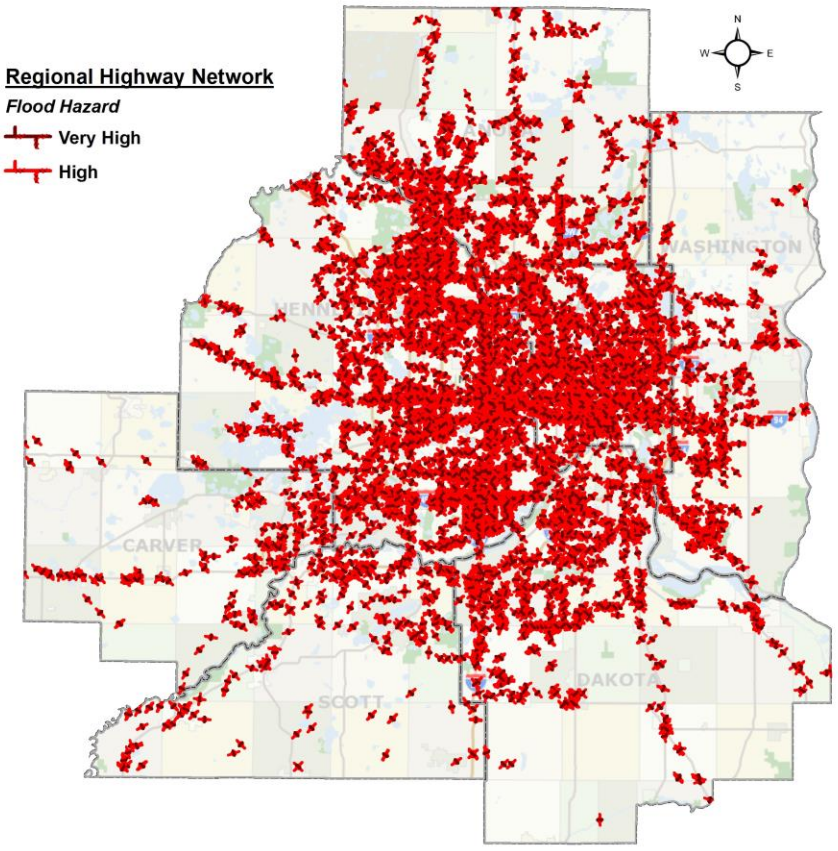
The highway network constitutes the primary component for all vehicle traffic throughout the region. While local streets account for the majority of overall road mileage, arterial routes (highways and related connecting and high-traffic roads) represent concentrations of traffic including personal, commercial, industrial, and transit uses. In many cases, these routes are more susceptible to traffic congestion or have restricted on/off access, further affecting sensitivity and exposure to flood events.

Functional Class was used to define sensitivity and exposure of the highway network. Functional Class is an attribute of all road features that serves to define the role of each roadway within a network, designed to provide a measure of traffic capacity, usage, accessibility, and travel speeds. For example, interstate highways carry the most traffic and the most people, and thus rank highest in exposure and sensitivity to a potential localized flood event (see Table 1).

Table 4. High & Very High Potential Flood Vulnerability Arterial Centerline Miles by County

Anoka	102.01 miles
Carver	19.14 miles
Dakota	137.47 miles
Hennepin	652.78 miles
Ramsey	239.85 miles
Scott	19.24 miles
Washington	61.27 miles
7-County Total	**1231.76 miles**

Figure 2. Regional Highway Network - Potential Flood Vulnerability



Methodology

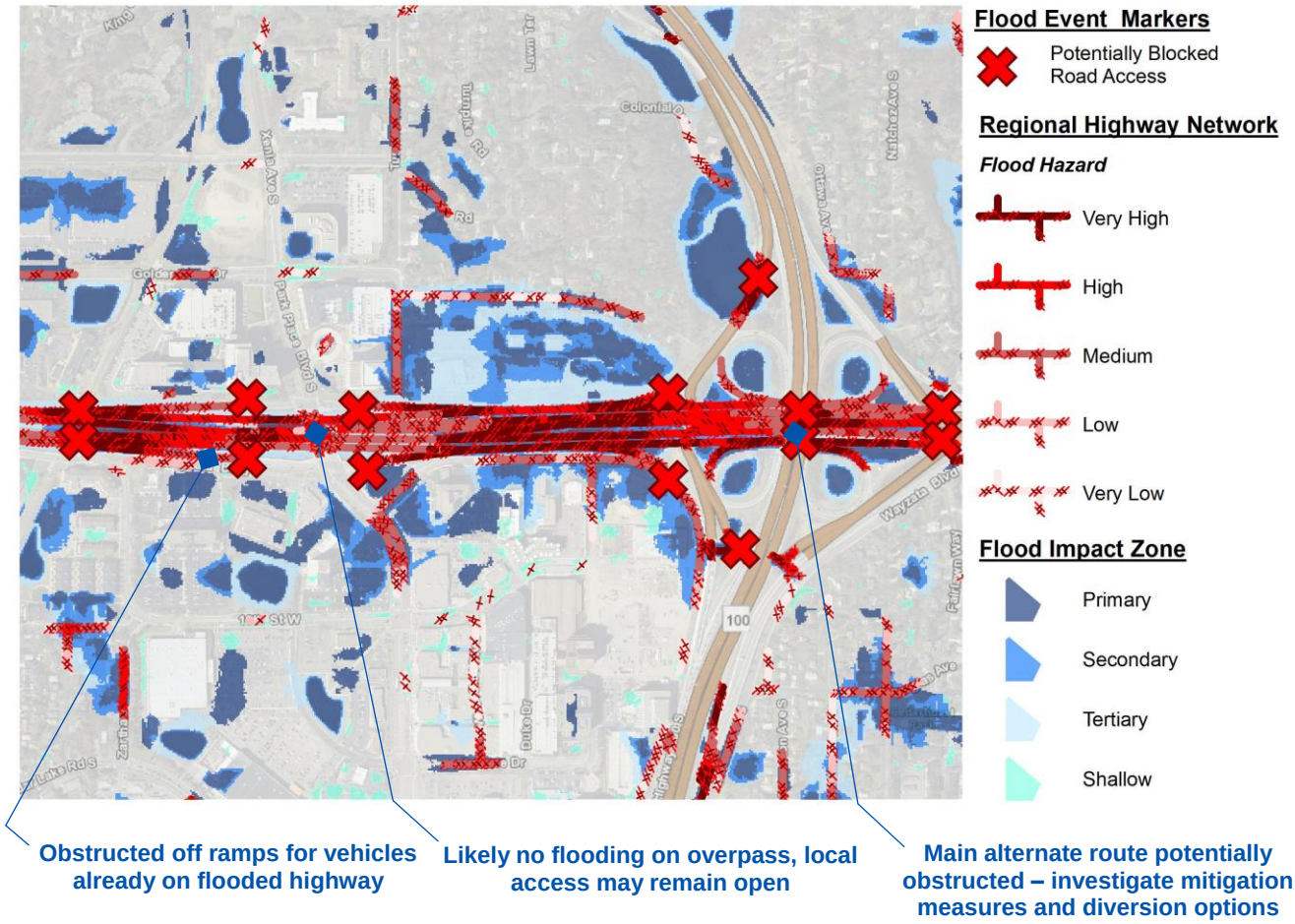
The Metropolitan Council's arterial roadways were compared with potential localized flood locations using an intersect operation. The arterial road classification was inputted into Table 2 to determine the level of sensitivity and exposure (low, medium, or high). The road was then intersected with the Flood Impact Zone (FIZ) to determine overall vulnerability, from Very Low to Very High.

Analysis

All arterial roadways in the regional network intersect multiple flood zones and are subject to at least some potential flood hazard. Table 4 provides the regional overview of roads in the network subject to greatest vulnerability, including Primary flood zones along all arterial roads and both Primary & Secondary flood zones along interstate highways. In Figure 2, localized flood vulnerability is concentrated in the urban center, which is a function of greater road density compared to exurban and rural areas.

As a more localized example, Figure 3 shows the intersection of an interstate and major state highway subject to potential localized flooding. At this more site-specific level, potential obstructions become evident. For example, on- and off-ramps are potentially impassable at two successive points, creating an increased possibility for stranding vehicles on the highway while reducing access for emergency services. Use of alternate routes via minor arterials and local roads may also be difficult or require very long detours, with limited passable crossings of either highway.

Figure 3. Potential Localized Flood Vulnerability at Major Regional Junction



Considerations

Management of the highway network has a wider range of authorities than other components of the regional transportation and transit systems. The Council and MnDOT share planning responsibility for the metropolitan highway system, while MnDOT carries out day-to-day operations and repair on the system. The metropolitan highway system also serves and connects to arterial routes that may be subject to one or more county and municipal jurisdictions, as well as the local street network. Meanwhile, Metro Transit and suburban transit providers operate vehicles and facilities across all parts of the network. Adaptive planning will often involve (or impact) multiple governmental units, as well as the wide array of transportation network stakeholders.

Existing Strategies

MnDOT and partner road authorities are responsible for responding to localized flooding on the metropolitan arterial network. Impassable roads are subject to road closures and rerouting for motorists. MnDOT and partner road authorities perform routine road maintenance to reduce the impacts of localized flooding on the metropolitan arterial network.

Potential Strategies

Metropolitan Council may consider the following:

- ☐ Conduct an arterial assessment of vulnerable areas through collaboration with relevant road authority and stakeholders
- ☐ Collaborate with relevant authorities and stakeholders to increase surface water infiltration, through green infrastructure practices where possible, in potential vulnerable areas
- ☐ Plan for rerouting and alternative routes with agency and community partners
- ☐ Facilitate the creation of a regional notification of road rerouting, similar to the *Hennepin County Transportation Map*

Local stakeholders may consider the following:

- ☐ Institute volunteer adopt-a-drain programs for local roads, using vulnerable areas for prioritization
- ☐ Engage with local Emergency Management to use prioritization of vulnerable areas to devise rerouting plans during extreme weather events

I35W North. Source: Metropolitan Council Digital Image Library

Light Rail/Commuter Rail

Rationale

The rail system is unique in its sensitivity to flooding, with a lower sensitivity and exposure threshold than other assets and generally high impact in terms of persons affected. Moreover, because it operates in a dedicated right-of-way with fixed points of access, rerouting or diverting vehicles is not an option, and a different set of mitigation and adaptive measures are required than might be applied for other modes of transit. Finally, the three lines have varying spatial, built, and use characteristics. As such, an individual analysis section is provided for each.

Methodology

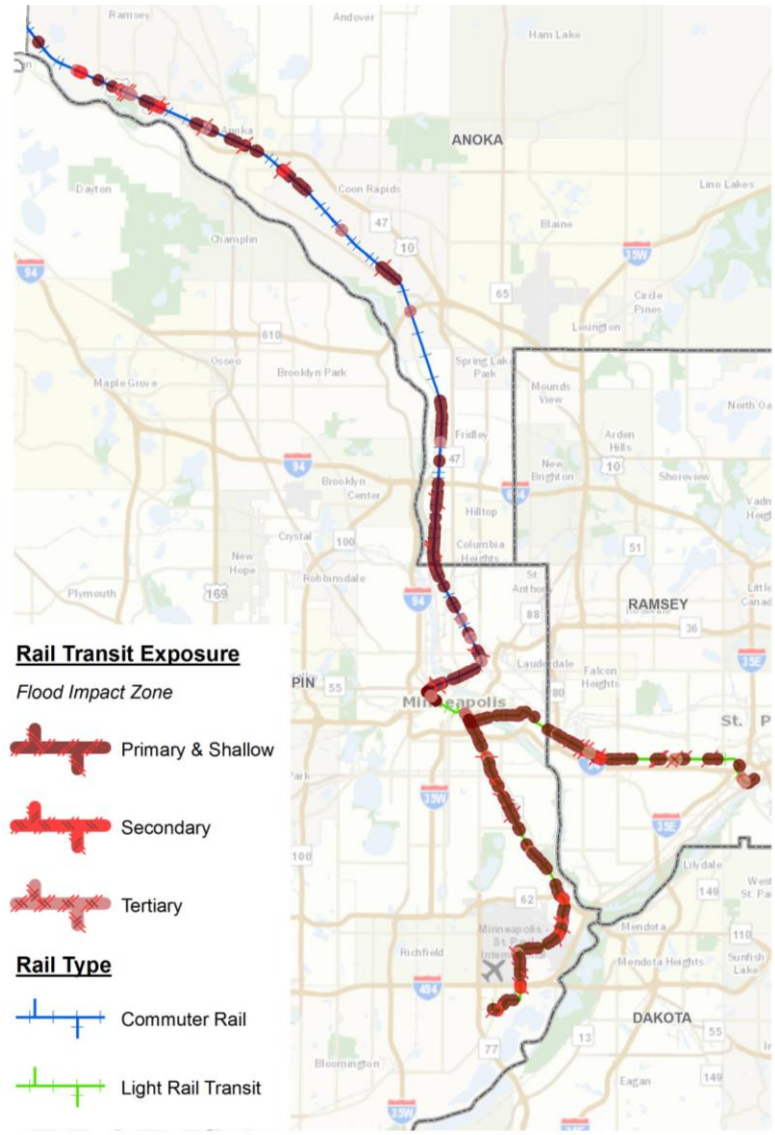
Potential flood exposure for the regional rail transit system is extensive. To consider the spectrum of impact in a potential event, train line infrastructure, nearby connecting road networks, and station level exposure were each evaluated. The localized flooding analysis encompasses the seven-county metro area, but excludes the terminus of the Northstar Line in Sherburne County. All measures and analysis below include only the Anoka and Hennepin County portions of the Northstar line.

