National Analysis of the Populations Residing Near or Attending School Near U.S. Airports

Final Report

United States
Environmental Protection
Agency

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Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

NOTICE

EPA United States
Environmental Protection
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Table of Contents

1.0 Introduction

According to Federal Aviation Administration (FAA) records, there are approximately 20,000 airport facilities[1] in the U.S.[2] At the vast majority of these landing facilities, setbacks for residential development and recreational activity can be less than 50 meters (m) from aircraft operations.[3, 4] By contrast, commercial airports (defined by FAA as those with at least 2,500 passenger boardings each year), typically have a large spatial footprint which provides greater distance between aircraft activity and residential or recreational spaces compared with other airport facilities. There are approximately 500 commercial airports in the U.S.[5]

This report focuses on estimating the number of people who live and attend school near airports for the purposes of characterizing the magnitude of people potentially exposed to lead in air from piston-engine aircraft operations at airports. For the purposes of this report we are considering the population to be near an airport if they live in a census block that intersects the 500 m buffer of a runway or the 50 m buffer of a heliport. We also evaluated educational facilities that intersects the 500 m buffer of an airport runway. These buffer distances were selected due to results of air quality modeling and monitoring data for lead at and near airport facilities and one study reporting a statistically significant increase in children's blood lead for children living within 500 meters of an airport.[6] EPA and local air quality management district studies indicate that over a 3-month averaging time (the averaging time for the EPA National Ambient Air Quality Standard for Lead), the impact of aircraft lead emissions at highly active airports, extends to approximately 500 m downwind from the runway.[7, 8] These same studies suggest that on individual days, the impact of aircraft lead emissions can extend to almost 1,000 m downwind from the runway of a highly active airport (i.e., hundreds of take-off and landing events by piston-engine aircraft per day). The horizontal and lateral dispersion of the lead plume from aircraft emissions depends on several variables, including: wind direction, wind speed, the amount of aircraft activity (i.e., the number of take-off and landing operations), and the time spent by aircraft in specific modes of operation that have been demonstrated to greatly impact the magnitude of the ground-based lead concentrations (i.e., emissions occurring during pre-flight engine safety checks).

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[1] In this paper 'airport facility' refers to airports, balloonports, seaplane bases, gliderports, heliports, STOLports, and ultralight facilities.

[2] FAA Office of Air Traffic provides a complete listing of operational airport facilities in the National Airspace System Resources (NASR) database available at: https://www.faa.gov/airports/airport_safety/airportdata_5010/

[3] U.S. FAA, 2012. General Aviation Airports: A National Asset. Available at: https://www.faa.gov/airports/planning_capacity/ga_study/media/2012AssetReport.pdf

[4] ASTM International (2005) ASTM F2507 – 05 Standard Specification for Recreational Airpark Design.

[5] FAA National Plan of Integrated Airport Systems 2013-2017. Available at: https://www.faa.gov/airports/planning_capacity/npias/

[6] Miranda, M., Anthopolous, R., Hastings, D. (2011) A geospatial analysis of the effects of aviation gasoline on childhood blood lead levels. Environmental Health Perspectives 119:1513-1519.

[7] Carr, E., Lee, M., Marin, K., Holder, C., Hoyer, M., Pedde, M., Cook, R., Touma, J. (2011) Development and evaluation of an air quality modeling approach to assess near-field impacts of lead emissions from piston-engine aircraft operating on leaded aviation gasoline. Atmos Env 45: 5795-5804.

[8] South Coast Air Quality Management District (2010) General Aviation Airport Air Monitoring Study Final Report.

Section 2.0 describes the data and methods used to quantify the number of people living near an airport runway and/or heliport where piston-engine aircraft operate, as well as the number of children attending school in this environment. Section 3.0 provides the resulting population demographics for the population, by race, living near an airport runway and/or heliport. This section also provides the results of the number of children attending school near a runway and/or heliport by race and free or reduced-price school lunch eligibility (a proxy for socioeconomic status of the population located in close proximity to airports) as well as the number of children attending preschool near a runway and/or heliport. A discussion of the sources of uncertainty in the methods applied is presented in Section 4.0.

2.0 Data and Methods

In order to quantify the population living near an airport runway and/or heliport, we first developed layers[9] to represent the location of all airport facilities (referred to here as the 'airport layer') using ArcGIS 10.0.[10] For airports with available data, the airport layer is represented by the location of the runway(s) at the airport and is more specifically referred to as the 'runway layer.' For airport facilities where data are not available to identify the location of the runways, the airport facility centroid represents the facility in the airport layer and is more specifically referred to as the 'facility layer.' The airport centroid is the approximate geometric center of all usable runways.[11]   We then developed buffers around each layer element that extend out to 500 m from the airport runway and 50 m from heliport centroids. We intersected the resulting buffers with 2010 U.S. Census data (at the block level[12]) and data identifying the location of public and private schools and preschools. In this section we describe the methods used to create airport layers, airport buffer layers, a census block population layer, education facility layers and the intersection analysis of airport buffer layers with population and educational facility layers. A detailed description of the data sources is described below.

2.1 Creation of Airport Layers

The availability of airport runway data that can be used to create airport layers varies among the almost 20,000 airport facilities in the U.S. Therefore, depending on the data elements available, different data sources and methods were used to generate the U.S. airport layers. There are seven methods used to create the airport layers, that are focused on seven categories of airports based on data availability as described below.

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[9] A layer is "the visual representation of a geographic dataset in any digital map environment. Conceptually, a layer is a slice or stratum of the geographic reality in a particular area and is more or less equivalent to a legend item on a paper map. On a road map, for example, roads, national parks, political boundaries, and rivers might be considered different layers." (from: https://support.esri.com/en/other-resources/gis-dictionary/)

[10] ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

[11] U.S. Department of Transportation (2004) FAA Advisory Circular 150/5200-35, 5/20/2004, 'Submitting the Airport Master Record in Order to Activate a New Airport.'

