Equity of the Pierce Transit System:
A Geospatial Comparison of Accessibility for Key Population Groups

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Abstract

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Transit systems provide critical access to both vital and social resources to many within a community, but particularly for those without other means of transportation. Lack of transportation options, or transportation disadvantage, can lead to social exclusion and lower well-being. With the impact that transit makes on everyday life, it is important to understand the equity impact of a transit system in a large and diverse county such as Pierce County, Washington. Therefore, the purpose of this study is to analyze the social equity of the Pierce Transit system with a goal of identifying any equity shortfalls or gaps and potentially providing recommendations for alleviating such shortfalls. This study reviews the theories behind and methodologies for assessing equity in transit. It analyzes the equity of the Pierce Transit system through measuring the accessibility of the system based on the number of jobs and community assets are accessible by transit and adding an equity component to that assessment through looking at key population groups. A potential gap analysis is conducted to ascertain any equity shortfalls. The results show equity gaps in the Pierce Transit system and lead to recommendations for alleviating the shortfalls.

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1. Introduction

Transit systems provide critical access to both vital and social resources to many within a community, but particularly for those without other means of transportation. Lack of transportation options, or transportation disadvantage, can lead to social exclusion and lower well-being (Ricciardi et al., 2015). Social exclusion is "the process by which marginalized individuals', groups', and communities' abilities to obtain resources, goods, and services are impeded upon" (Fields et al., 2019). For groups experiencing social exclusion, employment opportunities and stability, health, education, and social activities are all affected. Although transportation options may be limited for a number of different people within a community, groups that tend to be in danger of transportation disadvantage and the social exclusion related to that disadvantage include those living in low-density environments, older adults, racial and ethnic minorities, and low-income households. Lack of financial resources, health and disability challenges, and structural discriminatory practices all contribute to why these groups in particular are vulnerable to transportation related social exclusion (Fields et al., 2019).

Within the past two decades, the interest in social equity within urban transportation systems has expanded and research and theories, such as transportation justice, have gained footing (Manaugh, 2015; Oswald Beiler et al., 2016). In the field of transit, methods of assessing social equity have been developed using such measures as accessibility (Kaplan et al., 2014) and equity indicators (Mamun et al., 2013; Bertolaccini et al., 2018). When looking at the Puget Sound region in particular, most analyses of equity within transit systems focus on Seattle or King County as the most populous city and county in the region (Lovell, 2012). There is less focus on smaller systems, such as Pierce Transit, even though the system serves a large county.

1.1 Pierce County

With a population of 891,299, Pierce County is the second most populous county in Washington State after King County, which contains Seattle. Pierce County sits directly south of King County, and Tacoma, the largest city in Pierce County, is approximately 30 miles south of Seattle. Between 2010 and 2018, Pierce County experienced a 12.1% growth rate (Vleming, 2019). A 2016 report showed that between 2000 and 2015 unincorporated Pierce County grew more than incorporated municipal areas, in particular the unincorporated Urban Growth Areas (Population Trends and Growth). Pierce County as a whole is less affluent than King County, with a median income of $75,407 compared to $95,009 (datausa.io) and Tacoma, is more racially diverse than Seattle (datausa.io). As a whole, Pierce County has a poverty rate of 11.2% of its population. Its racial makeup consists of 66.1% white non-Hispanic, 7.08% white Hispanic, 6.87% multi-racial, 6.6% Asian, and 6.52% Black.

Pierce County is quite large, being 1,806 square miles in area. It also contains a large military base, Joint Base Lewis-McChord (JBLM), which is 142 square miles in area. Pierce County contains 23 incorporated cities. Those with a population over 25,000 include Tacoma, with a population of 198,900; Lakewood, with 58,190; Puyallup, with 37,240; and University Place, with 31,170. Among the incorporated cities are Auburn, Milton, and Pacific, which are partially in Pierce County and partially in neighboring King County. Auburn, the largest of the three, has a total population of 70,705, but only 7,655 residents live within Pierce County. Milton and Pacific each have a population under 7,000 (Pierce County). Figure 1 shows the city boundaries within Pierce County, along with the block groups in Pierce County.

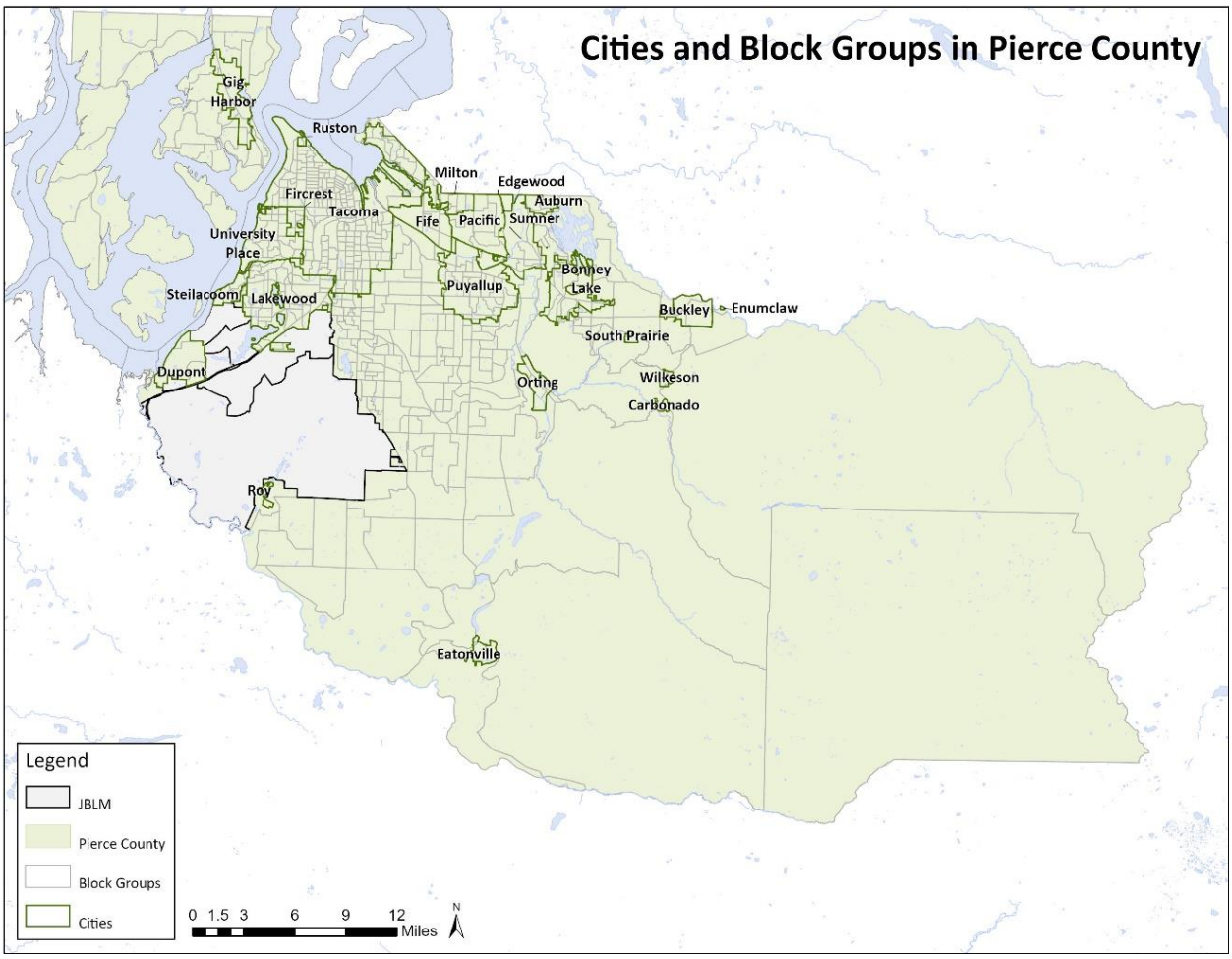

Figure 1: Cities and block groups in Pierce County.

1.2 Pierce Transit

With a mission to improving "people's quality of life by providing safe, reliable, innovative and useful transportation services that are locally based and regionally connected" (*Transit Development Plan: 2019 – 2024*) Pierce Transit has served Pierce County for 40 years. In 1978, Pierce County officials began discussing providing transit beyond just Tacoma Transit, and in 1979, 61% of voters approved a 0.3% sales tax to fund the Pierce County Public Transportation Benefit Area, thus creating Pierce Transit (*Destination 2040*). In 2002, voters approved an increase in this tax to 0.6%. The maximum sales tax percentage than can be authorized is 0.9% (*Comprehensive Annual Financial Report*). Today, Pierce Transit covers 292 square miles of Pierce County that holds approximately 70% of the county population (Pierce Transit). Its service

includes fixed routes, which will be the focus of this study; a paratransit shuttle; and a vanpool. Of its riders, 66% do not have a driver's license and 39% do not have access to a vehicle. Fifty-two percent of riders use Pierce Transit to commute to and from work (Pierce Transit).

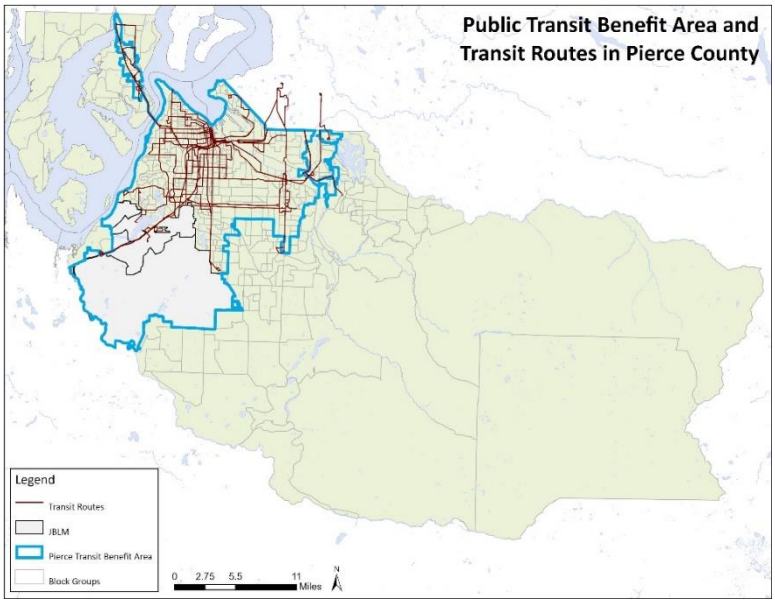

Figure 2: The Public Transit Benefit Area and transit Routes in Pierce County.

As indicated above, Pierce Transit does not serve the totality of Pierce Transit. Its service is limited to the Public Transit Benefit Area (PTBA), which is incorporated under Chapter 56.57A of the Revised Code of Washington (RCW). The PTBA includes 13 of the 23 incorporated cities within Pierce County – Auburn, Edgewood, Fife, Fircrest, Gig Harbor, Lakewood, Milton, Pacific, Puyallup, Ruston, Steilacoom, Tacoma, and University Place – as well as some unincorporated Pierce County (see Figure 2). Per RCW 56.57A, the PTBA may not include only part of a city; if a city is to be included in the service area, is must be included in its entirety. Additionally, as far as practicable, the service area boundary must follow school district lines or election precinct lines. Changing the boundaries of the PTBA involves multiple steps, including a public hearing and a vote by the Pierce Transit Board of Commissioners. The Board of Commissioners consists of ten members and is made up of elected officials representing the 13 cities that are currently included in the PTBA, Pierce County, and on non-voting union representative (Pierce Transit). Once the Board of Commissioners has approved a change in the PTBA boundaries, the county legislative authority may "disapprove and terminate the establishment" of the new PTBA boundaries. Thus,

the boundaries of the PTBA could be challenging to change. It is important to note that the 0.6% sales tax that contributes to the funding of Pierce Transit is only assessed to those areas of Pierce County that are within the PTBA.

1.3 Purpose and Research Questions

With the impact that transit makes on everyday life, it is important to understand the equity impact of a transit system in such a large and diverse county. Therefore, the purpose of this study is to analyze the social equity of the Pierce Transit system with a goal of identifying any equity shortfalls or gaps and potentially providing recommendations for alleviating such shortfalls. It is important to acknowledge, however, that, while important, equity is not the only concern facing transit agencies. With limited financial resources and the impact of transportation on the environment, equity must be balanced with efficiency and sustainability goals. Therefore, the goal of this study and its findings regarding social equity in the Pierce Transit system is not to dictate or even advocate for perfect equity within the system. Rather, it is to examine and identify where there may be equity shortfalls for further study and awareness when funding and service allocation decisions are made in balance with other transit agency considerations.

In framing this study, my overarching question is whether or not the Pierce Transit system is equitable. In order to answer that question, I plan to look at accessibility to destinations via transit in relation to key groups that generally are in danger of transportation disadvantage. The research questions I shall address include:

1) What are the key population groups that are in danger of transportation disadvantage?
2) What are the levels of accessibility that Pierce Transit provides to key destinations, such as jobs, food, and social services?
3) What are the differences in levels of accessibility for the key population groups relative to other population groups?

Question 1 will primarily be answered through a review of key literature. Questions 2 and 3 will be explored through data analysis. The implications and potential policy recommendations with then be explored based upon these findings.

2. Literature Review

2.1 Theoretical Basis for Equity in Transportation

In order to understand how to analyze the equity of a transit system, we must first understand equity within transportation and the theoretical reasoning behind its import. When considering equity, we first look at a basic definition of equity, which speaks to how costs and benefits of a system or good is distributed to the members of society (Di Ciommo and Shiftan 2017). In regards to transportation, this basic definition can be further delineated into three categories of equity: horizontal equity, vertical equity with respect to income and social class, and vertical equity with respect to mobility need and ability.

Horizontal equity looks at the distribution of goods or services among equal groups or individuals within a population. In this form of equity, the distribution should be equal across the population. Vertical equity with respect to income and social class, on the other hand, looks at the distribution of goods and services between groups or individuals that have different incomes or social class. This form of equity favors those with lower income and social class over those with high income and social class. Finally, vertical equity with respect to mobility need and ability looks at distribution of transportation services between groups and individuals who have different mobility needs and abilities. This form of transportation equity favors the needs of those who have restricted ability and strives for a universal design such that the transportation system can be utilized by those of all abilities (Di Ciommo and Shiftan 2017; Bullard, Johnson, and Torres 2004; Ricciardi, Xia, and Currie 2015).

The idea of horizontal equity is relatively self-explanatory: everyone in the population should enjoy an equal portion of the transportation system. Fifty percent of the service should be distributed to fifty percent of the population, one hundred percent of the service should be distributed to one hundred percent of the population, and so forth. The justification for vertical equity, on the other hand, requires an understanding of the theoretical underpinnings.

2.1.1 Walzer's Spheres of Justice

An important theory that informs vertical equity is Walzer's Spheres of Justice. In this theory, all goods are social goods whose meanings are constructs of society. Some goods will be deemed more valuable in some societies than others; they do not have intrinsic value. As constructs of society, some goods will hold a "distinct social meaning" (Martens 2012; Martens, Golub, and Robinson 2012) that sets them apart from other goods. These goods should have their own "distributive spheres" (Martens 2012; Martens, Golub, and Robinson 2012) that should be guided by something other than the free exchange. This theory puts forth the government as the entity that ought to help guide these distributive spheres.

While which goods can be classified as having a distinct social meaning will differ from society to society, in the U.S., transportation can be considered as such a good that requires its own separate distributive sphere outside the market. A person's ability to access transportation can shape their life. With transit in particular, access to transit and to job locations by transit contribute to increases in employment levels, particularly among those with low income (Chang 2006). Furthermore, although there is some disagreement within the literature (see Smart and Klein 2020), access to jobs via public transportation may affect employment as much or more than owning a private vehicle (Chang 2006). Additionally, after lack of child care, lack of reliable transportation is the second most common cause for missing work among welfare recipients (Chang 2006) and

public transit plays a significant role in improving job access for those with disabilities (Lubin and Deka 2012). Lack of availability to transportation also often leads to social exclusion (Martens 2012; Martens, Golub, and Robinson 2012). For groups experiencing social exclusion, employment opportunities and stability, health, education, and social activities are all affected (Fields et al. 2019). All these effects that transportation – or the lack thereof – has on people's lives shows that it is a good with a "distinct social meaning" and thus should have its own distributive sphere.

2.1.2 Rawls' Second Principle of Justice

To determine how this good – transportation – should be distributed, Rawls' second Principle of Justice can be applied. In his book *Theory of Justice*, Rawls lays out Two Principles of Justice, the second of which states that "social and economic inequalities are to be arranged so that they are…to the greatest benefit of the least advantaged" (Rawls 1971 as cited in Beatley 1988). This Second Principle of Justice can be applied to transportation. Policies ought to maximize the benefits of the least-advantaged economic and social group first (Beatley 1988). This application of equity theory ties in quite well with vertical equity with respect to income and social class. If broadening the principle to least-advantaged group in general and not restricting it solely to economic and social groups, this principle can also be applied readily to vertical equity with respect to mobility needs and ability. The idea behind this principle and its application to transportation vertical equity is that if those in the least-advantaged group are able to enjoy the system fully, the system will become better for all in society, also known as bottom-up inclusion (Di Ciommo and Shiftan 2017).

2.2 Methodology

2.2.1 Accessibility

The literature regarding transit equity focuses primarily on assessing the accessibility of the system. What accessibility means, however, is interpreted differently in different studies. The inclusion of destinations, rather than just an ability to move through a particular transportation system, is important, as travel is often a means to an end (Morris, Dumble, and Wigan 1979). Martens argues that accessibility can be person focused or place focused. Person accessibility examines whether or not a person has accessibility to a particular set of locations. On the other hand, place accessibility looks at whether or not a location is accessible for a particular set of people or from a particular set of other locations (Martens 2012). In the literature, the difference between the analysis of person accessibility and place accessibility can be seen in those studies that place the trip origin at a place (Xu, Li, and Wang 2016; Xu, Zhang, and Li 2017) or if they place the trip origin at residence locations, or with people (Ben-Elia and Benenson 2019; Golub and Martens 2014; Tribby and Zandbergen 2012).

Another distinction between different types of accessibility is that of to transit accessibility (TTA) and by transit accessibility (BTA). TTA examines how easily people are able to get to transit stops or stations (Xu, Li, and Wang 2016). This analysis is based on physical features of the system and location, such as walking time, on-board time, obstacles, or built environment factors. TTA analyses often place the stop as the center of their analysis and examine what parts of the population are able to get to the stop (Carleton and Porter 2018; Delbosc and Currie 2011a; 2011b). BTA, on the other hand, examines the convenience of a specific activity, such as shopping or commuting to work, by transit. In addition to accessing the transit stop or station, BTA also considers factors of the time and costs of the trip to reach the designated place or set of places.

BTA analyses often look at the round-trip (Xu, Li, and Wang 2016; Xu, Zhang, and Li 2017).

2.2.2 Including Equity

The inclusion of equity into a transit system study highlights additional factors to consider, such as which methods are best and which population groups to consider. Two popular methods for analyzing transit equity are the needs gap analysis and the utilization of the Lorenz curve and Gini coefficient.

A needs gap analysis looks at the mismatch between transit supply and mobility needs within the transit system. This requires a transit supply metric and a needs metric. Accessibility, as discussed previously, is a frequent metric to determine transit supply. Mobility needs is often determined through analyzing different populations groups either in the aggregate or disaggregate. This metric will be discussed further later in this section. A needs gap analysis is good for providing a spatial analysis of equity and allowing spatial equity patterns to appear. A challenge with this method, however, is that it requires transit need and service data to be rescaled to allow for direct comparison (Carleton and Porter 2018).

The Lorenz curve (see Figure 3) also bases its measurement of equity on transit supply, similar to a needs gap analysis (Delbosc and Currie 2011a; 2011b; Ricciardi, Xia, and Currie 2015; Carleton and Porter 2018), but the comparison is not spatial. Rather, a Lorenz curve analysis compares the cumulative proportion of transit supply to the cumulative proportion of the disadvantaged population. As with the needs gap analysis, the disadvantaged population can be looked at in either the aggregate or disaggregate. In a Lorenz curve, a line of equity, in which X (cumulative proportion of the population) equals Y (cumulative proportion of transit supply). If the curve and the line of equity are the same, that means that transit supply is equally distributed across the disadvantage population and thus is totally equitable. The Gini coefficient is the

proportion of the area between the Lorenz curve and the line of equity to the total area under the line of equity. This value is between 0 and 1, with 0 being total equity (the Lorenz curve and line of equity are equal) and 1 being total inequity. Thus, the larger the Gini coefficient, the more inequitable the system is. A disadvantage of the Lorenz curve is that it does not allow for spatial comparisons. The advantage, however, is that is provides simple comparisons of different populations (Carleton and Porter 2018). A Lorenz curve analysis also allows for determining both vertical and horizontal equity, in that the entire population can be examined (horizontal equity) or different populations groups can be examined (vertical equity) (Ben-Elia and Benenson 2019).

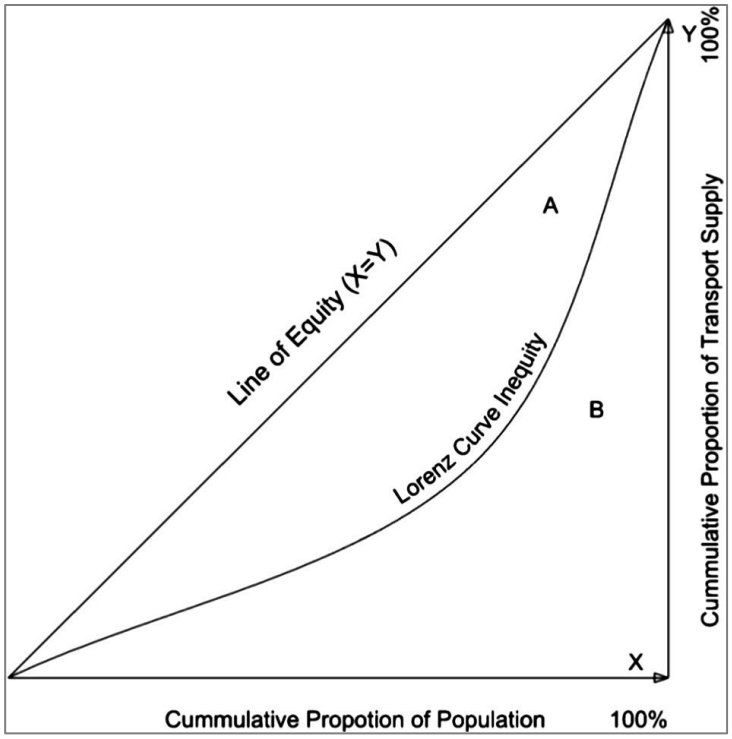

Figure 3: A typical Lorenz curve. Source: Ricciardi, Xia, and Currie 2015.

With both the needs gap analysis and Lorenz curve analysis, equity is assessed by studying disadvantaged populations, which can be either aggregated together into a general disadvantaged population, or disaggregated into individual groups. Aggregation of the different groups into a needs index is justified through the want of simplicity in determining equity in a transit system (Fransen et al. 2015; El-Geneidy et al. 2016). Although simplicity is desirable, aggregating disadvantaged groups together can mask underlying differences in equity between the difference groups (Carleton and Porter 2018; Delbosc and Currie 2011a). In fact, an aggregated group can lead a system appearing relatively equitable compared to the general population while

disaggregating the different groups show that some groups experience more inequity than others (Carleton and Porter 2018).

It should be noted that while both the needs gap and Lorenz curve analyses are commonly used in the study of equity within transportation systems, using only demographic data for the demand variable provides a potential demand or need for transit, rather than a true measure of actual demand or need for transit, and is not a particularly empirical analysis of demand or need. Many other factors contribute into the calculation of transit demand or need, which have been discussed in other academic and practical studies and literature. However, since this study is focusing on the social equity of a transit system, it will continue to use the common methods of other transit equity studies in looking at the potential demand per social group – i.e., key population groups.

In addition to aggregating or not, which groups to include in a potential mobility needs metric must also be addressed. Certain pieces of legislation, such as Title VI of the 1964 Civil Rights Act (Title VI), the 1994 Executive Order 12898 (EO 12898), the Transportation Equity Act for the 21st Century (TEA-21), and the National Environmental Protection Act (NEPA) mandate that particular populations be considered protected classes (Bullard, Johnson, and Torres 2004; Carleton and Porter 2018; Martens, Golub, and Robinson 2012). Title VI states lists "race, color, or national origin" (42 U.S.C. §2000d et seq.) as protected classes. NEPA expanded this definition to include low-income populations (42 U.S.C §4321). Literature on transport related social exclusion find that those living in low-density environments, older adults, racial and ethnic minorities, and low-income households are of particular concern (Fields et al. 2019).

In the U.S., race is of particular concern, not only because of its codified protected class status but also because of systemic racism. Such examples of unequal distribution of transportation

access as Jim Crow laws, redlining, and the effects of freeway expansion is well known and blatant in U.S. history. Yet, as the late Representative John Lewis wrote in the forward to *Highway Robbery*, "even today, some of our transportation policies and practices destroy stable neighborhoods, isolate and segregate our citizens in deteriorating neighborhoods, and fail to provide access to jobs and economic growth centers" (Lewis 2004). Furthermore, systemic racism in the U.S. is an explaining factor for such things as social inequality, political exploitation, social isolation, and poor health for people of color, and transportation systems and planning often reflect the biases of those who created them (Bullard, Johnson, and Torres 2004).

3. Methods and Data

3.1 Accessibility

Keeping in mind Walzer's Spheres of Justice as a theoretical foundation on which to base this assessment of equity of the Pierce Transit system, the methods of this analysis will look at transit as a good with social meaning that should be distributed outside the free exchange. Thus, the assessment of accessibility provided by Pierce Transit should focus on the people who may utilize the system. The methods used, therefore, to determine the accessibility of the Pierce Transit system, should focus on where the system allows a person to go, making residential locations the focus of origin. Additionally, in order to provide a spatial analysis of equity, the methods commonly utilized in the needs gap approach will also be used in this study. However, since using only demographic data to assess demand is not an empirical way to calculate actual need, the findings of the spatial analysis will only refer to potential gaps or areas of potential concern. Without empirically assessing the actual need or demand of these area, referring to the findings as a needs gap may be misleading and create unnecessary reactions against the transit agency. Identifying potential gaps or areas of concern, however, will still provide useful information

regarding social equity, which will be further discussed in the discussion section of this study.

For the demographic analysis, this study looks at groups that are historically underserved or are at risk of transportation-related social exclusion. These groups include racial minorities, low-income households, the elderly, youth, those with lower English proficiency, and those without a personal vehicle (Fields et al. 2019). While those with disabilities are often discussed as a group in danger of transportation disadvantage, because Pierce Transit offers a shuttle service outside of their fixed routes, this study will not include those with disabilities into the demographics studied.

3.2 Data

In order to assess the accessibility of the Pierce Transit system, the number of jobs and community assets key population groups are able to reach on a transit trip are counted. For this analysis, the following data were collected:

- Job locations in Pierce County
- Community asset locations, including health care facilities, social services, places of worship, schools, grocery stores, libraries, and parks
- Transit routes and stops, including those of Pierce, Intercity, and Sound Transit
- The frequency and schedules of the above listed transit routes
- Streets
- Parcels and residential units in Pierce County
- Demographics by Census block group, including the population, race, income, English proficiency, age, and car availability

Job locations were given as a count of the total number of jobs in a Census block and retrieved from the Longitudinal Employer-Household Dynamics (LEHD) of the Census Bureau. The location of public health care facilities, parks, libraries, and schools were available as shapefiles from Pierce County. The location of private health care facilities, including urgent care

clinics, pharmacies, mental health facilities and providers, and dentists; grocery stores, which excluded convenient stores; and places of worships were gathered from the Yellow Pages and Google Maps. Convenience stores were excluded from the grocery store category due to their general lack of healthy, low-cost food options, such as fresh produce and other unprepared foods. A review of food deserts found an increase in access to conveniences stores to be positively associated with a risk of obesity, as opposed to an increase in access to supermarkets showing a decrease in the prevalence of obesity (Beaulac, Kristjansson, and Cummins 2009). Locations of social services, which include community centers, adult education and job training resources, homeless resources, food banks, and meal sites, were gathered from the Pierce County Department of Human Resources website. All social service location points were aggregated into one community asset category, with no weighting. All of the community asset locations were in a point format, either initially through the original shapefile or through geocoding. See Appendix B, Data Dictionary, for further details.

Demographic data were obtained through the 2015-2019 5-Year American Community Survey data, via the tidycensus package in R, at the block group level, which was the highest resolution available. From data regarding race, those identified as white only were subtracted from the overall population. That number, representing the number of people of color, was then divided by the total population to give the percentage of the block group population that were people of color. Low-income households were determined to be those making 50% or less of the Area Median Income (AMI). For Pierce County, the median household income is $75,407, making 50% AMI $37,704. Due to the income categories of the ACS data, low-income households were adjusted to be those making less than $35,000 per year. The elderly are those who are 65 years or older, and youth are those 17 years or younger. Personal vehicle availability was given by household, with the

number of vehicles available to households of differing sizes. To determine those without a personal vehicle, the data was filtered to only include households without any car available. Finally, English proficiency was gathered by filtering the data for those households who speak English less than very well. The data were geographically placed through joining the demographic data tables with the 2010 block group shapefile obtained through Pierce County.

A parcels shapefile and additional parcel table, containing the number of residential units on each parcel, were obtained from Pierce County. The parcel table, however, was incomplete, and did not include the number of residential units for all parcels in a residential zone. Any parcels that were designated as single-family were given a value one residential unit. An additional table of mobile home data was obtained and joined to fill in missing residential units for parcels designated as mobile home. However, there were some parcels that were designated as multi-family that were without residential unit data. The residential unit data for these parcels were supplemented through visual inspection of the parcels via Google Maps and an estimation of the number of residential units for each parcel was made.

It should be noted that for all data, data inside JBLM were not considered. Not only are there constraints on collecting data of locations and services within a military base, but not all services or jobs inside a military base are available to the general public. For example, medical care and the commissary are only available to military personnel, veterans, and their families. Therefore, while JBLM does provide many jobs and services to those in the military, it will not be considered in this analysis. Additionally, this analysis did not consider jobs or community assets outside of Pierce County, due to data collection and time constraints.

3.3 Methods

In order to create a person-oriented origin point for the accessibility analysis, a residential-weighted centroid in each block group was created (see **Error! Reference source not found.**). This was done first through creating a geometric centroid in each residential parcel. All non-residential zoned parcels were filtered from the parcel data. The centroids were spatially joined with the block group polygon layer, associating each parcel centroid point with a block group. A mean center point was then calculated for each block group, weighted by the number of residential units associated with each parcel centroid point. This resulted in a point for each block group that was weighted for where residential units in the block groups were located, rather than a geometric centroid. It should be noted that there were three block groups in Pierce County that contained zero residential parcels, and therefore these three block groups were not included in the origin points. This is discussed further in the results sections of this paper.

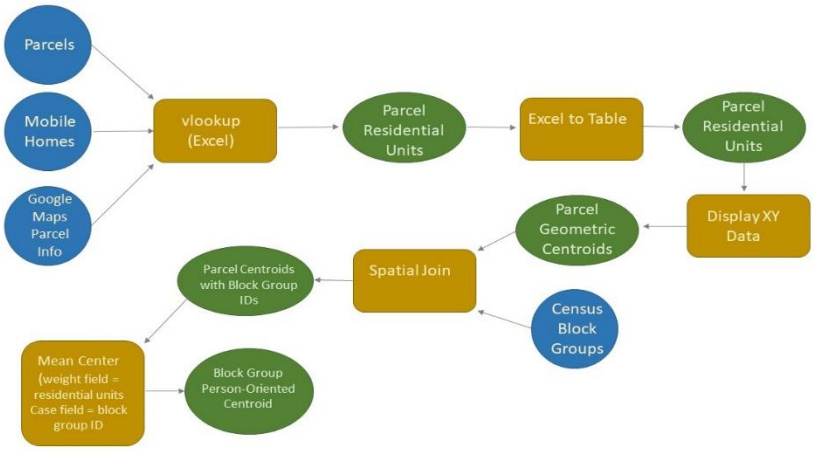

Figure 4: Method for creating person-oriented origin points.

With the origin points established, 60-minute travel sheds were then created, without time restrictions on either walking or transit individually because of software limitations (addressed further in the Limitations sections of this paper). Sixty minutes was chosen due to both its usage by other transit agencies for accessibility analysis (King County Metro, 2019) and based upon commute behavior in Pierce County. In 2019, 15.9% of workers over the age of 16 in Pierce County spent 60 minutes or more on their commute to work (see Figure 6). While this portion seems small at first glance and the mean time spent traveling to work was 33.7 minutes, 60 minutes or more was the commute time most reported (U.S. Census Bureau, 2019). This indicates both the reality of commute time for many workers in Pierce County as well as the willingness for workers to spend 60 minutes on their commute.

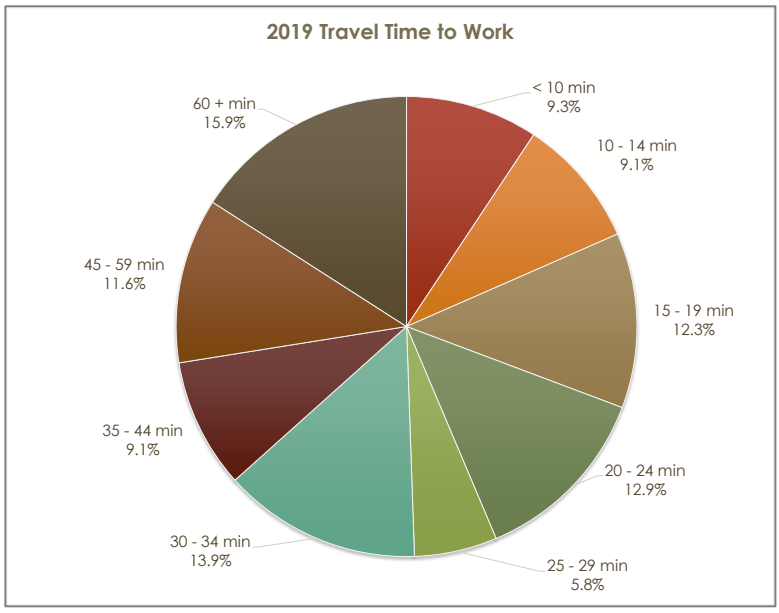

Figure 5: Travel time to work by workers over the age of 16 in Pierce County.