Immediate exposure is represented by flood waters that could affect the operation of rail vehicles on the track. The transit routes layer was compared with Flood Impact Zone locations using an intersect operation, providing segments of rail lines within potential flood areas (Figure 4). Because of the low water depth required for disruption (as little as 2” over the top of the rail), the Shallow category was grouped with the Primary Flood Impact Zone for the purposes of this analysis.

The road network serving regional rails provides the origin points for many rail trips, as well as access for relief buses or emergency service in the event of stranded trains and riders. The complete road network feature was clipped to a one-mile radius of rail lines and intersected with FIZ, identifying all access points subject to potential flood.

Riders connect to rail transit at stations, which are often reached via bus transfers and park & ride facilities. The Bus Transit section of this chapter considers vulnerability to transit stops throughout the system.

Figure 4. LRT and Commuter Rail - Potential Flood Vulnerability



Analysis: Metro Blue Line LRT

Metro Blue Line was the first operational LRT line in the system and currently provides well over 10 million annual trips. Features served include some of the region's largest employment centers, the international airport, and major recreation, commercial, institutional, and medical destinations. Red Line BRT extends service to the south, and transfer connections are available along the line to 149 additional Metro Transit and partner routes.

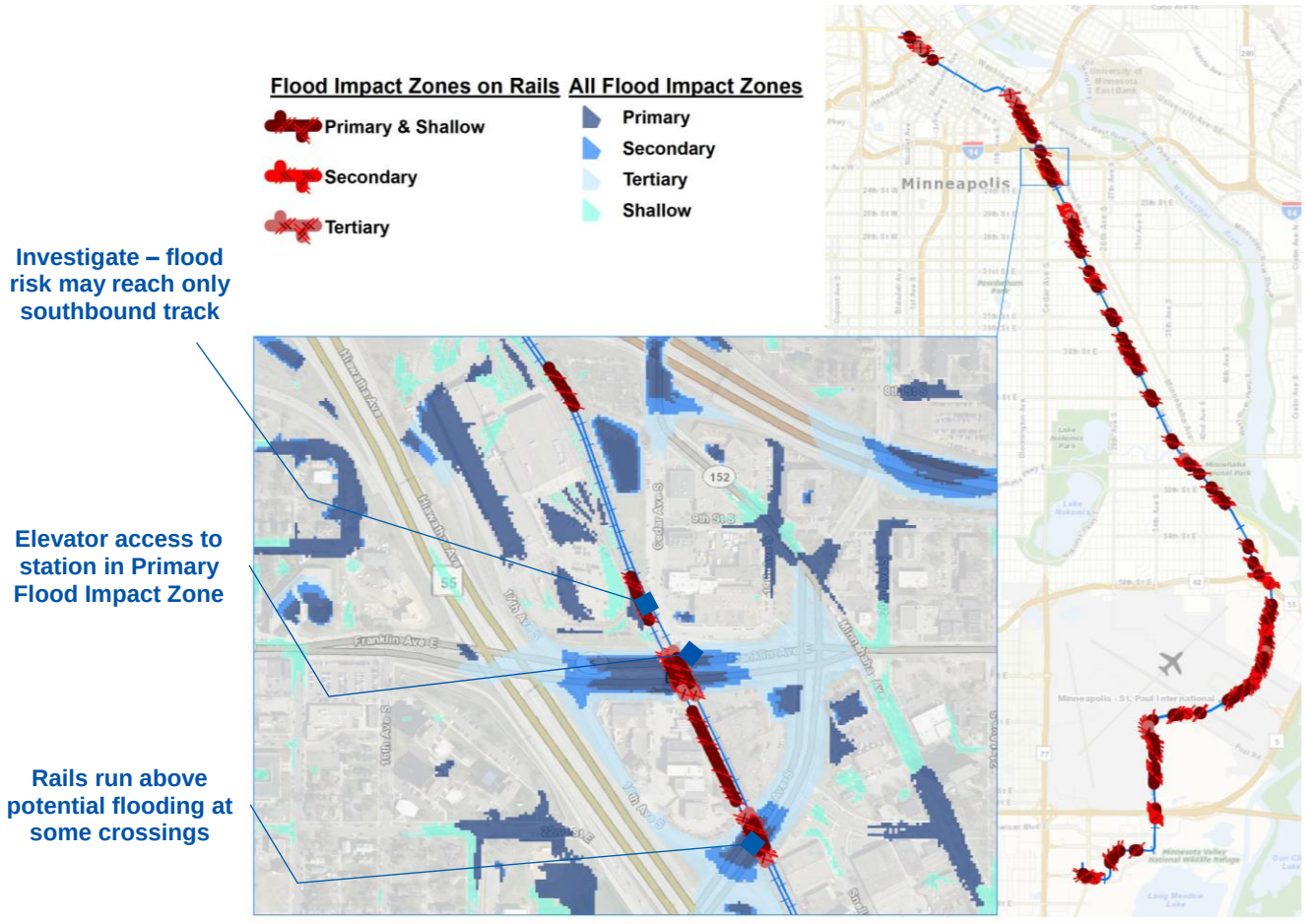
The Blue Line is intersected at short, frequent intervals by Flood Impact Zones and is subject to marginally greater total exposure than either the Green Line or Northstar. While Flood Impact Zones account for only 15.5% of mileage on the line, the greatest length without potential flooding is still less than one mile. Moreover, over 80% of all exposure occurs within the Primary or Shallow zones, which are the first to fill and most likely to create flooding in an intense storm event.

METRO BLUE LINE

23.5 miles of track
10.6 million trips in 2017
19 stations, 5 shared with Green Line
150 connecting transit routes
3.67 miles of line potentially subject to localized flooding
80.6% of potential flood zones are highest category of hazard

Blue Line LRT stations are typically, though not always, elevated 18-24" above grade, providing some degree of protection from flooding and reducing direct exposure to only a few stations on the line. Bus stops and park-and-ride lots providing transfer service to and from stations are, however, more broadly exposed, creating a second tier of potential disruption. Bus and transit stops are addressed in greater detail under the Bus Transit section of this analysis.

Figure 5. Metro Blue Line - Potential Localized Flood Vulnerability



Analysis: Metro Green Line LRT

The Metro Green Line was the second LRT line in the system and currently delivers more than 13 million annual trips. The line serves 18 stations connecting the Minneapolis and St. Paul downtowns, with the five westernmost stations shared by Metro Blue Line. BRT service on the A Line connects at the line's midpoint, and transfer access is available to 167 additional transit routes.

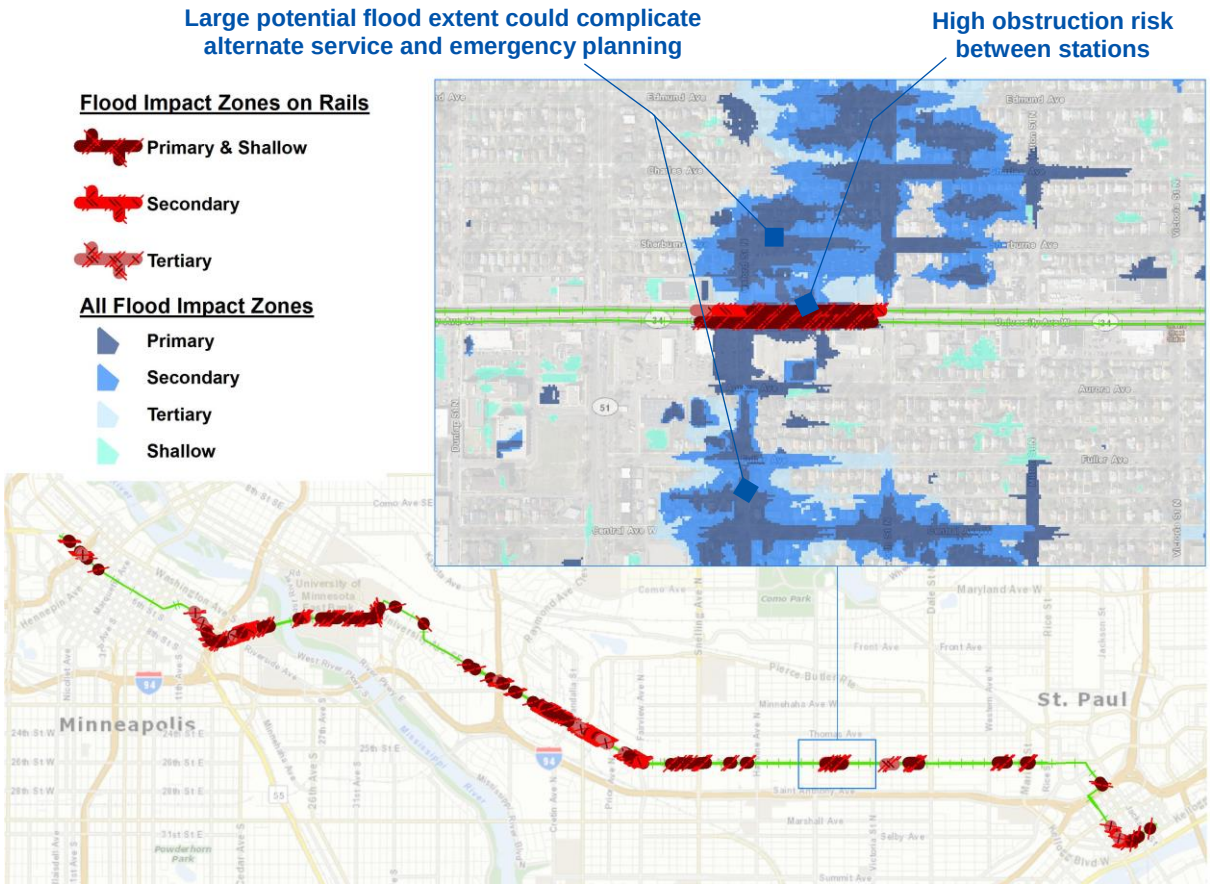
METRO GREEN LINE

18.01 miles of track
13.1 million trips in 2017
18 stations, 5 shared with the Blue Line
168 connecting transit routes
3.52 miles of line potentially subject to localized flooding
54.5% of potential flood zones are highest category of hazard

Of the 15.6% of the Green Line that intersects with Flood Impact Zones, potential Primary and Shallow flood hazard exposure consists of 54.5%. The Green Line exhibits several extents free of any flood exposure. Stations are generally elevated and have similar considerations to those of the Blue Line.

The elevation data used to create the localized flood data was captured in 2011, prior to the excavation and building of the line. As such, this analysis should only be considered as preliminary guidance, subject to further ground-truthing and evaluation depending on the final build characteristics at any given location along the line.