[12] Census blocks "are statistical areas bounded by visible features, such as roads, streams, and railroad tracks, and by nonvisible boundaries, such as selected property lines and city, township, school district, and county limits and short line-of-sight extensions of roads." (from https://www.census.gov/newsroom/blogs/random-samplings/2011/07/what-are-census-blocks.html)

The first method uses geospatial linear runway data produced by the FAA Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA/BTS), which is part of the National Transportation Atlas Databases (NTAD) 2010 data. These data are referred to in this report as the FAA geospatial data. This geographic dataset of U.S. runways contains information on runway geometry and is derived from the FAA's National Airspace System Resource Aeronautical Data Product.
The remaining method categories (II-VII) were applied to airport facilities for which FAA geospatial data were not available. The data used in these categories came from FAA's Office of Air Traffic which provides a complete list of operational airport facilities in the National Airspace System Resources (NASR) database, which is partly populated by airport submissions of Airport Master Record (5010) forms. The electronic NASR data report can be generated from the NASR database and is available for download from the FAA's website.[13] Reports are available both at the runway level (referred to here as the "5010 runway data report"), and the airport facility level (referred to here as the "5010 airport data report"). Both reports are updated every 56 days with any newly available information.[14] For some airports, tabular runway data in the 5010 runway data report were provided that included fields for the latitude and longitude coordinates of the runway base end and for the runway reciprocal end (opposite to the base end) or just one runway end. The base end of a runway is the runway end located to the west of the north-south line and the reciprocal end is the runway end located to the east of the north-south line. Base runway ends have a magnetic heading of 01 to 18 and reciprocal runway ends have a magnetic heading of 19 to 36. These data from the 5010 runway data report were used to create runway layers in methods II and III, as described below. For airports without runway end coordinate data, data from the 5010 runway data report were supplemented with airport centroid latitude and longitude data from the 5010 airport data report to create runway layers in methods IV and V, as described below. For airports without relevant runway data, we used the airport centroid latitude and longitude from the 5010 airport data report to create the facility layers in methods VI and VII. Appendix Table A-1 provides the summary of airport and population data by method.

Methods Used to Create Airport Layers

I. Runway layers were created directly from FAA geospatial data for 6,090 runways at 4,146 facilities. This dataset was downloaded in March 2011[15] and contained information for 6,159 runways, however, we excluded runways at airport facilities that are closed[16] as well as runways at facilities in U.S. territories since the U.S. Census data used in this analysis does not provide complete coverage of the U.S. territories.[17] In total, 69 runways were excluded from this dataset.

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[13] "Airport Data & Contact Information" at https://www.faa.gov/airports/airport_safety/airportdata_5010/

[14] This analysis used the 5010 airport and runway data reports downloaded on March 5, 2012.

[15] National Transportation Atlas Databases. Washington, D.C.: U.S. Department of Transportation, 2010. (accessed at: https://www.bts.gov/geospatial/national-transportation-atlas-database)

[16] Determined by comparing the geospatial data with the February 7, 2012 and September 25, 2013 versions of the FAA 5010 facility data report, which indicates if an airport is open, closed indefinitely, or closed permanently.

[17] U.S. Census Bureau (Revised 2012). 2010 Census Summary File 1 – Technical Documentation.

II. For 414 runways at 385 facilities, the latitude and longitude coordinates of the runway base end and runway reciprocal end were provided in the 5010 runway data report. The runway layer was created using the 'points to line' tool in ArcGIS to connect the reciprocal and base end coordinates to generate a line representing the runway.

III. For 4 runways at 4 facilities, latitude and longitude data for only one runway end – either base or reciprocal end - were provided in the 5010 runway data report. The magnetic heading of the runway and the runway length were also provided in the FAA database for these facilities. The coordinates for the runway end without available longitude and latitude data were calculated using equations 1 and 2 in Figure 1 below. Equations 1 and 2 use trigonometric functions to determine the runway location given either the base end latitude and longitude or the reciprocal end latitude and longitude. The constants in the denominator of both equations convert the changes from meters to degrees. The conversion constants were calculated by dividing the circumference of the earth in meters by 360 degrees to determine the length of one degree latitude and longitude at the equator. Multiplying by cos X_1 in the denominator of equation 2 accounts for the fact that the distance of one degree of longitude decreases significantly as the point moves closer to one of the earth's poles.[18] The runway length (designated as 'RunwayLength' in the FAA 5010 runway data report) was represented by l. Where the reciprocal end coordinates were available, they were designated as X_1 for the reciprocal end latitude, and Y_1 for the reciprocal end longitude in equations 1 and 2. Using the information provided for the length of the runway and the reciprocal end coordinates, the base end of the runway was calculated. The latitude of the base end of the runway was designated as X_2, and the longitude of the base end of the runway was designated as Y_2. For the runways with available base end data (i.e., X_2, Y_2 coordinates in equations 1 and 2), and the equations were used to solve for the reciprocal runway end latitude and longitude designated as X_1, and Y_1, respectively. The runway identification data (designated as 'runway ID' in the FAA 5010 runway data report) is provided by FAA in the 5010 runway data report and is defined by FAA as the whole number nearest the one-tenth of the magnetic azimuth of the direction to which the runway is pointing (measured clockwise, with 0^{o} at due north). These runway IDs were used to calculate θ as follows: the base end runway ID was converted to an angle using Table A-2. For purposes of the equation, θ is measured in degrees, counterclockwise from due east, with due east having a value of 0 degrees. A runway pointing due east has a magnetic heading of 27 as defined by FAA, therefore a conversion chart in Table A-2 in the appendix links runway magnetic headings with the value of θ used in this equation. This value of θ was adjusted using magnetic declination of the closest 15-arc minute declination contour.[19]. The runway layer was created

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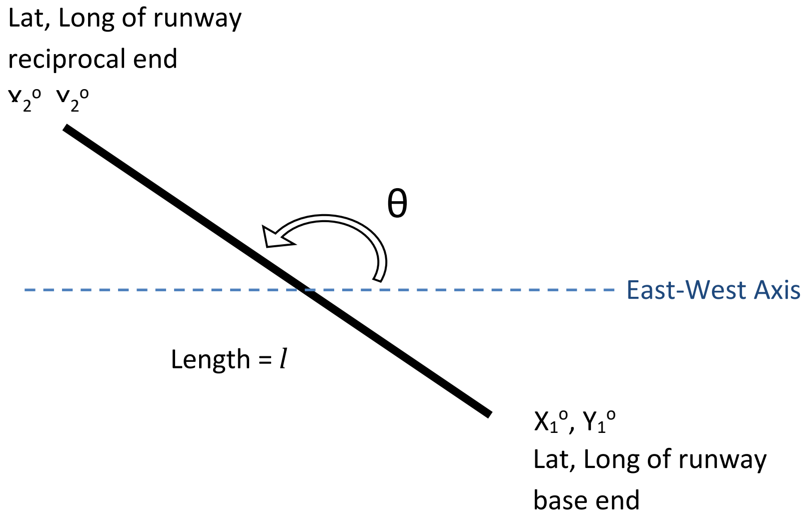
[18] The data for these conversion constants were obtained from https://oceanservice.noaa.gov/education/tutorial_geodesy/geo02_hist.html.