General Transit Feed Specification (GTSF) data from Pierce Transit, Intercity Transit, and Sound Transit were used through the GTFS to Network Dataset tool in ArcGIS Pro 2.6. This tool converted the GTFS data into feature classes that could be used in the Network Analyst tool. Within Network Analyst, a mode of travel was created, using travel attribute costs of transit travel time and length. Transit travel time, which was in minutes, accounted for 0.5 minutes when boarding and alighting transit and a 3-mile-per-hour (or 0.05 mile-per-minute) walking speed along the streets as a person walked to or from transit stops. GTFS data that had been converted

as described above was used to account for the amount of time a passenger spends on board a bus, train, or light rail. A restriction was also added, prohibiting the use of portions of the street layer that was a highway, interstate, or ramp on or off either for walking. Next, service areas, which in this study are the travel sheds, were created using Network Analyst for the Census block group weighted centroids (see Figure 6).

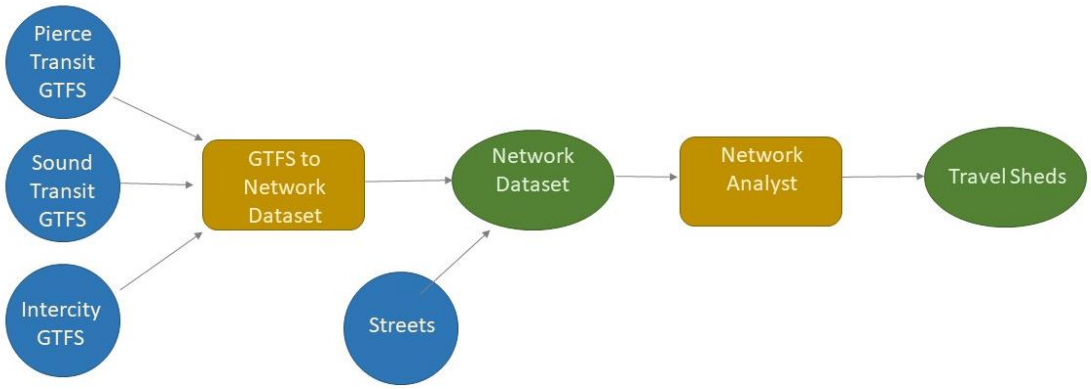

Figure 6: Method for creating the travel sheds.

To account for different possible work and life schedules, three sets of travel sheds were created. The first set calculated the travel sheds for travel at 7:30am on a weekday. The timing of this set of travel sheds would likely capture many people working the typical Monday through Friday, 8am to 5pm job. Furthermore, the morning rush hour near the Tacoma Dome in Pierce County was reported to last from 5:05am to 8:40am (Lynn 2016), indicating the time period in which many people are commuting to work in the morning. The second set of travel sheds was calculated for travel starting at 7:30pm on weekdays. This time was chosen to capture those workers who work a night shift. The travel will occur outside of the typical evening rush hour, which was reported to be between 2:05pm and 7:15pm (Lynn 2016), and, considering a possible travel time of 60 minutes, would accommodate those starting their night shift around 8:30pm or 9:00pm. The third set of travel sheds was calculated for travel starting at 8:00am on a Saturday.

This time was chosen to account for those who work on the weekend. Considering that low-income households and people of color are key population groups at risk of transportation related social exclusion, it is important to calculate travel sheds accounting for those working nonstandard hours. In 2010 to 2011, working nonstandard hours was common among low-income workers. For those earning less than the top 75% of the working population, 28% worked most of their hours outside of 6am to 6pm (Enchautegui 2013). In that same time period, 24% of Black workers and 23.9% of Hispanic workers 39 years old worked nonstandard schedules (Presser and Ward 2011).

To determine the number of jobs that could be reached in each travel shed, the jobs polygon layer was intersected with each travel shed polygon layer. Then the percentage of each jobs polygon (Census block) that was in each intersect was calculated, and that was multiplied by the total number of jobs within the Census block to estimate the number of jobs that intersect with the travel shed. These were then dissolved by travel shed ID (see Figure 7). This method assumes an equal distribution of jobs throughout each Census block.

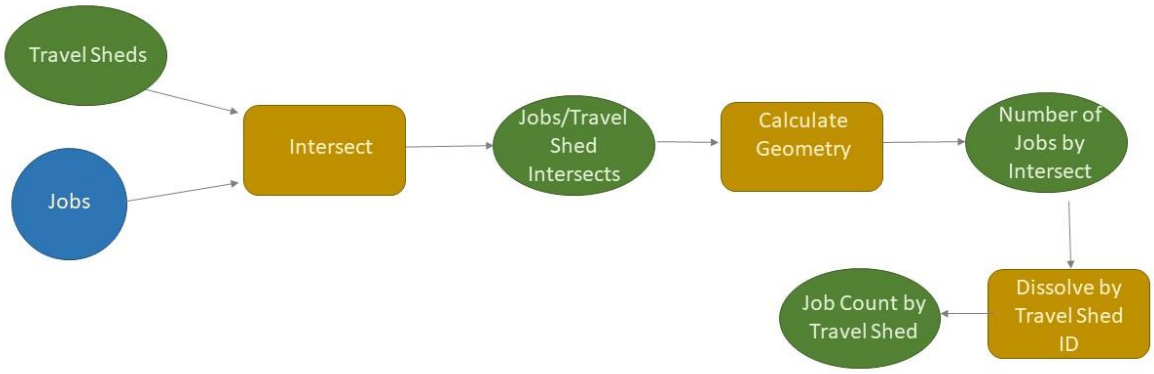

Figure 7: Method for counting jobs in each travel shed.

Because community asset locations were points, the number of community assets that could be reached in each travel shed was determined through the Summarize Within tool, which created a count of each community asset within each travel shed. Because the origin point for each travel shed was the person-oriented centroid for a specific Census block group, the number of each

community asset (social services, health care facilities, places of worship, grocery stores, schools, parks, and libraries) and the number of jobs that could be reached from each block group via 60 minutes of walking and transit had thus been determined.

Inspired by the Public Transport and Walking Index (PTWI) method developed by Mavoa et al. (2012), quartiles were then calculated for each community asset and jobs within each Census block group. For each block group, if a community asset or number of jobs was in the first quartile, it received a score of 1. If it was in the second quartile, it received a score of 2; third quartile received a score of 3; fourth quartile received a score of 4. If there were no points of a specific community asset or no jobs, it received a score of 0. The scores across all the community assets and jobs for each block group were then added together. Each block group could then have a total accessibility score between 0 and 32, with 0 representing block groups with no accessibility to any community asset, and 32 representing block groups that had accessibility in the fourth quartile for all community assets. Quartiles of these total scores were then calculated and levels of accessibility were determined. If a block group received a total accessibility score of 0, its level was "None". If a block group's accessibility score was in the first quartile, its accessibility level was "Low"; second quartile was an accessibility level of "Moderately Low"; third quartile was an accessibility level of "Moderately High"; and fourth quartile was an accessibility level of "High."

Similarly, for each Census block group, quartiles were calculated for each key population group and levels assigned. For the first quartile, a level of "Low" was assigned; for the second quartile, "Moderately Low"; third quartile, "Moderately High"; and fourth quartile, "High." For example, quartiles for the elderly population were calculated using the total number of those over 65 years of age living in each block group. The spread of these population numbers created the quartiles, and the elderly population in each block group was then used to determine which quartile

that block group fell into – Low, Moderately Low, Moderately High, or High – with those block groups in the Low quartile containing the fewest elderly people and those block groups in the High quartile containing the most elderly people. Next, for each block group, the levels of each key population group and the level of accessibility were compared. Based upon how the levels matched up, a potential gap level was assigned. Table 1 shows how the potential gaps were assigned. A potential gap of "Extreme" indicates the largest gap between the potential need (level of the key population group) and accessibility. Next were a potential gap of "Very High," "High," "Moderate," "Low," and "Very Low," with Very Low indicating the smallest gap between the potential need of that block group and the accessibility level of that block group. The results of this potential gap identification for each of the key population groups and for each of the three sets of travel sheds will be further discussed in subsequent sections of this paper.

Table 1: Potential Gap Matrix

		Accessibility Level				
Key Population Group	Level	None	Low	Moderately Low	Moderately High	High
	High	Extreme	Very High	High	Moderate	Low
	Moderately High	Extreme	Very High	High	Moderate	Low
	Moderately Low	Very High	High	Moderate	Low	Low
	Low	High	Moderate	Moderate	Low	Very Low

4. Results

4.1 Accessibility

The results of the accessibility analysis for the three travel times – weekday mornings, weekday evenings, and weekends – are shown in Figure 9. These maps will also be repeated in the sections of this paper discussing each population group for ease of comparison and visualization. It is important to note that three block groups, labeled as "N/A" on the accessibility maps and circled in Figure 9, do not contain any parcels zoned as residential, and therefore did not contain an origin point for the travel sheds. Thus, they are labeled as "N/A" because travel sheds were not calculated for those block groups and accessibility from those block groups was subsequently not calculated. The largest of these block groups, located in the southeastern corner of Pierce County, contains the Rainier National Park and therefore does not contain residential parcels. The block group located in Lakewood that is labeled as "N/A" is zoned as Major Institution and contains Historic Fort Steilacoom and a hospital. The final block group labeled as "N/A" is McNeil Island, located off the Key Peninsula. This island is zoned as Rural 4, and contains a wildlife sanctuary and two correctional facilities. These three block groups are therefore not included in the discussion for the elderly population or for any of the other population groups in the following sections.

Generally, High accessibility, denoted in the maps through the darkest shade of brown, is found primarily in Tacoma, concentrating in central Tacoma and extending to Fircrest, parts of east and south Tacoma, parts of Lakewood, and a bit south of the Tacoma city boundary. Nearly encircling the concentration of High accessibility is a ring of Moderately High accessibility, which covers the rest of Tacoma except for northeast Tacoma; most of Lakewood; and parts of University Place, Fife, Milton, Pacific, and Puyallup. Areas within the PTBA that generally have Moderately Low accessibility include parts of Gig Harbor, Steilacoom, University Place, Fife, Milton, Pacific, and Puyallup, as well as unincorporated portions of Pierce County within the PTBA. Low accessibility can generally be found in the northern part of Gig Harbor,

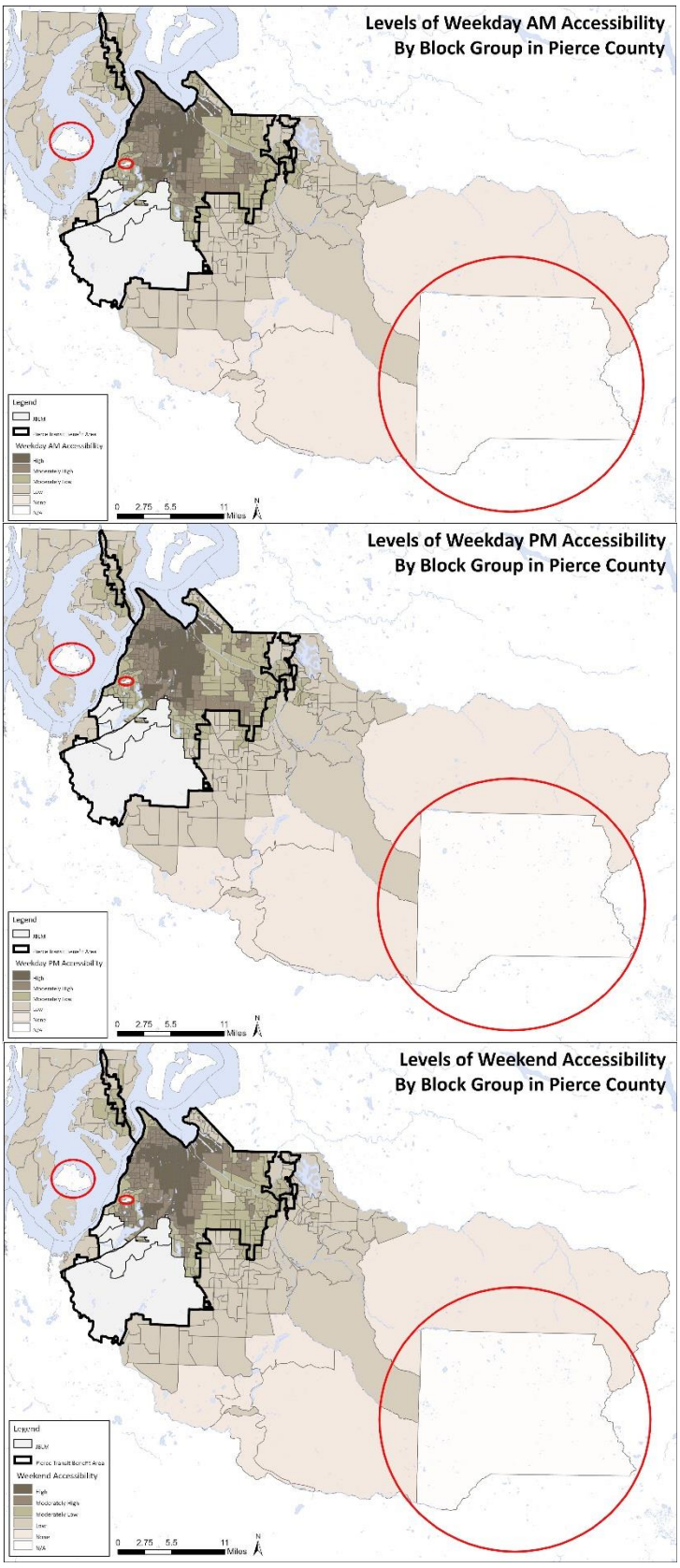

Figure 8: Accessibility analysis for the three travel shed times.

northeast Tacoma, and Auburn. Outside the PTBA, most block groups generally show Low or None accessibility, with a few exceptions near the PTBA boundary that show Moderately Low accessibility.

Some slight differences appear in the levels of accessibility between the different travel times. Most notably, the weekday travel times show greater accessibility in the unincorporated area east of JBLM and south f Puyallup, with Moderately High accessibility extending into that area during the weekday but Moderately Low accessibility during the weekend. On the other hand, the weekend travel time shows more Moderately High accessibility in the Fife, Pacific, and Milton area than the weekday travel time. Finally, during the weekend travel time, all of northeast Tacoma shows Low accessibility, with several block groups having Moderately Low accessibility on weekday evenings, and a few more having Moderately Low accessibility on weekday mornings.

4.2 Potential Gaps

The following sections will discuss the potential gaps found between the accessibility levels and the potential need levels within Pierce County. It is important to acknowledge that the gaps identified in the following sections are *potential* gaps, since the potential need levels are based solely on the location of key population groups and does not represent an empirically derived actual need measure. The purpose of identifying such potential gaps is to ascertain if there are any geographic areas within Pierce County that are potentially of concern and should therefore be considered, in conjunction with efficiency and sustainability goals, in the future when Pierce Transit makes funding and service allocation decisions. Furthermore, it should be acknowledged that just because a potential gap is identified, that does not then mean that there is a true need or demand for transit in that location, as other factors contribute to the transit need or demand of particular geographic locations.

4.3 Elderly

4.3.1 Accessibility and Population Levels

Figure 10 shows the accessibility for the three travel shed times alongside the levels of elderly population in each block group in Pierce County. The areas with high levels of elderly population include the Gig Harbor and Key Peninsula areas, a couple block groups in southern portion of Pierce County, and a spattering of block groups in the Puyallup, north and northeast Tacoma, University Place, Steilacoom, and DuPont areas. Areas with low levels of elderly population include a few block groups in Tacoma, Sumner, and the unincorporated area between JBLM and Orting.

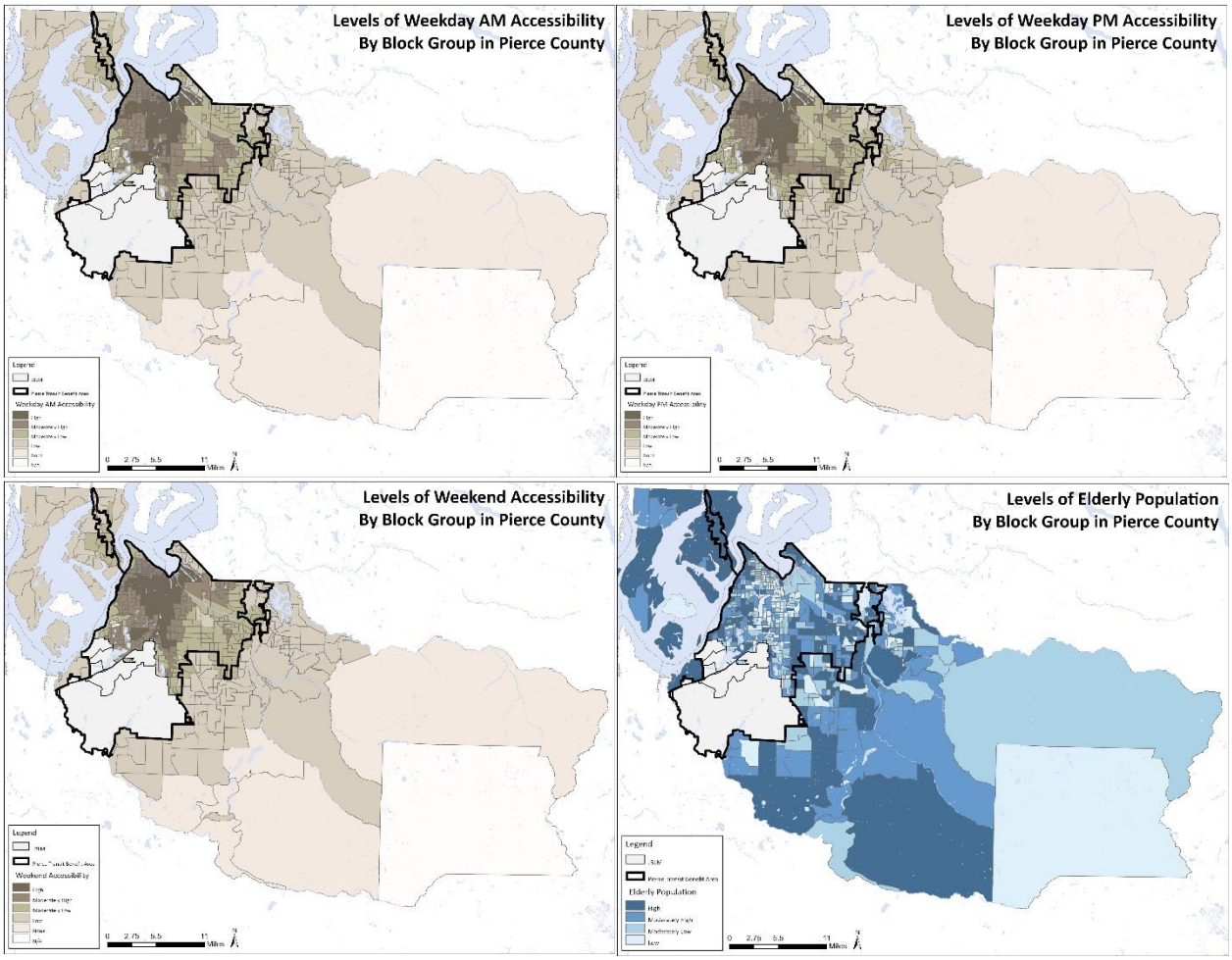

Figure 9: Levels of weekday morning (upper left), weekday evening (upper right), and weekend (lower left) accessibility, alongside levels of the elderly population (lower right) in Pierce County.

4.3.2 Potential Gap Identification

The potential gap maps, one for each set of travel sheds, are represented in Figure 12. The geographic areas within the PTBA that will be discussed in this section are circled in red in Figure 11. Overall, for the three times for which the travel sheds were calculated, the results appear to be quite similar. Furthermore, overall, the potential gaps within the PTBA for all three time periods for the most part are no more severe than Moderate with some areas being High. There are some notable exceptions to this generalization, however.

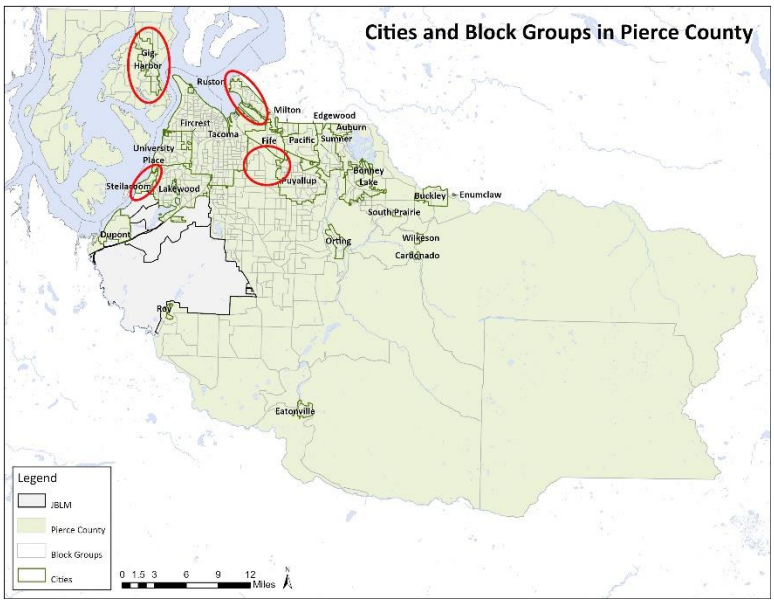

Figure 10: Key geographic areas to be discussed in the elderly potential gap identification.

For all three time periods, the most northwestern part of the PTBA, which is located in the northern end of Gig Harbor, has a Very High gap. The rest of Gig Harbor that is within the PTBA has a High gap. This result is not overly surprising, as there are a higher number of the elderly living in the Gig Harbor area (see Figure 10), combined with few transit routes serving that area.

Two other areas of potential concern for the elderly population within the PTBA for all three time periods are just south of Fife and west of Puyallup, and northeast Tacoma near the port. Both of these areas contain Census block groups that have a gap of Very High. During the weekend travel time, nearly all of northeast Tacoma has a Very High potential gap for the elderly, with the exception of two block groups that have a High gap. During the weekday evening travel time, two

more block groups shift down to a High gap and one block group shifts down to a Moderate gap. In the weekday morning travel time, only four block groups remain with Very High gaps, with all other block groups except for one having High gaps. With only one block group in this area having a potential gap less than High during all three travel times, however, this area is of potential concern.

In the area south of Fife and west of Puyallup, one block group has a Very High potential gap during all three travel times. During the weekend travel time, the block group shifts up from a High gap to a Very High gap. Notably, the block groups surrounding these two block groups nearly all have High gaps. These High potential gaps, which are mostly in the unincorporated area of Pierce County that is south of Fife and west of Puyallup but also extend into

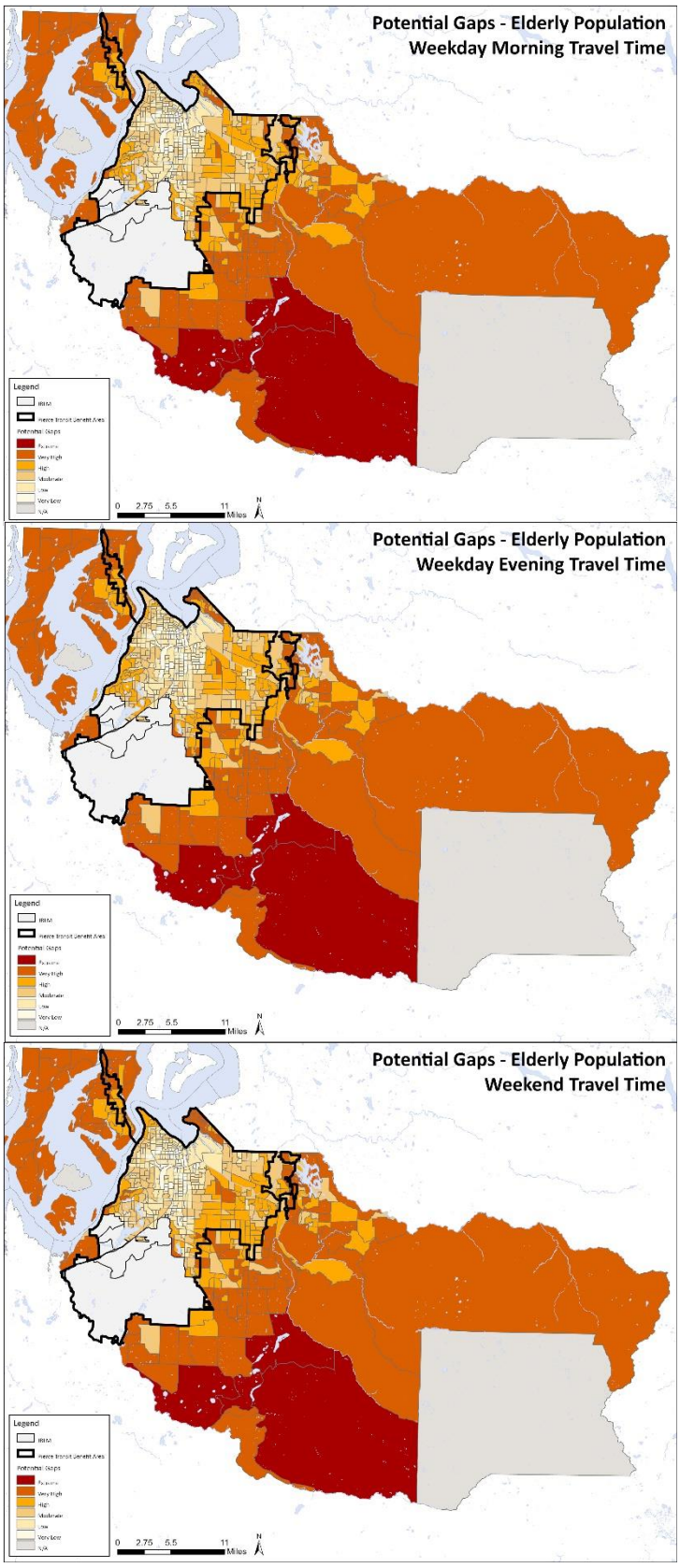

Figure 11: Potential gaps identification results for the elderly population for all three travel times.

Puyallup and the western part of Pacific, are a sizable area of potential concern for the elderly population for all three time periods.

The final block group that has a Very High gap is in southwestern portion of Steilacoom. This gap, however, was lessoned to High during the weekday evening travel time. The surrounding block groups in Steilacoom and the southwestern portion of University Place also all have High gaps, making this area another potential area of concern for the elderly population. One further block group in the northwestern part of Lakewood, bordering University Place and Steilacoom, shifts from having a High gap to a Very High gap during the weekend travel time.

Unsurprisingly, the areas outside of the PTBA have, in general, much higher levels of potential gaps. The one area, for all three time periods, that shows an Extreme potential gap is in the south-central part of the county, including the block groups where Eatonville is located. Many of the other block groups outside of the PTBA have Very High gaps, with only a few sporadic block groups showing High or Moderate gaps. Nearly the entirety of the Key Peninsula shows a Very High gap. Otherwise, the mainly Very High and Extreme levels of potential gaps outside the PTBA are to be expected since these areas are outside the area that Pierce Transit serves and therefore would have low or no accessibility levels.

4.4 Youth

4.4.1 Accessibility and Population Levels

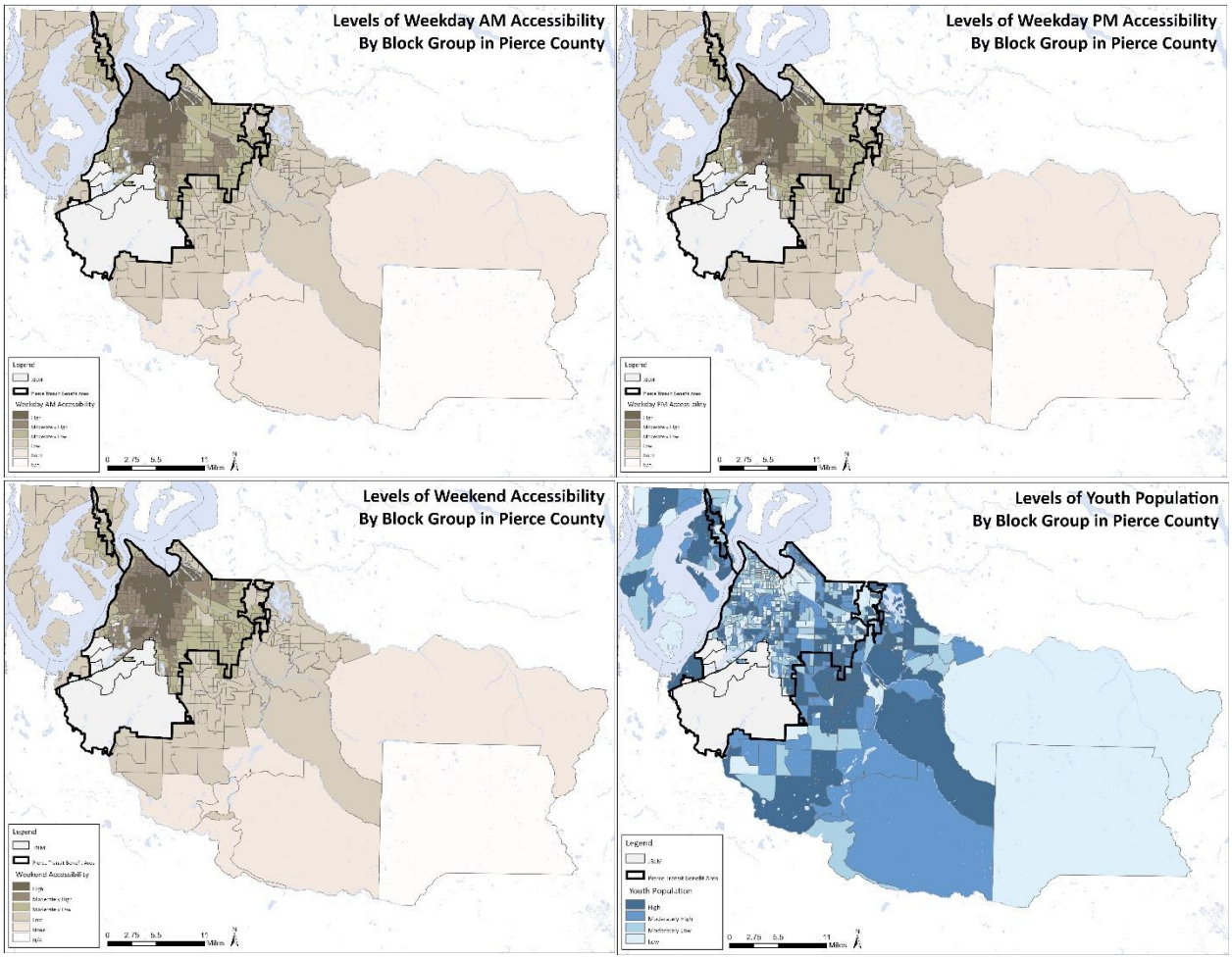

Figure 12: Levels of weekday morning (upper left), weekday evening (upper right), and weekend (lower left) accessibility, alongside levels of the youth population (lower right) in Pierce County.

The youth population in Pierce County (see Figure 13) is high in parts of Gig Harbor and the Key Peninsula areas, the Puyallup area, east Tacoma, parts of Lakewood and University Place, DuPont, and Puyallup. Outside the PTBA, there are sizable areas with high youth population, including a large block group just west of the Rainier National Park, the unincorporated areas west and north of Orting, the northern edge of the county, and the south-central part of the county. Areas with low levels of youth within the PTBA include around the Port of Tacoma, scattered blocks within Tacoma and Lakewood, and Sumner. Outside the PTBA, the block group north of the

Rainier National Park has low youth population, along with a few other scattered block groups in unincorporated Pierce County and in Orting.

4.4.2 Potential Gap Identification

The potential gap identification results for the youth population show little variation between the three travel times (see Figure 15). Figure 14 shows the key geographic areas within the PTBA that will be discussed. One of the primary areas of potential concern within the PTBA for the youth population is the Gig Harbor area.

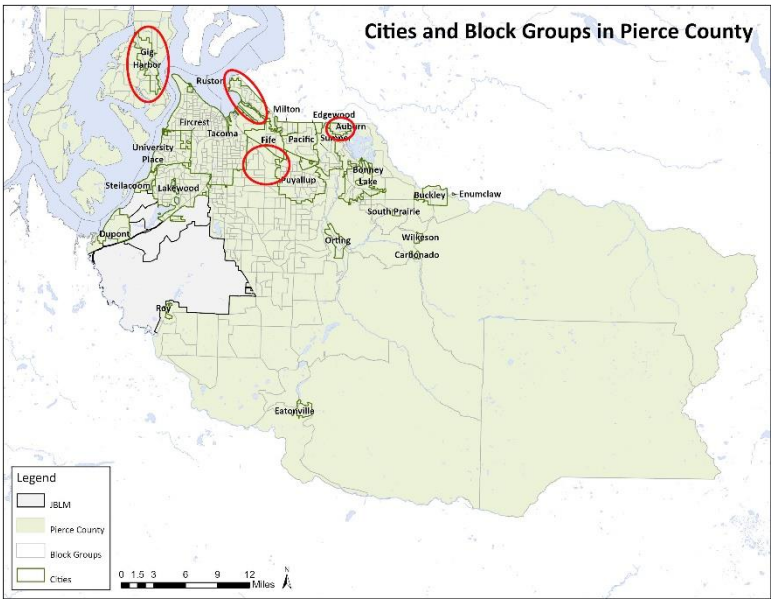

Figure 13: Key geographic areas to be discussed in the youth potential gap identification.

For all three travel times, there is at least one block group, and portions of two other block groups, that show a Very High potential gap. Other block groups in the Gig Harbor area exhibit High or Moderate potential gaps. Gap levels remain the same in Gig Harbor for all travel times.