Figure 6. Metro Green Line - Potential Localized Flood Vulnerability



Analysis: Northstar Commuter Rail

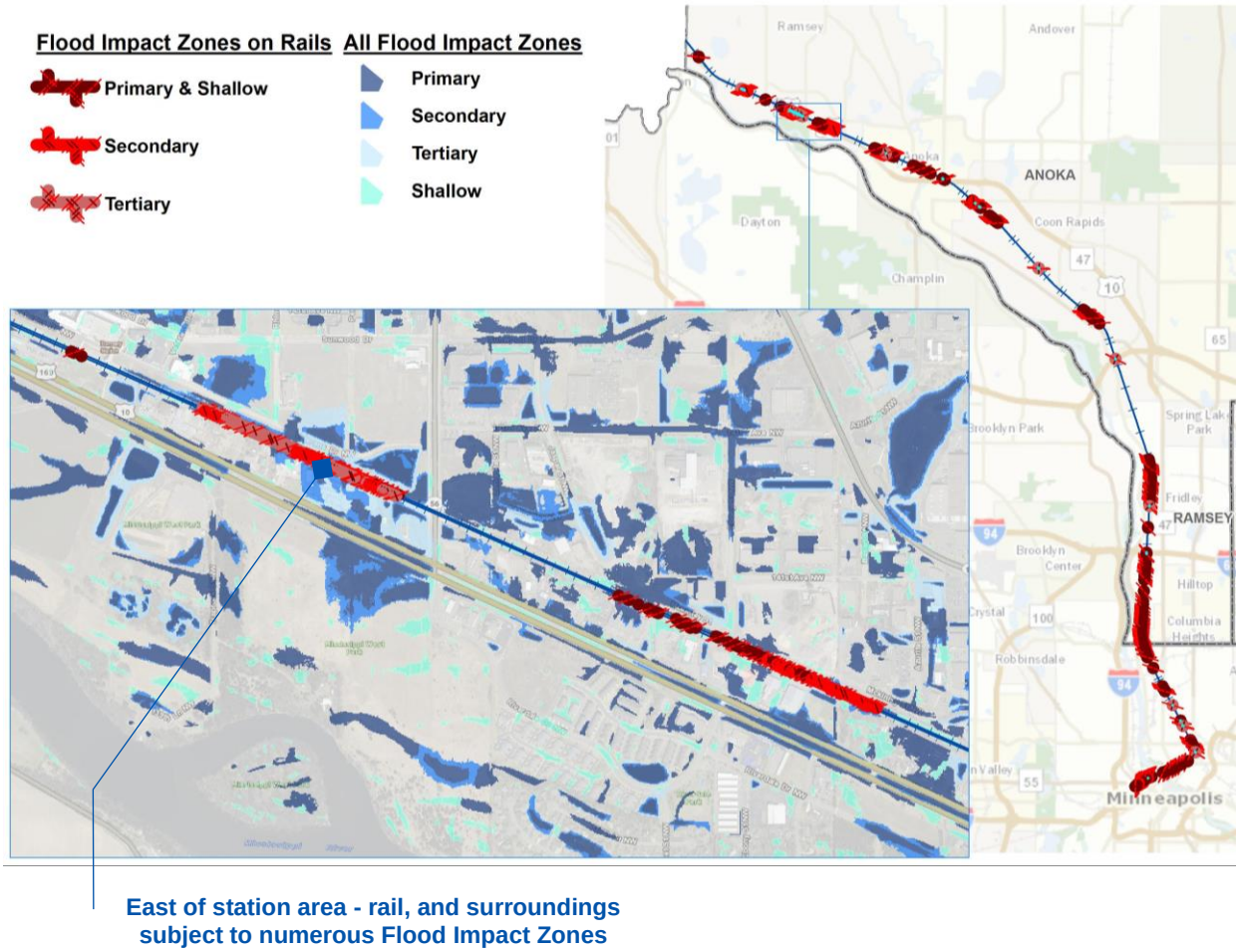
The Northstar Line serves long distance commuters between the north metro area and downtown Minneapolis. Since commencing operations in 2010, annual trips have fluctuated but have always exceeded 700,000. Northstar riders can transfer to any of 69 additional transit routes near the line terminus in Minneapolis.

Within Anoka & Hennepin Counties, Northstar intersects 3.5 total miles of Flood Impact Zones, only 5% of total track length and a much lower proportion than either LRT line. Several extents of the Northstar line are free of any flood exposure. This is likely due in part to the elevated protection afforded by operating on a raised rail bed. Stations are again generally elevated to accommodate the larger rail vehicles, but otherwise have similar considerations to those of the LRT stations.

NORTHSTAR LINE

69.81 miles of track in metro
793,000 trips in 2017
7 current stations
69 connecting transit routes
3.5 miles of line potentially subject to localized flooding
73.2% of potential flood zones are highest category of hazard

Figure 7. Northstar Commuter Line - Potential Localized Flood Vulnerability



Considerations

The Northstar commuter line operates on freight rails, with larger, heavier rolling stock and different motive power (diesel) than the two LRT lines (electric). However, the braking or traction control systems for each are comparable and subject to the same limitations in flood conditions. Safety protocols on the Northstar Line are dictated by BNSF procedure, including inspections on the line and speed reductions in the event of flooding. Similar procedures are in place for Metro Transit LRT operators.

Rail operations hardware, such as signal and crossing control houses, were not assessed for localized flooding vulnerability. These components are typically sealed metal structures with electronic equipment responsible for controlling crossing gates, lights, and other functions supporting public and operational safety. Technical information regarding sensitivity to water infiltration was not available on these structures at the time of analysis.

The nature of the rail system means that in the event of a flood, a train unable to proceed at any single point may create an impassable obstruction, causing an entire line to be out of service. Average total weekday rail (both LRT and commuter rail) ridership in 2017 was 74,883. With average 2017 systemwide weekday transit trips of 264,347, alternate bus or shuttle relief service may be insufficient. To a greater degree than other assets, adaptive planning may need to focus more on proactive solutions that can either prevent or quickly drain flood areas along the rail line, rather than more reactive measures.

Existing Strategies

Northstar Commuter Rail

The Northstar Line is a federally mandated and regulated railroad. The Federal Railroad Administration (FRA) published the Passenger Train Emergency Preparedness Rule in the Code of Federal Regulations (CFR) in 1998. The Rule is located in the Title 49, Department of Transportation, Part 239. CFR 49, Part 239 requires one full scale emergency response exercise every two calendar years.

The Northstar Line is operated by Metro Transit, with BNSF engineers. The Northstar Line is governed by a joint Northstar/BNSF Passenger Train Emergency Preparedness Plan which complies with federal requirements. Metro Transit has also adopted the Northstar Commuter Rail System Safety Program Plan (SSPP), with the express purpose of safety enhancement through coordination, satisfaction of federal and state requirements, and identification and elimination of identified hazards through an established framework.

Light Rail Transit

The Light Rail Transit System Safety Program Plan (SSPP), the Light Rail Operations Emergency Management Plan, and the Metro Transit Security and Emergency Preparedness Plan work in concert with one another to ensure internal and external coordination and preventative measures that embrace hazard mitigation in line with an all-hazards approach to emergency management within the federal National Incident Management System (NIMS). Metro Transit conducts emergency response exercises periodically with agency partners. The NIMS protocols are in place to ensure cross-agency management of emergency situations, be they related to inclement weather or a public safety issue.

The LRT System Safety Plan requires one emergency response exercise every calendar year. Processes and decision-making emphasize coordination and integration of capabilities, hazard identification and mitigation, and restoration of service.

Metro Transit staff indicated that the Standard Operating Procedures for the LRT requires operators to reduce speed to 10 mph if as little as 2 inches of water covers the rail. If the diameter of flood area is

over 2 feet, the LRT operator should not proceed without Rail Operations Manager approval. Any train exposed to water deeper than 2" above the rail must be written up for a maintenance inspection. This practice ensures that areas prone to localized flooding are constantly analyzed for potential increase in vulnerability.

Proposed Strategies

While Metro Transit and BNSF have robust protocols and procedures in place for hazard mitigation, it is advised that the localized flooding data be used to identify areas for a focused assessment of potential localized flooding hazards, coupled with use of the data as a front-end planning tool to assist in providing route redundancy in the event of operations disruption.

Northstar Commuter Rail Train in downtown St. Paul. Source: Metro Transit Flickr account: https://www.flickr.com/photos/metrotransitmn/

Metro Transit may consider the following:

- ☐ Perform site review and audit of all Shallow & Primary rail segments
- ☐ Document all flood areas that disrupt LRT operations and compare these to localized flooding data
- ☐ Enact protocols for relief transit vehicles in advance of forecasted severe storms
- ☐ Assess localized flooding impacts on rail operations hardware using technical structure specifications for water infiltration
- ☐ Work with local jurisdictions and stakeholders to enact stormwater best management practices and ongoing maintenance in jurisdiction's right-of-way along LRT and commuter transit corridors
- ☐ Prioritize vulnerable station areas to communicate localized flooding potential to riders in a variety of formats and languages

Bus Transit

Rationale

Although bus routes and stops are closely linked, exposure to flood hazards differs for bus routes (the linear street network along which the bus itself travels) versus bus stops (the points at which pedestrians embark or disembark). On routes, a bus is generally able to operate safely at a water depth of one foot and is not likely to experience great difficulty until depths reach two feet or more. As such, unique among the transit assets, Shallow flood areas are omitted from consideration with Bus Routes. Conversely, according to the National Weather Service and NOAA, an adult can be knocked down and even swept away by flood depths as shallow as six inches. Since most transit stops do not provide physical protection from flooding, independent Shallow flood areas (up to 1 foot deep) remain a concern there.

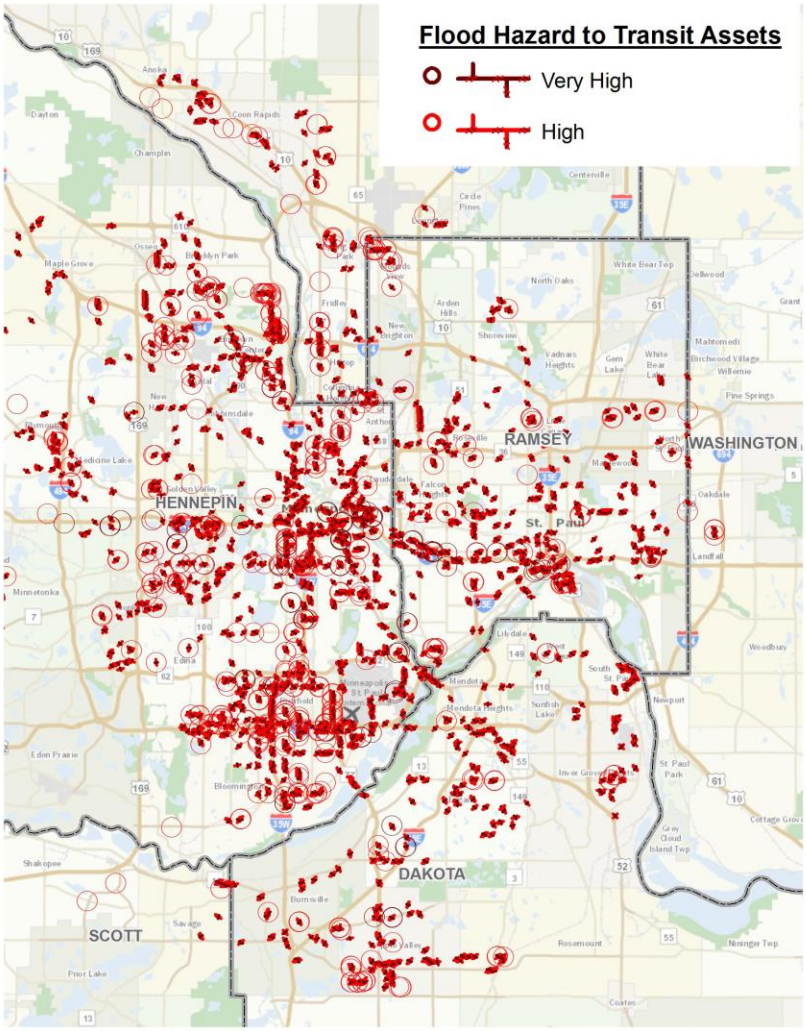
Asset-specific sensitivity and exposure was quantified based on available data, as shown earlier in Table 1. The Route Type provides a measure of ridership, with High Frequency, Urban/Suburban, and Express representing high to low sensitivity and exposure for each route. Bus stops were assessed based on potential ridership impact, considering number and type of routes served by each stop.

Methodology

The regional Bus Transit system is both extensive and complex, with over two hundred different bus routes serving nearly 20,000 stops along 6,000 road miles. Metro Transit administers the core system infrastructure and routes, and partners including SouthWest Transit and MVTA provide additional service on extended networks between the urban center and suburban commuting centers. Riders connect to the system at street corner bus stops and other transit hubs including park and ride lots, rail stations, and Transit Centers – multi-route sites offering amenities designed to enhance convenience and the transit experience.