[19] The magnetic declination data were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center World Magnetic Model 2010 at https://www.ngdc.noaa.gov/geomag/data.shtml (follow links to: 'maps and shape files,' 'wmm2010,' 'shapefiles,' and 'WMM2010_Shapefile_15min_for_NGA.zip').

using the 'points to line' tool in ArcGIS to connect the reciprocal and base end coordinates to generate a line, representing the runway.



$$X_2^0 = X_1^0 + \frac{l\sin\theta}{111{,}112} \qquad (1)$$

$$Y_2^0 = Y_1^0 + \frac{l\cos\theta}{111{,}112\cos X_1^0} \qquad (2)$$

Figure 1. Calculation of Runway Latitude and Longitude Coordinates for Category III

Where X_1 and Y_1 are the latitude and longitude of the reciprocal end of the runway, respectively; X_2 and Y_2 are the latitude and longitude of the base end of the runway, respectively; theta (θ) is the runway angle from the east-west line.

IV. For 8,597 runways at 8,597 airports, the airport centroid (which is the center of the runway on the runway centerline) was used to create the runway layer.[20] The coordinates for the runway ends were calculated in a similar manner to those in category III. Both the base and reciprocal runway end coordinates were calculated from the reference point of the centroid (coordinate pair X_3, Y_3 in Figure 2). Base end coordinates, X_2, Y_2, were calculated using equations (3) and (4), which uses the distance of half the runway length ($l/2$) since the centroid bisects the runway. The reciprocal end coordinates, X_1, Y_1, were solved for using equations (5) and (6), again with the distance of $l/2$. In both sets of runway end calculations the runway identification data (designated as 'runway ID' in

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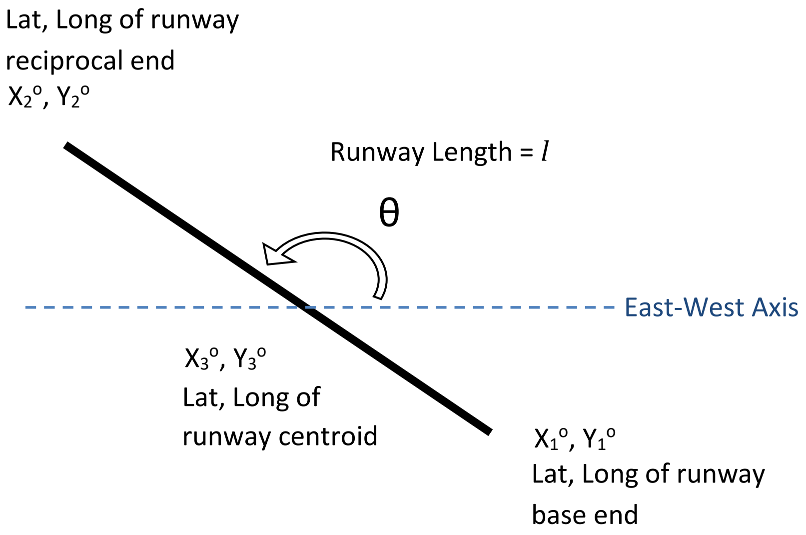
[20] U.S. Department of Transportation (2004) FAA Advisory Circular 150/5200-35, 5/20/2004, 'Submitting the Airport Master Record in Order to Activate a New Airport.'

the FAA 5010 runway data report) were used to calculate θ as follows: the base end runway ID was converted to an angle using Table A-2.[21] Runway IDs are based on the magnetic heading[22] of each runway end, therefore magnetic declination data from the NOAA National Geophysical Data Center World Magnetic Model 2010 were obtained[23] and the angle resulting from the use of Table A-2 was adjusted by the magnetic declination of the closest 15-arc minute declination contour to calculate the value of θ used in equations (3) through (6). The runway lines for these facilities, which comprise the runway layer, were then generated in ArcGIS using the 'points to line' tool to connect the calculated runway end latitude and longitude pairs.



$$X_2^0 = X_3^0 + \frac{(l/2)\sin\theta}{111{,}112} \tag{3}$$

$$Y_2^0 = Y_3^0 + \frac{(l/2)\cos\theta}{111{,}112\cos X_3^0} \tag{4}$$

$$X_1^0 = X_3^0 + \frac{(l/2)\sin\theta}{111{,}112} \tag{5}$$

$$Y_1^0 = Y_3^0 + \frac{(l/2)\cos\theta}{111{,}112 cos X_2^0} \tag{6}$$

Figure 2. Calculation of Runway Latitude and Longitude Coordinates for Category IV

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[21] θ is measured in degrees, counterclockwise from due east.

[22] The runway designation is the whole number nearest the one-tenth of the magnetic azimuth of the direction to which the runway is pointing (measured clockwise, with 0° at due north).

[23] https://www.ngdc.noaa.gov/geomag/data.shtml (follow links to: 'maps and shape files,' 'wmm2010,' 'shapefiles,' and 'WMM2010_Shapefile_15min_for_NGA.zip').

V. For 41 runways at 41 facilities, the runway ID in the 5010 runway data report was “ALL/WAY” (i.e., the runways were not identified with a runway magnetic heading because aircraft can take off and land in many directions). An additional facility had an ALL/WAY runway and a helipad. These facilities were all designated as seaplane bases and ultralight[24] facilities. The 5010 runway data report contained data on the length and width of each runway. Assuming the facility latitude and longitude was located at the center of the ALL/WAY runway and using the runway length and width data, coordinates for the four vertices of a rectangle were calculated[25]: the rectangle was assumed to be oriented such that the four sides ran north-south or east-west and that the two hypotenuses of the rectangle represented ℓ in Figure 1. The runway length was assigned from East to West and the runway width was assigned the distance from North to South. The method described in III above was then used to calculate the two latitude/longitude pairs for the ends of each hypotenuse, after geometrically determining the angle, θ, between each hypotenuse and the east-west mid-line of the rectangle (based on the given length and width). The four latitude/longitude pairs were calculated and connected with the ‘minimum bounding geometry’ tool (using the convex output type option) in ArcGIS to generate a rectangular polygon, which represented the possible landing and take-off paths at these facilities.[26] The rectangular polygons comprised the runway layer for these facilities.