Another potential area of concern for the youth population is the northeast Tacoma area. Here, the weekend travel time shows nearly all block groups as having Very High gaps, with the exception of two block groups that show High and Moderate gaps. During the weekday evening travel time, three more block groups shift down to High gaps, and several more move down to High gaps during the weekday morning travel time. During all three times, however, at least four

block groups in northeast Tacoma show Very High potential gaps.

The unincorporated area south of Fife and west of Puyallup is another area of potential concern for the youth population. Here, we see many block groups showing High and Moderate potental gaps during all three travel times. There is little difference in this area between the weekday morning and evening travel times, but the weekend travel time shows one block group shifting up to a Very High gap during the weekend travel time. It should be noted that while much of the area that shows Very High, High, and Moderate gaps is the unincorporated portion of Pierce County, many of the High gap block groups in this area are within the Puyallup and Edgewood city limits.

There are also a few block groups in the very northeastern corner of the PTBA that show Very High gaps.

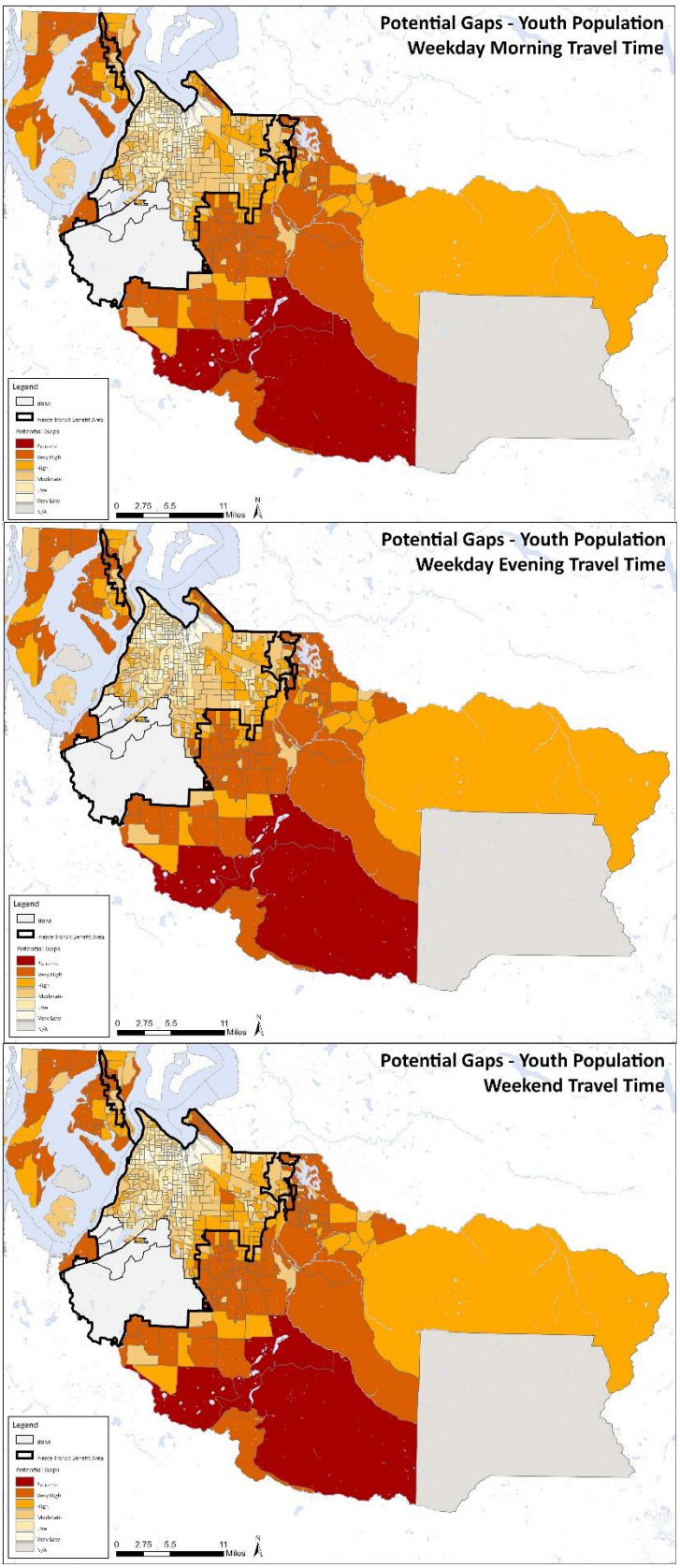

Figure 14: Potential gaps identification results for the youth population for all three travel times.

This may be explained, however, with this study only including jobs and community assets within Pierce County. These block groups that show Very High gaps are within Auburn city limits and abut King County, and, if this study included jobs and community assets outside Pierce County, the accessibility levels for those block groups may have been higher.

Outside of the PTBA, the potential gaps are greater, which is to be expected. The south-central part of the county shows Extreme gaps, and many other parts of the county show either High or Very High gaps. There are a few block groups here and there that show Moderate gaps, but those are few and not adjacent to each other. Notably, the Key Peninsula shows greater variation in potential gaps for the youth population than it did for the elderly population, with a few Moderate gaps, several High gaps, and several Very High gaps.

4.5 People of Color

4.5.1 Accessibility and Population Levels

As seen in Figure 16, within the PTBA High levels of the people of color population are concentrated in the central, east, and south parts of Tacoma, extending into Lakewood, with a few block groups in Fife also having High levels. Moderately High levels are interspersed in central and east Tacoma, as well as appearing in Lakewood, Steilacoom, parts of University Place, northeast Tacoma, and Puyallup. One block group that is partially in Gig Harbor also show Moderately High levels of people of color. Low levels are seen in the north end of Tacoma, Milton, Pacific, Auburn, and the unincorporated area west of Puyallup. Outside the PTBA, levels of people of color are generally Low or Moderately Low, with the exception of a block group on the Key Peninsula that shows Moderately High, DuPont that shows High and Moderately High, and the unincorporated area just south of the PTBA boundary and east of JBLM.

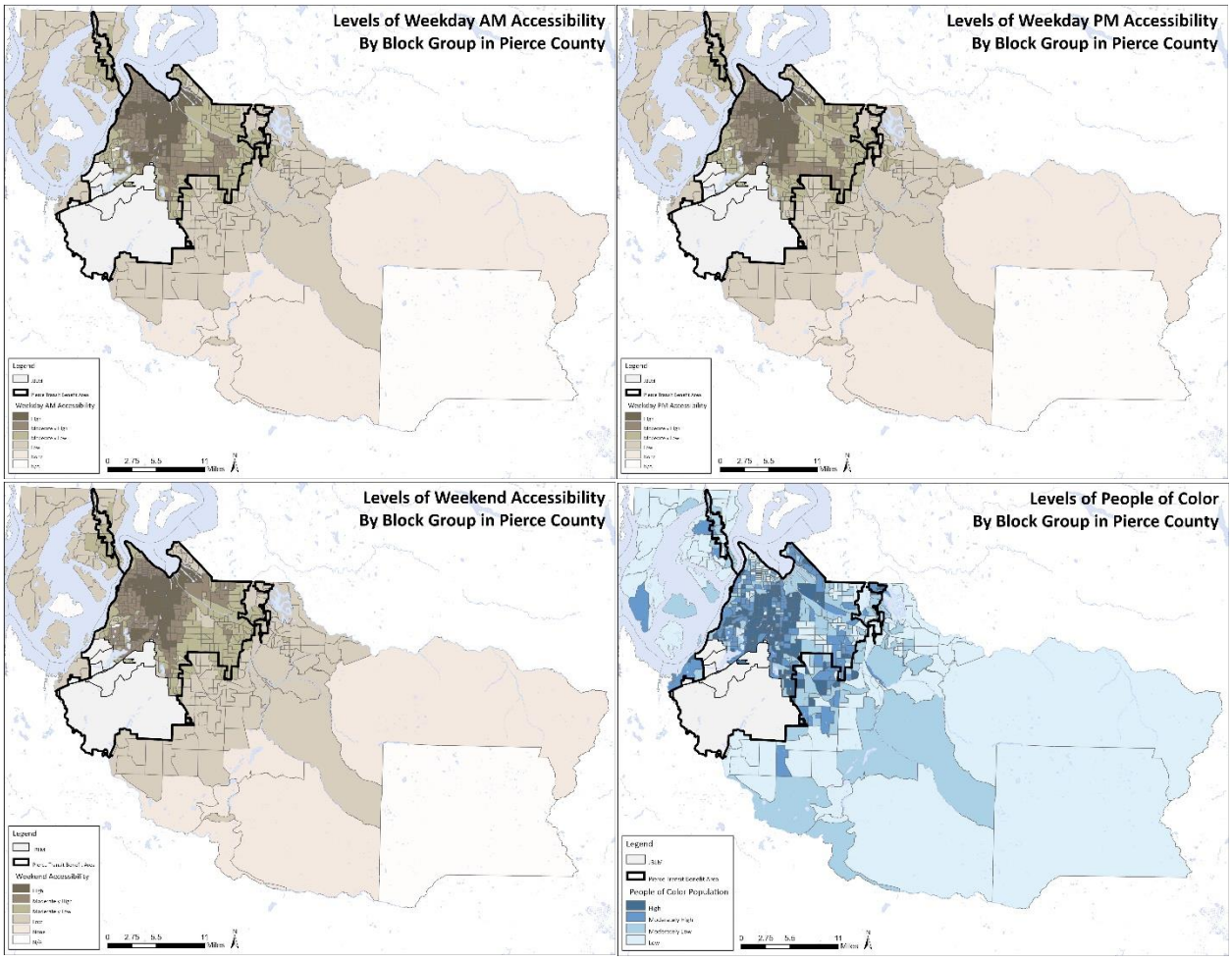

Figure 15: Levels of weekday morning (upper left), weekday evening (upper right), and weekend (lower left) accessibility, alongside levels of the people of color population (lower right) in Pierce County.

4.5.2 Potential Gap Identification

The most notable aspect of the potential gap identification results for the people of color population (Figure 18) is that there are no Extreme gaps. This holds true across all three travel times. The largest cluster of block groups that show Very High gaps are located in northeast Tacoma. (For reference of the key geographic areas discussed in this section, see Figure 17.) During the weekend travel time, all but three block groups in northeast Tacoma have Very High gaps, with two of the remaining three having High gaps and the last block group having a Moderate gap. During the weekday evening travel time, a couple block groups shift down to High gaps, and

one of the block groups that had a High gap during the weekend had a Moderate gap during the weekday evening travel time. An additional block group shifted down to a Moderate gap from a High gap during the weekday morning travel time, and three more block groups moved down from Very High to High gaps as well.

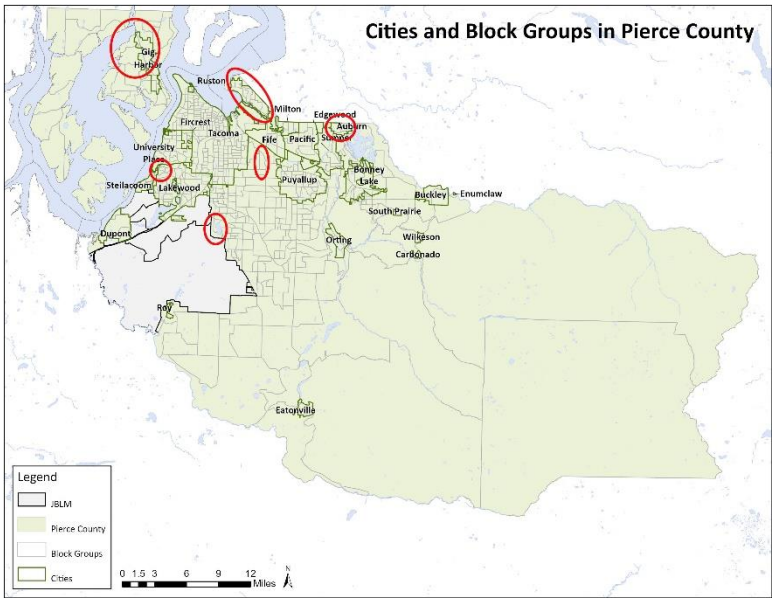

Figure 16: Key geographic areas to be discussed in the people of color potential gap identification.

The block groups within the Auburn city limits also showed Very High potential gaps for all three travel times. Very High gaps were also seen in a singular block group in the unincorporated area south of Fife and west of Puyallup. In the non-peninsula portion of Pierce County within the PTBA, no other block groups showed a Very High gap for the weekday morning travel times. A block group in the northwestern part of Lakewood, bordering University Place and Steilacoom, shifts from a High to a Very High gap during the weekend travel time. Other block groups in that area, particularly in Steilacoom, show High gaps for all three travel times. An additional block group in the unincorporated area of Pierce County adjacent to the north central part of JBLM shows a Very High gap for the weekday evening and weekend travel times, and a High gap during the weekday morning time. Just to the east of that block group, still unincorporated, three block groups show Very High gaps during the weekday evening travel time, and High gaps during the weekday morning and the weekend travel times.

In Gig Harbor, only one block group that is only partially within the PTBA shows a Very High gap during all three travel times. Other than that, an additional block group in the north end of Gig Harbor, has a High gap during all three time periods. The remaining block groups in Gig Harbor have Moderate gaps during all times.

While not showing Very High gaps during any of the travel times, several block groups in Fife and the unincorporated area north of Fife and between Milton and northeast Tacoma show High gaps in the weekday morning travel time. One of the block groups shifts down to a Moderate gap during the weekday evening travel time, and an additional block group shifts down to a Moderate gap during the weekend travel time.

More block groups show Very High and High potential gaps outside of

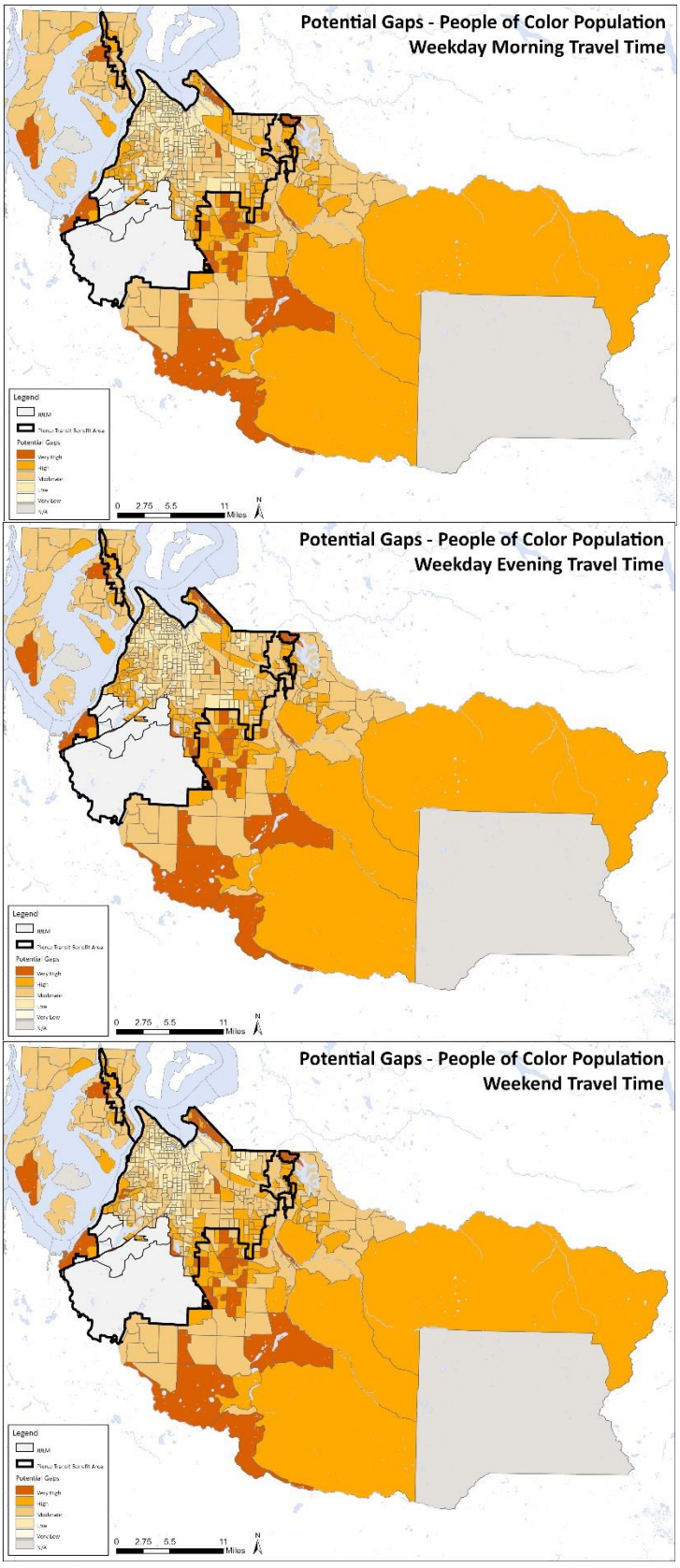

Figure 17: Potential gaps identification results for the people of color population for all three travel times.

the PTBA. The area just south of the PTBA and east of JBLM show multiple block groups that have Very High gaps and many with High gaps. In that area, only a few show Moderate gaps. A few block groups in the south-central part of the county show Very High gaps, and the large block groups surrounding the Mount Rainier National Park show High gaps. The DuPont area shows two of its three block groups with Very High gaps during all three travel times and the third with a High gap. Two block groups on the peninsula portion of Pierce County – one adjacent to Gig Harbor and one on the Key Peninsula – show a Very High gap and two other block groups show High gaps.

4.6 Low-Income Households

4.6.1 Accessibility and Population Levels

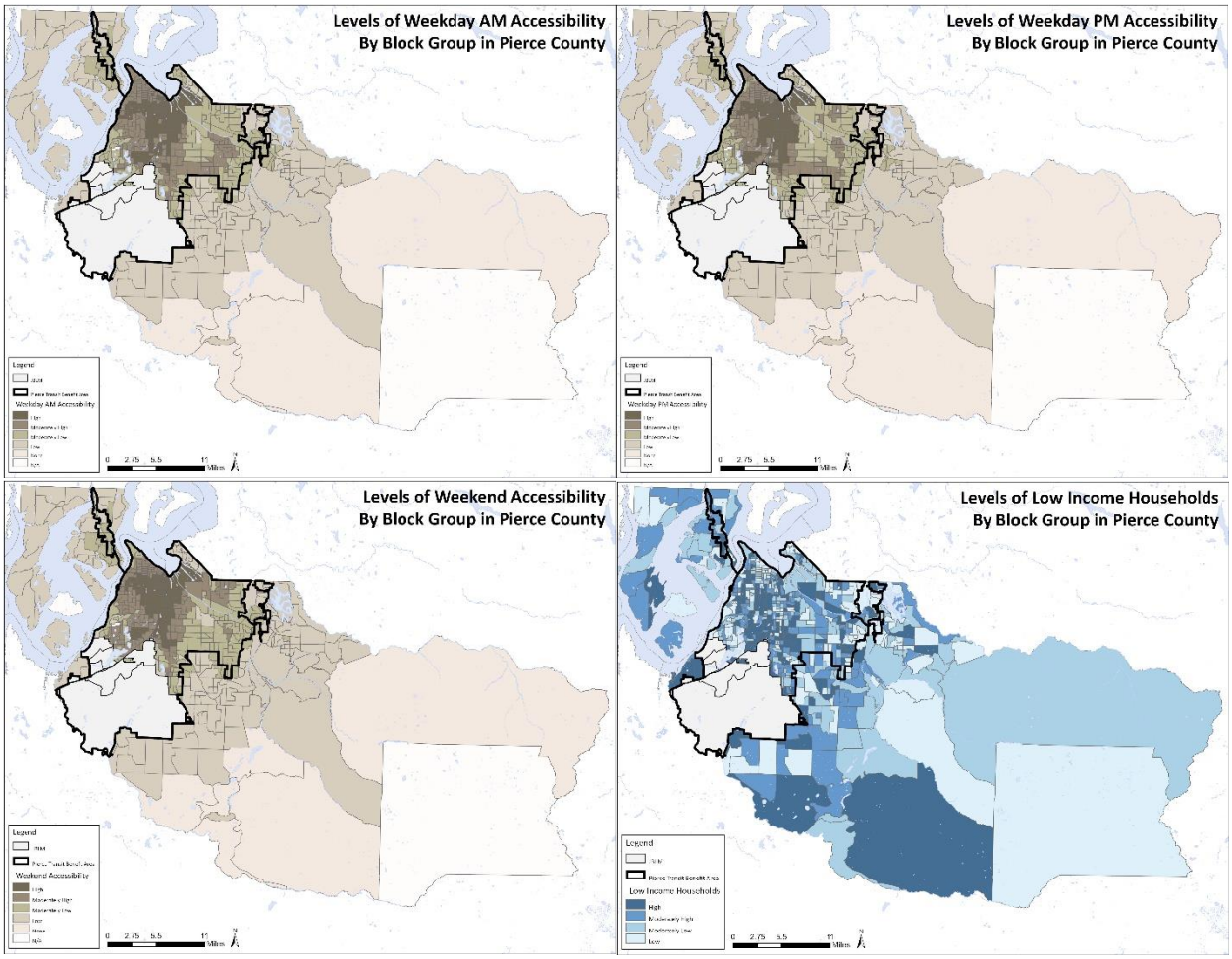

Figure 18: Levels of weekday morning (upper left), weekday evening (upper right), and weekend (lower left) accessibility, alongside levels of low-income households (lower right) in Pierce County.

Levels of income is fairly dispersed throughout the PTBA, with pockets in west, central, and south Tacoma, and Lakewood that show High levels of low-income households. In Gig Harbor, most block groups show High or Moderately High levels of low-income households. Areas with Low levels of low-income households include the north end and northeast Tacoma, Milton, Pacific, Steilacoom, parts of University Place, and parts of Puyallup.

4.6.2 Potential Gap Identification

Figure 20 shows the key geographic areas that will be discussed in regards to the potential gap identification for low-income households. Within the PTBA (Figure 21), the area with the most Very High gaps is in Gig Harbor. There, several block groups show Very High potential gaps, several block groups with High gaps, and one full and one partial block group with Moderate gaps during all travel times.

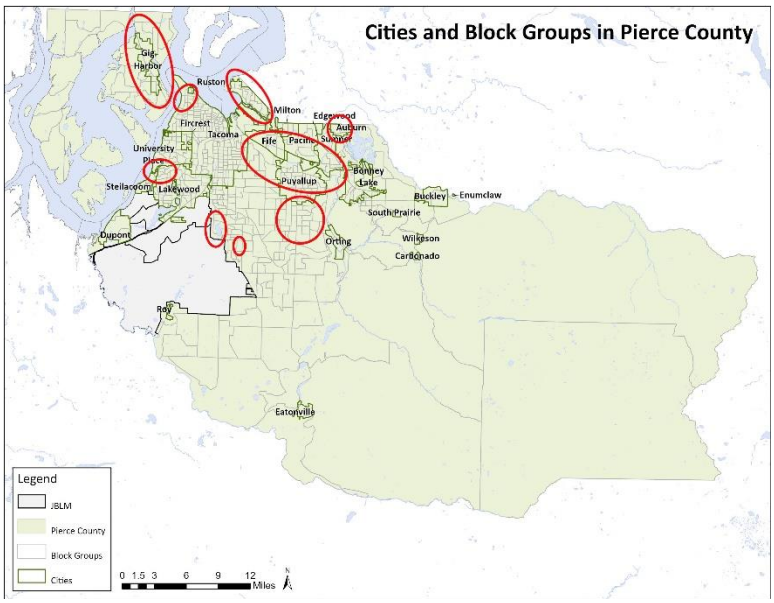

Figure 19: Key geographic areas to be discussed in the low-income household potential gap identification.

During the weekend travel time, two bock groups in northeast Tacoma have Very High potential gaps. Five of the surrounding block groups in that area show High gaps, and three show Moderate gaps. During the weekday travel times, only one block group in northeast Tacoma maintains a Very High gap, while the other block group shifts down to a High gap. One block group that had a High gap during the weekend shows a Moderate gap during the weekday travel times. All the other block groups in northeast Tacoma show the same gaps regardless of travel time.

In the unincorporated area south of Fife and west of Puyallup, one block group has a Very High gap during the weekend travel time. This block group, however, shifts down to a High gap during the weekday travel times. Several other block groups in this area and extending into the western part of Puyallup show High gaps regardless of the travel time. Of these block groups with High gaps, one shifts down to a Moderate gap during the weekday morning travel time. Other block groups with High gaps appear in the Fife, Edgewood, and Milton areas, more so during the weekday travel times than the weekend. In fact, two block groups in Milton show Low gaps during the weekend that are Moderate during the weekday, with two additional block groups having Low gaps during the weekend and weekday evening while having a Moderate gap during the weekday morning.

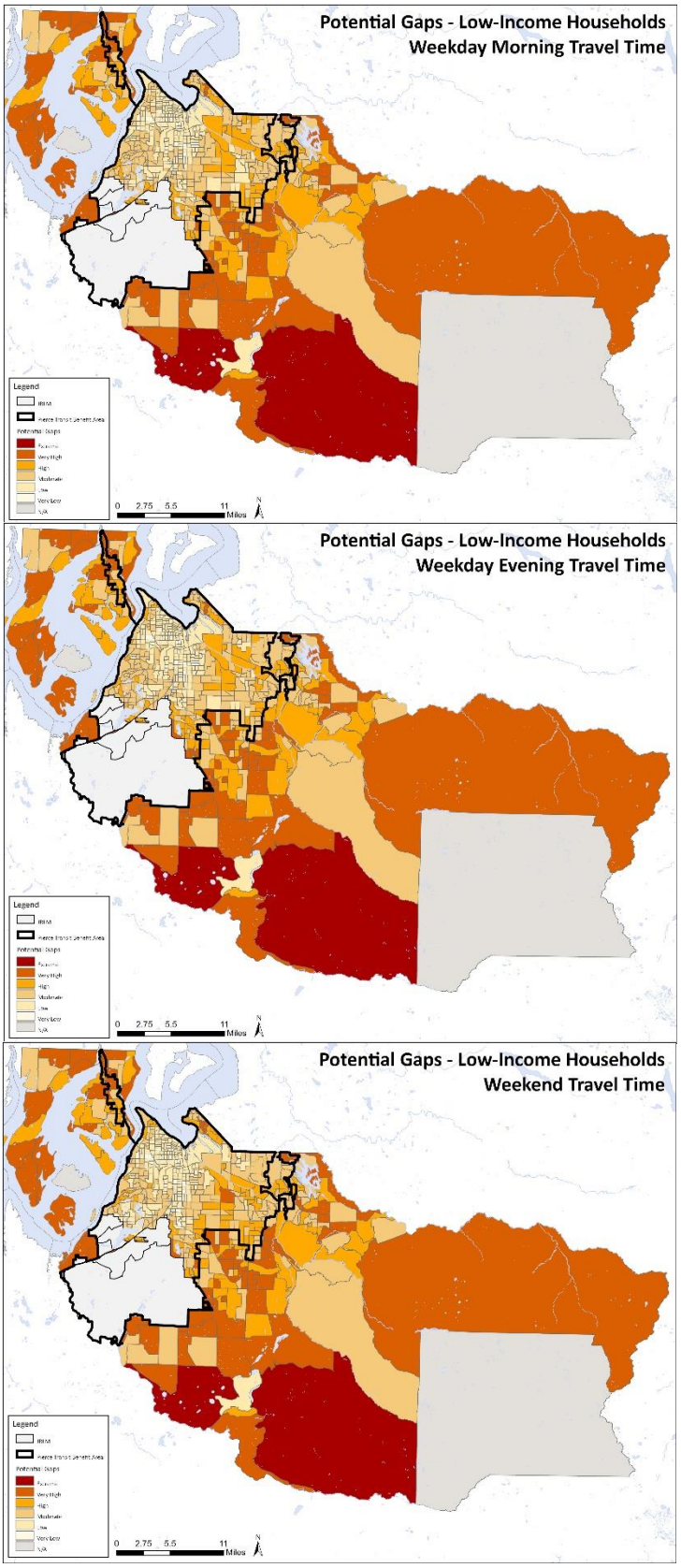

Figure 20: Potential gaps identification results for low-income households for all three travel times.

Within the PTBA, other areas with Very High gaps include Auburn and unincorporated Pierce County east of the northern portion of JBLM. In Auburn, the block groups show Very High gaps during all three travel times. In the unincorporated area, one block group, at the eastern edge of the PTBA, shows a Very High gap during all three travel times. An additional block group, abutting JBLM, shows a Very High gap during the weekend and weekday evening times, and two further block groups show Very High gaps during weekday evenings. During the weekday evening time, several other block groups show High gaps, with some of those becoming Moderate gaps during the weekend and weekday morning times.

Other areas showing High gaps include unincorporated Pierce County south of Puyallup, a couple block groups near Point Defiance, and a few block groups in the Steilacoom, University Place, and Lakewood juncture. South of Puyallup, several block groups have High gaps during the weekend and weekday morning times, with several of those changing to Moderate gaps during the weekday evening. Near Point Defiance, three block groups have High gaps during the weekend, two during the weekday evening, and no block groups have High gaps during the weekday morning. Two block groups have High gaps during the weekday, with one of those block groups keeping the High gap in the weekend but the other changing to Moderate. An additional block group at the Steilacoom, University Place, Lakewood juncture has a High gap during the weekend that was Moderate during the weekdays.

Outside of the PTBA many more Very High gaps are seen as well as two large block groups with Extreme gaps. There is one block group in the south-central part of Pierce County that shows a Low gap, between the two Extreme block groups, a Very High block group, and a High block group. There are also some block groups scattered throughout the area outside of the PTBA that have Moderate potential gaps.

4.7 Low English Proficiency

4.7.1 Accessibility and Population Levels

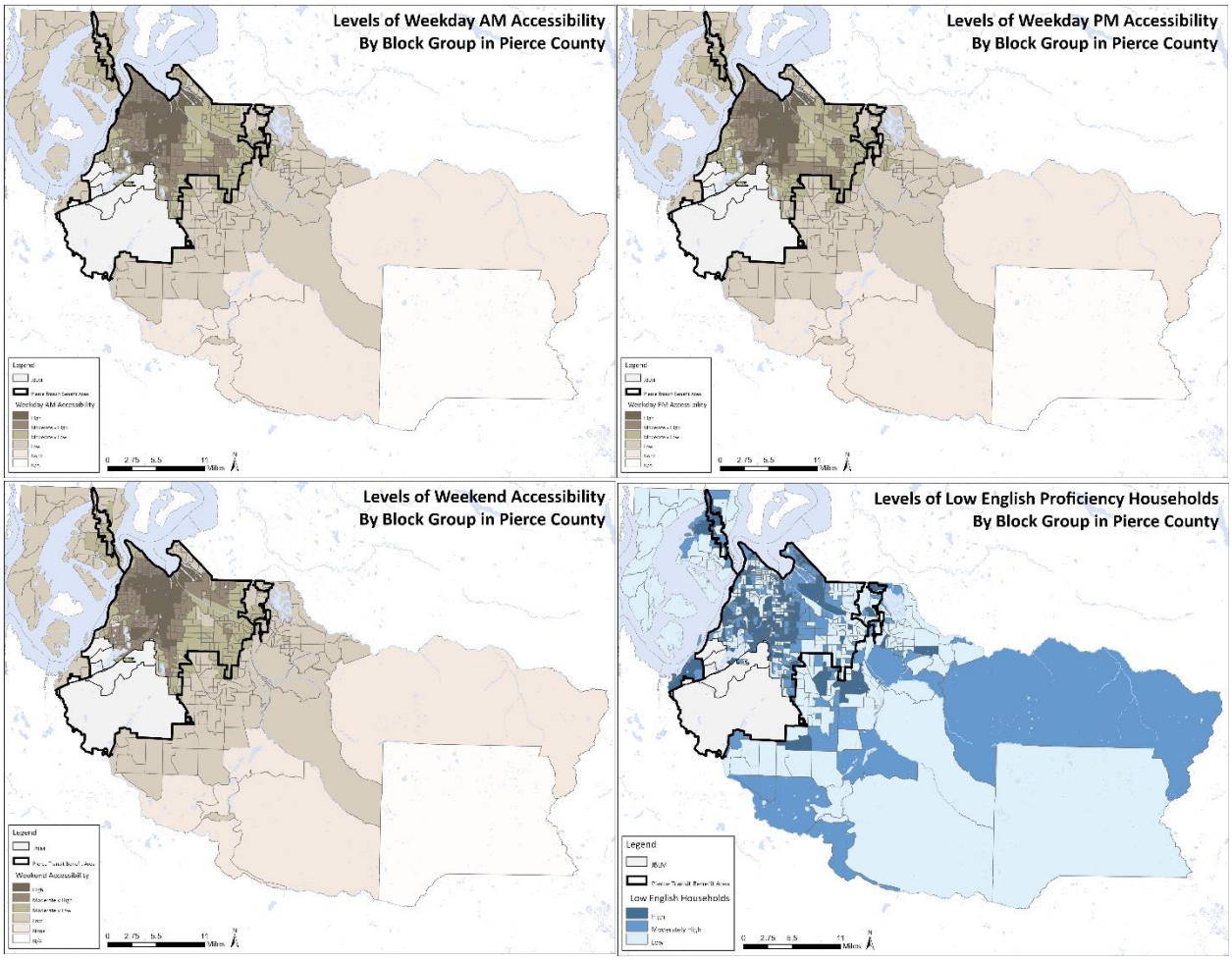

Figure 21: Levels of weekday morning (upper left), weekday evening (upper right), and weekend (lower left) accessibility, alongside levels of low English proficiency households (lower right) in Pierce County.