Data on active bus routes from all providers (distinct from the three rail transit lines) was intersected with Flood Impact Zones to identify points of exposure and consolidate the line and flood attributes. Transit from all providers was assessed by merging individual layers for bus stops, park & ride stops, transit centers, and rail stations. The combined layer with all stop types was then intersected with FIZ, identifying which stops would be vulnerable and to what degree. Figure

Figure 8. Bus Routes and Stops - Potential Localized Flood Vulnerability



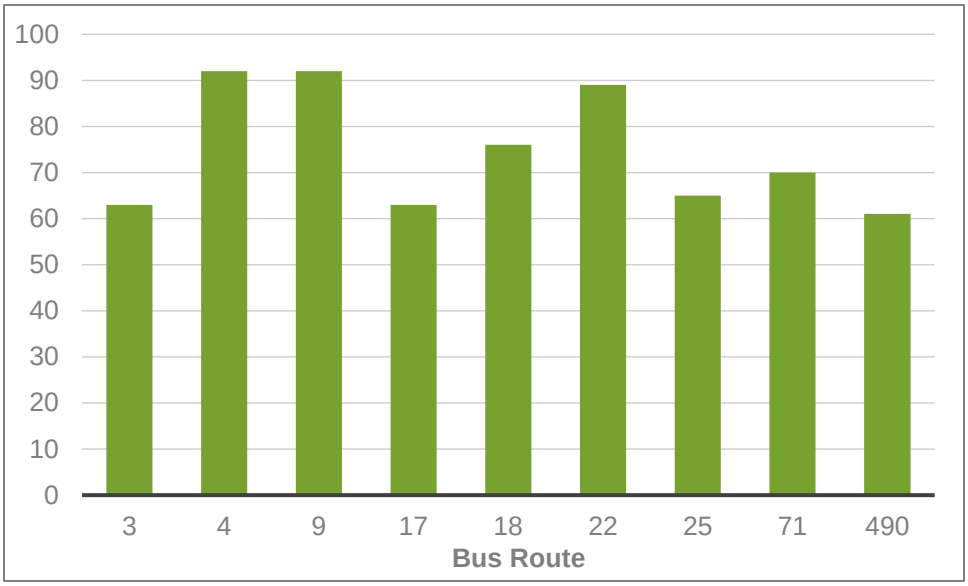
8 provides a regional overview of the greatest potential flood hazards to the bus transit system. A total of 529 bus stops (2.7% of all stops) fall into the highest vulnerability categories (High, Very High) along with numerous points along every route. The circles signify potentially impacted transit stops, while the segments depict potentially impacted routes.

The assessment of the bus routes consists of analysis of the routes themselves, not the start and terminus of the journey from a bus garage. Bus garage access and egress impacts to localized flooding will be assessed in a separate Council Facilities chapter.

Analysis

All routes traverse some Flood Impact Zones, and all serve bus stops also at some level of flood hazard. On average, all bus routes traverse 26 potentially affected stops. Figure 8 exhibits concentrations of exposure in several areas, including major destinations Minneapolis & St. Paul downtowns and the MSP Airport & Mall of America vicinity. Figure 9 illustrates the specific routes serving the greatest number of vulnerable stops, peaking at 92 vulnerable stops on Routes 4 and 9.

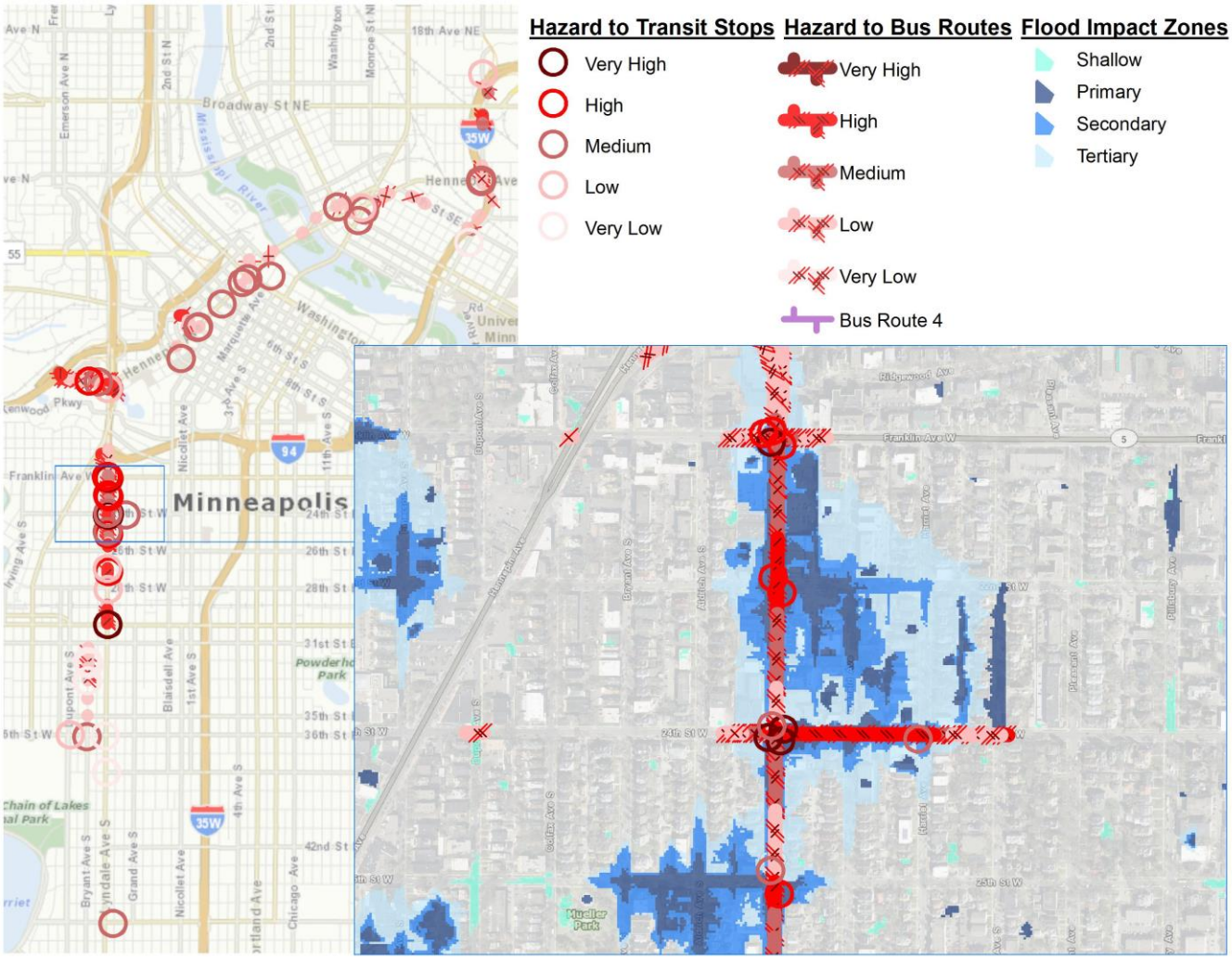
Figure 9. High Vulnerability Bus Routes by Number of Stops in Flood Impact Zones



Route 4 is one of the longest in the system, traversing over 20 miles and four hundred stops in each direction. Figure 10 highlights an extended portion of the line, with hazards identified at each stop and along the on-street route. Flood Impact Zones typically encroach on the route for short extents but at frequent intervals, so that while some stops are not directly affected, the potential for service disruption and hazard to riders boarding or alighting remains present in every neighborhood served.

Figure 10 also provides a closer look at a low-lying location along Route 4 with a history of storm-related flooding. Six bus routes in total provide service to this area, with stops at every intersection along the major thoroughfares. The confluence of high ridership and a broad contiguous Flood Impact Zone creates a localized concentration of High to Very High asset vulnerability.

Figure 10. Portions of Bus Route 4 - Potential Localized Flood Vulnerability



Considerations

Buses are a resilient and adaptable resource relative to much of the other transit infrastructure. They can utilize the entire surface road network to reroute quickly in accordance with emergency plans. Buses can traverse deeper levels of flood water than most other vehicles on the road. In broad terms, buses are therefore subject to lower risk than bus stops, riders, trains, and other components of the transit system.

By comparison, bus stops represent a more vulnerable component of the system due to the required pedestrian accessibility. Alternative stops might be sited to higher elevations or other safe locations and employ rerouted buses, but implementing and communicating that strategy to vulnerable pedestrians during a flood event may be challenging.

Existing Strategies

The Metropolitan Council employs an ‘all hazards’ approach to emergencies that affect Metro Transit operations. Metro Transit identifies potential hazards, and potential impacts to operations. Metro Transit also engages in scenario planning and emergency planning with partner agencies.

In Minnesota, public safety emergency responders are trained to follow the National Incident Management System (NIMS). NIMS employs the Incident Command System (ICS), which allows agencies to communicate and operate during an emergency through use of common terminology and cooperative operating procedures. The ICS applies from the time an emergency occurs until the requirement for management and operations no longer exists. The staff person in charge of ICS at Metro Transit is referred to as the Incident Commander and is required to have obtained a State Certification in Emergency Management.

Bus in downtown Minneapolis. Source: Metro Transit Flickr account: https://www.flickr.com/photos/metrotransitmn/

Metro Transit's Bus Operations Emergency Plan embraces the National Incident Management System (NIMS). The existing Plan was developed in collaboration with partner public safety agencies within Metro Transit's operational jurisdiction. The Transit Control Center (TCC) unit manages the Standard Operating Procedures and the Continuity of Operations Plan (COOP), both of which are deployed in the event of operation disruption.

Following the 2007 I-35 bridge collapse, the Minnesota Legislature passed legislation and Governor Dayton issued Executive Order 10-06 to enhance State-level coordination of emergency preparedness, planning, response, recover, hazard mitigation, and continuity of operations and service continuation responsibilities. Metro Transit is assigned emergency responsibilities through these measures.

Proposed Strategies

While Metro Transit has robust protocols and procedures in place for hazard mitigation, it is advised that the localized flooding data be used for a focused assessment of potential localized flooding risk, coupled with use of the data as a proactive measure to assist in providing route redundancy in the event of operations disruption. The localized flooding data can also be utilized when planning new bus routes or changes to existing bus routes.

Metro Transit may consider the following:

- ☐ Conduct a more detailed analysis and prioritization of all vulnerable routes and stops across the network
- ☐ Develop rerouting plans for potential vulnerable areas on a route-by-route basis
- ☐ Leverage local knowledge of experienced drivers for rerouting and temporary stop planning
- ☐ Work with relevant local stakeholders to institute volunteer adopt-a-drain programs for local bus stops, using vulnerable routes and bus stop areas for prioritization
- ☐ Prioritize vulnerable routes and bus stops to communicate localized flooding potential to riders in a variety of formats and languages

Metro Transit Facilities

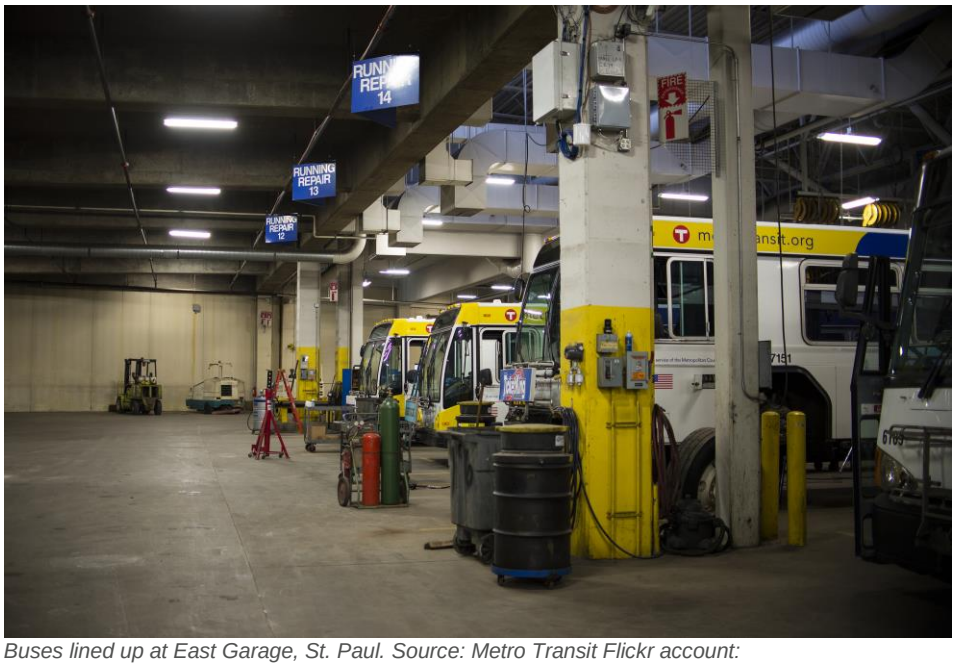
Rationale

Unlike modes of transit that are impacted locally at bus stops or along train tracks, facilities exposure to localized flooding is widespread over the entire facility area. Although different types of facilities have site-specific vulnerabilities to localized flooding, it is important to understand the significance of potential exposure by examining the entire parcel. Bus Garages are analyzed separately from other facilities to highlight the potential localized flood risk to buses as they access and depart from garages to commence their routes.