VI. For 1,881 runways at 856 multi-runway facilities, the 5010 airport data report provided the airport centroid coordinates, which were used to create the facility layer for these facilities.[27] These facilities had runways which were in a parallel configuration at some airports, while others had runways that intersected at varying angles or were perpendicular or some combination of these configurations. Additionally, some of these facilities had one or more helipad. Therefore, the centroid coordinates could not be used to calculate the coordinates of the runway ends as was done for category IV facilities. Instead, the coordinate points comprised the facility layer for these facilities.

VII. There were 5,387 heliports[28] with only one helipad and 202 heliports with more than one helipad. The heliport centroid coordinates from the 5010 airport data report were the only

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[24] Ultralight facilities have activity by ultralight aircraft, which are single-occupant aircraft that if unpowered weigh less than 155 pounds, or if powered, weigh less than 254 pounds and have a fuel capacity less than 5 gallons. (https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=550836984d4438af2f5c15d80dff5c99&rgn=div5&view=text&node=14:2.0.1.3.16&idno=14)

[25] In this analysis these facilities were modeled with a rectangular runway area since the dimensions of the runway area that were given were length and width.

[26] It was assumed that the runway length represented the distance from East to West and the width represented the distance from North to South.

[27] U.S. Department of Transportation (2004) FAA Advisory Circular 150/5200-35, 5/20/2004, ‘Submitting the Airport Master Record in Order to Activate a New Airport.’

[28] A heliport is a facility with only helipads, so these facilities are separate from airports with runways that also have a helipad (which we have characterized in categories IV – VI in this document). For airport facilities that also

location data available, and this centroid location was used to create the facility layer for heliports. For heliports with one helipad, these centroid coordinates provide a reliable identification of the helipad location. For heliports with multiple helipads, visual inspection of a subset of the 202 multi-helipad facilities (using Google Earth software) suggested that there is no standard layout for the location of helipads at airfields with multiple helipads and they were largely removed from densely populated areas by significant setbacks or because the facility is in a rural area. The centroid provided in the 5010 report was used for this small subset of facilities as the best available data.

2.2 Creation of Airport Buffer Layer

For runways in categories I – IV above (15,156 runways at 13,183 facilities), 500 m round-end buffers, termed 'whole perimeter buffers' in this analysis, were created around each element in the runway layer using the ArcGIS 'buffer' tool. As described in the air quality modeling and monitoring studies by Carr et. al., 2011 and Feinberg, et. al., 2016,[29] the maximum impact area for ground-based lead emissions from piston-engine powered aircraft occur at a standardized location at or near each runway end where preflight run-up checks and take-off operations occur. In order to identify the population most highly exposed to ground-based emissions from aircraft during preflight run-up checks and take-off operations, an end-of-runway buffer was created. This was accomplished by first creating 500 m flat-end buffers around each runway line using the ArcGIS buffer tool. The 'symmetrical difference' tool was then used to subtract the 500 m flat-end buffers from the 500 m round-end buffers, creating 'end-of-runway buffers.' The end-of-runway buffers are effectively two semicircles with a 500 m radius, with centers at each end of a runway (Figure 3).

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have a helipad, we are not separately evaluating the population in a buffer around the helipad since the buffer around the runway would include the helipad at an airport facility.

[29] Feinberg, S., Heiken, J., Valdez, M., Lyons, J., Turner, J. (2016) Modeling of lead concentrations and hot spots at general aviation airports. *Transportation Research Record: Journal of the Transportation Research Board, No. 2569,* Transportation Research Board, Washington, D.C., 2016, pp. 80–87..

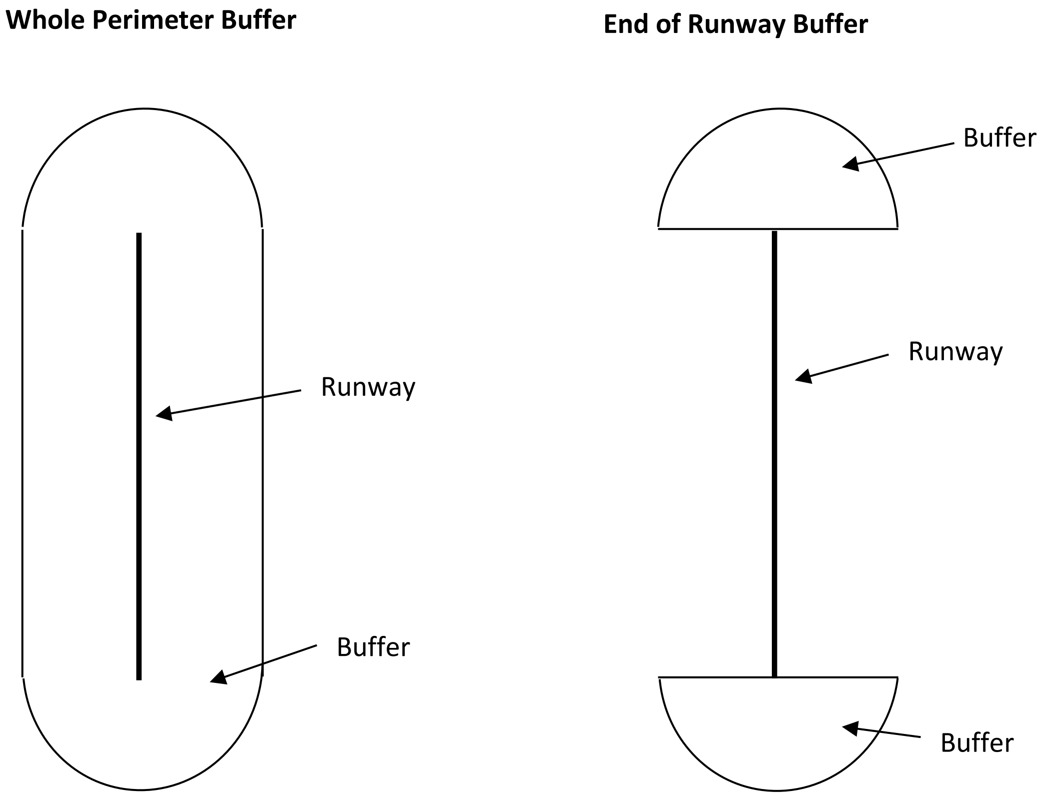

Figure 3. Whole Perimeter Buffer and End-of-Runway Buffer

For the category V runways (42 facilities), which are the "ALL/WAY" facilities, 500 m buffers were created around each rectangle runway shape in the runway layer using the ArcGIS buffer tool (Figure 4). Since aircraft can take off in any direction from these runways, no 'end-of-runway buffer' was created.