High levels of households with low English proficiency (see Figure 22) are concentrated in east, south, and northeast Tacoma, extending south of the Tacoma boundary. Much of Lakewood also shows high levels, as well as parts of University Place, much of Fife, and parts of Gig Harbor. The remaining part of Gig Harbor, with the exception of one block group, shows Moderately High levels of households with low English proficiency. Moderately High levels are also seen in the Port of and northeast Tacoma, parts of Milton and Pacific, the unincorporated area south of Fife and west of Puyallup, and scattered throughout Lakewood, Steilacoom, and

University Place. The areas showing Low levels of households with low English proficiency are primarily Fircrest; north, central, and west Tacoma; and parts of Milton, Edgewood, Pacific, Sumner, and Puyallup. Outside the PTBA, Moderately High levels of households with low English proficiency are seen in the large block group just north of Rainier National Park, scattered in the central portion of the county, and along the southern edge of the county. Low levels are seen in the Key Peninsula and throughout the rest of the county outside the PTBA.

4.7.2 Potential Gap Identification

The potential gap identification results for the population with low English proficiency show a few areas within the PTBA with Very High gaps (Figure 24). The key geographic areas that are discussed in this section are shown in Figure 23. Gig Harbor shows several block groups with Very High gaps, several with High potential gaps, and one whole and one partial block group with Moderate gaps. In this area, these gap levels remain constant for all travel times.

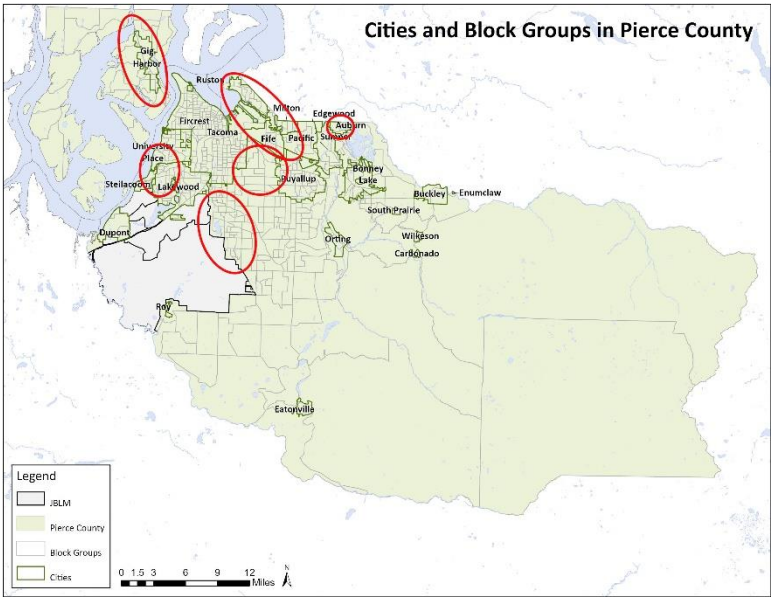

Figure 22: Key geographic areas to be discussed in the low English proficiency household potential gap identification.

Northeast Tacoma also shows many block groups with Very High gaps. During the weekend travel time, all but one block group, which shows a Moderate gap, have Very High gaps. During the weekday evening travel time, three block groups shift from Very High to High gaps, and during the weekday morning travel time, two more block groups shift from Very High to High. Near to northeast Tacoma, the unincorporated Pierce County just east of northeast Tacoma, Fife,

and Milton areas, more High gaps are seen, particularly during the weekday travel times. During the weekend travel time, several of those block groups move from having High to Moderate potential gaps.

In the unincorporated area south of Fife and west of Puyallup, two block groups show Very High gaps during the weekend travel time. Several of the block groups surrounding these two show High gaps. During the evening travel time, one of the block groups shifts from having a Very High to a High gap, and one of the nearby Moderate block groups shifts to having a High gap. During the weekday morning travel time, two of the block groups with High gaps shift to having Moderate gaps, but many of the other gaps stay at the same level as during the evening time.

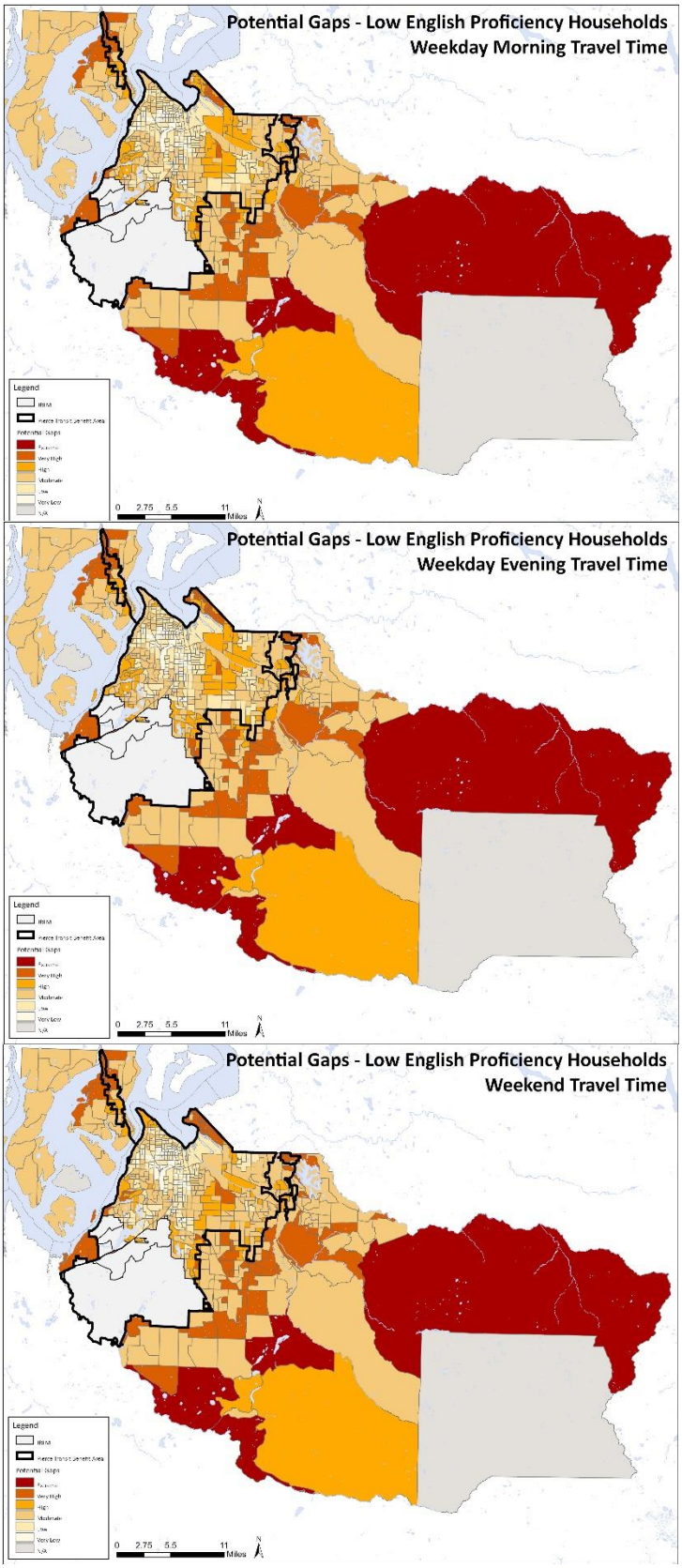

Figure 23: Potential gaps identification results for the low English proficiency population for all three travel times.

The unincorporated area east of JBLM but still in the PTBA shows a few block groups with Very High gaps in the very southeastern part of that area during the weekday evening travel time, as well as many block groups with High gaps. The weekday morning travel time shows one block group with a Very High gap and several with High gaps. There are more Moderate gaps in the weekday morning travel time than during the evening travel time, as well as a few Low gaps. The weekend travel time results are quite similar to the weekday morning travel time, with just one block group showing a Very High gap, some High gaps, some Moderate, and a few Low gaps.

The final two areas within the PTBA that show Very High gaps are the area where Steilacoom, University Place, and Lakewood meet and the Auburn area. One block group that is just partially within the Auburn city limits shows a Moderate gap, but the rest of the block groups in Auburn show Very High gaps for all three travel times. In the Steilacoom, University Place, Lakewood juncture area, two block groups – one along the Steilacoom coast and the other in the northwestern part of Lakewood abutting Steilacoom and University Place – show Very High gaps during the weekend travel time. During the weekend time, several of the block groups next to these have High gaps, and remaining block groups in this area are a mixture of Moderate and Low gaps. During the weekday morning travel time, the block group along the Steilacoom coast also has a Very High gap. The other block group that was Very High during the weekend has a High gap during the weekday morning. There are several other block groups that show High gaps during the weekday morning time, and the rest are Moderate and Low. During the weekday evening travel time, there are no Very High gaps in this area, but a mixture of High, Moderate, and Low gaps.

Outside of the PTBA, there are a few Extreme gaps, some Very High gaps, and a quite a few Moderate gaps. The Extreme gaps are seen in the south-central part of Pierce County as well as the large block group north of the Mount Rainier National Park. The block group just west of

the national park shows a High gap. All of the block groups in DuPont show Very High gaps and several block groups in the northern and western area near Gig Harbor have Very High gaps for all three travel times. Interestingly, the Key Peninsula has only Moderate gaps for all the travel times.

4.8 No Car Availability

4.8.1 Accessibility and Population Levels

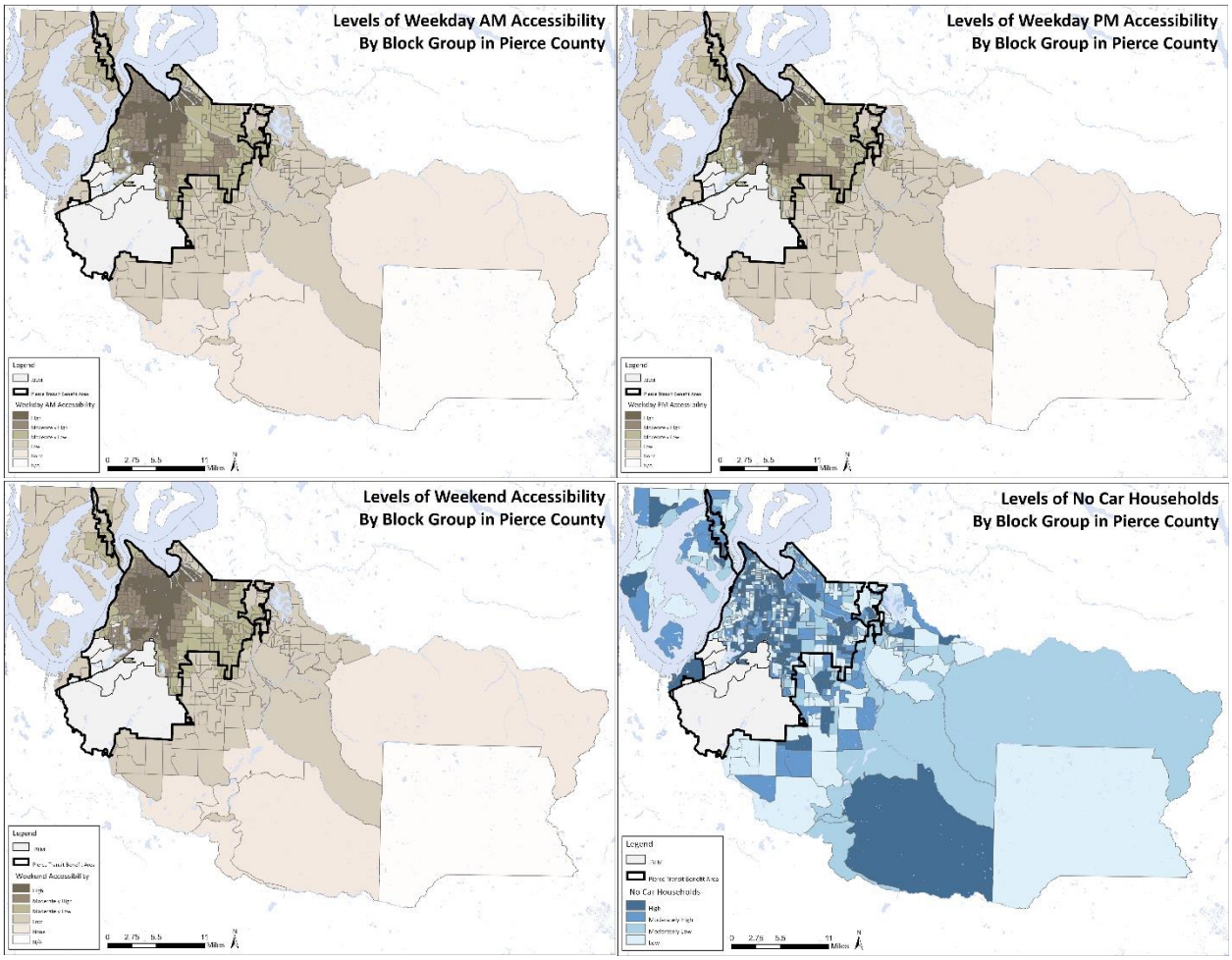

Figure 24: Levels of weekday morning (upper left), weekday evening (upper right), and weekend (lower left) accessibility, alongside levels of no-car households (lower right) in Pierce County.

Levels of households without a personal vehicle are scattered throughout the PTBA. The most noticeable pockets of High levels are areas in west, central, and downtown Tacoma; south Lakewood; Fife; south Gig Harbor; and parts of Puyallup. Much of the rest of Gig Harbor shows Moderately High levels of households without a personal car, as wells as the Port of Tacoma, and

parts of Fife, Pacific, Puyallup, and Lakewood. Areas with Low levels of no-car households include parts of north and east Tacoma, Steilacoom, University Place, Pacific, Edgewood, Auburn, and unincorporated Pierce County south of Puyallup. Outside the PTBA, most areas show Moderately Low or Low levels of households without a car. Notably, the large block group west of Rainier National Park show a High level, and some High and Moderately High block groups are scattered about in the central portion of the county. Some High and Moderately High levels are also seen in some block groups in the Key Peninsula.

4.8.2 Potential Gap Identification

The potential gap identification results for the population without access to a car show several areas within the PTBA with Very High or High gaps (Figure 27). Key geographic areas to be discussed in this section are circled in Figure 26. Gig Harbor has a few block groups with Very High gaps and a few with High gaps for all three travel times. Three block groups with Very High gaps can also be found in northeast Tacoma during the weekend travel time. During this time, the remaining block groups in northeast Tacoma show High gaps. During the weekday evening travel time, one of the block groups moves from having a Very High to a High gap, and two block groups move from having High to Moderate gaps. In the weekday morning time, three more block groups shift from having High to Moderate gaps in northeast Tacoma.

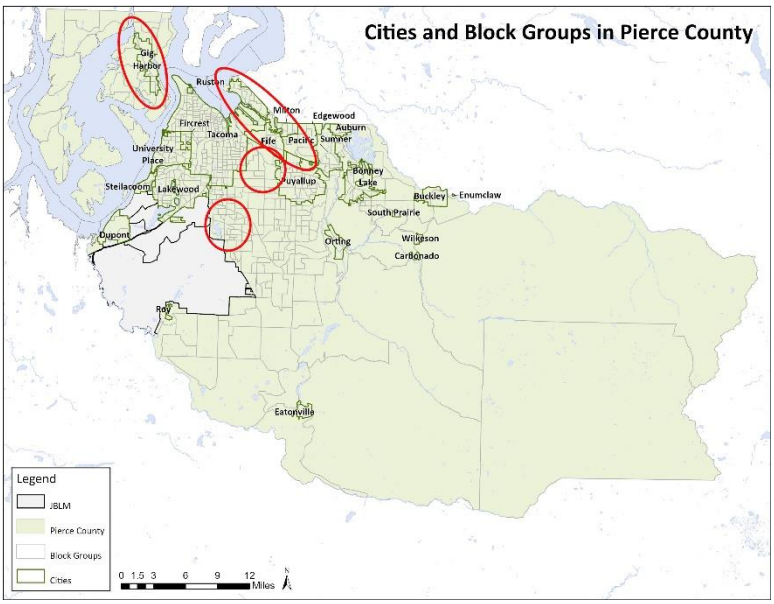

Figure 25: Key geographic areas to be discussed in the no-car household potential gap identification.

Many of the block groups in the unincorporated area between Tacoma and Milton, and some of the block groups in Fife and Milton show High potential gaps during the weekday morning travel time. The remaining block groups in this area show Moderate gaps during the morning. During the weekday evening travel time, one of those block groups shifts from a High to a Moderate gap, and three block groups shift from Moderate to Low gaps. During the weekend travel time, only a few block groups in this area remain with High gaps and a couple more block groups shift to Low gaps.

In the unincorporated area south of Fife and west of Puyallup, one block group has a Very High gap for all three travel times. During the weekend travel time, several of the block groups in this area show High gaps, with some of

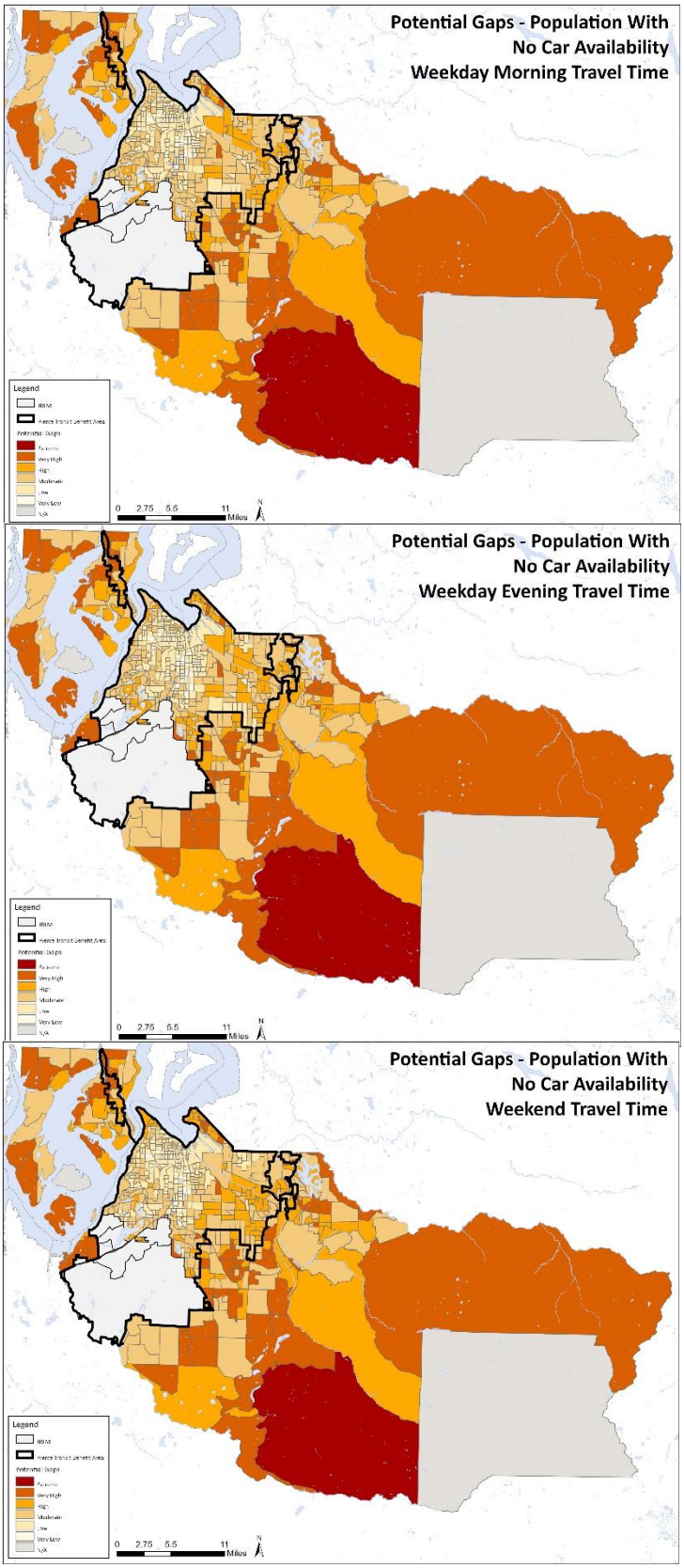

Figure 26: Potential gaps identification results for the population with no car availability for all three travel times.

those block groups shifting to Moderate gaps during the weekday times. Some block groups in Puyallup also have High potential gaps during all three travel times, although more block group do during the weekend. The unincorporated area east of JBLM shows one block group during the weekend travel time with a Very High gap, and a few with High gaps. During the weekday evening travel time, two additional block groups show Very High gaps and a few more block groups show High gaps. During the weekday morning travel time, none of the block groups in this area have Very High gaps and only a few have High Gaps. Most of the block groups have Moderate gaps, with a couple Low Gaps.

Outside the PTBA, more Very High and High gap block groups are seen, as well as one with an Extreme gap. The Extreme gap is found in the block group west of the Mount Rainier National Park and along the southern boundary of Pierce County. The large block group north of the national park has a Very High gap and the other block group west of the park has a High Gap. The block groups surrounding the Extreme gap have either Very High or High gaps, and several other block groups scattered throughout the County have Very High gaps as well. In the peninsula portion of the County, there are several block groups with Very High gaps, several with High gaps, and several with Moderate gaps. These results are consistent regardless of the travel time.

5. Discussion

5.1 The Gig Harbor Area

The potential gap identification for many of the key population groups showed Moderate to Very High gaps for all travel times in the Gig Harbor area within the PTBA. These results are not particularly surprising. While Gig Harbor is included in the PTBA, service in, to, and from Gig Harbor is limited and infrequent. Currently, only Pierce Transit Route 100 and Sound Transit Route 595 serve that area (Figure 28). Prior to the COVID-19 pandemic, Pierce Transit Route 102 also served the Gig Harbor area during peak commute hours, but that route's service has been discontinued during the pandemic. Additionally, Sound Transit Route 595 is an express commuter line, and therefore its service is limited to peak commute hours, with service only on weekdays between 5:00am to 8:21am and between 3:02pm and 7:05pm. Furthermore, since this route is an express bus, its stops within Pierce County are limited to three park and rides in Gig Harbor, Tacoma Community College, and the Tacoma Dome Station. Pierce Transit Route 100 connects Gig Harbor with the

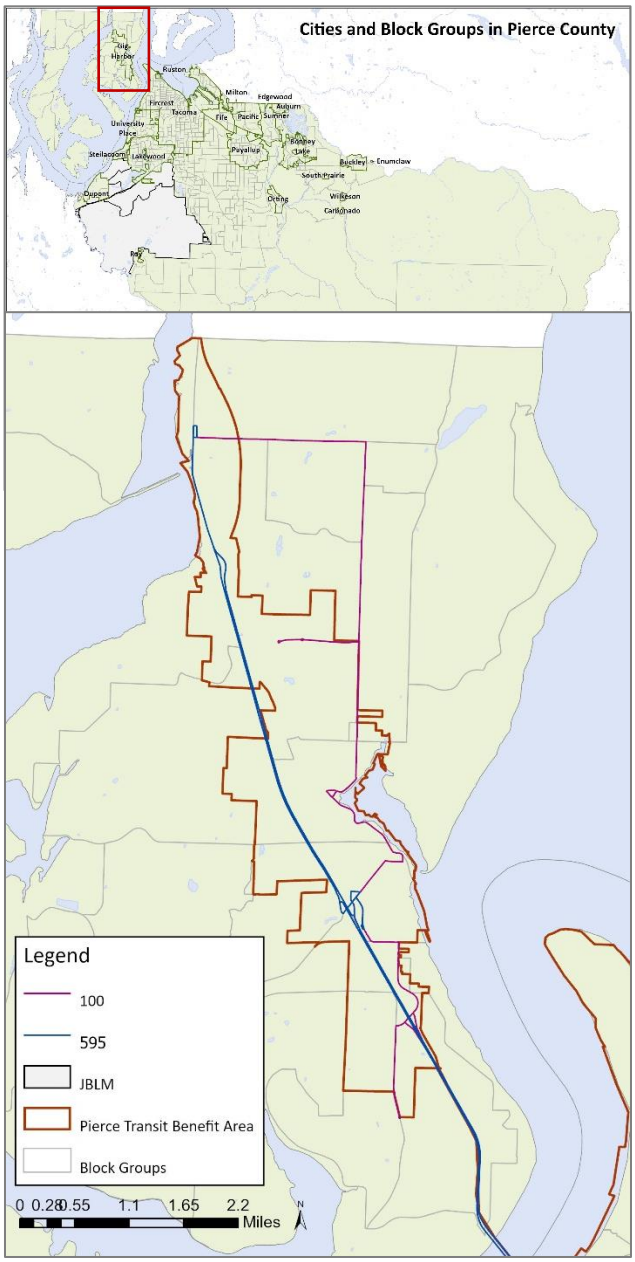

Figure 27: Gig Harbor transit routes.

non-peninsula portion of Pierce County by crossing the Tacoma Narrows Bridge. However, this route has a frequency of only once an hour, and its service runs only from 6:45am to 8:34pm on weekdays, and from 9:45am to 6:37pm on Saturdays. Sundays offer the same hours of service as Saturdays, but with less frequency. Considering that the 595 and 100 are the only transit lines that connect the peninsula portion of Pierce County to the non-peninsula portion, this very much limits the accessibility of those living across the Tacoma Narrows.

It should also be noted that Gig Harbor is on the northwestern portion of Pierce County and borders Kitsap County. Because this study only includes jobs, community assets, and transit routes inside Pierce County, there is the possibility of a boundary effect, with additional destinations that are accessible to Gig Harbor resident outside of Pierce County and Pierce Transit. Kitsap Transit, however, only offers one transit routes that connects with Pierce County at the Purdy Park and Ride at the very northern edge of the PTBA. This route is only offered for weekday service and has low frequency of once an hour and only between 6:05am to 8:35am and 3:05pm to 5:40pm. Furthermore, the population and community amenity center within Kitsap County closest to Pierce County is Port Orchard, which is approximately 11 miles north of the Purdy Park and Ride, making it out of walking distance. Due to the limited service provided through Kitsap Transit and the distance between Pierce County and the nearest population center in Kitsap County, the analysis of the Gig Harbor area remains of importance to Pierce Transit.

5.2 Unincorporated Pierce County

5.2.1 South of Fife and West of Puyallup

Unincorporated Pierce County south of Fife and west of Puyallup, extending down to the boundary of the PTBA also consistently showed potential gaps of High and Very High. In this area, five Pierce Transit routes run: the 4, 400, 409, 500, and 501 (Figure 29). Route 4 runs between Lakewood to the South Hill area of Puyallup. On weekdays, it has a frequency of once every 30 minutes, and runs from 5:45am to 8:50pm. On weekends, its frequency decreases to once every hour, and on Saturday its service is from 7:45am to 10:25pm and on Sunday its service is limited to 8:05am to 7:53pm. Route 400 runs between downtown Tacoma to South Hill. On weekdays it runs from 4:44am to 8:54pm with frequency every 30 minutes during peak commute hours and every 60 minutes during off-peak hours. Route 400 currently does not run on weekends. Route 409 runs from east to west in Puyallup. On weekdays, it provides service between 9:20am and 6:16pm, with frequency at once an hour.

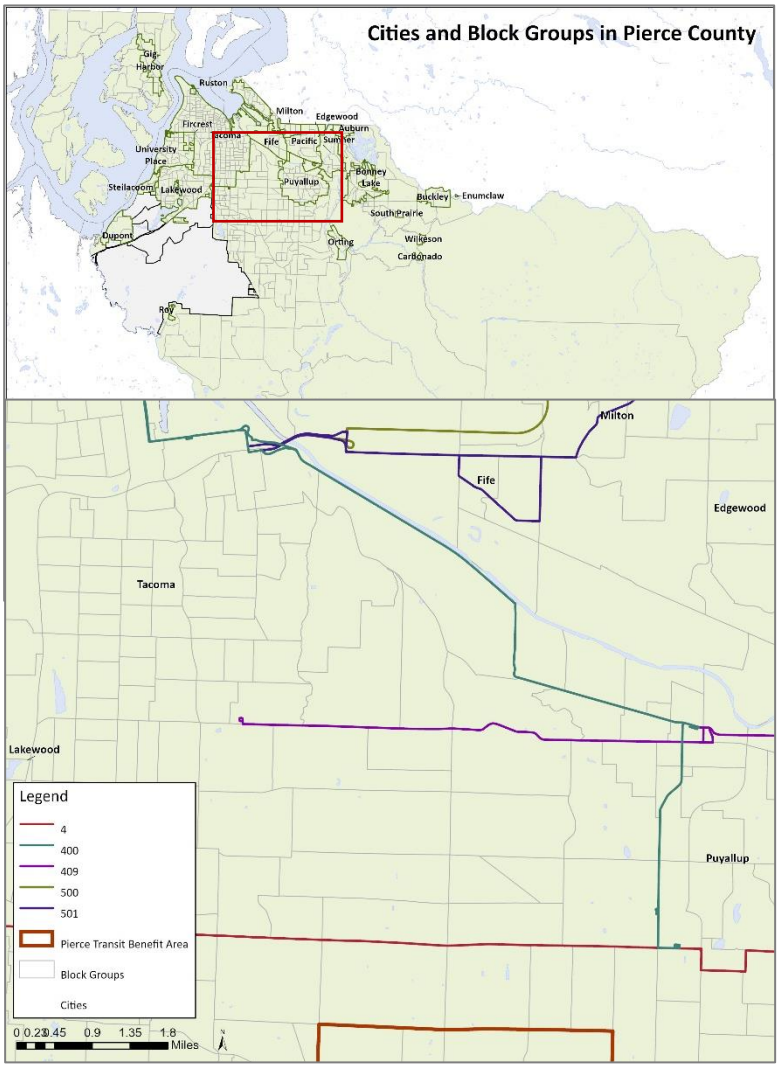

Figure 28: Transit routes in unincorporated Pierce County south of Fife and west of Puyallup.

Its frequency is also once an hour on weekends, with service between 9:07am and 6:25pm on Saturdays and between 9:05am and 6:05pm on Sundays. Route 500 runs between downtown Tacoma and Federal Way, going through Fife, extending outside of Pierce County. On weekdays, it provides service between 5:10am and 11:25pm, with 30 minute frequency during peak hours and 60 minute frequency during off-peak. On weekends, service runs between 6:55am and 10:35pm with frequency every 30 minutes between 9:55am and 5:55pm. Route 501 runs between Milton and Federal Way, also passing through Fife. On weekdays, it runs between 5:25am and 8:21pm with once an hour frequency. Frequency on the weekend is also once an hour, with service provided between 8:10am and 7:55pm on Saturdays, and between 9:10am and 6:10pm on Sundays.

Considering that route 400 is the only route that connects Puyallup with Tacoma without any transfers, the fact that it does not run on the weekends is likely a contributing factor for lack of accessibility during the weekend. This is likely particularly true when it comes to access to jobs since Tacoma is the largest city in the county, with over 150,000 more residents. Additionally, route 409 is the only transit route that provides any service between Fife and the what is nearly the southern edge of the PTBA. This route only comes once and hour and has limited service hours, providing limited service to that area.

5.2.2 East of JBLM

A second part of unincorporated Pierce County that showed consistent High and Very High gaps are the block groups between the eastern boundary of JBLM and the PTBA boundary. Through this area, only three Pierce Transit routes run: the 1, 4, and 55 (Figure 30). Route 1 is Pierce Transit's highest ridership route and also provides the most frequent service. It runs from Tacoma Community College to downtown Tacoma and then down Pacific Avenue finishing in unincorporated Pierce County just north of the east central boundary of JBLM. On weekdays, it provides service between 4:05am to 11:40pm with frequency every 15 minutes starting at 5:05am and staying at that frequency until 6:15pm. Outside those hours, frequency on weekdays is once every 30 minutes in the early morning hours and once an hour in the late even hours. On Saturdays, the route provides service from 5:55am to 11:51pm (depending on the location and direction of the route) and frequency is once every 30 minutes for most of the day, with once every 60 minutes late in the evening. Sunday service runs from 6:30am to 9:50pm, with frequency once every 30 minutes. Route 4, which was discussed in the previous

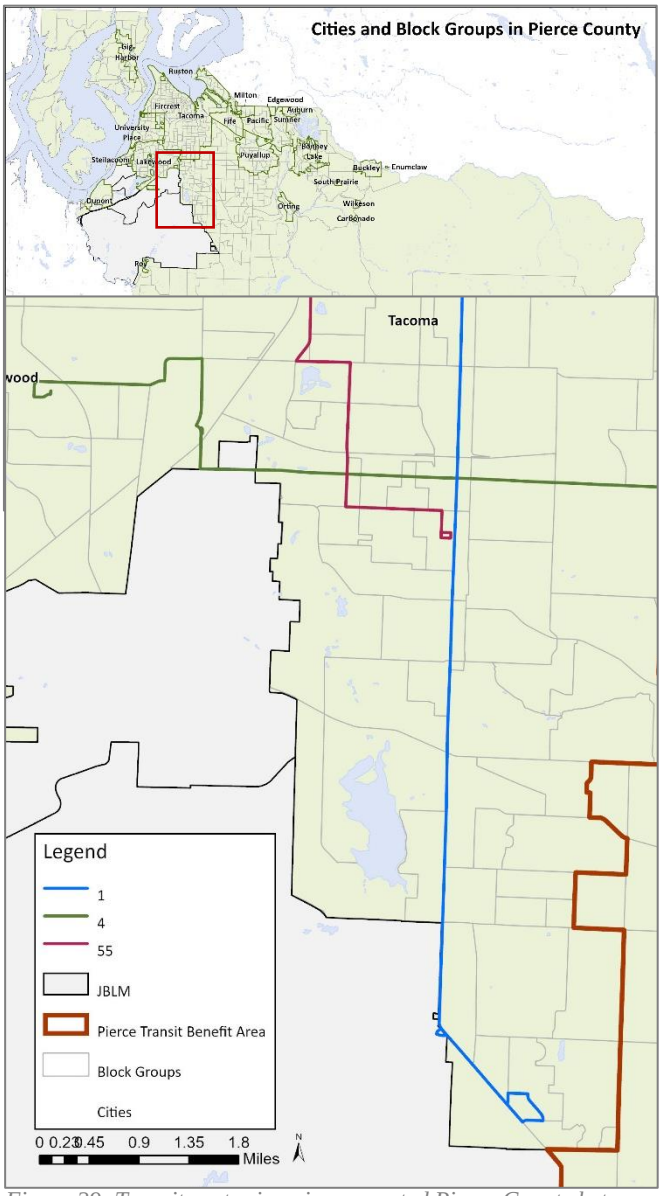

Figure 29: Transit routes in unincorporated Pierce County between JBLM and the PTBA boundary.

subsection, runs between Lakewood and Puyallup. Route 55 runs between Parkland, which is inside this unincorporated area, to the Tacoma Mall. On weekdays, it runs from 5:52am to 10:22pm with frequency once every 30 minutes for most of the day until 6:52pm when it changes to once every 60 minutes. Saturday service runs from 8:10am until 8:10pm with 30-minute frequency between 9:45am and 6:40pm. Outside those hours, frequency is once an hour. Sunday service runs from 9:25am to 7:55pm with once an hour frequency.