Methodology

Localized flooding around facilities has the potential to impact buildings, employees, and modes of transit. To consider localized flood risk, parcels were analyzed rather than building footprints. All major transit facilities, except for facilities defined as 'employment centers,' are included in this analysis.

Potential impact from localized flooding was calculated by percent of facility area covered by Flood Impact Zones (FIZ). Each FIZ represents a different level of vulnerability and was treated separately during analysis. The complete FIZ layer was added to the site to capture only the FIZ locations on the facility site. The area of each FIZ within a parcel was divided by the total area of the site, to calculate percent coverage of each Flood Impact Zone at each facility.



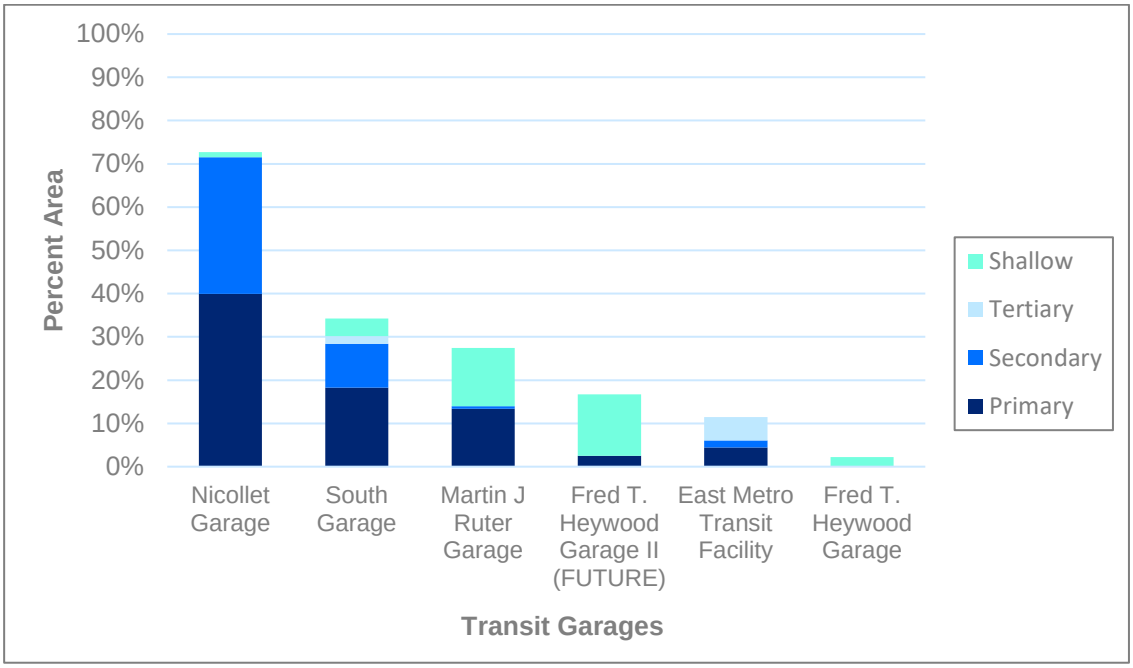
Buses lined up at East Garage, St. Paul. Source: Metro Transit Flickr account: https://www.flickr.com/photos/metrotransitmn/

The road network provides access to and from facilities, as well as emergency access. Flood hazards on roads are displayed and analyzed for each facility. A facility is considered to have 'No Access' when all entry/exit points are impacted by the Flood Impact Zones.

Analysis: Metro Transit Bus Garages

All bus garages are potentially impacted to some degree by Flood Impact Zones. The severity of impact varies greatly, from under 5% to over 70% coverage. Primary flood areas have potentially the largest impact on the Nicollet, South and Ruter Garages. Localized flooding will impact these garages during a heavy rain event, especially if existing stormwater infrastructure becomes obstructed or fails. Buses are generally capable of driving through the Primary FIZ. However, bus drivers may be at risk when trying to access their buses, and facilities may be damaged during sustained and heavy rain events.

Figure 11. Percentage of Bus Garage Parcels within Flood Impact Zones



Nicollet Garage has nearly 40% of the parcel covered by Primary FIZ, as shown in Figure 11. This relatively high level of risk for Primary flooding has the potential to impact the facility and bus access and egress from the facility. Approximately 150 buses are housed in this garage, providing urban local service to the City of Minneapolis. The site also consists of around 300 drivers and 30 mechanics.

South Garage has FIZ on 34% of the parcel, as shown in Table 5, with little potential impact on the building itself. A portion of the reported FIZ includes a retention pond, so this parcel should include a site-specific analysis for verification. Almost the entire employee parking lot outside of South Garage is in a Primary Flood Impact Zone. Finally, South Garage is at risk for 'no access' in an extreme localized flooding event because the main entrance and exits are at risk of flooding and may obstruct access and egress from the building.

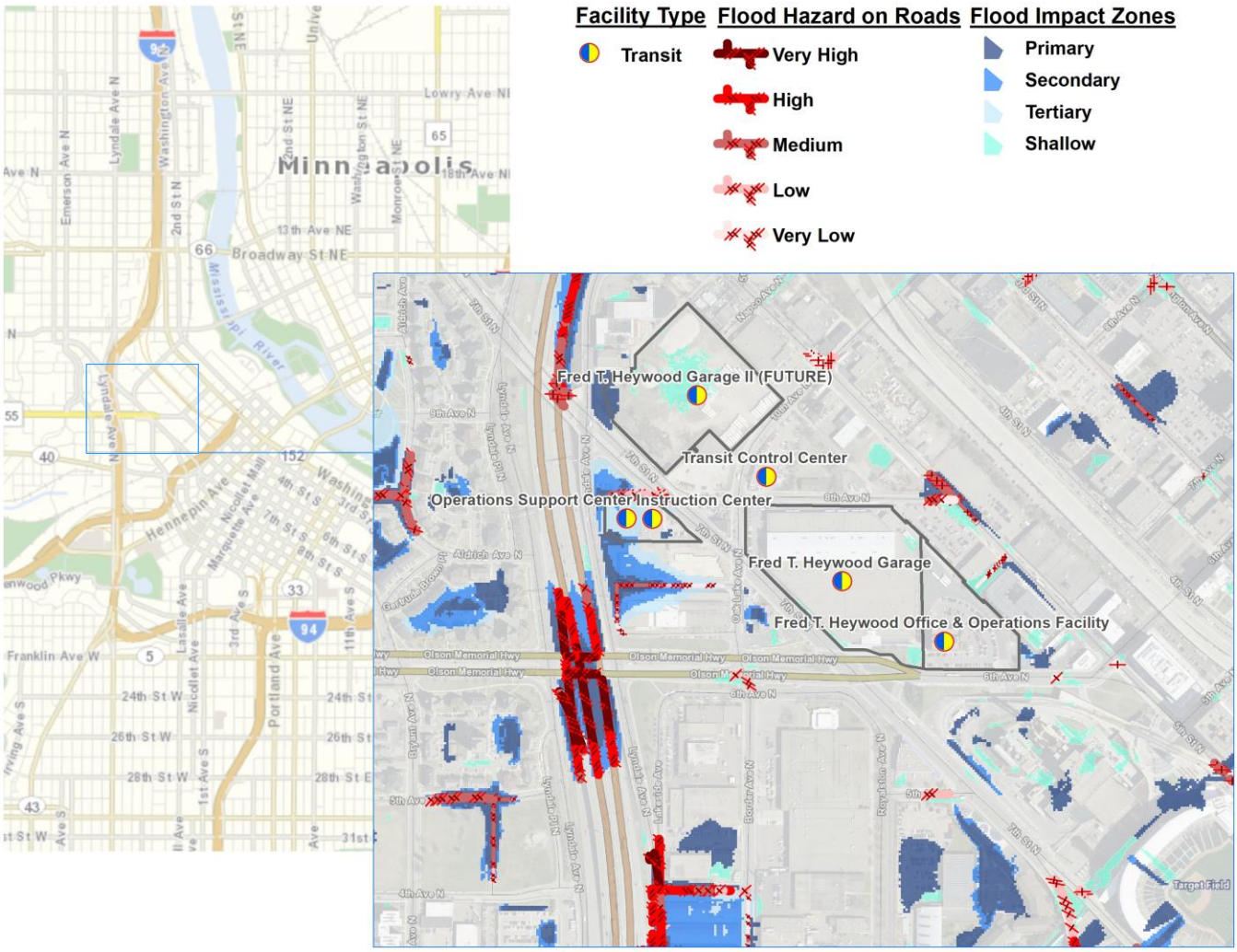
Table 5. Percent of Bus Garages Facility Parcel Area Covered by FIZ

Facility	Primary % Parcel	Secondary %	Tertiary %	Shallow %	Total FIZ %
Nicollet Garage	39.92%	31.58%	0.00%	1.23%	72.72%
South Garage	18.24%	10.14%	1.82%	4.08%	34.28%
Martin J Ruter Garage	13.38%	0.61%	0.00%	13.46%	27.46%
Fred T. Heywood Garage II (Future)	2.54%	0.00%	0.00%	14.17%	16.71%
East Metro Garage	4.46%	1.57%	5.40%	0.00%	11.44%
Fred T. Heywood Garage	0.00%	0.00%	0.00%	2.24%	2.24%

The existing Heywood Garage shows very little potential impact from localized flooding; only 2.4% of the parcel is covered by Shallow FIZ. The future Heywood Garage shows the potential for more risk within the parcel. However, this potential risk is subject to change as construction and site grading will

likely alter the topography. Figure 12 shows that both the current and future Heywood garages display potential flood risk along road access points.

Figure 12. Transit Facilities Potential Localized Flood Vulnerability



Considerations

To understand the severity of facilities flooding, it is necessary to look at the site characteristics and FIZ. Potential flooding within an employee parking lot poses a different level of risk than flooding by bus garage entrances. This analysis presents potential flooding hazards, and Metro Transit employees may know of areas within transit facility sites that have previously flooded. Organizational knowledge of specific flooding events can assist in verification of potential localized flood risks at specific locations.

Existing Practices

The Metro Transit Security and Emergency Preparedness Plan functions to ensure internal and external coordination and preventative measures that embrace hazard mitigation in line with an all-hazards approach to emergency management.

Proposed Strategies

While Metro Transit has robust protocols and procedures in place for hazard mitigation, it is advised that the localized flooding data be used for a focused, site-by-site assessment of potential localized

flooding risk at bus garages. Special consideration should be made for analysis of access routes for buses to and from bus garages, with particular focus on Nicollet, South, and Martin J Ruter garages. The localized flooding data should also be utilized to ensure employee safety at bus garages, both within the buildings and employee parking areas.