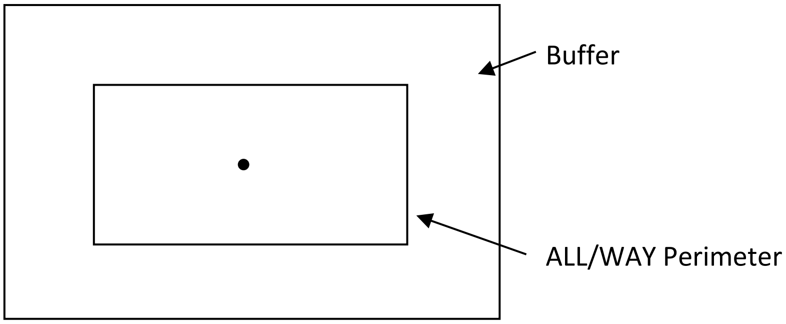

Figure 4. Buffer around ALL/WAY Airport Facilities in Category V

For the category VI runways (856 facilities), the only data available from which to determine the size of the buffer layer were the length of the runways. We calculated the average length of the runways at these facilities (737 m) and chose to generate a 1,000 m radius circular buffer around each facility centroid coordinate pair in the facility layer (Figure 5[30]). In section 4 we discuss the resulting uncertainties inherent in this approach.

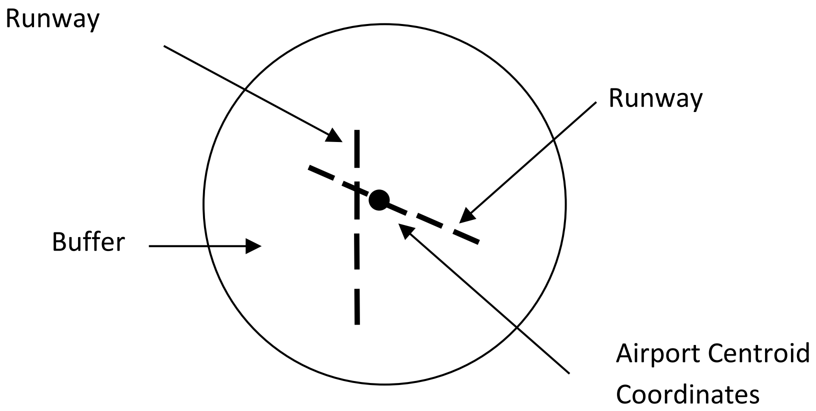

Figure 5. Buffer for Facilities with Multiple Runways and Only Airport Centroid Coordinate Data Available for Category VI

For the category VII helipads at heliports (5589 facilities), 50 m buffers around the heliport centroid coordinate pairs in the facility layer were generated using the buffer tool in ArcGIS (Figure 6).

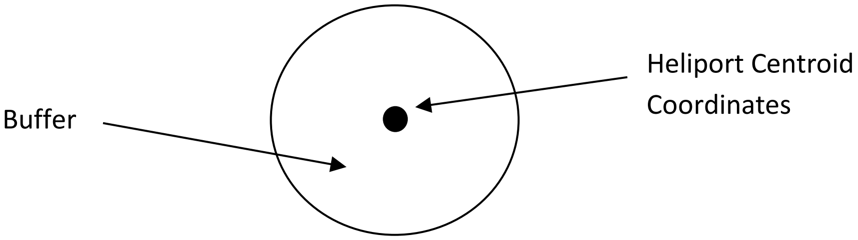

Figure 6. Buffer Layer for Heliports with One or More Helipad for Category VII

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[30] Note that the geographic location of runways in category VI are not available; the runways drawn in this figure are hypothetical and for illustrative purposes only.

2.3 Creation of U.S. Census Block Population Layer

Using ArcGIS 10.0, 2010 U.S. Census Summary File 1[31] tabular data at the block level was joined with the 2010 U.S. Census TIGER/Line Shapefiles[32] geospatial data at the Census block level to create the population layer used in this analysis.

2.4 Creation of Education Facility Layers

Public and private school data for grades kindergarten through twelfth grade (K-12th grade) were obtained from the U.S. Department of Education's Institute of Education Sciences National Center for Education Statistics.[33, 34] At the time this analysis was conducted, the most recent public school data available were for the academic year 2010 – 2011 and the most recent private school data available were for academic year 2009 – 2010. The public school and private school databases contained latitude and longitude coordinates of the reported school physical addresses,[35,36] which were imported into ArcGIS as point data.

Data for the location of all Head Start facilities (including Head Start, Early Head Start, and Migrant and Seasonal Head Start facilities) were obtained from the Department of Health and Human Services, Office of Head Start. The data contained latitude and longitude coordinates for each facility. Facility enrollment data were not available.

2.5 Intersection Analysis

Whole Perimeter Analysis

The 500 m 'whole perimeter' buffers for runways in categories I - IV, as well as the buffers for the category V - VII facilities were intersected with the population and education facility layers. Census block populations were included in the final population count if any part of a census block intersected the airport buffer. People living in census blocks that intersected the buffers of more than one facility or runway were included only once. The total population, by race, and the population of children 5 and younger in census blocks that intersected the 500 m whole perimeter buffers were calculated.

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[31] 2010 Census Summary File 1 [United States]/prepared by the U.S. Census Bureau, 2011 (accessed from: http://mcdc.missouri.edu/cgi-bin/uexplore?/pub/data/sf12010)

[32] Accessed from: https://www.census.gov/cgi-bin/geo/shapefiles2010/main

[33] http://nces.ed.gov/ccd/bat/

[34] https://nces.ed.gov/surveys/pss/pssdata.asp

[35] https://nces.ed.gov/ccd/CCDLocaleCode.asp

[36] https://nces.ed.gov/pubs2011/2011322.pdf

End-of-Runway Only Analysis

The 500 m 'end-of-runway' buffers for runways in categories I – IV were intersected with the population and education facility layers. As with the whole-perimeter analysis, census block populations were included in the final population count if any part of a census block intersected the airport buffer; and, as with the whole perimeter analysis, people living in census blocks that intersected more than one facility or runway buffer were included only once. The total population, by race, and the population of children 5 and younger in census blocks that intersected the 500 m end-of-runway buffers were calculated. End-of-runway buffers could not be created for category V – VII facilities because the precise location of the runway at these facilities was not known.