For the most part, route 1 is really the only transit route that runs through this area of unincorporated Pierce County; rotes 4 and 55 run east-west only at the very northern part of this area. While route 1 is the most frequent route with the longest service hours, service is quite limited with only one route running north-south. This provides a reasonable explanation for the wide gaps between accessibility and potential need in this area.

5.3 Steilacoom / University Place / Lakewood Juncture

The area where Steilacoom, University Place, and Lakewood city limits meet is another area of concern for many of the key populations. Only two Pierce Transit routes serve this area: routes 212 and 214 (Figure 31). Route 212 runs between downtown Steilacoom and the Lakewood Transit Center. On weekdays, it runs between 5:30am and 10:02pm with a frequency of every 30 minutes between 7:30am and 5:50pm and once every hour outside those times. Frequency on weekends is once every hour, with service on Saturdays running from 9:20am to 8:37pm, and Sunday service running from 9:40am to 6:27pm. Roughly half of route 212's trips, however, do not serve downtown Steilacoom, but start or stop at Pierce College in Steilacoom, except for Sundays. Route 214 runs between Pierce College – Steilacoom and the Lakewood Transit Center. On weekdays, it runs from 5:16am to 10:32pm, with frequency once every 30 minutes until 5:45pm when it changes to once an hour. Weekend frequency is once an hour, with Saturday service

running from 8:20am to 8:37pm and Sunday service running from 9:20am to 6:37pm.

With only two transit routes in this area and the northern part of this area without any transit service at all, accessibility is limited. Additionally, frequency in the downtown Steilacoom area is even more limited because route 212 does not serve that area on all of its runs. It is also worth noting that route 214 extends into JBLM, although JBLM is not considered in this study.

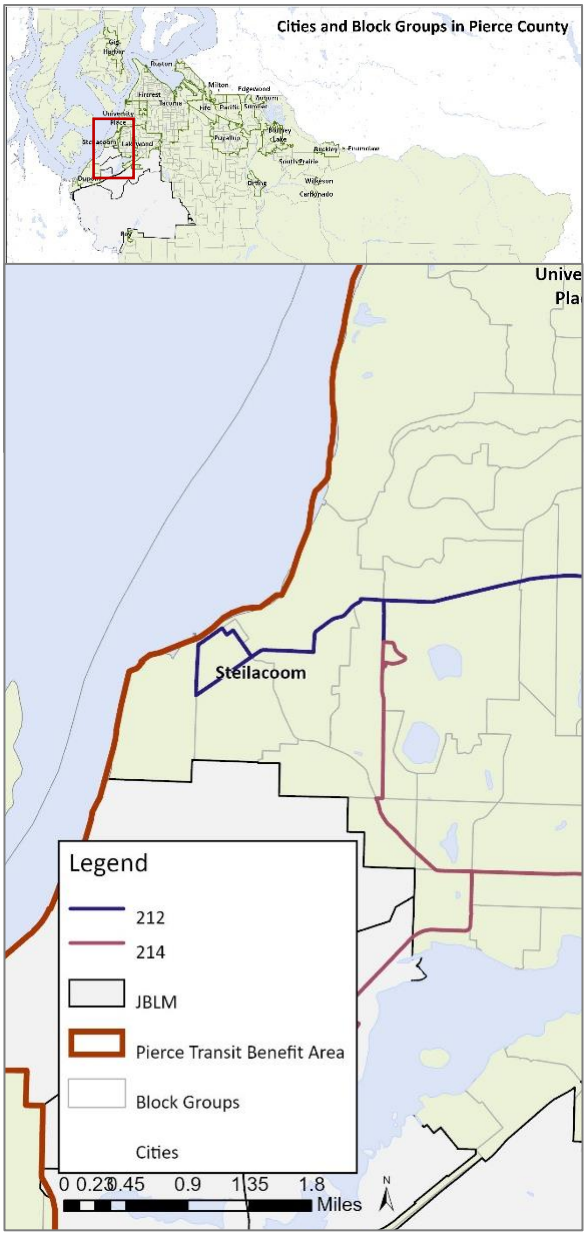

Figure 30: Transit routes in the Steilacoom / University Place / Lakewood juncture area.

5.4 Auburn

For many of the key population groups, the block groups within the Auburn city limits showed Very High or High gaps. However, this assessment may not be wholly accurate since the Auburn city limits lie within both Pierce and King Counties, with the majority being in King County. This study did not take into account any King County Metro transit lines, nor did it take into considerations jobs or community assets located outside of Pierce County. These limitations, discussed further in subsequent sections, could result in skewed accessibility measures and therefore inaccurate potential gaps results. Therefore, this study will not further assess this area or make recommendations regarding Auburn.

5.5 Areas Outside the PTBA

For all key populations groups and all travel times, the areas in Pierce County that are outside of the PTBA show higher levels of potential gaps. This is to be expected since transit does not serve these areas, and therefore accessibility will be quite low. Therefore, differences in the potential gaps in the areas outside the PTBA should be attributed to the levels of each key population group in that area.

5.6 Recommendations

5.6.1 Community Engagement

For all areas that are of potential concern, either inside or outside the PTBA, because the potential needs measure in this study does not calculate an empirical need for transit, if Pierce Transit were to consider adjusting funding or service to these areas, engaging with those who live in those areas is recommended. Aside from answers that an empirical study of transit need, community engagement can help transit agencies assess the need and demand of those living in areas of concern, as well as provide agencies with an opportunity to present potential solutions to the community. This could be particularly relevant if considering alternative solutions to traditional, fixed-route service, which is often what most community members think of when considering transit options. Engaging with the community, either through surveys, community meetings, or through other methods, could prove to be very useful in gauging interest in alternative solutions, the need for transit, and the opportunity for increasing ridership through various solutions.

5.6.2 Inside the PTBA

For the areas of concern inside the PTBA, it is recommended that Pierce Transit considers both the availability of routes and route frequencies. In Gig Harbor, only two transit routes in total

connect Gig Harbor with the non-peninsula part of the county and one of those routes only runs during peak commute hours. Because of the limited availability of routes, riders will often need to transfer buses. Therefore, an increase in frequency would likely assist with raising the levels of accessibility experienced by riders in Gig Harbor.

Lack of transit routes results in large areas of unincorporated Pierce County having low or moderately low levels of accessibility. This was seen particularly in the area south of Fife and west of Puyallup and the area east of JBLM but still within the PTBA. In both these areas there were very limited transit service and low frequencies, with the exception of route 1 near JBLM. Increasing service in could help to alleviate the gaps in these areas.

The final area within the PTBA that is of concern for many of the key population groups is the area where Steilacoom, University Place, and Lakewood meet. Here, again, we see both lack of transit routes and low frequency. In particular, the northern portion of this area, closer to University Place, shows no transit route at all. Increase in service, both with additional routes and increased frequency, would help to alleviate these gaps.

It is acknowledged, however, that due to budget and personnel constraints, increasing service of fixed routes may not be feasible in all areas. Future studies assessing the true transit need and demand in the main areas of concern, as described in previous sections, is recommended to best assess where funding and services may best be allocated. It is also acknowledged that other considerations aside from equity, such as efficiency and sustainability, are factors that must be taken into account when making service decisions.

Solutions alternative to increased fixed-route solution may include multi-mobile solutions, which could involve partnerships with private companies. Pierce Transit has already shown an example of such a partnership. From 2018 to 2019, Pierce Transit partnered with Lyft, a

transportation network company (TNC), in a pilot project to solve first-last mile solutions in particular identified areas of Pierce Transit's service area. Such a program, but in a more permanent capacity, could prove to be a potential solution. Pierce Transit is also currently offering the Pierce Transit Runner, which provides on-demand service between the Ruston Way corrido and downtown Tacoma and the Tacoma Dome. While this service is another example of an alternative to traditional fixed-route service to provide first-last mile solutions within the PTBA, the Ruston Way corridor is not one of the geographic areas that of potential concern found in this study. However, the current rendition of this program can provide valuable data and lessons learned to be utilized in future implementations of such a program.

In addition to partnering with TNCs or other microtransit solutions, looking to increased micromobility may prove successful in connecting people with existing transit routes. In the past, Tacoma has had shared scooters available for use. Shared scooters have recently returned to Tacoma, and data from such micromobility programs could be insightful into how they can be used to connect people with transit. Shared bike programs could be used in a similar way. For some areas in the PTBA, however, this may not be wholly feasible. If utilizing micromobility to connect riders with transit, the pedestrian and bicycle infrastructure must be considered when predicting the success of such programs. While some cyclists may be comfortable riding on streets, this is the case for many. Additionally, some of the key population groups, who are using transit for not only work commutes but also to run errands, may not be ablet to use scooters or bikes to accomplish all of their needs, especially if considering trip chaining or trying to carry multiple items, such as grocery bags, during their trip. These considerations are all quite nuanced, and this is where community engagement can provide useful insights in determining the needs of a community and the potential success of possible solutions.

5.6.3 Outside the PTBA

There are many areas outside the PTBA that shows Very High, High, or even Extreme gaps. As mentioned previously, however, this is to be expected since there is no transit service in these areas. Furthermore, remedying these gaps is difficult as it could require changing the boundaries of the PTBA. As discussed in the Introduction, changing the PTBA is a complicated and difficult process, and is not something to be recommended lightly or can be done easily. Additionally, per the Washington Revised Code, the PTBA may not have areas that are detached from the rest of the PTBA and if a city is to be included, the entire city area must be included into the PTBA. Nonetheless, Pierce Transit could consider including Bonney Lake, Orting, Sumner, and/or the unincorporated area northeast of JBLM into the PTBA. These areas show higher population densities in comparison with other areas outside the PTBA and comparable to many areas within the PTBA (see Figure 32). However, these areas, while they may benefit from inclusion in the PTBA, used to be inside the PTBA and withdrew from the service area in 2012. Because nearly 10 years has passed since this decision, it may be beneficial to conduct community engagement to determine if the residents of these areas would desire or benefit from rejoining the Pierce Transit service area.

Similarly, Eatonville could be considered for inclusion into the PTBA. For the populations that Extreme gaps were found – the elderly, youth, low English proficiency, low-income households, and no car availability – these gaps were in the block groups around Eatonville, with the exception of the Extreme gap north of the Mount Rainier National Park for the population with low English proficiency. Therefore, including Eatonville into the PTBA and providing some sort of transit service in that area would greatly help alleviate those Extreme gaps. This would have to be considered carefully, however, so as to follow the prescriptions found in RCW 56.57A.

5.6.4 Low Density Areas

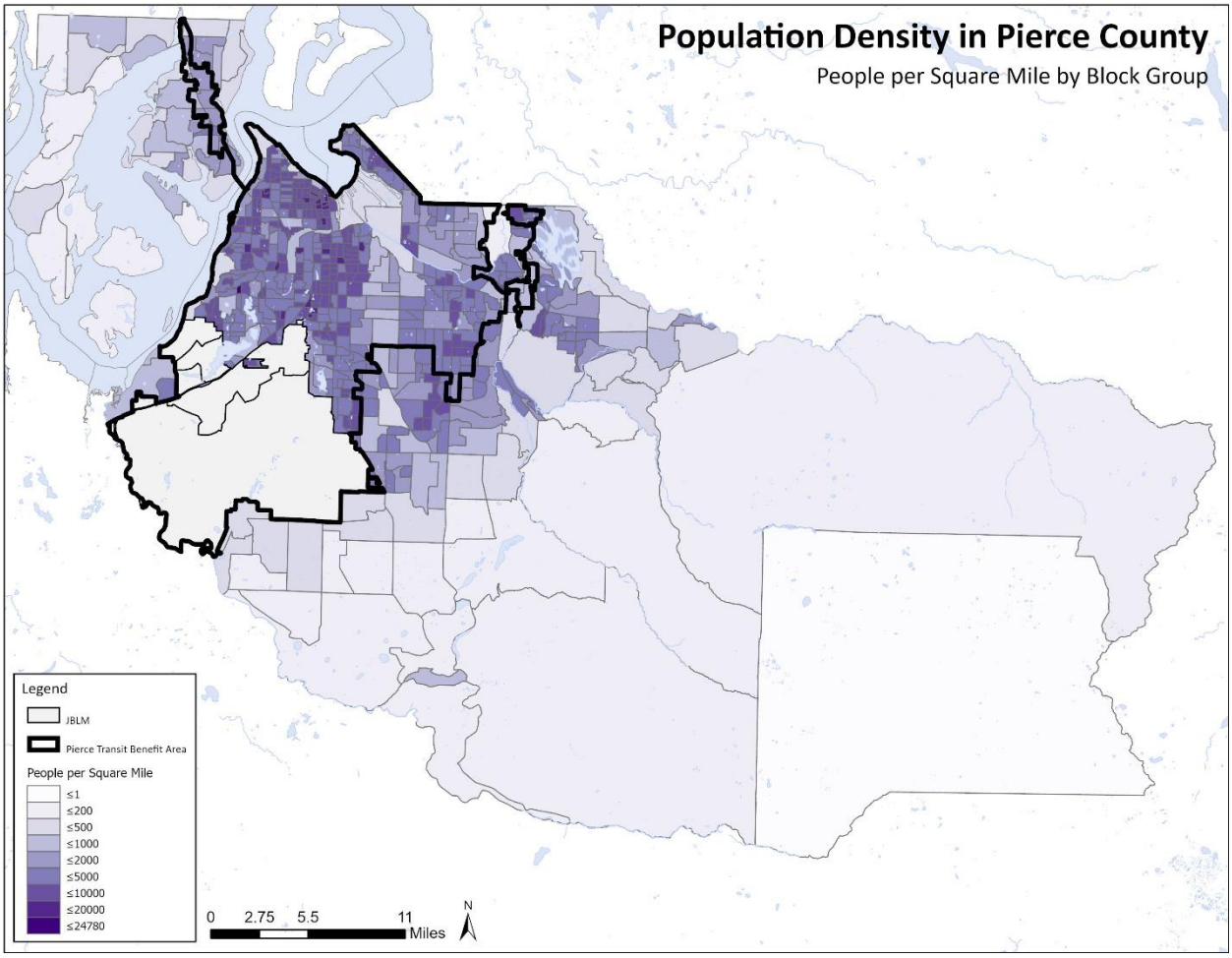

Figure 31: Population density of Pierce County.

Both inside the PTBA and outside the PTBA, much of Pierce County has low population density, making any increases in the number of transit routes or frequency difficult from a financial standpoint. Because of this, leaving the key population groups disaggregated is advantageous. Pierce Transit can determine which of the key population groups it wants to focus on and cater any service improvements to the areas of greatest concern for those groups. For example, because Pierce Transit offers a paratransit shuttle service as well as services offered by nursing home facilities, the elderly may not be the highest priority for Pierce Transit, and therefore the areas of greatest concern for the elderly population may not be the highest priority for the transit agency.

Additionally, alternatives to fixed routes could be explored as methods of increasing service at lower cost to the agency. For population centers that are separated from other population centers with mostly rural land between, such as the proposed addition of Eatonville to the PTBA, demand responsive transit, such as dial-a-ride shuttles, or express routes could offer alternate solutions. Demand responsive transit could provide lower-cost transit options for low-density areas where Pierce Transit may not want empty buses running on fixed routes and schedules. Or, creating express routes with few stops between population centers, with smaller, demand responsive feeder buses or shuttles connecting small neighborhoods or rural housing to the main express line could help provide accessibility to those in low-density areas who are still at risk for transportation related social exclusion.

6. Limitations

This analysis has several important limitations to consider. First, the reliability and completeness of the data must be considered. Some of the data was obtained from reliable, official sources, such as Pierce County, Pierce Transit, Sound Transit, and the US Census Bureau. Other data, however, was either not available through these sources or incomplete. For example, locations of such community assets as grocery stores, places of worship, and private health care facilities, were not available and therefore had to be researched and collected by hand via Google Maps and the online Yellow Pages. It was unclear how frequently these sources update their data and what classification systems they use to identify when a location is of a particular type. For example, on both Google Maps and the Yellow Pages, convenience stores were frequently listed as grocery stores even though they provided no fresh produce and little other foods that were not pre-prepared. Visual inspection of these locations through pictures of the insides of the stores had to be utilized to determine if a location was indeed a grocery store.

An example of a dataset that was incomplete was the parcel dataset provided by Pierce County. While there was a field listing the number of residential units on each parcel, this was incomplete and many apartment complexes did not list any residential units. To estimate the number of units on a parcel, visual inspection of the parcel via Google Maps street view and ariel imaging was used. However, at times these images were up to three years old and some parcels were shown as in the midst of construction. Furthermore, since the parcels could only be seen from an ariel or street view, the number of units on the parcel was truly an estimate and not precise.

Another limitation of this study was that during the travel shed analysis, walking time was not limited. Ideally, the time spent walking either to or from a bus stop would be limited to 10 minutes, as studies have shown that ridership decreases the farther away a bus stop is from the origin point. However, ArcGIS Pro currently does not have the capability to limit the time or distance of one travel mode in a multimodal service area analysis.

This study also did not include jobs or community assets outside of Pierce County. This is a limitation in that some routes, particularly Sound Transit express routes, begin in Pierce County but extend outside of the County and the Puget Sound region as a whole is an interconnected, regional economy. Within a 60-minute travel shed, residents of Pierce County could likely reach jobs or community assets in such locations as Federal Way and Auburn, which are in King County. This limitation could have resulted in lower accessibility levels for some areas, particularly in the Puyallup, North Puyallup, and Fife areas, which are closer to King County.

As mentioned in previous sections, this study also did not consider those with disabilities as a key population group. While those with disabilities are indeed in danger of transportation disadvantage, Pierce Transit has a shuttle program that is separate from their fixed routes. This study only analyzed fixed routes, and therefore did not include those with disabilities. Future

studies may look at this separately, but that would likely include different variables to assess the equity of the shuttle program.

Finally, this study did not include monetary costs of riding transit nor the accessibility of stops. While some sidewalks data was available on the Pierce County Open GIS Portal, it was quite incomplete, and therefore sidewalks were not included in the travel shed analysis. Data regarding crosswalks and curb cuts were also not available and therefore not included. The monetary costs of riding transit, while quite important for equity, was also not included. Because Pierce and Sound Transit do not offer transfers for those paying in cash, the equity implications of the fare systems is quite important, but is outside the scope of this study. This could be the subject of future analysis.

7. Conclusion

With key population groups at risk for transportation related social exclusion, it is important to understand where, within a public transportation system, there are equity gaps that ought to be addressed. Due to its nature as a good with social meaning, public transportation should be provided outside the free market. Furthermore, based upon Rawls' Second Principle of Justice, the greatest benefit should be given to those most disadvantaged first. Therefore, understanding gaps between potential need – where key population groups are located – and the supply – the accessibility of the transit system – and working to lessen these gaps is of great importance.

Based upon a geospatial analysis of the Pierce Transit system, potential gaps for six key population groups were identified. These population group included racial minorities, low-income households, the elderly, youth, those with low English proficiency, and those without access to a car. The supply was determined through creating 60-minute travel sheds with person-oriented origin points in each Census block group within Pierce County and counting the number of jobs

and community assets, including social services, health care, places of worship, grocery stores, schools, parks, and libraries, were inside each travel shed. From there, levels of accessibility were determined based upon quartiles. These accessibility levels were compared to the levels of each population group inside each block group to determine where potential gaps exist and at what severity.

While the population groups were kept disaggregated, some common areas of potential concern were discovered. Key among these were Gig Harbor, unincorporated Pierce County south of Fife and west of Puyallup, unincorporated Pierce County east of JBLM but still within the PTBA, and the Steilacoom, University Place, and Lakewood juncture area. Many of these areas had limited accessibility due to lack of transit routes and/or low frequency. Increased service in these areas is recommended as a potential solution to help alleviate the potential gaps in these areas, as well as exploration of alternatives to fixed-route service. Many areas outside the PTBA show large gaps. Among these, it was recommended that Pierce Transit consider potentially including Sumner, Orting, Bonney Lake, unincorporated Pierce County northeast of JBLM, and/or Eatonville into the PTBA because of the proximity to block groups that had Extreme gaps for many of the population groups and relatively higher population density. Changing the PTBA boundaries, however, is a difficult process, so this recommendation must be considered with care and with seeking community input. Furthermore, it is acknowledged that much of the area with large gaps has low population density. Therefore, some alternatives to fixed routes were recommended for further exploration, such as demand responsive buses or shuttles, or an express line with feeder shuttles.

Regardless of any recommendations explored or adapted by Pierce Transit, it is useful to understand where there are social equity gaps within a transit system so that they can be considered. Keeping the population groups disaggregated is useful because it allows the transit agency to focus

their resources on particular locations and prioritize funding allocations. A geospatial analysis is also advantageous because it allows for the agency to visualize where service may be lacking and where, geographically, improvements may be made.

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Appendix A

Data Dictionary

Data Dictionary

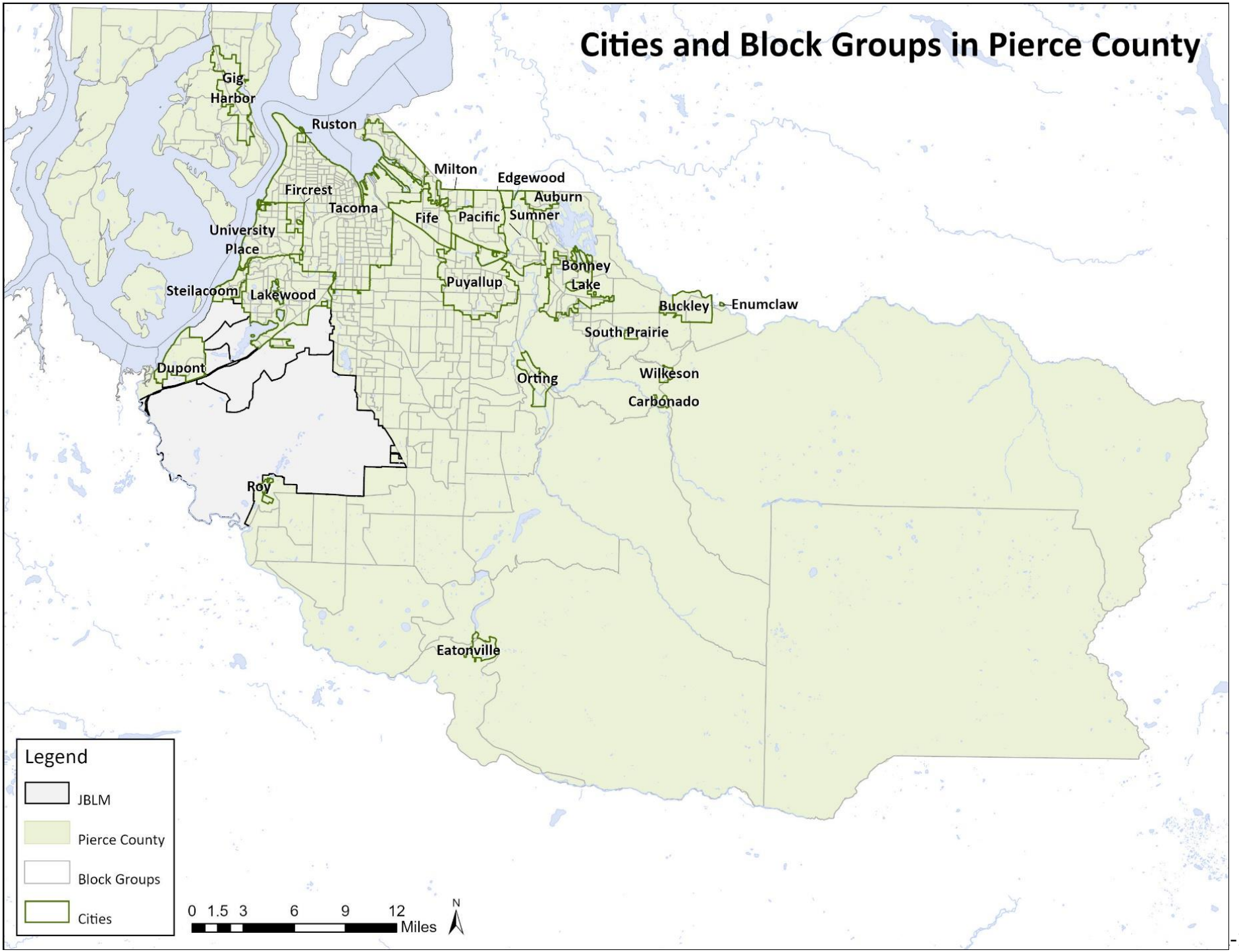
Jobs and Community Assets Datasets	
Jobs Counts (2019)	
Source	Longitudinal Employer-Household Dynamics
Format	Excel Spreadsheet
Attributes	Block ID, Total Jobs
Scale	Pierce County
Public Health Care Facilities (2019)	
Source	Pierce County Open GIS
Format	Shapefile, points
Attributes	Name, Address, Type
Scale	Pierce County
Private Health Care Facilities (2021)	
Source	Yellow Pages
Format	Excel Spreadsheet
Attributes	Name, Address, City, Zip Code
Scale	Pierce County
Social Services	
Source	Pierce County Department of Human Services
Format	Excel Spreadsheet
Attributes	Name, Address, City, Zip Code
Scale	Pierce County
Schools (2020)	
Source	Pierce County Open GIS
Format	Shapefile, points
Attributes	Name, Address, Grade, X- and Y-Coordinates
Scale	Pierce County
Grocery Stores	
Source	Yellow Pages
Format	Excel Spreadsheet
Attributes	Name, Address, City, Zip Code
Scale	Pierce County
Libraries (2019)	
Source	Pierce County Open GIS
Format	Shapefile, points
Attributes	Branch, Street, X- and Y-Coordinates
Scale	Pierce County

Parks (2020)	
Source	Pierce County Open GIS
Format	Shapefile, points
Attributes	Name, Park Type, Address
Scale	Pierce County
Transit Datasets	
Pierce Transit Routes (2020)	
Source	Pierce Transit Open GIS
Format	Shapefile, lines
Attributes	FID, Designator, Shape Length
Scale	Pierce County
Pierce Transit Benefit Area (2020)	
Source	Pierce Transit Open GIS
Format	Shapefile, polygon
Attributes	Perimeter, Name
Scale	Pierce County
Pierce Transit GTFS (2020)	
Source	Sound Transit Open Data
Format	Text Document
Attributes	Agency, Calendar, Calendar Dates, Fare, Routes, Stop Times, Trips, Stops
Scale	Pierce County
Sound Transit GTFS (2020)	
Source	Sound Transit Open Data
Format	Text Document
Attributes	Agency, Calendar, Calendar Dates, Fare, Routes, Stop Times, Trips, Stops
Scale	Pierce and King Counties
Intercity Transit GTFS (2020)	
Source	Sound Transit Open Data
Format	Text Document
Attributes	Agency, Calendar, Calendar Dates, Fare, Routes, Stop Times, Trips, Stops
Scale	Pierce and Thurston Counties
Infrastructure Datasets	
Pierce County Streets (2021)	
Source	Pierce County Open GIS
Format	Shapefile, lines
Attributes	Left From, Left To, Right From, Right To, Name, Type, Direction, Shape Length
Scale	Pierce County

Pierce County Parcels (2021)	
Source	Pierce County Open GIS
Format	Shapefile, polygons
Attributes	City, Address, Tax Area Code, Tax Parcel Number, Tax Parcel Type, Tax Parcel Unit, Use Code, X-Coordinate, Y-Coordinate
Scale	Pierce County
Pierce County Assessor-Treasurer Data, Improvement Built-As Table (2021)	
Source	Pierce County
Format	Excel Spreadsheet
Attributes	Parcel Number, Units
Scale	Pierce County
Mobile Homes (2021)	
Source	Pierce County Open GIS
Format	Shapefile, points
Attributes	Parcel Number, X-Coordinate, Y-Coordinate
Scale	Pierce County
Missing Residential Units (2021)	
Source	Google Maps, Yellow Pages
Format	Excel Spreadsheet
Attributes	Address, Number Residential Units
Scale	Pierce County
Demographic Datasets	
2015-2019 5-Year American Community Survey	
Source	US Census Bureau via tidycensus
Attributes	Population, Race, Income, Age, Car Availability, English Proficiency
Scale	Pierce County, block groups