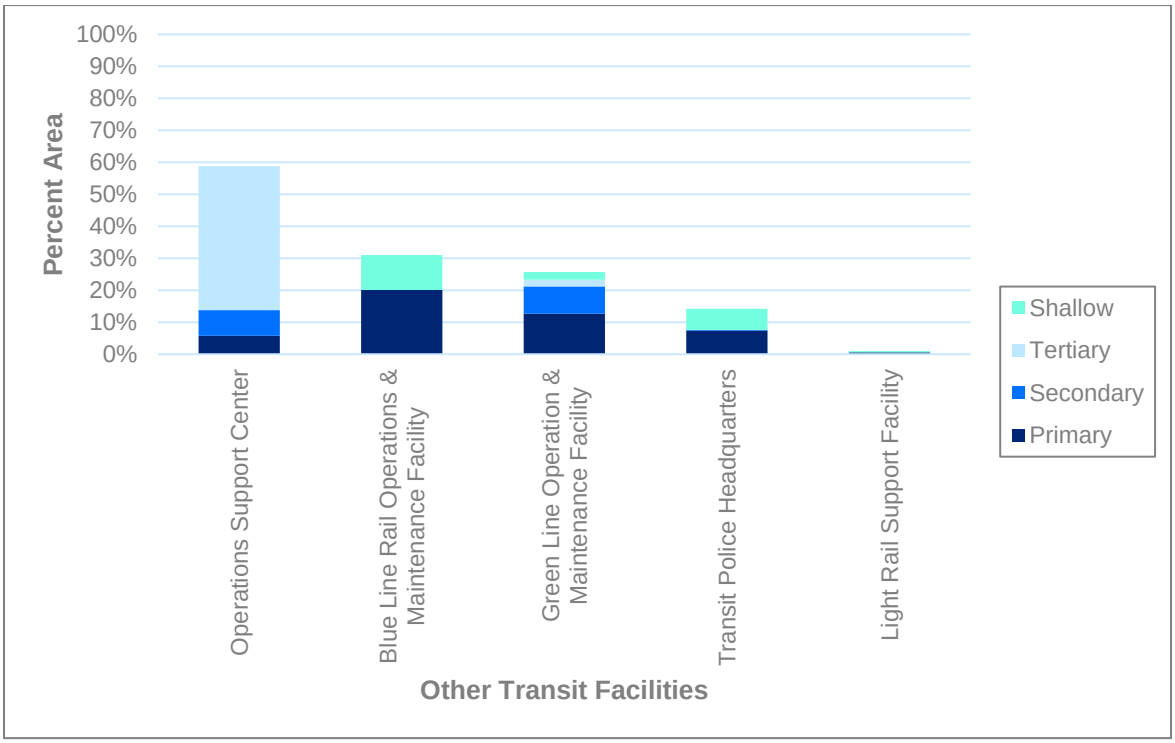
Metro Transit may consider the following:

- ☐ Conduct a more detailed analysis to address potential impact to bus garages and streets utilized by bus drivers to connect to bus routes
- ☐ Leverage local knowledge from experienced drivers to understand flooding impacts and locate areas at and around bus garages that are most vulnerable to localized flooding
- ☐ Develop mitigation strategies and plans for bus drivers to utilize in a localized flooding event

Analysis: Metro Transit Other Facilities

This analysis examines transit facilities, excluding bus garages, together as 'other facilities'. The various facility types have differing levels of susceptibility to localized flooding. The five facilities within Flood Impact Zones (FIZ), shown in Figure 13, have relatively small areas potentially impacted by localized flooding. When considering the highest risk areas, those within the Primary FIZ, the five analyzed sites never exceed 20% of Primary FIZ per site. However, depending on the assets and areas affected, small localized flood areas can pose a risk to certain facilities.

Figure 13. Percentage of Other Transit Facilities within Flood Impact Zones



As seen in Table 6, three facilities included in the analysis were not within Flood Impact Zones. These facilities include the Commuter Rail Operations and Maintenance Facility, the Overhaul Base, and the Transit Control Center. The Commuter Rail Facility is outside of the metro area, and therefore this facility is not considered in this analysis. However, that does not mean that this facility is not vulnerable to localized flooding impacts. It is important to verify potential facility impacts with ground-truthing and local knowledge. As shown in Table 6, the Overhaul Base and Transit Control Center are not impacted directly by FIZ, but these facilities may experience impacts from nearby potential flood risk areas.

Table 6. Percent of Other Transit Facility Parcel Areas Covered by FIZ

Facility	Primary % Parcel	Secondary %	Tertiary %	Shallow %	Total FIZ %
Operations Support Center	5.79%	8.03%	45.04%	0.00%	58.86%
Blue Line Rail Operations & Maintenance Facility	20.07%	0.06%	0.00%	10.88%	31.01%
Green Line Operation & Maintenance Facility	12.69%	8.52%	2.13%	2.40%	25.73%
Transit Police Headquarters	7.35%	0.26%	0.00%	6.54%	14.16%
Light Rail Support Facility	0.55%	0.00%	0.00%	0.48%	1.03%
Fred T. Heywood Office & Operations Facility	0.00%	0.00%	0.00%	0.24%	0.24%
Overhaul Base	0.00%	0.00%	0.00%	0.00%	0.00%
Transit Control Center	0.00%	0.00%	0.00%	0.00%	0.00%
Commuter Rail Operations & Maintenance Facility*	N/A	N/A	N/A	N/A	N/A

**This facility was not included within the scope of the analysis because it is outside the seven-county metropolitan area.*

When considering the Blue and Green Line Operations and Maintenance facilities, the risk posed to light rail differs from bus transit facilities because light rail is affected at Shallow levels of flooding, and light rail vehicles cannot be rerouted. Relative risk at light rail facilities depends on the proximity of potential flood risk areas to the tracks and to the trains.

Transit Police Headquarters is primarily at risk from Primary and Shallow FIZ. The Primary risk area is concentrated along the eastern portion of the parking lot, and the Shallow risk area is located on the northwest portion of the building. Primary flooding may impact employee parking and vehicles accessing or exiting the site.

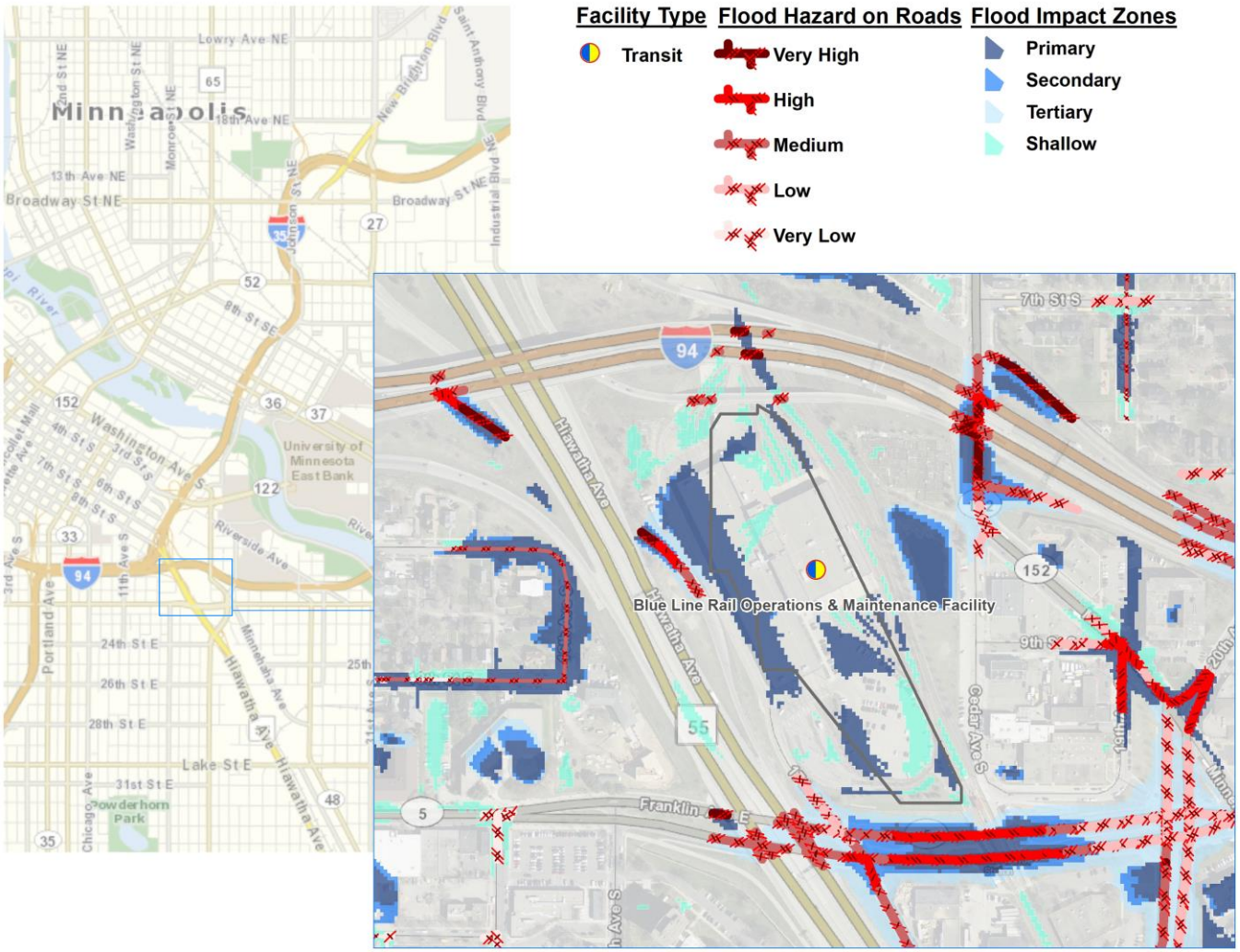
The Operations Support Center (OSC) has relatively low levels of Primary and Secondary FIZ, with high percentage coverage of Tertiary flooding. Tertiary level flooding is less likely to occur and therefore poses less risk. The road network around the OSC is mostly clear of any potential flood risk.

Figure 14 shows the FIZ and flood hazards on roads for the Blue Line Operations and Maintenance Facility. The Primary flood zone affects the facility as well as the parking lot on the west side of the building. Affected portions of the parking lot are close to the facility which may impact employee access to the facility. Nearly 11% of the parcel is covered by Shallow

Lowertown Operations & Maintenance Facility, St. Paul. Source: Metro Transit Flickr account: https://www.flickr.com/photos/metrotransitmn/

FIZ. Isolated potential flooding areas are located on the edges of the site and away from the facility but are still important to consider in terms of operations and public safety during a sustained and heavy rain event.

Figure 14. Blue Line Rail Operations & Maintenance Facility – Potential Localized Flood Vulnerability



Considerations

As with bus garages, it is important to consider local knowledge and site characteristics which can help verify potential localized flood areas shown on the map. This information can help inform and validate hazard mitigation plans. The different flood impact zones pose different risks to different facility types and should be considered accordingly.

The facilities data layer used in identification of transit facilities was last updated in 2017, so any recent changes or additions to facilities may not have been captured in this analysis. Also, there is currently no data custodian for the data layer, so there may be some transit facilities missing from this analysis, especially smaller support facilities.

Existing Practices

The Metro Transit Security and Emergency Preparedness Plan functions to ensure internal and external coordination and preventative measures that embrace hazard mitigation in line with an all-hazards approach to emergency management.

Proposed Strategies

While Metro Transit has robust protocols and procedures in place for hazard mitigation, it is advised that the localized flooding data be used for a focused, site-by-site assessment of potential localized flooding at Metro Transit facilities that support transit operations, such as LRT Operations and Maintenance facilities. Special consideration should be made for analysis of rail access and egress for LRT vehicles at both the Blue Line Rail and Green Line Rail Operations and Maintenance Facilities. The localized flooding data should also be utilized to ensure employee safety at facilities, both within the buildings and employee parking areas.

Metro Transit may consider the following:

- ☐ Conduct detailed analysis that addresses the variety of facility uses and site characteristics
- ☐ Develop strategies to reduce impacts from high vulnerability flood areas (especially Primary areas)
- ☐ Develop specific adaptation strategies to address vulnerabilities on different portions of facility sites
- ☐ Leverage local knowledge within analysis and strategies, and prioritize interventions at facilities that show higher vulnerability to potential flooding

Track Maintenance Crew in St. Paul. Source: Metro Transit Flickr account: https://www.flickr.com/photos/metrotransitmn/

Aviation

Rationale

According to Federal Aviation Administration (FAA) guidelines, ⅛ inch of standing water is enough to present a hydroplaning hazard to aircraft attempting to land. As such, runway exposure and sensitivity are defined only by Flood Impact Zone, with no additional weighting metric.

Surface roads are the means of connecting to or from airport services and resources, including possible evacuation from a flood event, access to emergency service resources or shelter staged on site, and flow of relief supplies and equipment arriving from outside the immediate vicinity. Connectivity to the airport is important for its capacity in reducing the impacts from flood events.

Methodology

Eleven facilities make up the regional aviation assets, detailed in Table 7. Minneapolis-St. Paul International (MSP) is the region's commercial airport, while St. Paul Downtown provides significant corporate and general aviation reliever airport services. Seven minor airports provide primarily general aviation services, while Flying Cloud, Anoka/Blaine, and South St. Paul provide additional corporate flying operations. The two seaplane bases are privately owned, but they are part of the aviation system.