3.0 Results

Data comparing the population residing near an airport runway and/or heliport with the total U.S. population are shown in Tables 1 and 2 for the entire population and those 5 years of age and under, respectively. These data indicate that 5,179,000 people live in census blocks that intersected the 500 m whole perimeter buffers, 363,000 of whom are children age 5 and under.

Table 1: 2010 U.S. Population, by Race, Residing in Census Blocks that Intersect 500 meter Whole-Perimeter Buffers and 2010 U.S. Total Population, by Race

	Total Population	**White, alone**	**Black or African American, alone**	**American Indian or Alaska Native, alone**	**Asian, alone**	**Native Hawaiian or Other Pacific Islander, alone**	**Some Other Race, alone**	**Two or More Races**
U.S. Population Residing in Airport 500 m Whole-Perimeter Buffers	5,179,000	4,134,000 (79.8%)	463,000 (8.9%)	78,000 (1.5%)	154,000 (3.0%)	8,000 (0.2%)	215,000 (4.2%)	127,000 (2.5%)
Entire U.S. 2010 Population	308,746,000	223,553,000 (72.4%)	38,929,000 (12.6%)	2,932,000 (1.0%)	14,674,000 (4.8%)	540,000 (0.2%)	19,107,000 (6.2%)	9,009,000 (2.9%)

Table 2: Number of Children 5 Years and Under, by Age, Residing in Census Blocks that Intersect 500 meter Whole-Perimeter Buffers and U.S. Total Population 5 Years and Under, by Age

	Total Population 5 years and under	Under 1 year	Age 1 year	Age 2 years	Age 3 years	Age 4 years	Age 5 years
U.S. Population 5 Years and Under Residing in Airport 500 m Whole-Perimeter Buffers	363,000	58,000 (16.0%)	59,000 (16.3%)	61,000 (16.8%)	62,000 (17.1%)	61,000 (16.8%)	62,000 (17.1%)
Entire U.S. 2010 Population 5 Years and Under	24,258,000	3,944,000 (16.3%)	3,978,000 (16.4%)	4,097,000 (16.9%)	4,119,000 (17.0%)	4,063,000 (16.8%)	4,057,000 (16.7%)

Data comparing those residing in census blocks that intersect the 500 m end-of-runway buffers with those residing in census blocks that intersect the 500 m whole-perimeter buffers are compared in Tables 3 and 4 for the entire population and those 5 years of age and under, respectively. This analysis indicates that 3,630,000 people live in census blocks that intersected the 500 m end-of-runway buffers (89% of the population that lives in census blocks that intersected the 500 m whole-perimeter buffers at the same set of airports). Among this population, 261,000 were children age 5 and under.

Table 3: 2010 U.S. Population, by Race, Residing in Census Blocks that Intersect 500 meter End-of-Runway Buffers and Whole-Perimeter Buffers (category I – IV facilities only)[37]

	Total Population	White, alone	Black or African American, alone	American Indian or Alaska Native, alone	Asian, alone	Native Hawaiian or Other Pacific Islander, alone	Some Other Race, alone	Two or More Races
U.S. Population Residing in Airport 500 m End-of-Runway Buffers	3,630,000	2,955,000 (81.4%)	302,000 (8.3%)	57,000 (1.6%)	82,000 (2.3%)	5,000 (0.1%)	143,000 (3.9%)	85,000 (2.3%)
U.S. Population Residing in Airport 500 m Whole-Perimeter Buffers	4,078,000	3,281,000 (80.4%)	344,000 (8.4%)	68,000 (1.7%)	107,000 (2.6%)	7,000 (0.2%)	171,000 (4.2%)	100,000 (2.5%)

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[37] End-of-runway buffers were not able to be generated for category V, VI, or VII airport facilities, therefore the population which resides in census blocks that intersect the 500 m whole-perimeter buffers from only category I – IV airport facilities is shown in row two in order to enable comparison of the results of the two buffer types across the same set of airports.

Table 4: Number of Children 5 Years and Under, by Age, Residing in Census Blocks that Intersect 500 meter End-of-Runway Buffers and Whole-Perimeter Buffers (category I – IV facilities only)[38]

	Total Population 5 years and under	Under 1 year	Age 1 year	Age 2 years	Age 3 years	Age 4 years	Age 5 years
U.S. Population 5 Years and Under Residing in Airport 500 m End-of-Runway Buffers	261,000	41,000 (15.7%)	42,000 (16.1%)	43,000 (16.5%)	45,000 (17.2%)	45,000 (17.2%)	45,000 (17.2%)
U.S. Population 5 Years and Under Residing in Airport 500 m Whole-Perimeter Buffers	293,000	46,000 (15.7%)	48,000 (16.4%)	49,000 (16.7%)	50,000 (17.1%)	50,000 (17.1%)	51,000 (17.4%)

The total number of schools (K-12th grade) and student enrollment, by race/ethnicity, of public and private schools that intersected the 500 m whole-perimeter buffers is shown in Table 5, below. This analysis indicates that 163,000 K-12th grade students attend the 573 public and private schools that intersected the 500 m whole-perimeter buffers. The bottom half of the table provides private and public school and enrollment data for the entire U.S.

Table 5: Number of Schools (Public and Private) and Enrollment, by Race/Ethnicity, at Schools that Intersect 500 meter Whole-Perimeter Buffers and at All U.S. Schools (Public and Private)

	Number of Schools	Total Student Enrollment	White Students	Black Students	American Indian/ Alaska Native Students	Asian/ Native Hawaiian/ Pacific Islander Students[39]	Hispanic Students	Two or More Races Students
Private Schools within 500 m Whole-Perimeter Buffers	115	15,000	10,000 (66.7%)	1,000 (6.7%)	Less than 100 (0%)	1000 (6.7%)	2,000 (13.3%)	Less than 500 (2%)
Public Schools within 500 m	458	147,000	92,000 (62.6%)	16,000 (10.9%)	5,000 (3.4%)	5,000 (3.4%)	26,000 (17.7%)	4,000 (2.7%)

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[38] Similar to Table 3 and as described in footnote 40, Table 4 presents data for only category I – IV airport facilities in order to enable comparison of the two buffer types across the same set of airports.