Appendix B

Maps


Cities and Block Groups in Pierce County
Gig Harbor
Ruston
Milton
Edgewood
Auburn
Fircrest
Tacoma
Fife
Pacific
Sumner
University Place
Bonney Lake
Puyallup
Steilacoom
Lakewood
Buckley
Enumclaw
South Prairie
Dupont
Orting
Wilkeson
Carbonado
Roy
Eatonville
Legend
JBLM
Pierce County
Block Groups
Cities
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Miles
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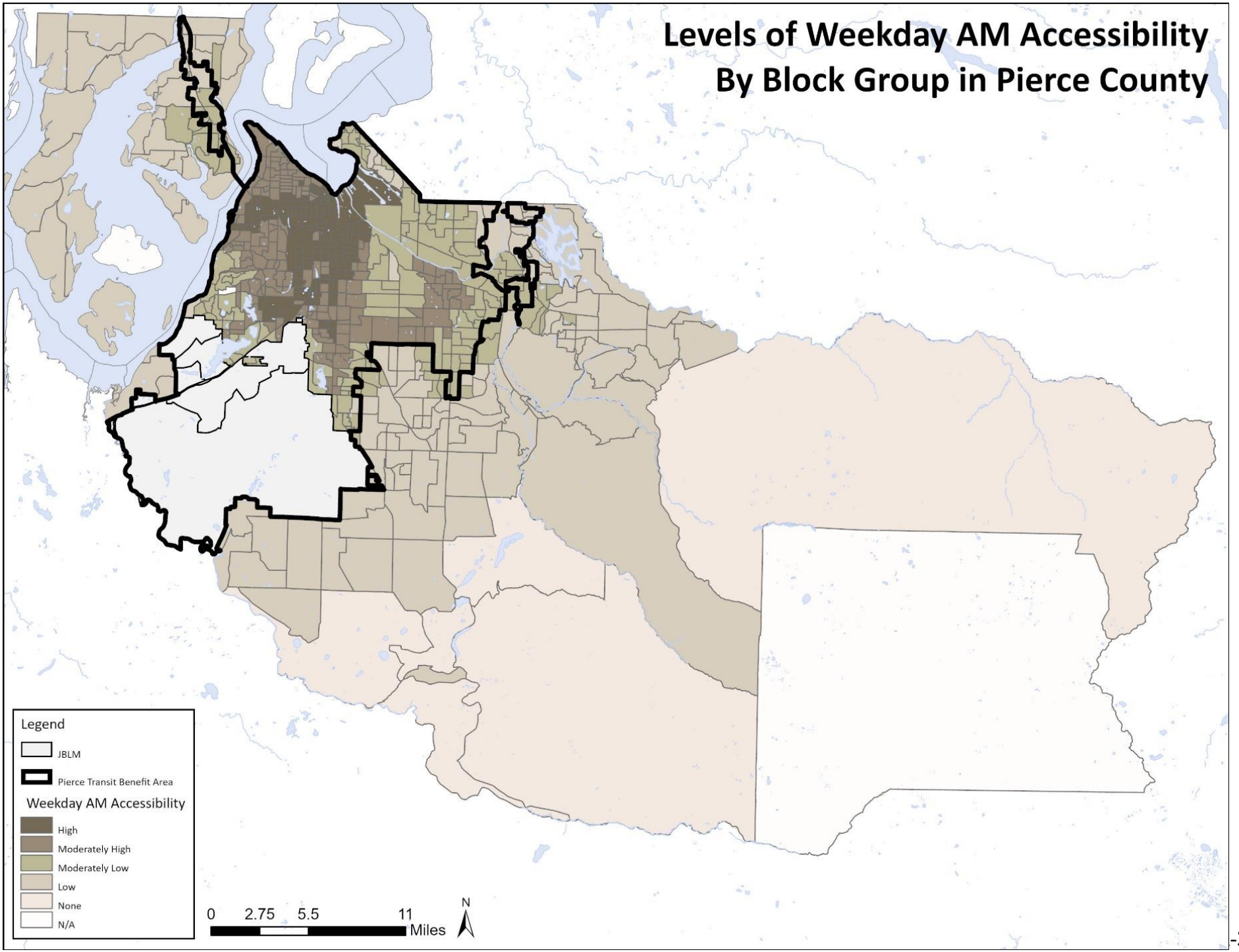
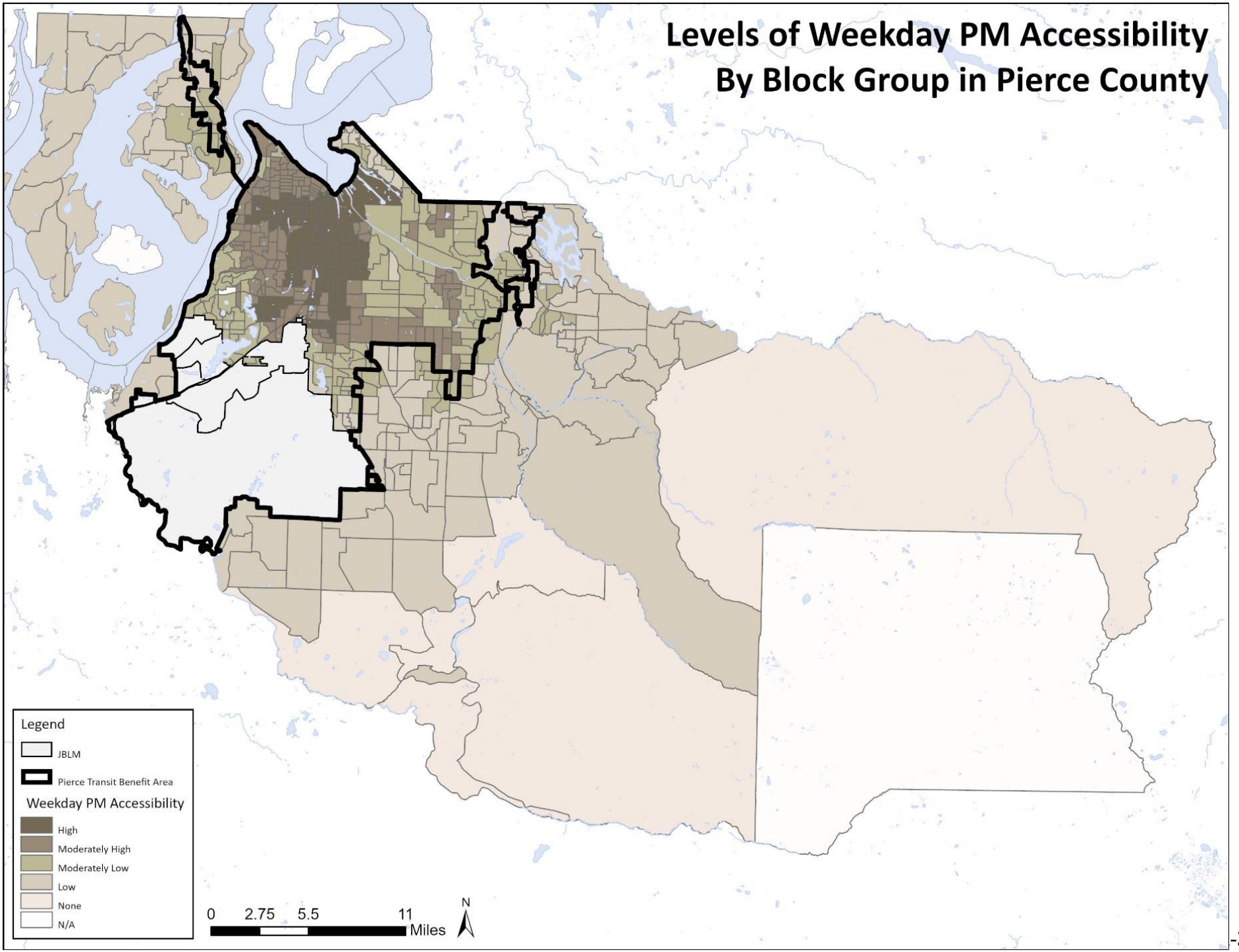
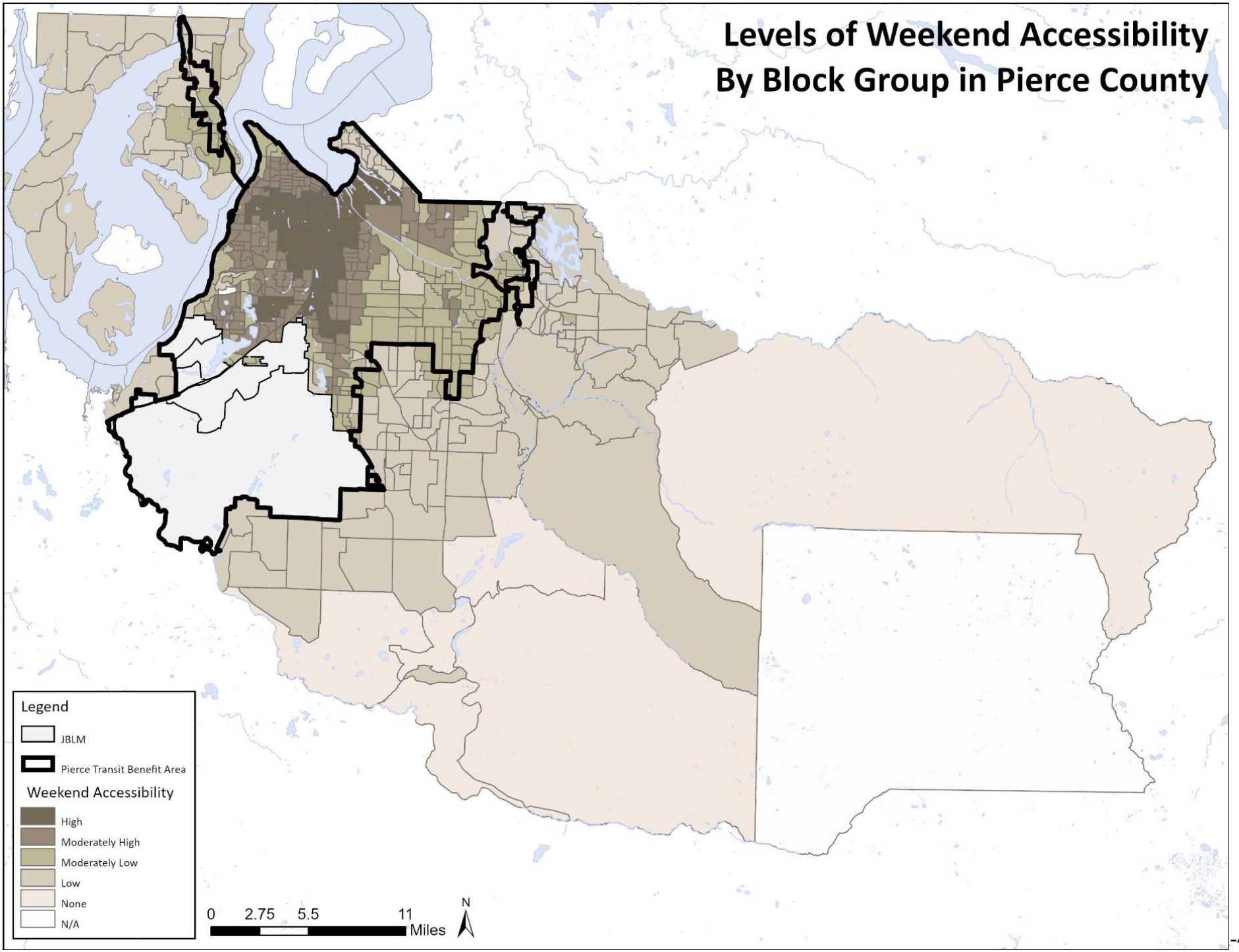

Levels of Weekday AM Accessibility
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
Weekday AM Accessibility
High
Moderately High
Moderately Low
Low
None
N/A
0
2.75
5.5
11
Miles
N


Levels of Weekday PM Accessibility
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
Weekday PM Accessibility
High
Moderately High
Moderately Low
Low
None
N/A
0
2.75
5.5
11
Miles
N


Levels of Weekend Accessibility
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
Weekend Accessibility
High
Moderately High
Moderately Low
Low
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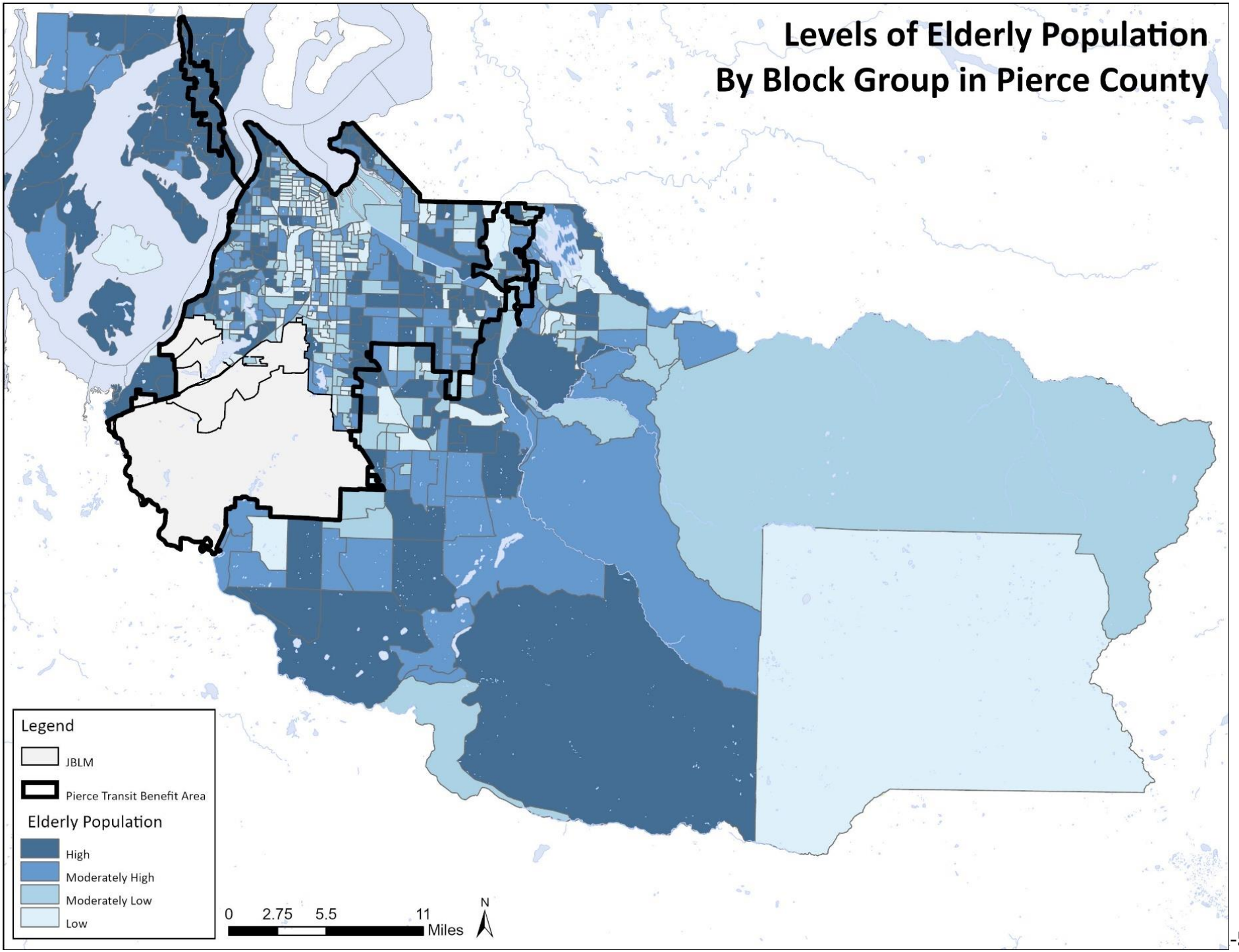
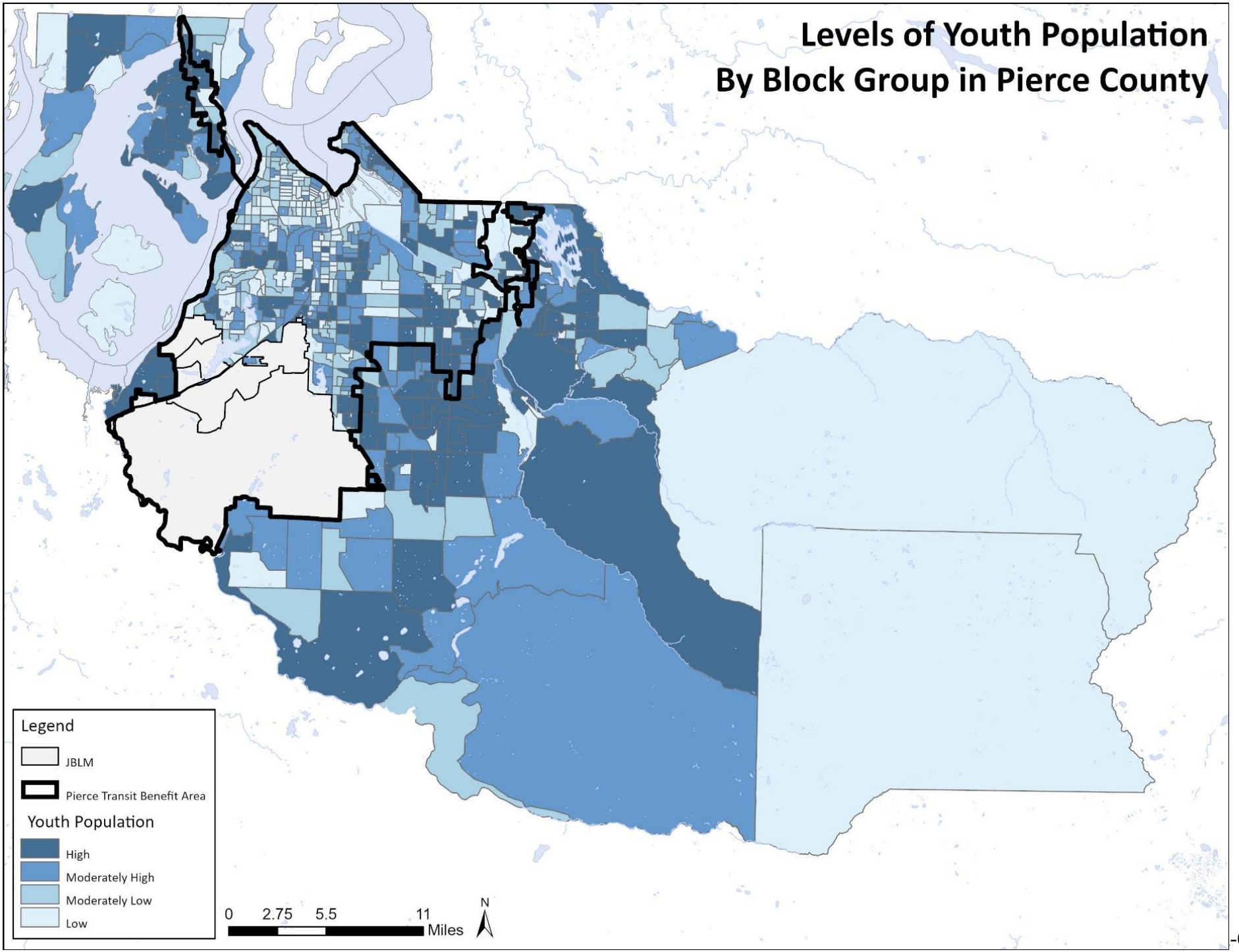
N/A
0
2.75
5.5
11
Miles
N


Levels of Elderly Population
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
Elderly Population
High
Moderately High
Moderately Low
Low
0
2.75
5.5
11
Miles
N


Levels of Youth Population
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
Youth Population
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Moderately Low
Low
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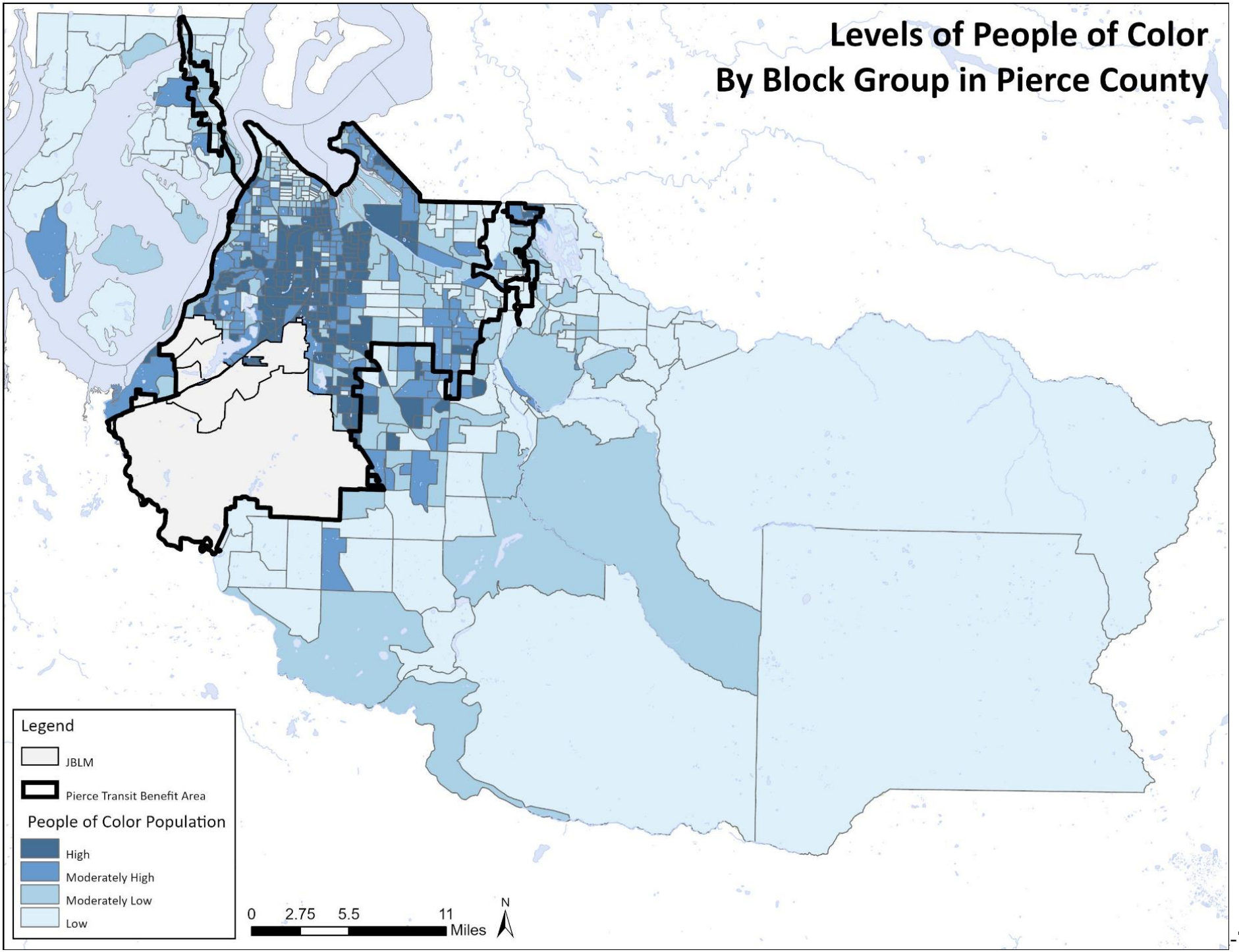
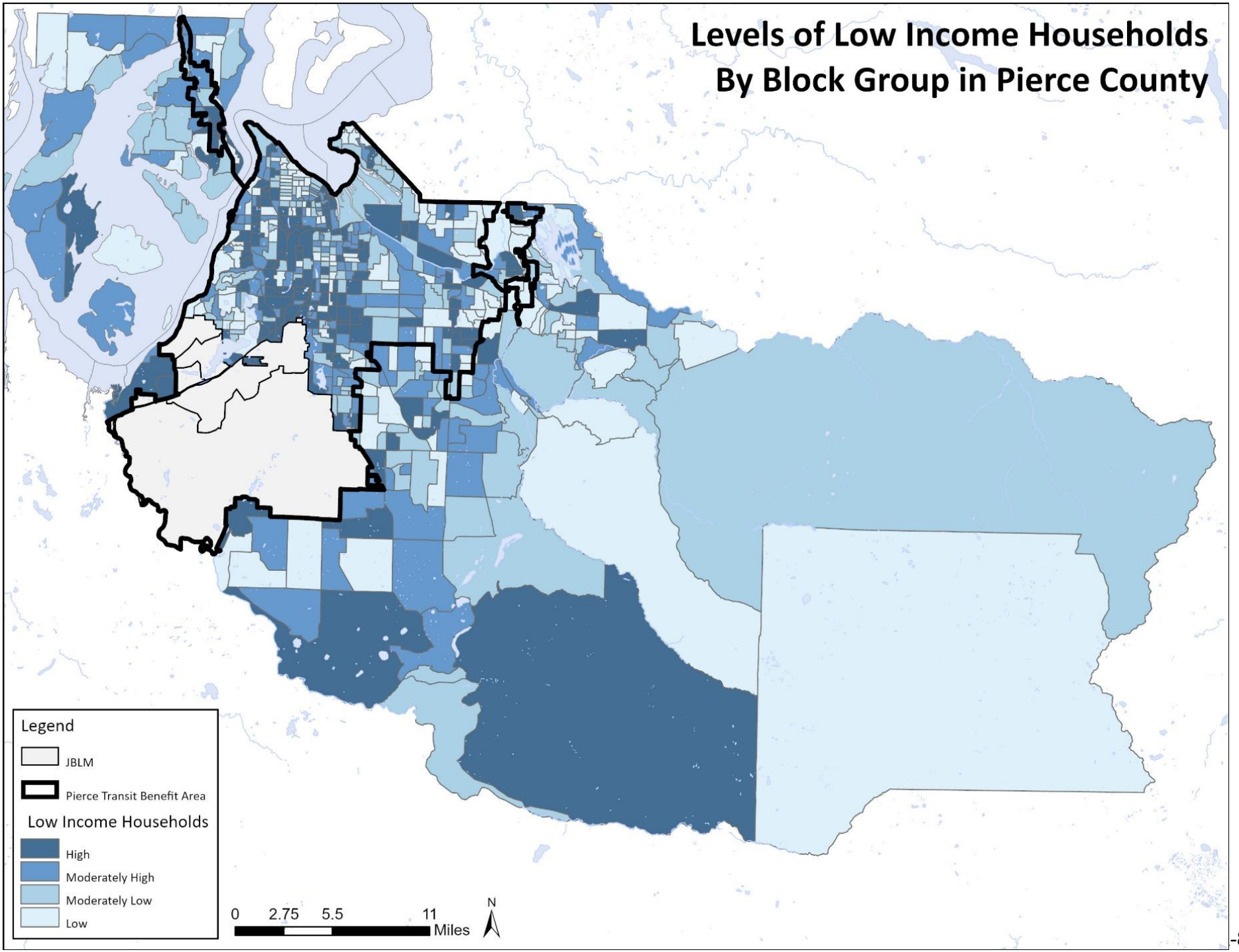
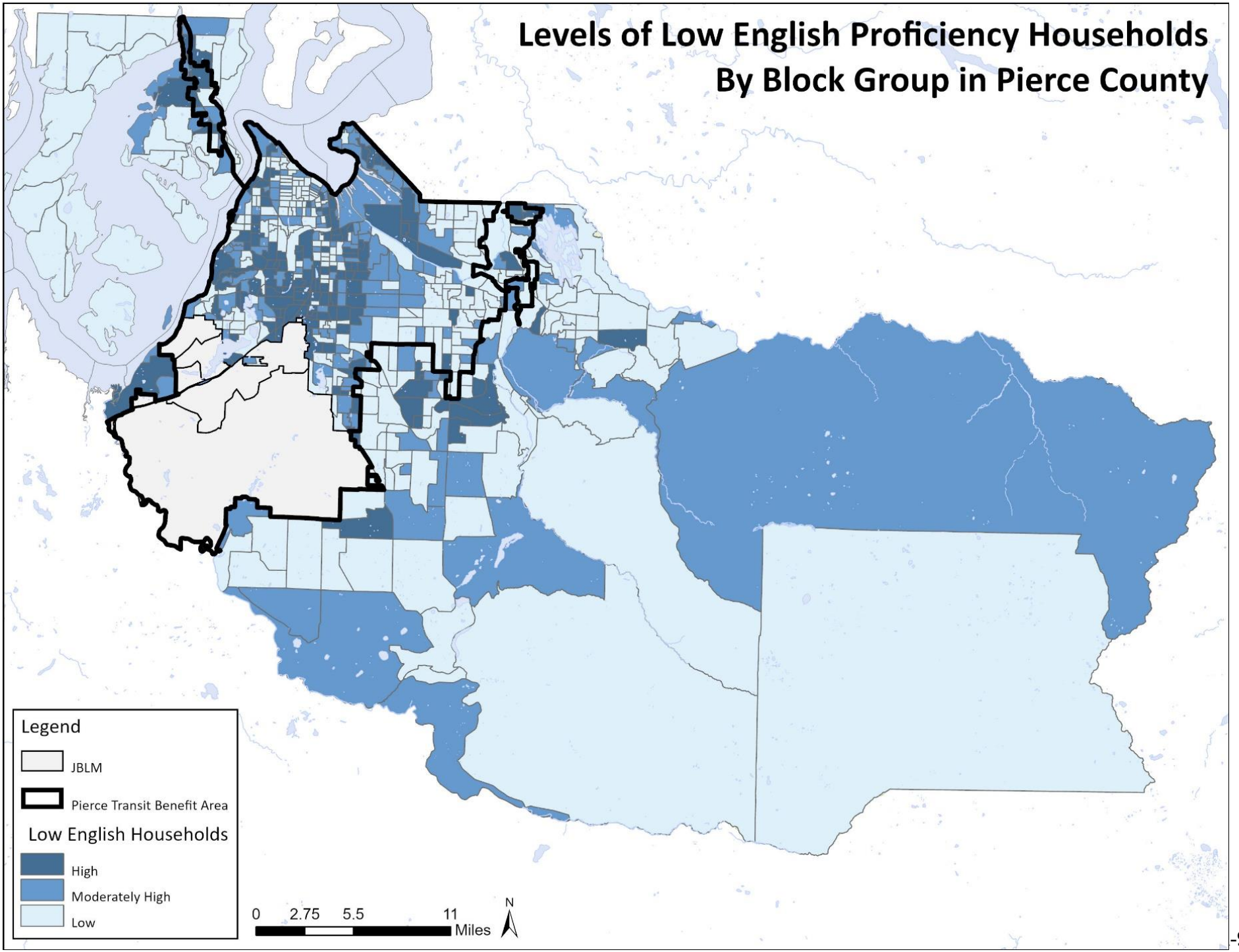
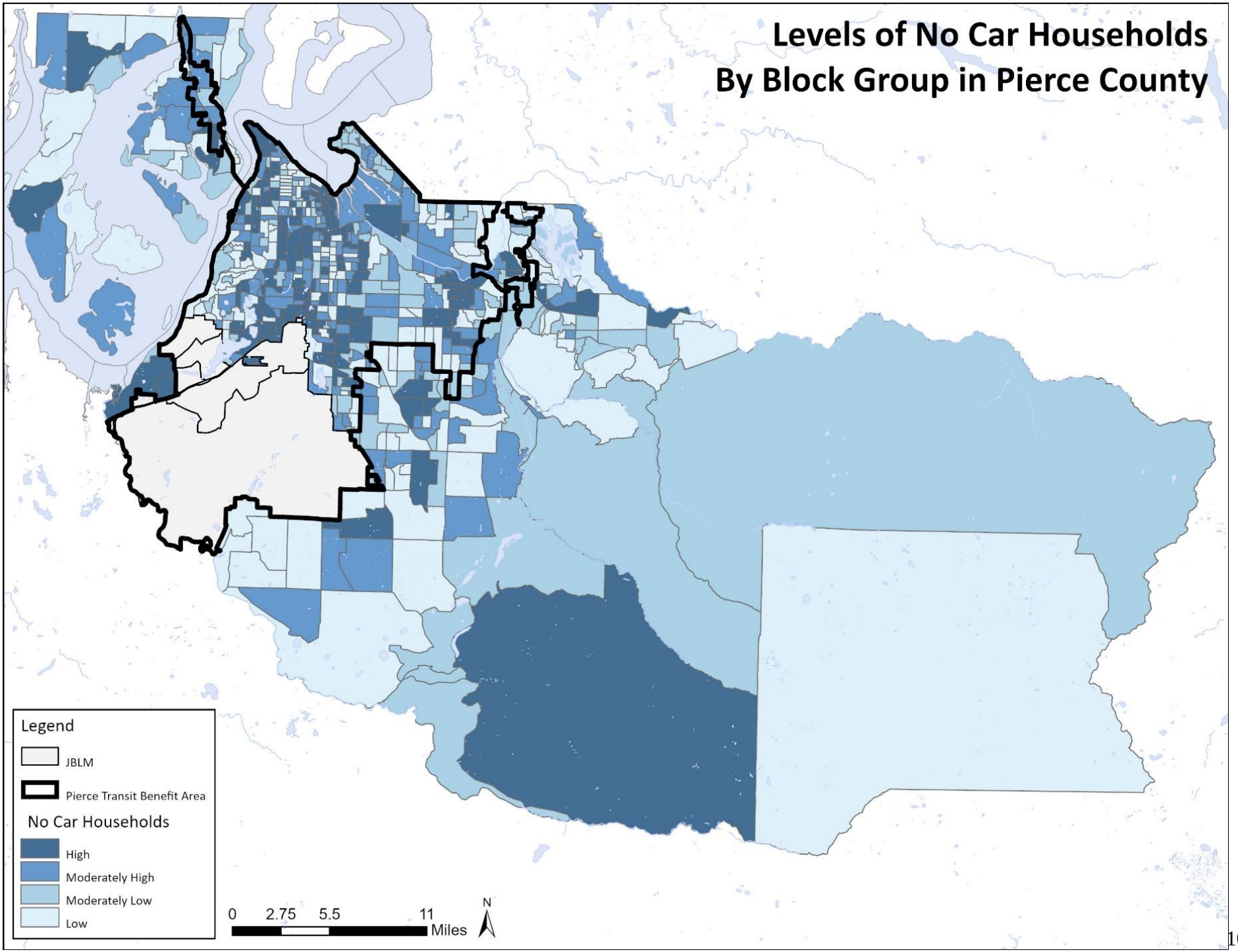
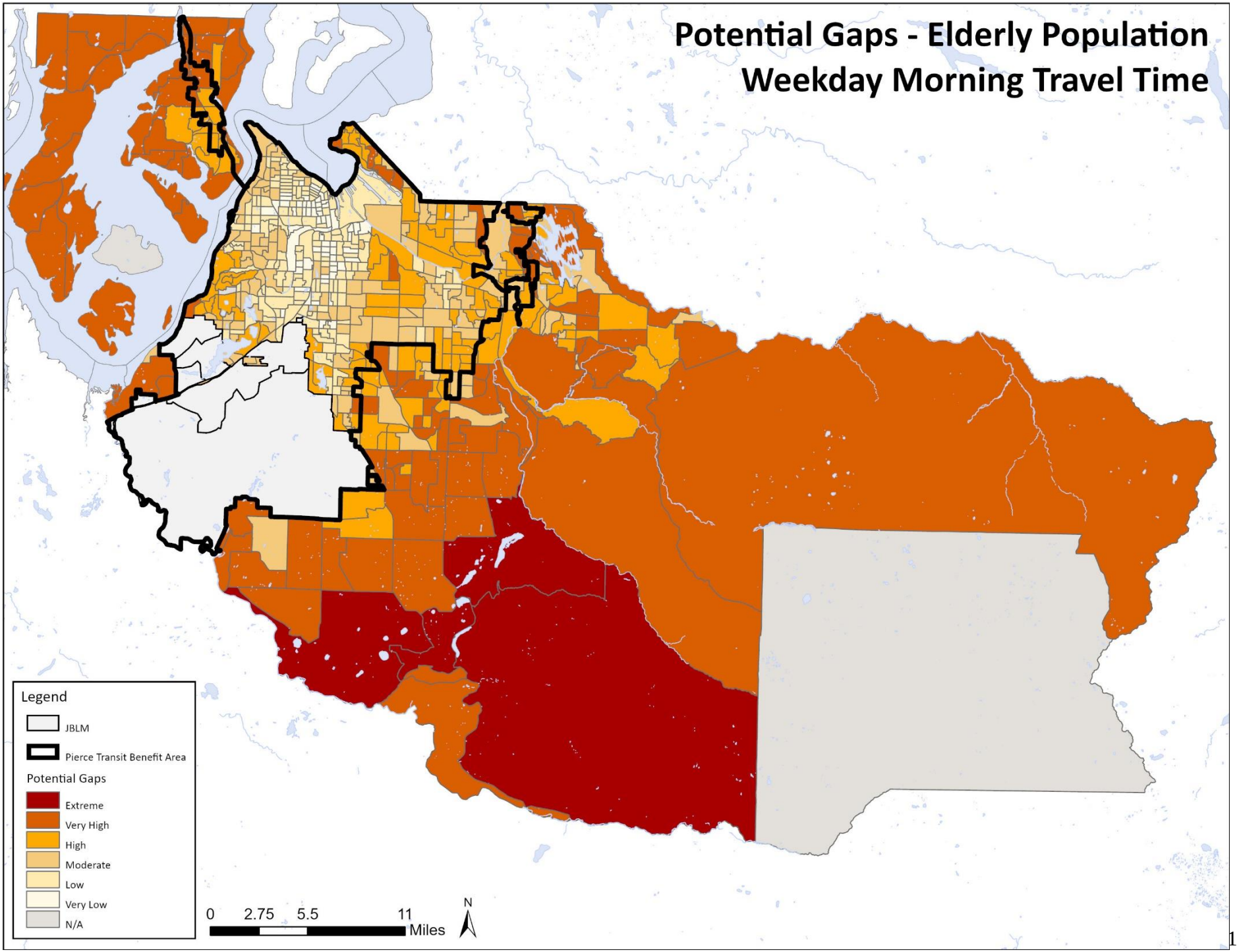
2.75
5.5
11
Miles
N