Table 7. Metropolitan Airports

Airport Name	Classification	2016 Take-offs & Landings
Minneapolis - St. Paul International	Major	412,898*
St. Paul Downtown	Intermediate	54,548*
Airlake	Minor	38,618*
Anoka County/Blaine	Minor	80,845*
Crystal	Minor	36,967*
Flying Cloud	Minor	84,038*
Lake Elmo	Minor	27,275*
South St. Paul	Minor	51,000
Forest Lake	Special Purpose	8,030
Lino Lakes Seaplane Base	Special Purpose	4,108
Wipline Seaplane Base	Special Purpose	Not Available

**Information provided by MAC staff on October 16, 2017.*

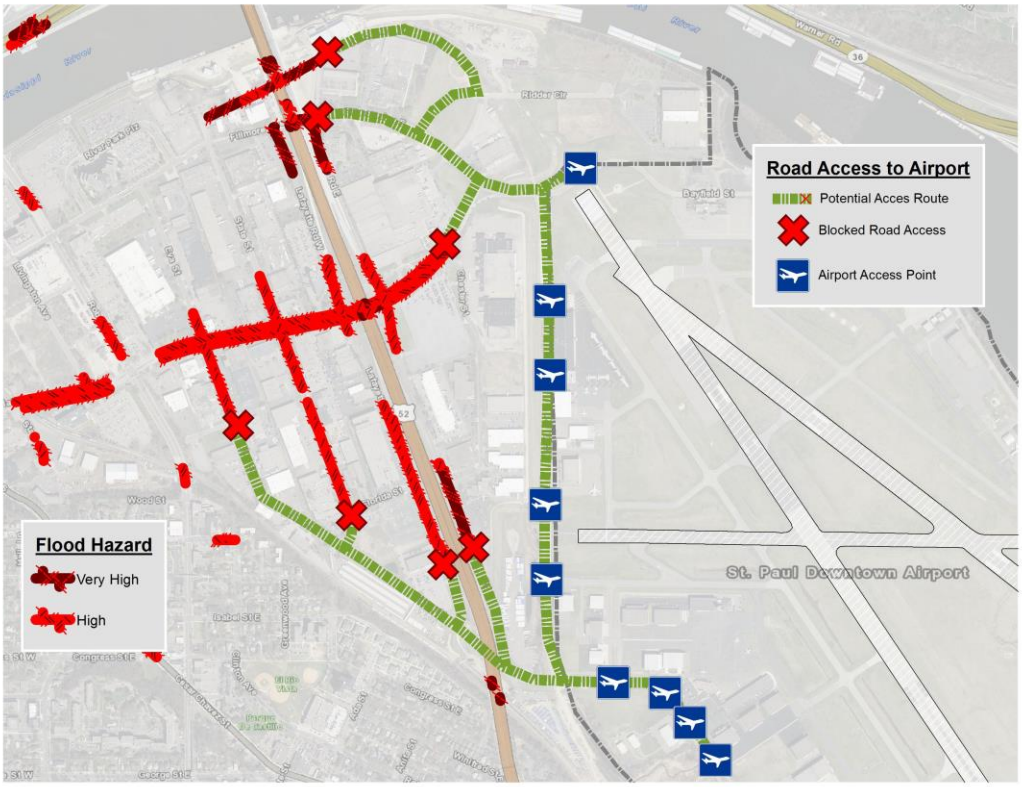
The Metropolitan Airports Commission (MAC) is a public corporation that owns and operates MSP and 8 smaller reliever airports throughout the region. The Council works with MAC to ensure that planned airport improvements are consistent with regional plans.

For localized flooding analysis, airport runways were assessed using an intersect operation with Flood Impact Zones, defining the location and exposure for all runway surfaces subject to flooding. To assess connectivity with surrounding communities, all roads within one mile of each airport were intersected with potential flood areas.

Analysis

Runways were found to be subject to minimal flood risk in total, with very little flood encroachment. For ten out of eleven airports, roadway access was also found to be maintained with at least one route available reaching an arterial roadway without passing through a Flood Impact Zone. This limited risk is due to the extensive planning and engineering that goes into developing and operating the aviation system.

Figure 15. Surface Access to St. Paul Downtown Airport Under Potential Localized Flood Conditions is at High to Very High Vulnerability of Obstruction



The St. Paul Downtown airport is located in a low-lying flood plain on the banks of the Mississippi River and therefore has a history of riverine flooding. In 2008, a flood wall was installed to protect against riverine flooding. Besides potential riverine flooding impacts, the localized flood analysis shows considerable exposure and sensitivity to localized flooding as well, with all connecting surface roadways at risk of obstruction by High or Very High vulnerability to flooding. In the most severe scenario (Figure 15), vulnerable areas potentially block access to all roads, arterial or local, within 4 blocks or less of all airport gates, completely isolating the airport from surface access to or from the surrounding community.

Considerations

Aviation safety and facility resilience are, in general, recognized as important components of design standards, operating protocols, and the regulatory environment encompassing airports.

The St. Paul Downtown Airport houses several corporate tenants and a National Guard base. These stakeholders are sensitive to operational disruption and may be potential partners in adaptation efforts.

Existing Strategies

In 2016, MAC commissioned a Climate Vulnerability Assessment Report for MSP. The Report utilized climate projection data and first-hand information from staff to create a series of actions and recommended next steps related specifically to climate hazards and subsequent impacts brought on by climate change. One of the objectives of the assessment is for MAC to apply its understanding of vulnerability at MSP to plan for adaptation measures at its reliever airports which would expand climate adaptation strategies throughout MAC's assets. This effort goes beyond the existing hazard mitigation practices in place at metropolitan airports.

Tails of planes at Minneapolis-St. Paul International Airport. Source: Metropolitan Council Digital Image Library

Proposed Strategies

For all airport facilities, except St. Paul Downtown Airport, surface water flooding is generally low risk. With relatively large open areas, structures, and emergency resources sometimes already stationed on-site, these airports may be well positioned to provide relief service, a rescue staging area, or emergency shelter to local populations during or after an extreme event.

The St. Paul Downtown Airport faces flood challenges unique to the region, and due to its history of riverine flooding, the airport does have riverine flood protection already in place. Additional measures for St. Paul Downtown Airport might include:

Metropolitan Council may consider the following:

- ☐ Collaborate with MAC to incorporate localized flood planning with existing riverine flood plans
- ☐ Collaborate with MAC to work with local road authorities to reduce peak vulnerability on one or more access roads at St. Paul Downtown Airport

Metropolitan Airports Commission may consider the following:

- ☐ Expand its Climate Vulnerability Assessment Report to encompass reliever airports, with special emphasis on the St. Paul Downtown Airport

Regional Bicycle Transportation Network (RBTN)

Rationale

Flood waters can have widely varying impacts on bicyclists. Flowing water can cause instability or impassable conditions even at low depths, just as for a pedestrian. Conversely, relatively still water as much as 2-3 feet deep can still be traversed under optimal conditions.

The Regional Bike System Inventory does not include usage data or other attributes that can be evaluated systemwide, so a route by route comparison is not possible. Moreover, surface or pavement types vary widely and do not respond uniformly to flood conditions. As such, the Flood Impact Zone currently provides the best and most consistent means of assessing bike network exposure, with no further metric added for exposure and sensitivity.

Methodology

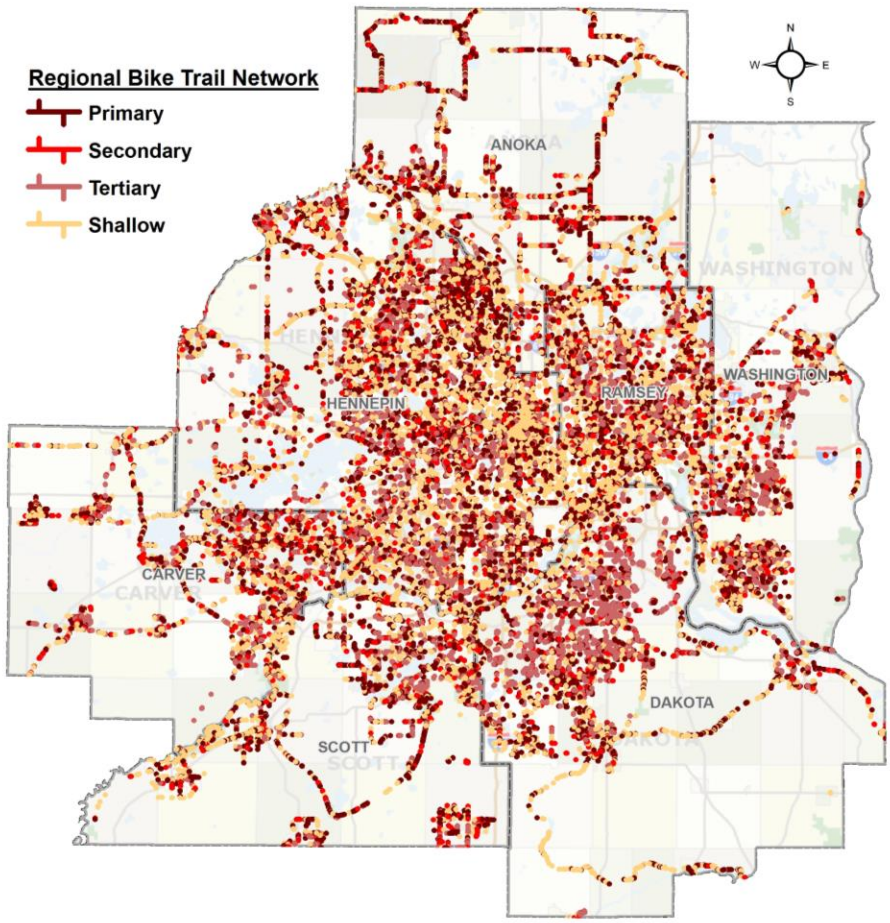
Bicycle commuting and recreation are supported by over 6,700 miles of trails and other dedicated or co-use bike routes across the metro area. A new Regional Bicycle System Inventory was compiled in 2016 by Council staff in coordination with city, county, and park authorities from around the region, and this inventory was intersected with Flood Impact Zone locations.

Analysis

Network wide, 15.5% of all route mileage (1,049 miles) traverse potential flood areas. Affected portions of the bicycle network are well-distributed across the metro area, with trails extending beyond the urban core to the regional park system and along repurposed freight rail rights-of-way (Figure 16).

The Midtown Greenway in Minneapolis (Figure 17) is one high-use component of the network, with year-round daily ridership, connections to two Transit Centers, and numerous popular recreational and commercial activities along the length of the route. However, much of the Greenway is at low elevation relative to the surrounding landscape due to its location along a vacated below-grade railway, thus increasing flood

Figure 16. RBTN - Potential Localized Flood Vulnerability



exposure. Safely diverting flows and increasing infiltration are desirable adaptation strategies, but such strategies may be difficult or costly within this type of physical setting. Strategies such as access management during flooding or establishing alternate routes may be more desirable for the Midtown Greenway and other area trails with similar elevation characteristics.

Considerations

Critical Bicycle Transportation Links are part of the *2040 Transportation Policy Plan*, representing defined locations that improve accessibility to and connectivity across the network. As these links are defined and developed, they, and other facilities and resources that contribute to ridership and access (such as Nice Ride stations), may represent priorities for further assessment.