[39] The public school data had a race/ethnicity category labeled 'Asian and Pacific Islander Students' while the private school data had a race/ethnicity category labeled 'Asian Students' and a separate category labeled 'Native Hawaiian and Pacific Islander Students.' In order to combine the results of the private and public school analysis, in this table the 'Asian/Native Hawaiian/Pacific Islander Students' column contains results from the public school data that correspond to the 'Asian and Pacific Islander Students' category and from the private school data that correspond to the sum of the counts from the 'Asian Students' and 'Native Hawaiian and Pacific Islander Students' categories.

Whole-Perimeter Buffers								
TOTAL	**573**	**163,000**	**101,000**	**17,000**	**5,000**	**6,000**	**28,000**	**4,000**
Total Private School Population	28,000	5,013,000	3,104,000 (61.9%)	397,000 (7.9%)	20,000 (0.4%)	249,000 (5.0%)	416,000 (8.3%)	119,000 (2.4%)
Total Public School Population	100,000	49,049,000	25,704,000 (52.4%)	7,812,000 (15.9%)	560,000 (1.1%)	2,442,000 (5.0%)	11,326,000 (23.1%)	1,153,000 (2.4%)
TOTAL	**128,000**	**54,062,000**	**28,808,000**	**8,209,000**	**579,000**	**2,690,000**	**11,742,000**	**1,272,000**

The total number of schools (K-12th grade) and student enrollment, by race/ethnicity, of public and private schools that intersected the 500 m end-of-runway buffers are shown in the top half of Table 6. This analysis indicates that 77,938 K-12th grade students attend the 254 public and private schools that intersected the 500 m end-of-runway buffers (compared to the 120,892 K-12th grade students who attend the 383 schools that intersected the whole-perimeter buffers at the same set of airport facilities).

Table 6: Number of Schools (Public and Private) and Enrollment, by Race/Ethnicity, at Schools that Intersect 500 meter End-of-Runway Buffers and Whole-Perimeter Buffers (category I – IV facilities only)[40]

	Number of Schools	Total Student Enrollment	White Students	Black Students	American Indian/Alaska Native Students	Asian/ Native Hawaiian/ Pacific Islander Students[41]	Hispanic Students	Two or More Races Students
Private Schools within 500 m End-of-Runway Buffers	48	5,443	3,564 (65%)	254 (5%)	17 (<1%)	242 (4%)	480 (9%)	48 (1%)

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[40] End-of-runway buffers were not able to be generated for category V, VI, or VII airport facilities, therefore the total number of schools (K-12th grade) and student enrollment, by race/ethnicity, of public and private schools that intersected the 500 m whole-perimeter buffers from only category I – IV airport facilities is shown in the bottom portion of the Table 6 in order to enable comparison of the results of the two buffer types across the same set of airports.

[41] The public school data had a race/ethnicity category labeled 'Asian and Pacific Islander Students' while the private school data had a race/ethnicity category labeled 'Asian Students' and a separate category labeled 'Native Hawaiian and Pacific Islander Students.' In order to combine the results of the private and public school analysis, in this table the 'Asian/Native Hawaiian/Pacific Islander Students' column contains results from the public school data that correspond to the 'Asian and Pacific Islander Students' category and from the private school data that correspond to the sum of the counts from the 'Asian Students' and 'Native Hawaiian and Pacific Islander Students' categories.

Public Schools within 500 m End-of-Runway Buffers	206	72,495	44,656 (62%)	8,463 (12%)	973 (1%)	2,503 (3%)	14,310 (20%)	1,590 (2%)
TOTAL	**254**	**77,938**	**48,220**	**8,717**	**990**	**2,745**	**14,790**	**1,638**
Private Schools within 500 m Whole-Perimeter Buffers	92	11,568	7,211 (62%)	812 (7%)	49 (0%)	580 (5%)	1,273 (11%)	207 (2%)
Public Schools within 500 m Whole-Perimeter Buffers	383	120,892	75,717 (63%)	12,065 (10%)	3,711 (3%)	4,517 (4%)	21,815 (18%)	3,067 (3%)
TOTAL	**475**	**132,460**	**82,928**	**12,877**	**3,760**	**5,097**	**23,088**	**3,274**

In addition to evaluating a potential in racial disparity among the children attending schools near airports, this analysis would ideally inform whether there is a socioeconomic disparity among the children attending schools near airports compared with the US school population generally. There are minimal data available in the U.S. Census at the block level to evaluate this question; data regarding free and reduced-price school lunches was used as a surrogate here for potential socioeconomic disparity. The total number of students (K-12th grade) eligible for free or reduced-price school lunches who attend public schools that intersected the 500 m whole-perimeter and end-of-runway only buffers is shown in Table 7. This analysis indicates that at the public schools that intersected the 500 m whole-perimeter buffers, 67,000 of the K-12th grade students were eligible for free or reduced-price school lunches. The bottom half of Table 7 indicates that at the public schools that intersected the 500 m end-of-runway buffers, 34,000 of the K-12th grade students were eligible for free or reduced-price school lunches (equal to 51% of the K-12th grade students who were eligible for free or reduced-price school lunches at schools that intersected the 500 m whole-perimeter buffers at the same set of airports).

Table 7: Number of Free and Reduced-Price School Lunch Eligible Students at all U.S. Public Schools and at Public Schools that Intersect 500 meter Whole-Perimeter Buffers and End-of-Runway Buffers[42]

	Number of Students Eligible for Reduced-price School Lunches	Number of Students Eligible for Free School Lunches	Total Number of Students Eligible for Free or Reduced-Price School Lunches
Total U.S. Public School Population	3,400,000 (7%)	20,082,000 (41%)	23,483,000 (48%)
Public Schools within 500 m Whole-Perimeter Buffers (all airport categories)	11,000 (8%)	56,000 (38%)	67,000 (45%)
Public Schools within 500 m End-of-Runway Buffers (only category I – IV facilities)	5,000 (8%)	29,000 (40%)	34,000 (47%)
Public Schools within 500 m Whole-Perimeter Buffers (only category I – IV facilities)	9,000 (8%)	47,000 (39%)	56,000 (47%)

The intersection of the Head Start preschool facilities with the 500 m whole perimeter buffers showed that 92 out of the 16,794 Head Start Facilities (including Head Start, Early Head Start, and Migrant and Seasonal Head Start facilities) were located within the 500 m whole-perimeter buffers.[43] The analysis of end-of-runway buffers identified 37 Head Start Facilities (compared to 84 for the whole-perimeter buffers for the same set of airport facilities) within the 500 m end-of-runway buffers.