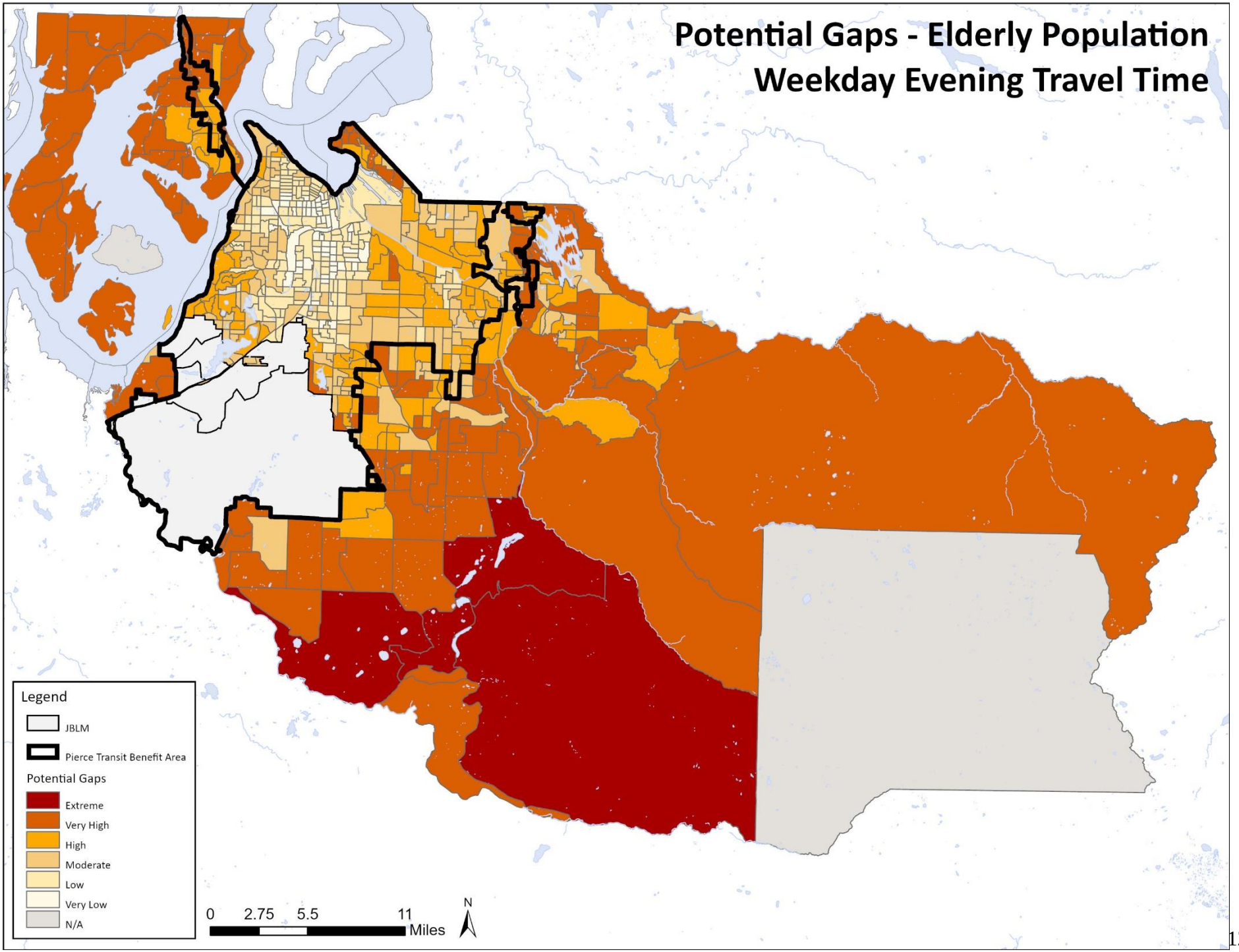

Levels of People of Color
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
People of Color Population
High
Moderately High
Moderately Low
Low
0
2.75
5.5
11
Miles
N

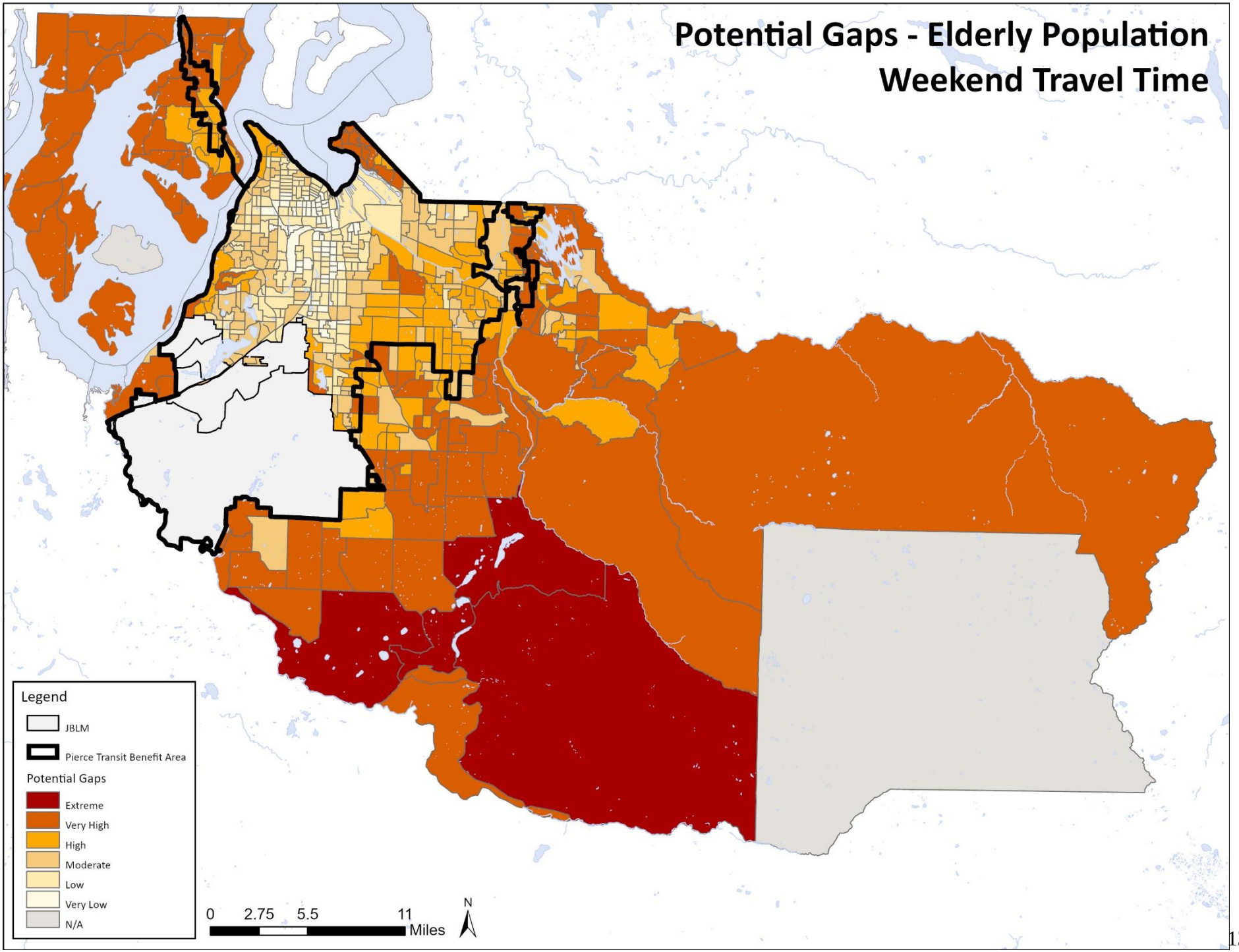

Levels of Low Income Households
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
Low Income Households
High
Moderately High
Moderately Low
Low
0
2.75
5.5
11
Miles
N

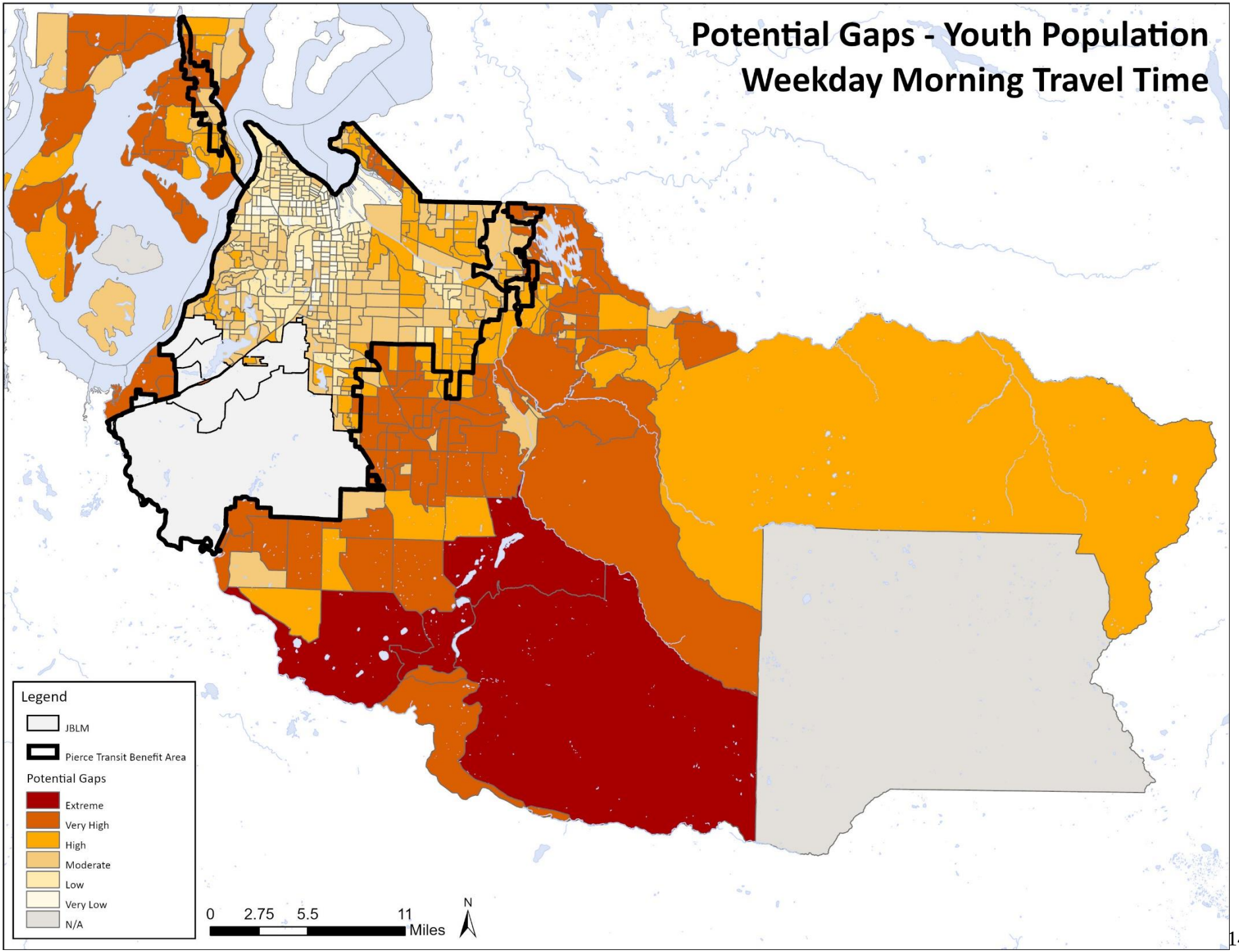

Levels of Low English Proficiency Households
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
Low English Households
High
Moderately High
Low
0
2.75
5.5
11
Miles
N

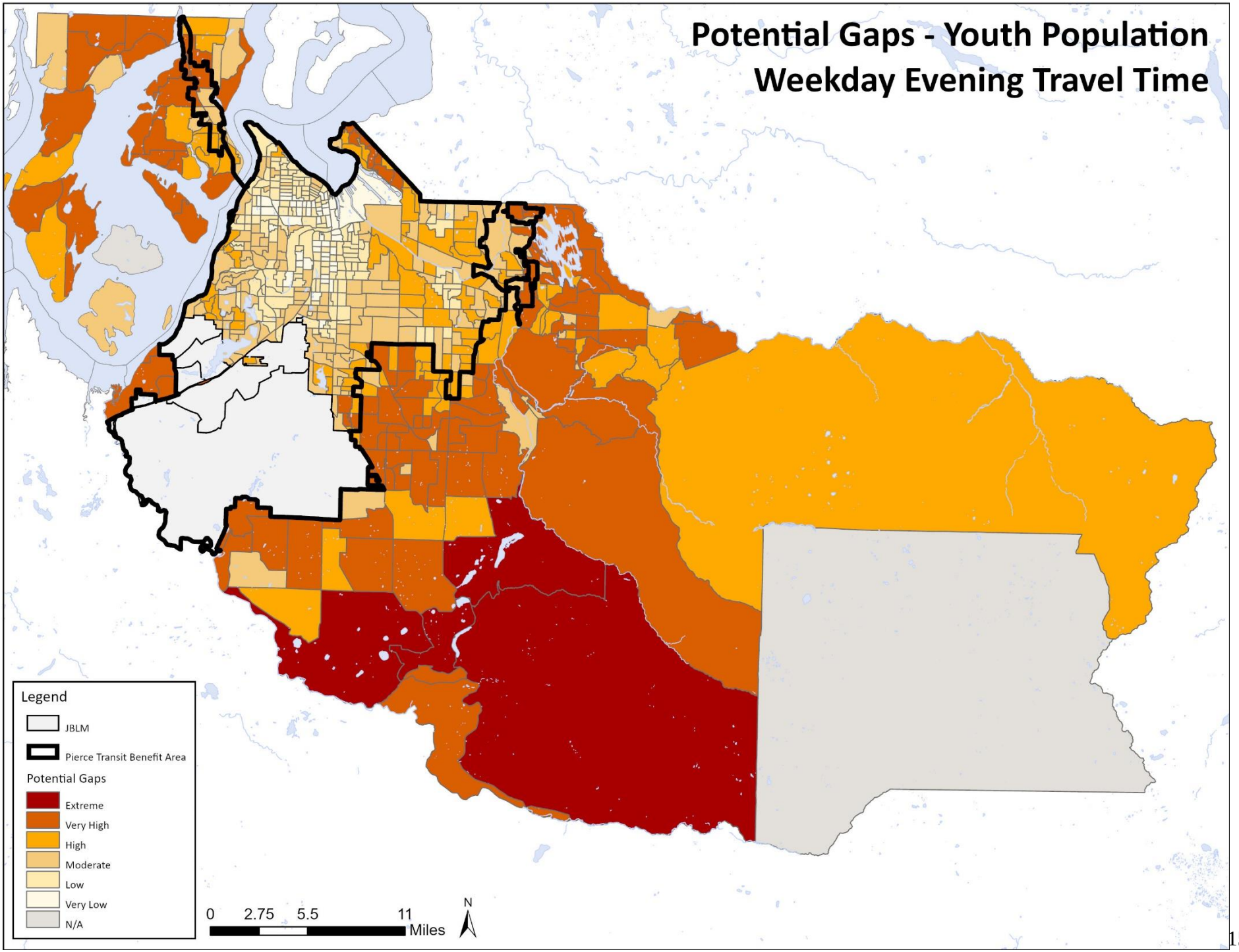

Levels of No Car Households
By Block Group in Pierce County
Legend
JBLM
Pierce Transit Benefit Area
No Car Households
High
Moderately High
Moderately Low
Low
0
2.75
5.5
11
Miles
N

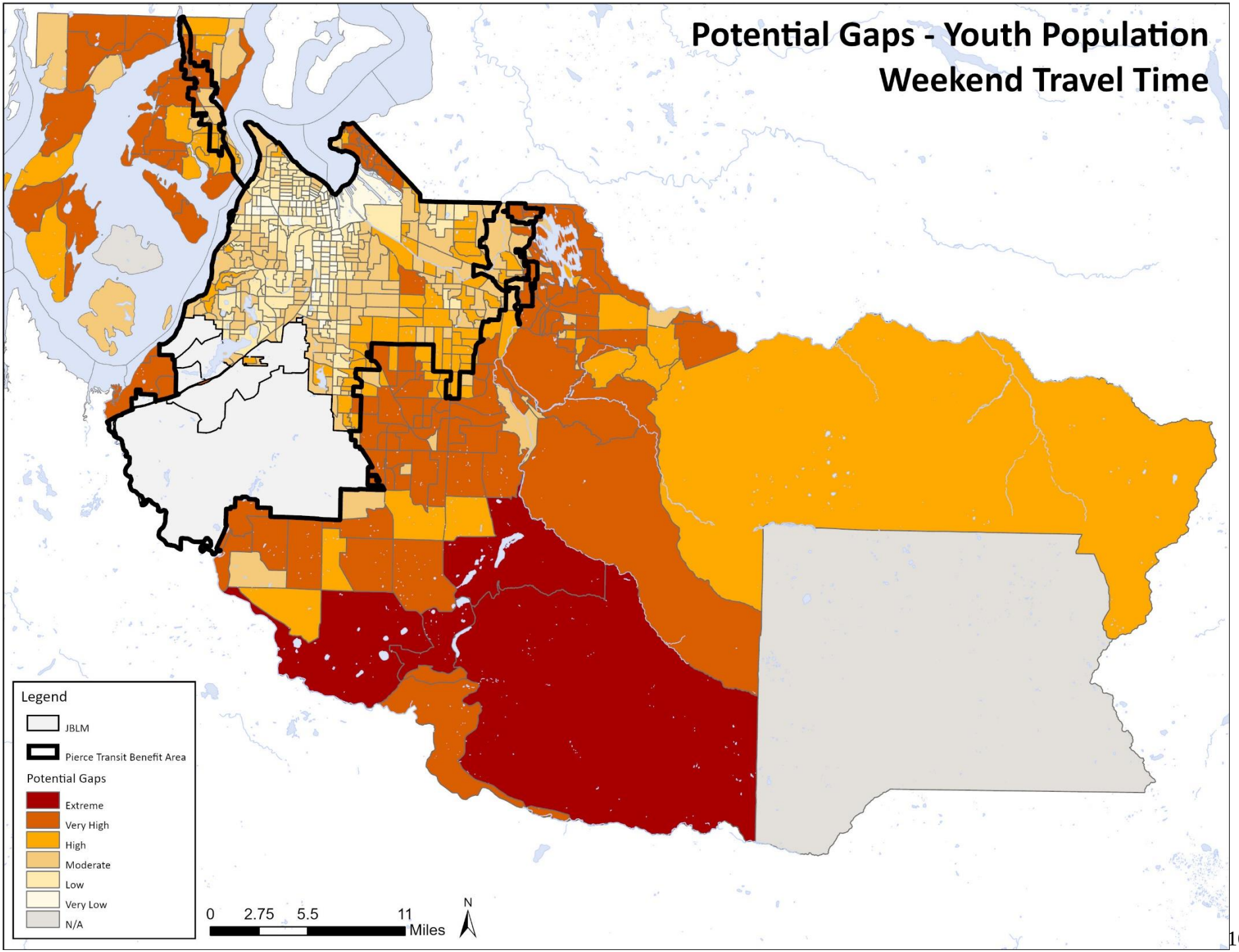

Potential Gaps - Elderly Population
Weekday Morning Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N

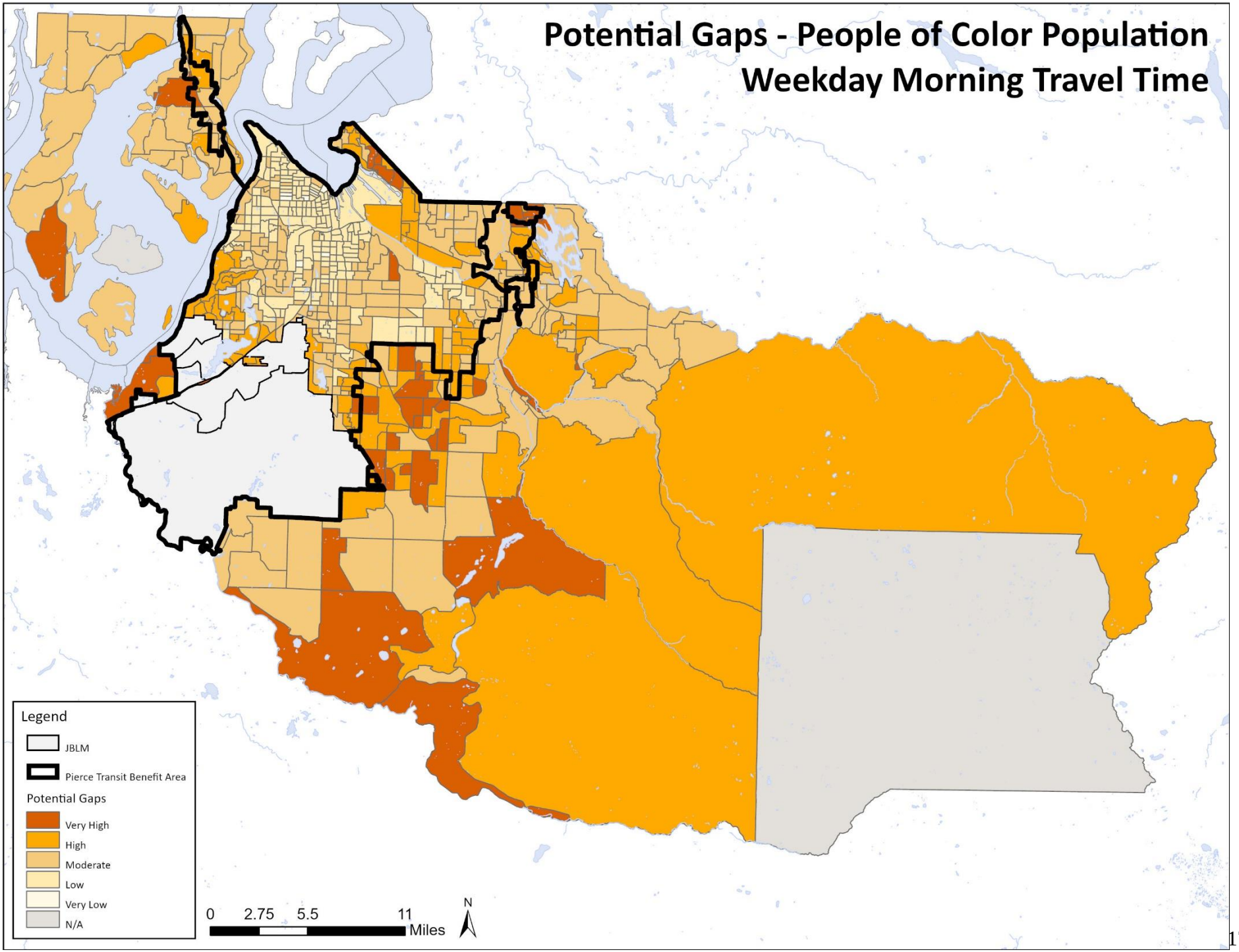

Potential Gaps - Elderly Population
Weekday Evening Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N

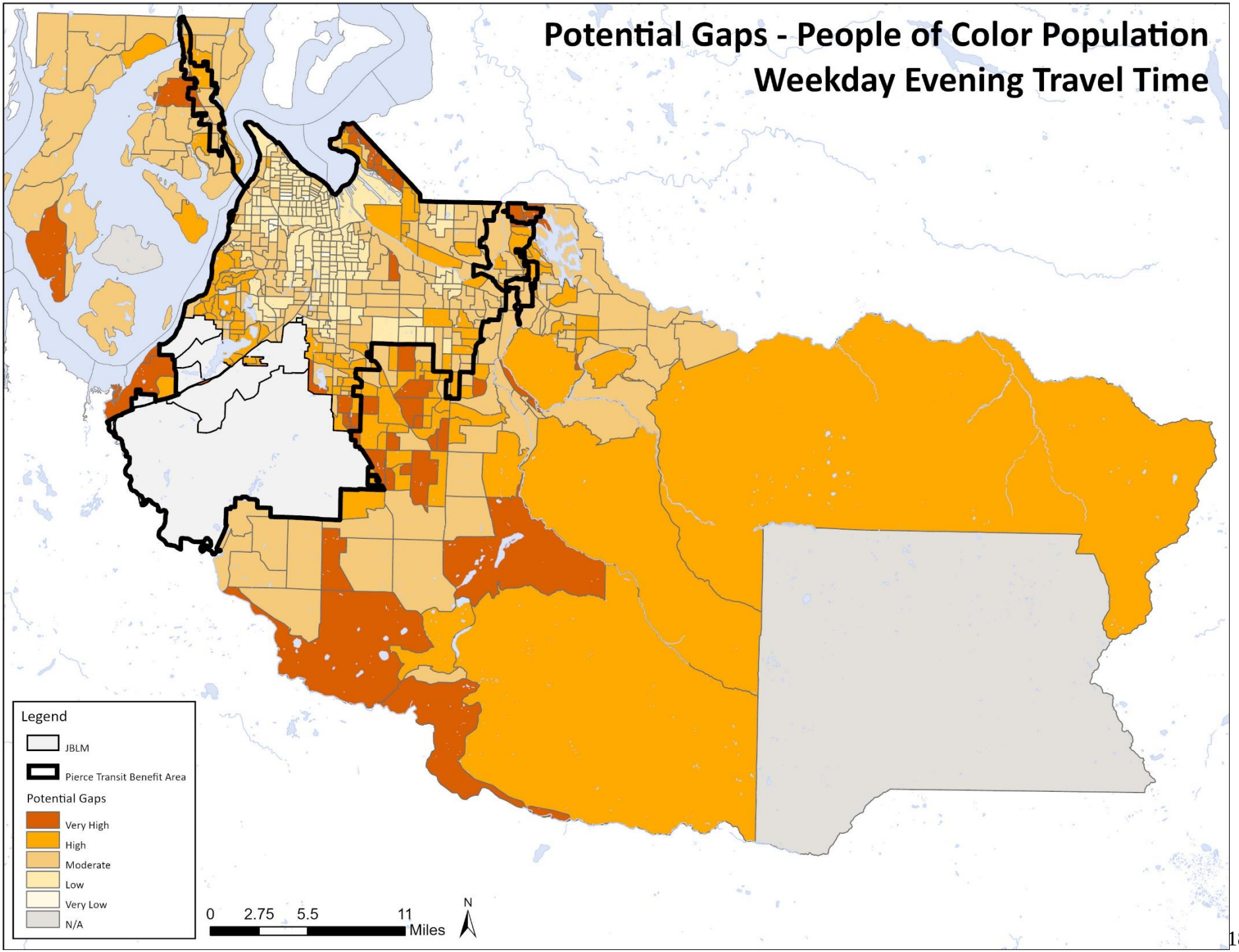

Potential Gaps - Elderly Population
Weekend Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N

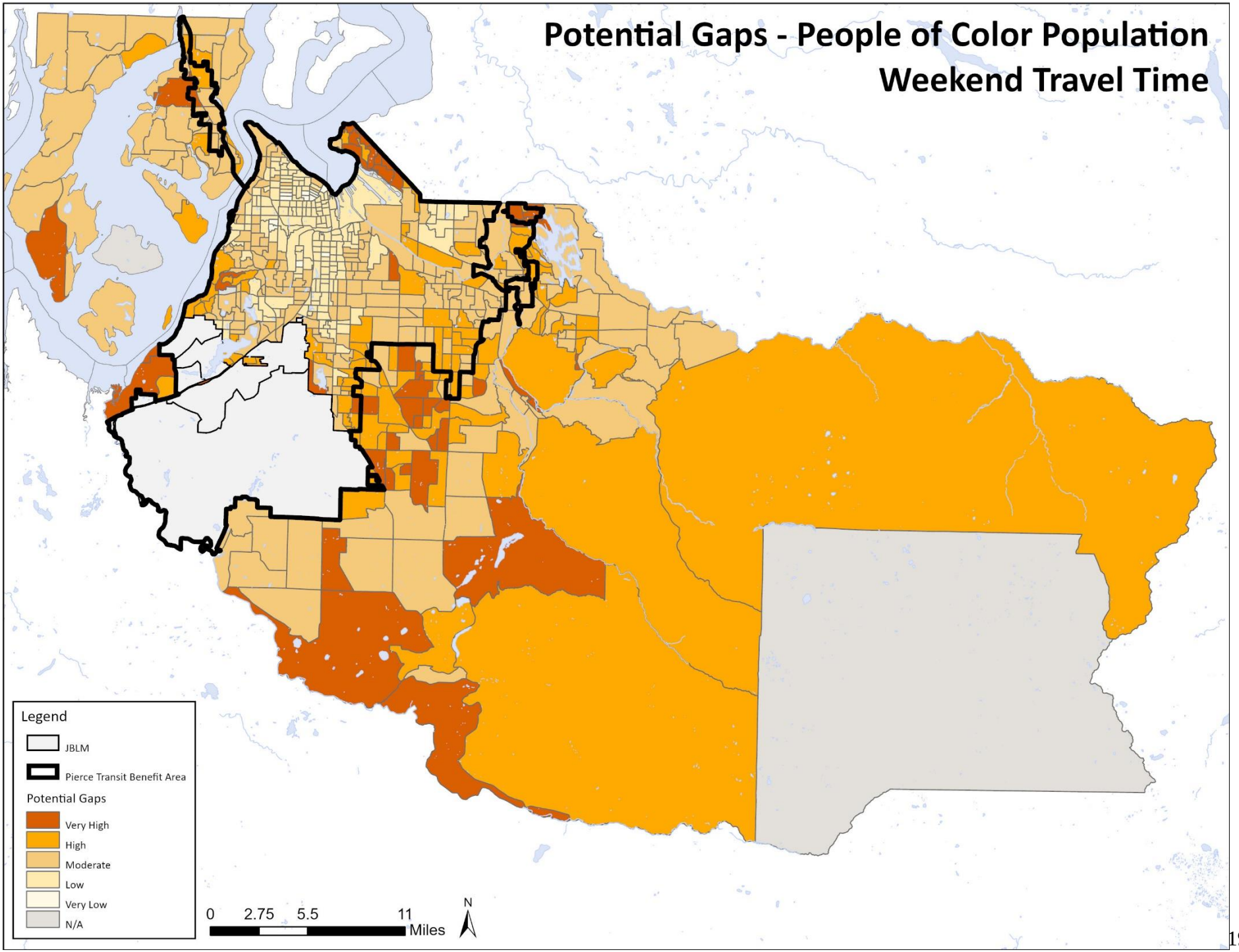

Potential Gaps - Youth Population
Weekday Morning Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N

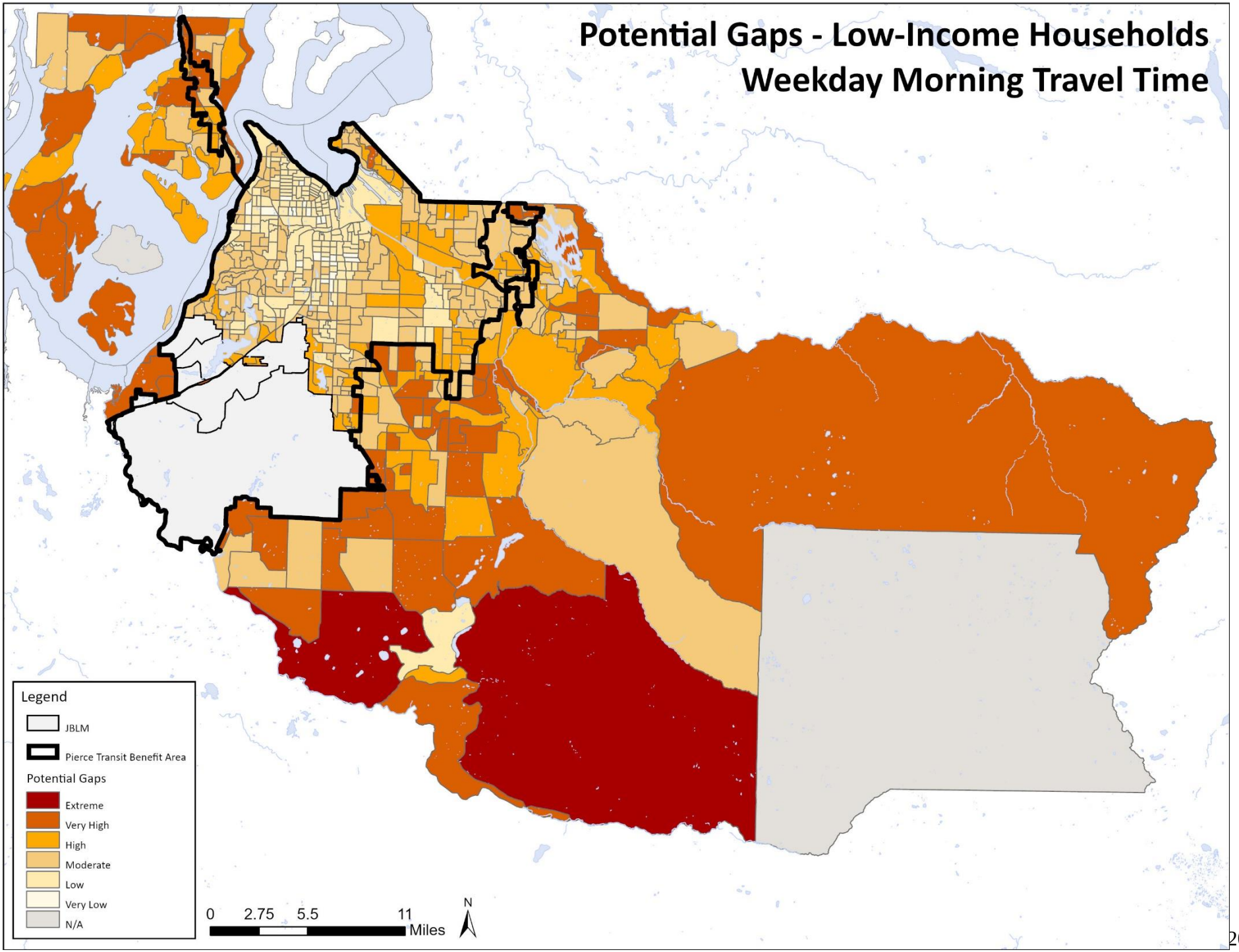

Potential Gaps - Youth Population
Weekday Evening Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N