MIDTOWN GREENWAY

5.5 miles dedicated trail

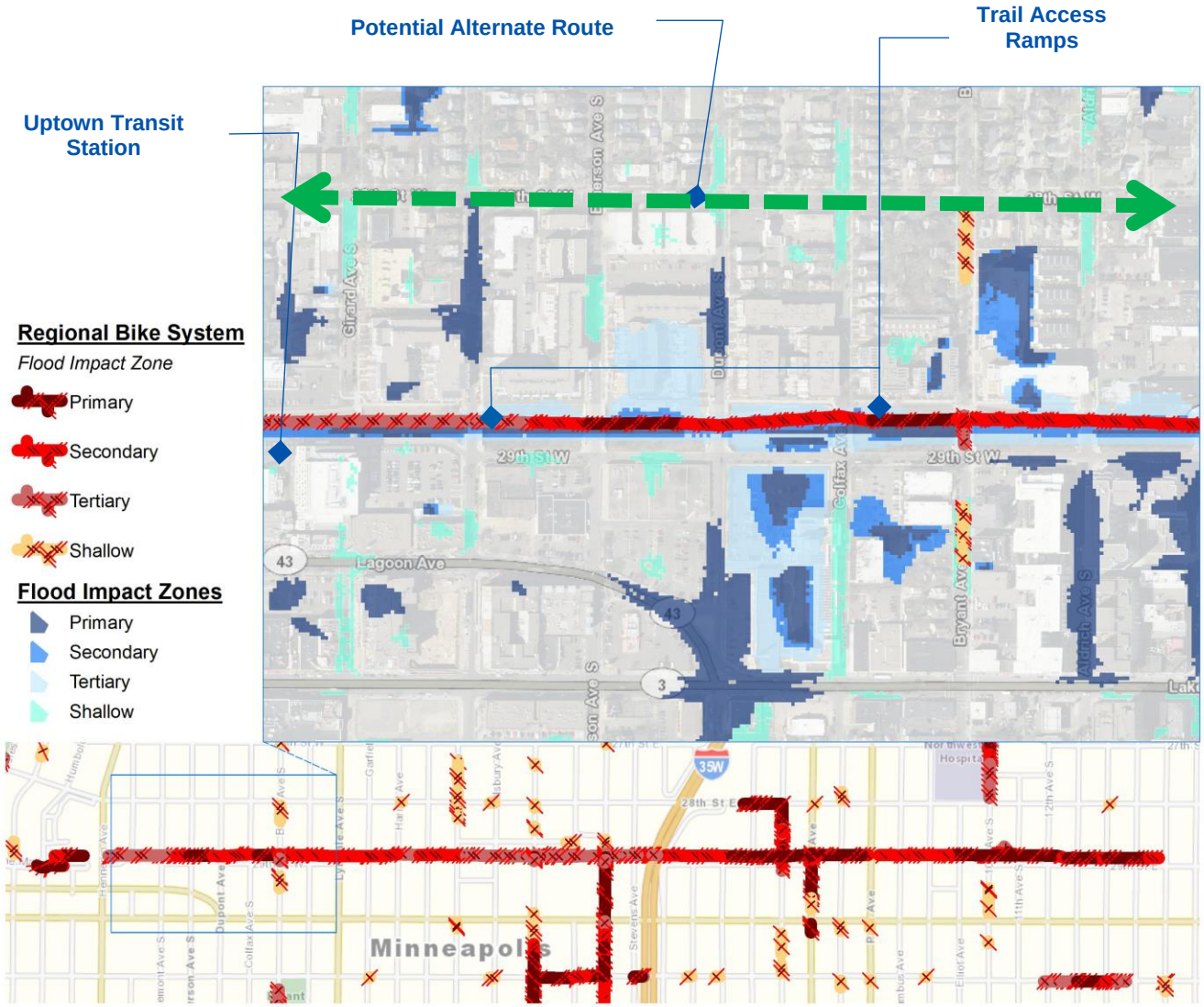
Over **2000** daily trips

More than **120** transit stops within 1 block

2.3 miles of continuous Flood Impact Zone

Much of route below grade

Figure 17. Section of Midtown Greenway - Potential Localized Flood Vulnerability



Existing Strategies

The Regional Bicycle Transportation Network (RBTN) spans a large area, and the response to localized flooding across the regional network is not coordinated given the number of jurisdictions involved. It can be argued that a collaborative planning process should be utilized to identify potential areas and bicycle corridors susceptible to localized flooding prior to route finalization and subsequent implementation.

The Midtown Greenway, Minneapolis, MN. Source: Metropolitan Council Digital Image Library

Proposed Strategies

Metropolitan Council may consider the following:

☐ Convene a regionwide stakeholder planning group to assess the potential impacts of localized flooding on the RBTN network to inform current maintenance and future planning

Local stakeholders may consider the following:

☐ Assess viability and impact of access management (temporary closures) versus other solutions
☐ Analyze bicycle transportation alongside adaptation measures for co-use routes and transit hubs

Next Steps

This assessment is regionwide and high level; its intention is to elicit a conversation about how best to embed use of the localized flood data into Council practice across department divisions. The assessment presents systemwide data and a more localized example for each transportation and transit asset. To get the most out of the data, staff propose a more in-depth analysis of specific bus routes, transit stops, bicycle commuter routes, LRT and commuter rail routes and connections, arterial road and local road networks, and airport connectivity and infrastructure. A rigorous analysis, coupled with other, complimentary data sources, will help the Council and relevant stakeholders prepare for the impacts of localized flooding within our region.

Metropolitan Council Desired Outcomes

The following desired outcomes can provide a foundation for the strategy development for each system asset. These high-level outcomes apply to all system assets for transportation and transit.

Prioritize operations and asset management through verification of localized flooding vulnerability. The auditing and verification of vulnerable areas within the transportation and transit system will assist Council operations and asset management. Ground-truthing areas of highest vulnerability will facilitate operational and asset management prioritization across each respective system.

Manage stormwater locally, on site, as much as possible. This outcome can be achieved through deployment of low-tech strategies that absorb rainwater locally, with special attention given to High and Very High vulnerability areas. These strategies require collaboration with local and agency stakeholders to, for instance, reduce the percentage of impermeable surfaces in High and Very High vulnerability areas through installation of permeable paving, green stormwater infrastructure, and maintenance of existing stormwater conveyance through volunteer adopt-a-drain programs available in many cities. Such practices and programs could be employed to reduce transit disruptions due to localized flooding.

Ensure that flooding takes place only where it does the least damage. System planning should consider that flooding will occur and will affect the transportation and transit systems. System assets should be planned to ensure that flooding does not impact large amounts of riders or vehicles using the systems and that redundancy plans are made that consider High and Very High vulnerability areas. When new roads or routes are planned, the localized flooding data can assist in showing where to incorporate surface water features based on existing topography that provides infiltration and diverts water from high priority assets to allow flooding of areas that are less critical to operations and public safety.

Ensure that public safety information is available for riders. When the Council performs a more rigorous asset by asset analysis of localized flooding, it should prioritize conveying potential public safety matters related to localized flooding in higher priority areas and on higher risk routes in a variety of media formats and languages.

Convene a regional stakeholder group and continue collaboration. In considering climate-related hazards and subsequent strategies for the regional transportation and transit networks, the Council should convene a regional collaborative stakeholder group representing multiple jurisdictions. One of the greatest challenges to strategy implementation to reduce the impact of localized flooding on regional systems is the multijurisdictional nature of the work. Oftentimes, there are layers of responsibility to consider when implementing adaptation strategies at the ground level. Through convening a regional stakeholder forum on system impacts from climate hazards, the Council can increase regional and local climate resiliency through collaboration.

Going Beyond Hazard Mitigation

While Metro Transit and its partners have robust protocols and procedures in place for hazard mitigation, it is recommended that Metro Transit perform a focused assessment of potential localized flooding impacts. In addition, the localized flood data can also be used as a preliminary planning tool to assist in providing transportation and transit route redundancy in the event of operations or asset disruption.

Hazard mitigation is key in ensuring that procedures are in place to effectively react in a crisis situation, but it cannot always account for the more incremental, chronic climate stresses to Council systems. An additional and more focused consideration of climate hazards and subsequent impacts can allow for a more proactive approach to identifying potential vulnerabilities in our transportation and transit systems.

The Council should work with partners to go beyond the hazard mitigation approach, which tends to focus on how best to prevent and react to disasters or emergencies. To further the work, the localized flooding analysis could be incorporated into the Council's transportation and transit planning efforts as well as in its ongoing assessment of system assets, be they bus routes, access to and from an airport, or our growing regional bicycle transportation network.

Building Equity into Policies and Strategies

Equity is a desired outcome identified in *Thrive MSP 2040*, but planners do not often consider the disparate impacts of climate change on underserved or vulnerable populations. Human vulnerability to climate change should be considered in the planning and operations of the transportation and transit network in areas with populations that are more vulnerable to climate change impacts. Often, human vulnerability to climate change impacts is more difficult to measure than infrastructure vulnerability, due to the many variables that may contribute to a person, family, or community's vulnerability.

It is important that the Council considers its system vulnerability to climate change with equitable outcomes in mind. For instance, some parts of the region may rely more heavily on the transit system for travel to work, business, school, and leisure activities. It is vital to consider system and asset vulnerability with such factors in mind so that the Council can work to reduce human vulnerability to climate change through its asset management responsibilities.

Green Line Light Rail Transit Station, St. Paul. Source: Metro Transit Flickr account: https://www.flickr.com/photos/metrotransitmn/

Summary of Proposed Council Strategies

Table 8. Highway Network, Proposed Strategies

Potential Strategy	Authority	Collaboration Required	Existing Practice	Priority	Cost/Time
Conduct arterial assessment of vulnerable areas through collaboration with relevant road authority and stakeholders	MnDOT; MC-MTS; Counties; LGU	Yes	MnDOT culvert study	High	Low/Low
Collaborate with relevant authorities and stakeholders to increase surface water infiltration in potential vulnerable areas	MnDOT; MC-MTS; Counties; LGU	Yes		Med	High/High
Plan for rerouting/alternative routes with agency and community partners	MnDOT; MC-MTS; Counties; LGU	Yes		Med	Low/Med
Facilitate creation of a regional notification of road rerouting, similar to the *Hennepin County Map*	MnDOT; MC-MTS; Counties; LGU	Yes	*Hennepin County Map*	Med	Med/Med

Table 9. Light Rail/Commuter Rail, Proposed Strategies

Potential Strategy	Authority	Collaboration Required	Existing Practice	Priority	Cost/Time
Perform site review & audit of all Shallow & Primary rail segments	Metro Transit; BNSF	Likely		Med	Low/Low
Document all flood areas that disrupt LRT operations and compare these to localized flooding data	Metro Transit	No	SOPs	Med	Med/Med
Enact protocols for relief transit vehicles in advance of forecasted storms	Metro Transit	No	SOPs	Low	Med/Med
Assess localized flood impacts on rail operations hardware using structure technical specifications for water infiltration	Metro Transit	No	SOPs	Low	Med/Med
Work with local jurisdictions and stakeholders to enact stormwater best management practices and ongoing maintenance in jurisdiction's right-of-way along LRT and commuter transit corridors	Metro Transit; Road Authority	Yes		Low	High/Med
Prioritize vulnerable station areas to communicate localized flood potential in a variety of formats and languages	Metro Transit; BNSF	Likely		Med	Low/Med

Table 10. Bus Transit, Proposed Strategies

Potential Strategy	Authority	Collaboration Required	Existing Practice	Priority	Cost/Time
Conduct a more detailed analysis and prioritization of all vulnerable routes and stops across the network	Metro Transit; Partners	Likely		High	Med/Med
Develop rerouting plans for potential vulnerable areas on a route-by-route basis	Metro Transit; Partners	Likely	SOPs	Med	Med/Med
Leverage local knowledge of experienced drivers for rerouting and temporary stop planning	Metro Transit; Partners	Likely		Med	Low/Med
Work with relevant local stakeholders to institute volunteer adopt-a-drain- programs for local bus stops, using vulnerable routes and stop areas for prioritization	Metro Transit; Partners	Likely	SOPs	Med	Low/Med
Prioritize vulnerable routes and bus stops to communicate localized flood potential to riders in a variety of formats and languages	Metro Transit; Partners	Likely	SOPs	Med	Low/Low

Table 11. Metro Transit Facilities, Proposed Strategies

Potential Strategy	Authority	Collaboration Required	Existing Practice	Priority	Cost/Time
Assess transit facilities, site by site, for potential risk to the facility, transit mode, and route.	Metro Transit; Partners	Likely	SOPs	Med	Med/Med
Assess transit facility, site by site, for potential risk to employees, especially to accessing and leaving the facility.	Metro Transit; Partners	Likely	SOPs	Med	Med/Med

Table 12. Regional Bicycle Transportation Network (RBTN), Proposed Strategies

Potential Strategy	Authority	Collaboration Required	Existing Practice	Priority	Cost/Time
Convene a regionwide stakeholder planning group to assess the potential impacts of localized flooding on the RBTN network to inform current maintenance and future planning	MC-MTS; Counties; Road Authority	Yes		Med	Low/Med

Table 13. Aviation, Proposed Strategies

Potential Strategy	Authority	Collaboration Required	Existing Practice	Priority	Cost/Time
Collaborate with MAC to incorporate localized flood planning with existing riverine flood plans	MC-MTS; MAC	Yes		Med	Med/Med
Collaborate with MAC to work with local road authorities to reduce peak vulnerability on one or more access roads at St. Paul Downtown Airport	MC-MTS; MAC; Road Authority	Yes		Med	Med/Med

Acronyms

BNSF – Burlington Northern Santa Fe Railroad
BRT – Bus Rapid Transit
CFR – Code of Federal Regulations
CVA – Climate Vulnerability Assessment
DEM – Digital Elevation Model
DFIRM – Digital Flood Insurance Rate Map
GIS – Geographic Information Systems
GHG – Greenhouse Gas
FEMA – Federal Emergency Management Administration
FAA – Federal Aviation Administration
FIZ – Flood Impact Zone
FRA – Federal Railroad Association
ICS – Incident Command System
LiDAR - Light Detection and Ranging
LGU – Local Governmental Unit
LST – Land Surface Temperature
LRT – Light Rail Transit
MAC – Metropolitan Airports Commission
MC-MTS – Met Council - Metropolitan Transportation Systems
MSP – Minneapolis-St. Paul International Airport
MVTA – Minnesota Valley Transit Authority
NOAA – National Oceanic and Atmospheric Administration
NIMS – National Incident Command System
RBTN – Regional Bicycle Transportation Network
SOP – Standard Operative Procedure
SSPP – System Safety Program Plan
TCC – Transit Control Center
TPP – 2040 Transportation Policy Plan
TP40 – Technical Paper 40 - Rainfall Frequency Atlas
UHI – Urban Heat Island Effect

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