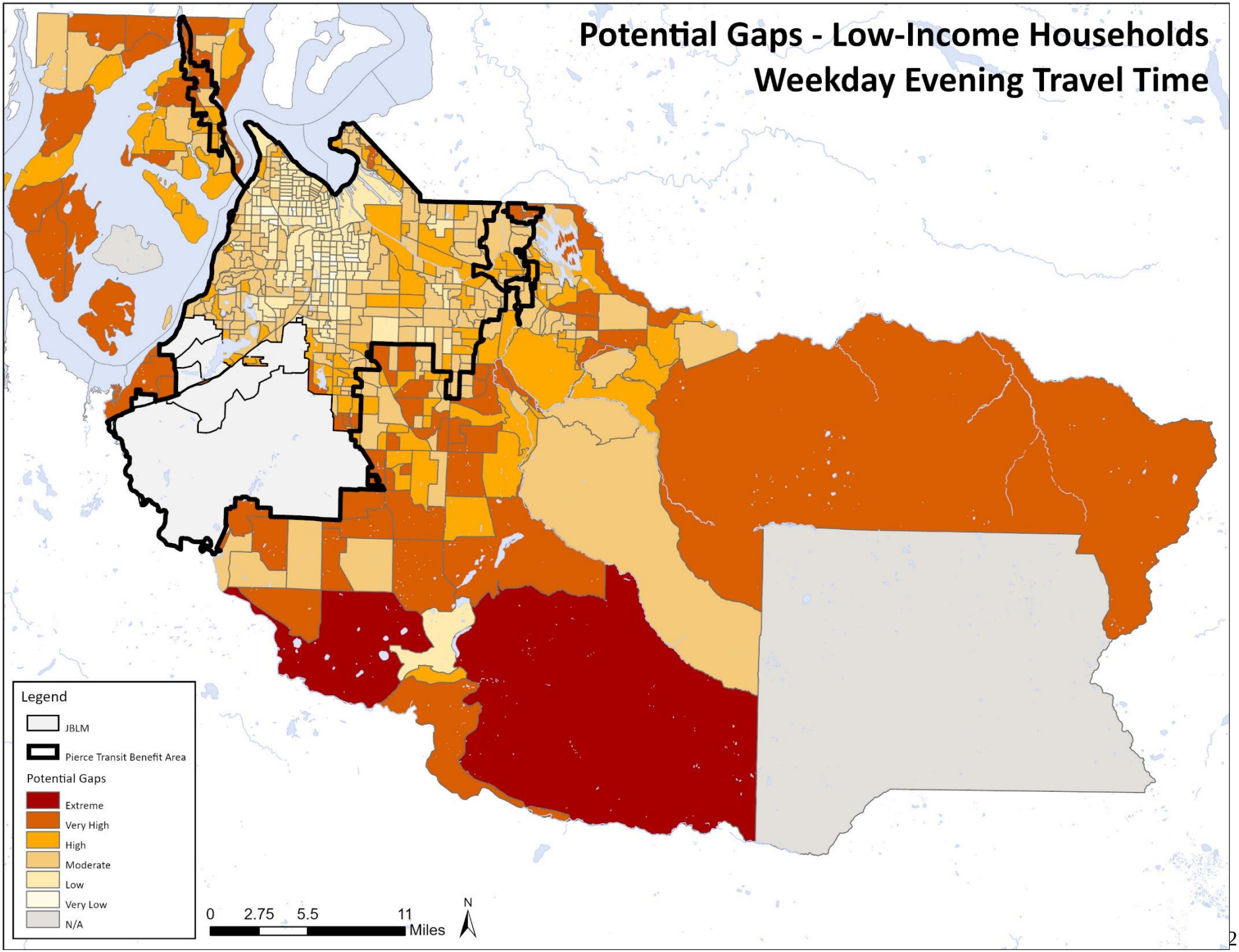

Potential Gaps - Youth Population
Weekend Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N

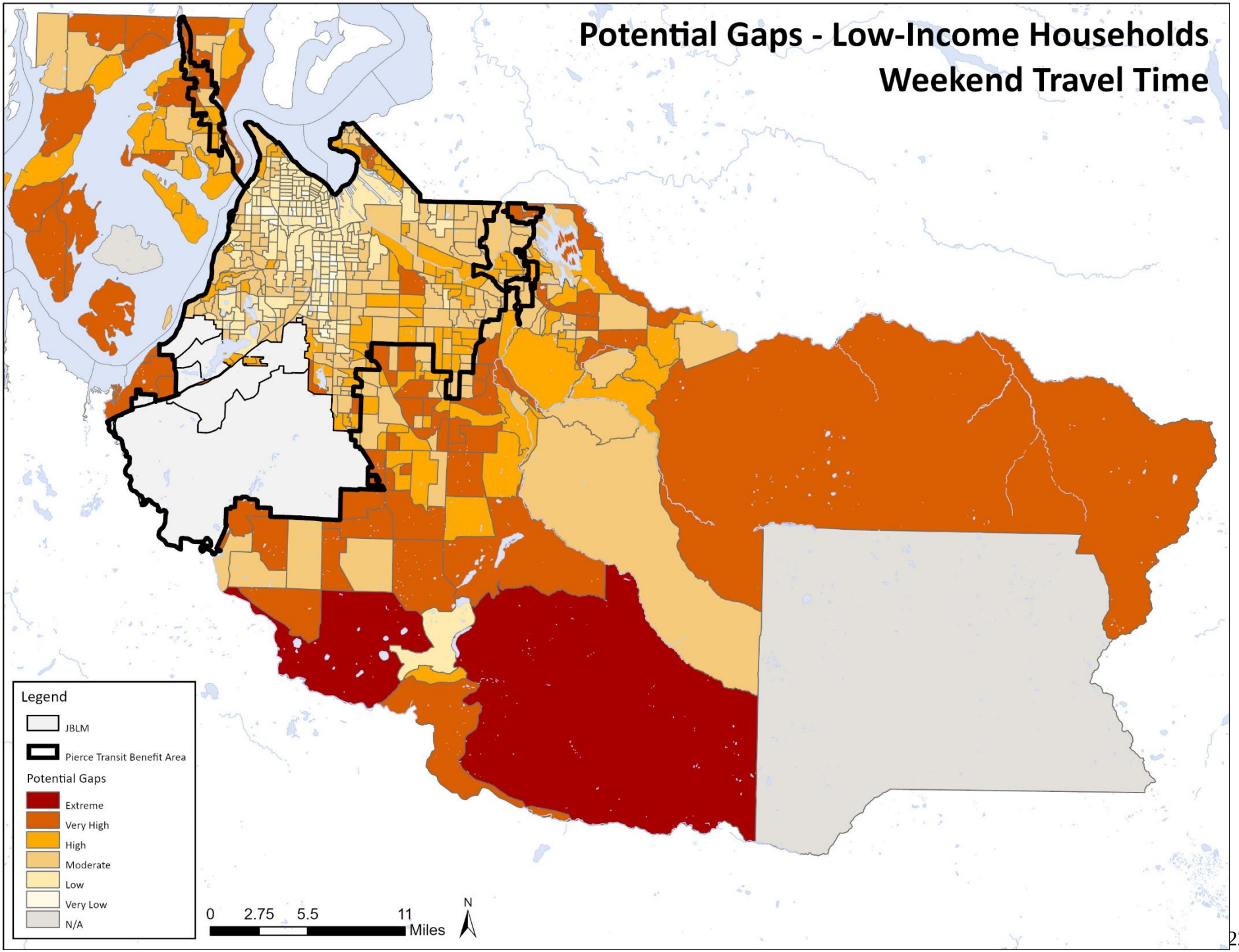

Potential Gaps - People of Color Population
Weekday Morning Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N


Potential Gaps - People of Color Population
Weekday Evening Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N


Potential Gaps - People of Color Population
Weekend Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N


Potential Gaps - Low-Income Households
Weekday Morning Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N


Potential Gaps - Low-Income Households
Weekday Evening Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N


Potential Gaps - Low-Income Households
Weekend Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
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2.75
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Miles
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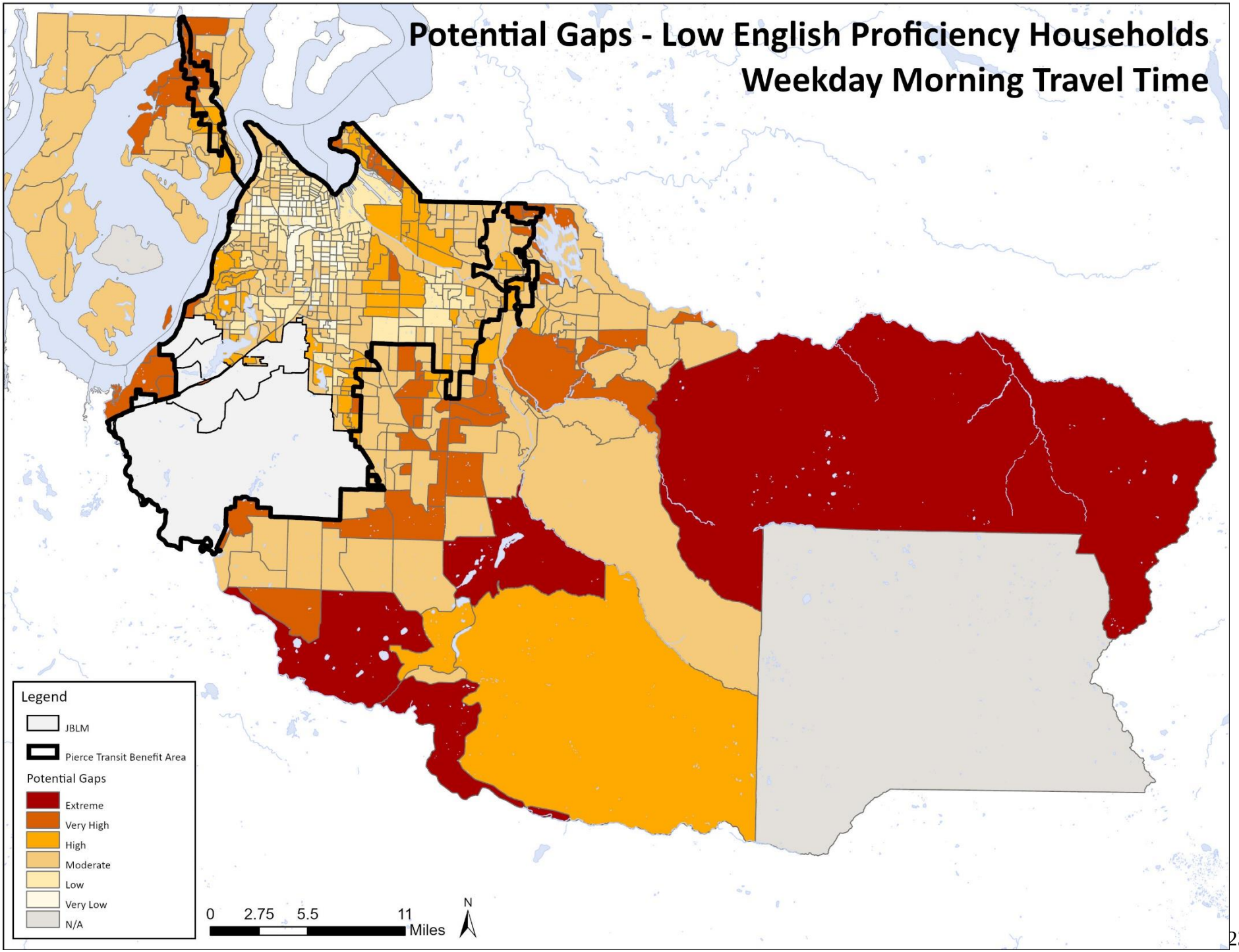
Potential Gaps - Low English Proficiency Households
Weekday Morning Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
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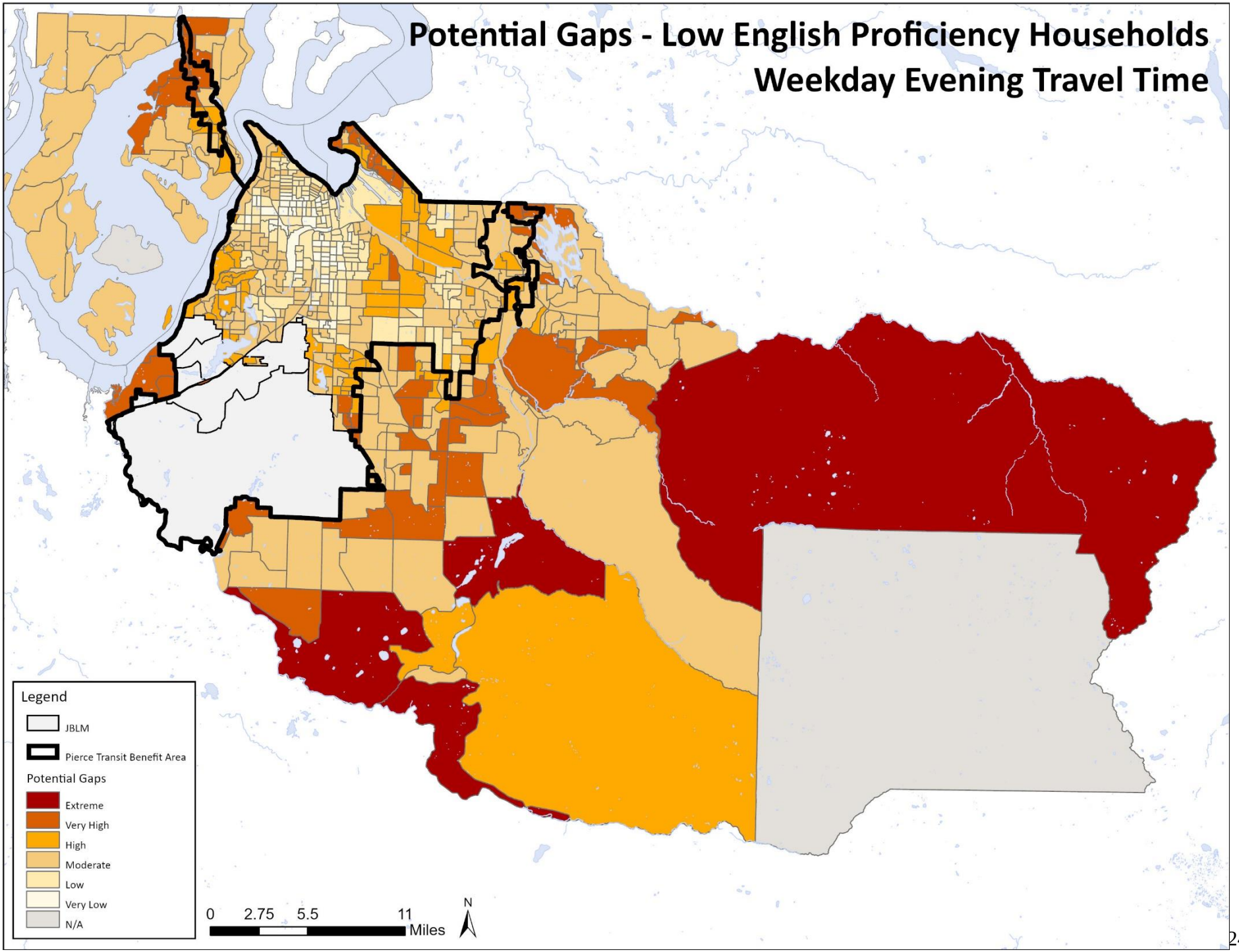
Potential Gaps - Low English Proficiency Households
Weekday Evening Travel Time
Legend
JBLM
Pierce Transit Benefit Area
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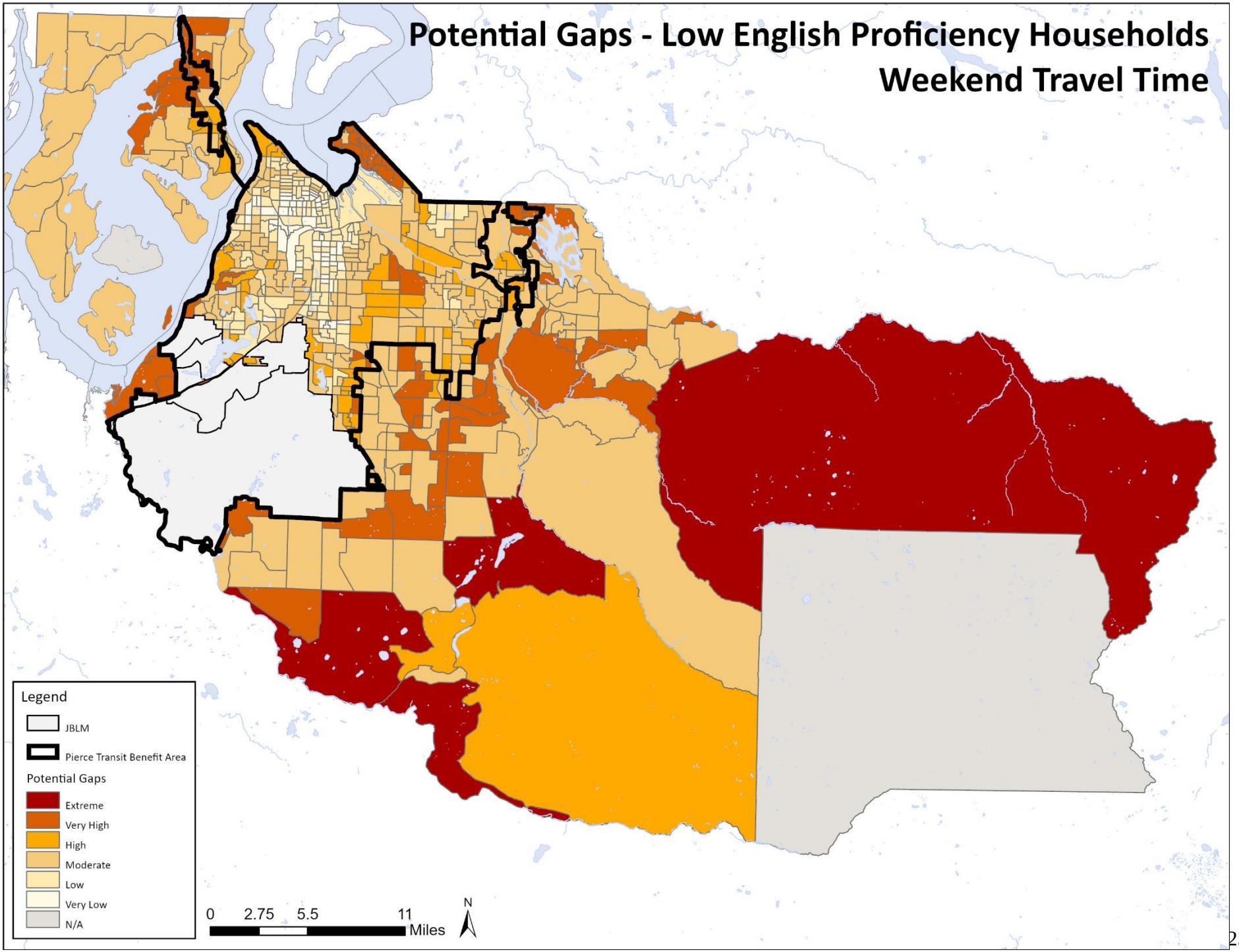
Potential Gaps - Low English Proficiency Households
Weekend Travel Time
Legend
JBLM
Pierce Transit Benefit Area
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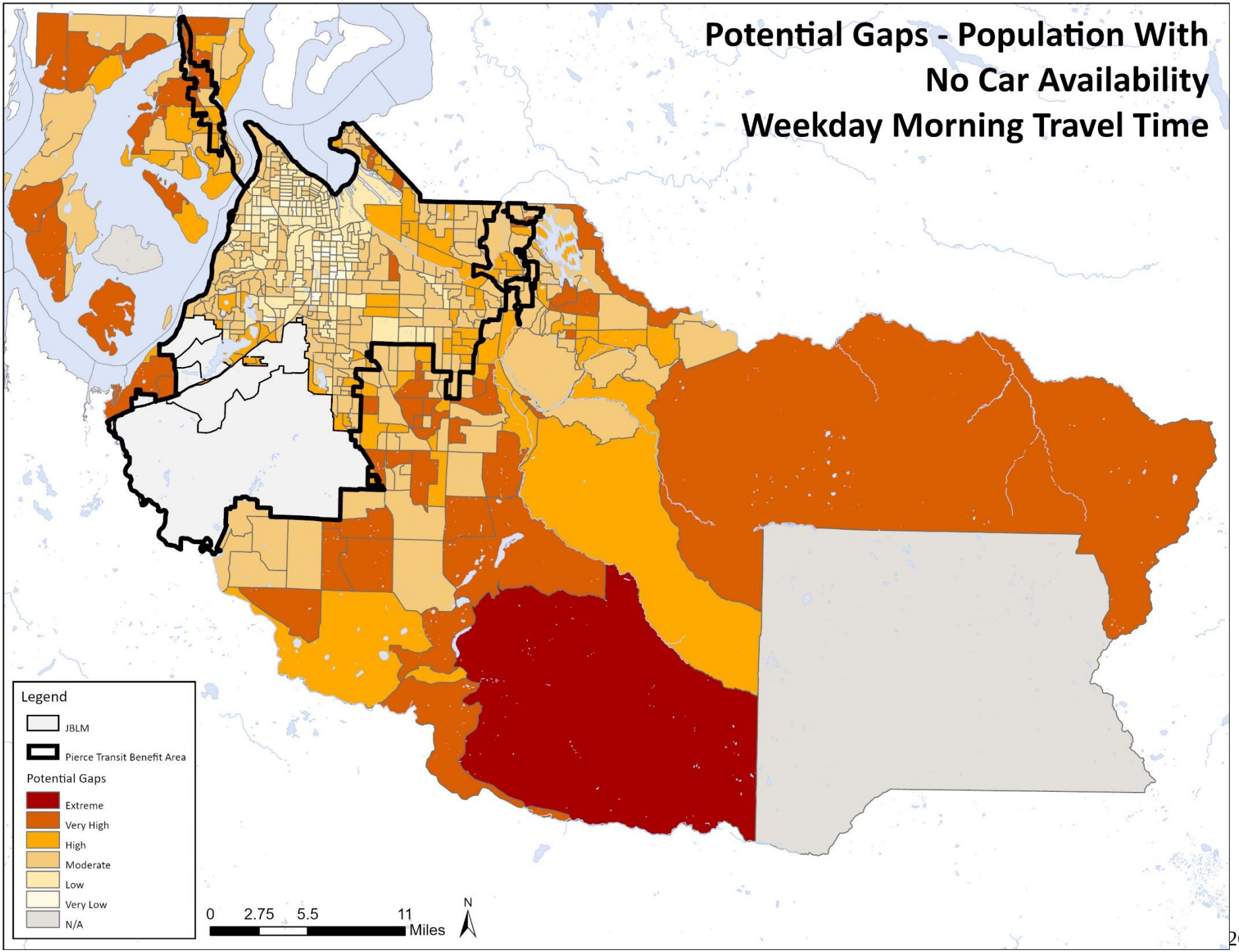
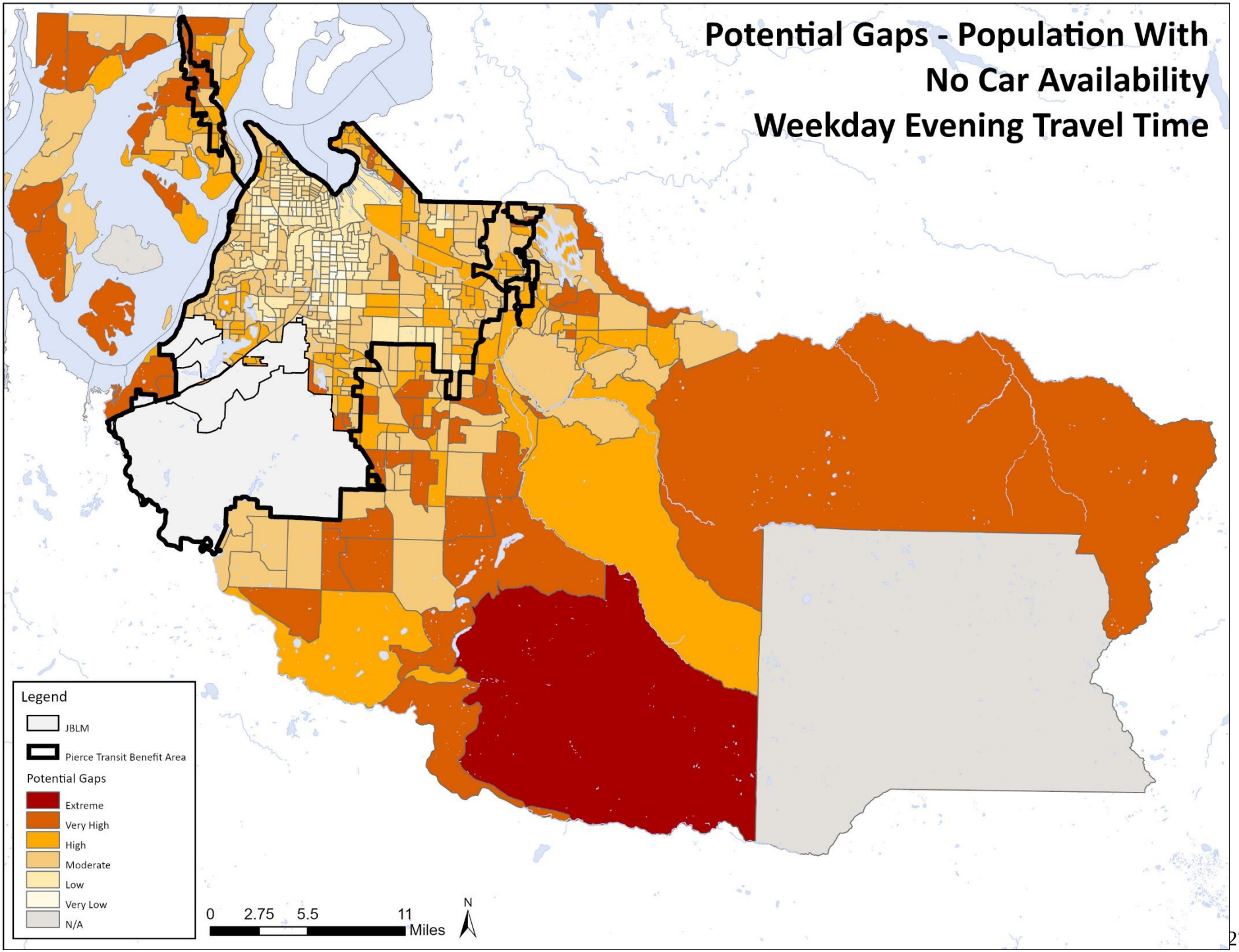

Potential Gaps - Population With
No Car Availability
Weekday Morning Travel Time
Legend
JBLM
Pierce Transit Benefit Area
Potential Gaps
Extreme
Very High
High
Moderate
Low
Very Low
N/A
0
2.75
5.5
11
Miles
N


Potential Gaps - Population With
No Car Availability
Weekday Evening Travel Time
Legend
JBLM
Pierce Transit Benefit Area
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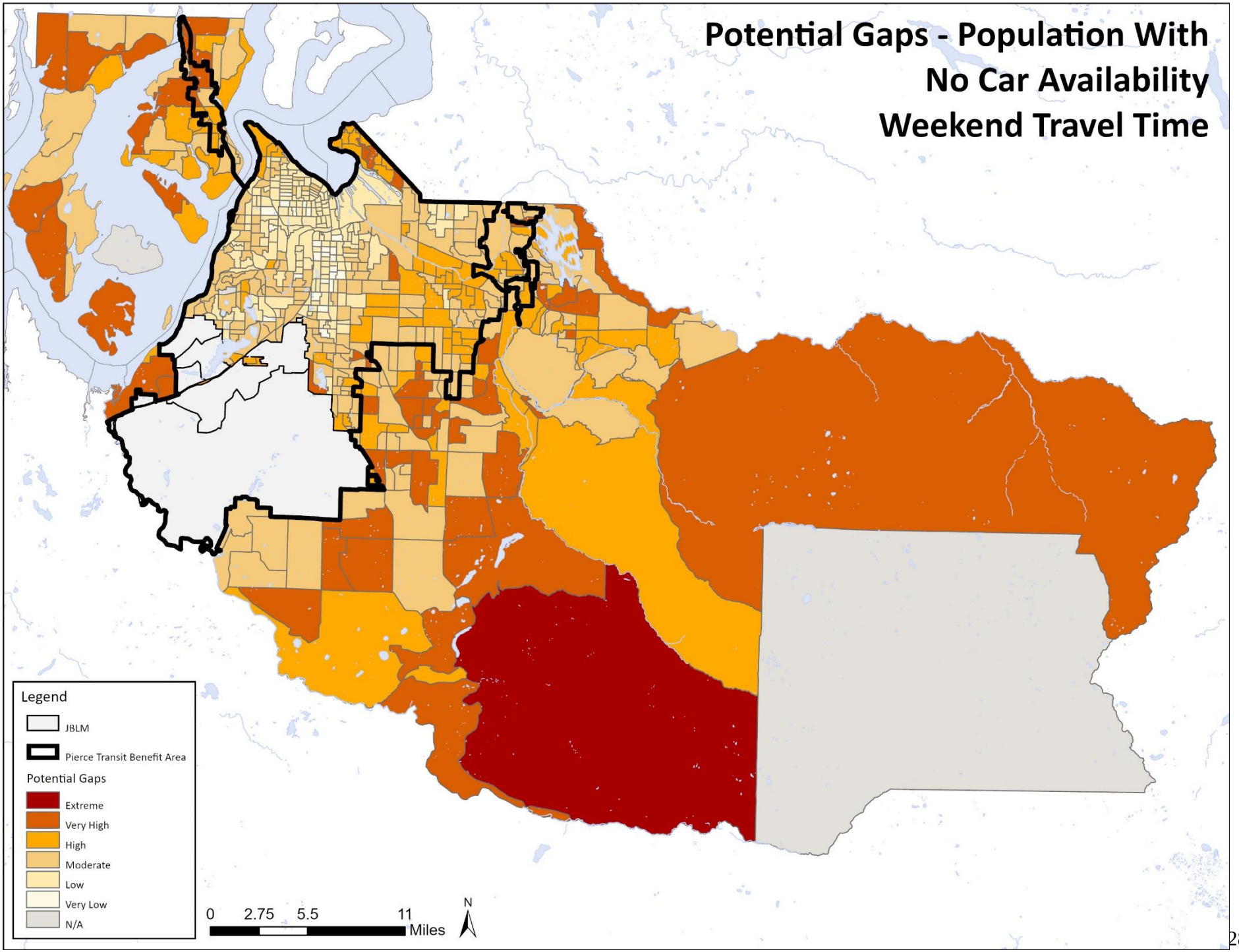
Potential Gaps - Population With
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Weekend Travel Time
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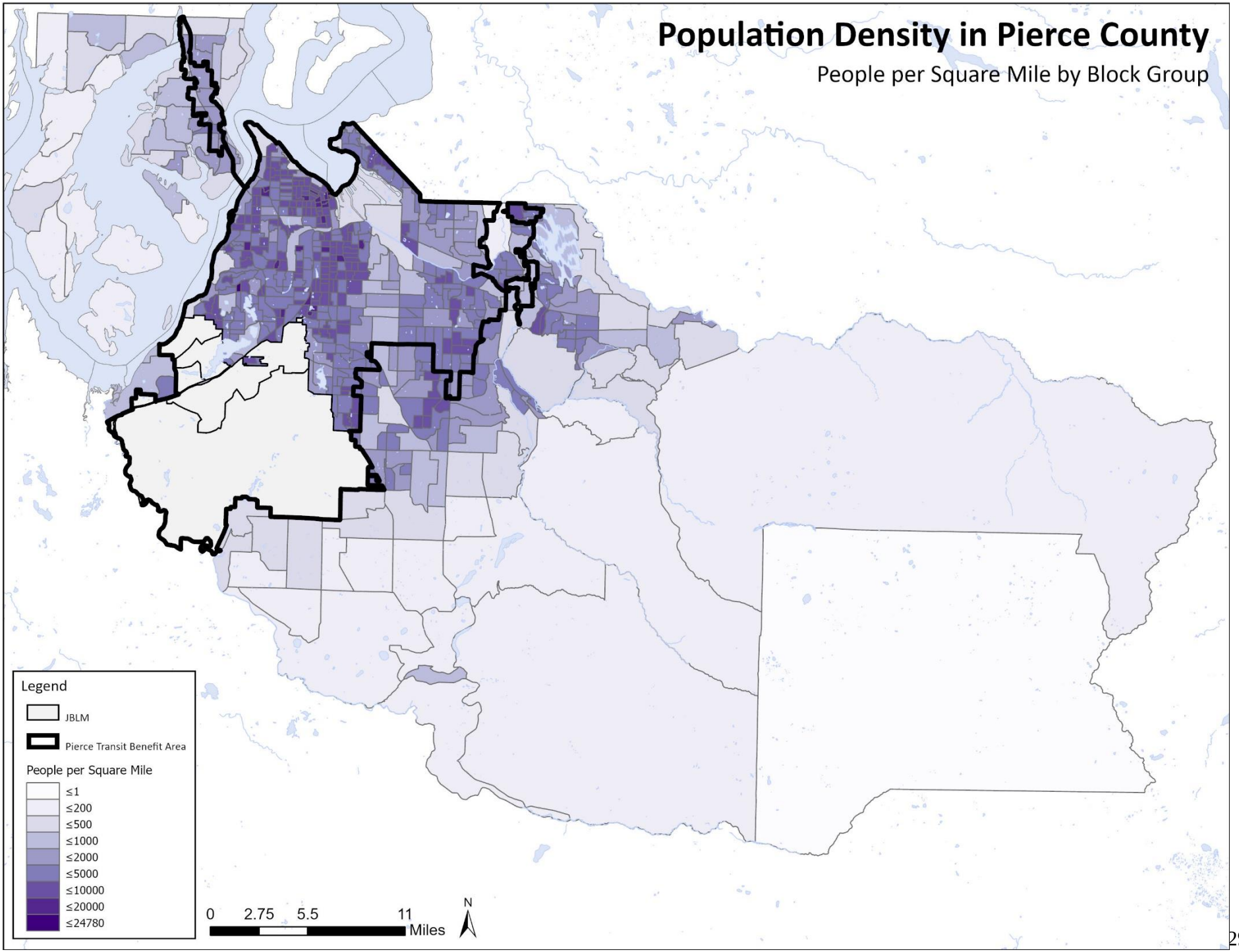
Population Density in Pierce County
People per Square Mile by Block Group
Legend
JBLM
Pierce Transit Benefit Area
People per Square Mile
≤1
≤200
≤500
≤1000
≤2000
≤5000
≤10000
≤20000
≤24780
0
2.75
5.5
11
Miles
N