4.0 Discussion

This section describes data limitations and sources of uncertainty in the demographic analysis method provided for airports in this report. We first describe the portion of the total populations reported in Table 1 that are derived from each of the methods used to create airport layers, I-VII, described above (this information is also summarized in Table A-1). We then discuss the uncertainty in population

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[42] End-of-runway buffers were not able to be generated for category V, VI, or VII airport facilities, therefore the total number of students (K – 12th grade) eligible for free or reduced-price lunches who attend public schools that intersected the 500 m whole-perimeter buffers from only category I – IV airport facilities is shown in the bottom portion of Table 7 in order to enable comparison of the results of the two buffer types across the same set of airports.

[43] Enrollment data are not available for the Head Start facilities.

included as living near a runway in urban versus rural areas and lastly, we describe uncertainty in the precise location of educational facilities.

4.1 Uncertainties in Developing Runway Layers

Geospatial data were available for 4,146 airport facilities, which are typically the busiest airports in the U.S.; method I was used for these facilities. The majority of these facilities are at airports that FAA considers significant to national air transportation and are therefore listed in the FAA National Plan of Integrated Airport System (NPIAS). These airports tend to be located in more densely populated areas of the country compared with the other roughly 15,000 airport facilities in the U.S. The population residing near the 4,146 facilities accounts for 35% of the population residing near any U.S. airport facility (Table A-1), as calculated in this analysis. For methods II, III and IV, the data provided in the 5010 airport data report and 5010 runway data report were assumed to provide an accurate record of the data elements needed to draw the runway line. Uncertainty in the creation of these runway layers is limited to the accuracy of the data provided to FAA for runway length, base and/or reciprocal end coordinates, airport centroid coordinates, and magnetic heading. The approach applied in methods II, III and IV accounts for 44% of the population reported in this analysis. Collectively, the most robust data available for developing runway layers (i.e., methods I through IV) accounted for 79% of the population residing near 13,132 airport facilities (approximately 68% of all U.S. airport facilities).

Facilities for which method V was used are largely seaports where aircraft are landing and taking off from water in a near-shore environment, and we introduced uncertainty in the population counts by assuming that the landing and take-off areas were rectangles oriented with the reported length along the due east-west axis and the reported width along the due north-south axis. If the landing and take-off areas were rotated around the north-south axis or if the length and width were switched, the specific census blocks included in the population count could vary, resulting in either an under- or over-estimate of the population. This method was used for 41 facilities and accounts for 1% of the total population reported in this analysis. While alternative assumptions could be made regarding runway orientation, it is expected that since the population living near these facilities is limited to onshore locations, different runway orientations with the requisite buffer would likely include the relevant census block(s). In addition, given the small number of facilities characterized using this method, we anticipate that the assumptions made do not impart a significant source of uncertainty in the overall results of the population analysis presented in this report. When conducting an analysis of potentially impacted populations near a specific seaport, data could be collected regarding dominantly used landing and take-off patterns.

The method used to create airport layers for category VI facilities creates uncertainty in the population estimates since buffers were drawn relative to the centroid of the airport facility instead of relative to the actual runways. The approach applied using this method accounts for 7% of the population reported in this analysis. As described above, for the method applied to these facilities we generated a

1,000 m radius circular buffer around the facility centroid. On average, the runway length at all of these facilities was 737 m with a minimum runway length of 61 m and a maximum runway length of 3,200 m. Therefore, the method used and the selected 1,000 m distance led to instances when the population included in the demographic count was from an area more distant than 500 m from the runway end and in other cases where the runway length extended beyond the 1,000 m buffer and the relevant population was therefore not included. Of the 856 facilities in this category, 789 (92%) are in areas defined as rural by the U.S. Census Bureau and therefore have low population densities.[44] We expect that the method used to estimate people living near these facilities is a reasonable approach for the purpose of conducting a national estimate of people living near airport facilities.

Beyond the specific methods used to create runway buffer layers, it is worth noting that for category I - IV facilities, runways were treated as lines.[45] In actuality, runways are rectangles with a width element. If the buffers had been drawn relative to the edges of the runway rectangle instead of the centerline, the buffers would have extended farther and in some instances would have intersected additional census blocks. In the March 5, 2013 version of the FAA 5010 runway data report the runways at airports had an average width of 92 feet.[46] Therefore on average, the buffers would have extended an additional 14 m in all directions if they had been drawn relative to the edges of runway polygons as opposed to the runway centerline.

Uncertainty related to the category VII facilities (heliports), is attributable to the relative scale of the buffers used around these facilities (50 m) and the much larger size of census blocks (which vary with population density). As a result, we anticipate that in general, the analysis conducted may overestimate populations that live within 50 m of a helipad. In contrast, the method used to create airport layers for the 202 heliports with more than one helipad is expected to result in an underestimate of the population in this analysis because the selection of a single centroid may exclude relevant helipad locations and nearby populations from this analysis. This underestimate is likely mitigated by the fact that several of these heliports have significant setbacks between helipads and populated areas.

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[44] The U.S. Census Bureau defines urban areas as densely settled core areas of census tracts with a density of more than 1,000 persons per square mile (ppsm) as well as census tracts that are contiguous to the core area and that have a population density of at least 500 ppsm; all remaining territory not included within an urban area is classified as rural. (from: "Urban Area Criteria for the 2010 Census" Department of Commerce Bureau of the Census, 76 FR 53030 – 53043 (August 24, 2011)).

[45] As described in section 2.0, buffers for category VI and VII facilities were drawn relative to the facility centroid point, therefore this uncertainty does not apply to those facilities. Buffers for category V facilities were drawn in a manner that incorporated the length and width elements, therefore this uncertainty does not apply to these facilities.

[46] Runways specifically at airports were analyzed by limiting the runway records to only those where the 'Site Number' variable ended in an 'A,' which is the identifier used by the FAA for airports. Runway records where the Site Number variable, for example, ended in an 'H' belonged to heliports and were therefore excluded.

4.2 Uncertainty Associated with the Estimate of Population Living Near a Runway

Uncertainty is associated with the estimate of people living near a runway because census block populations were included in the total population count if any part of a census block intersected the 500 m airport/runway buffer. Census blocks are the smallest geographic unit that contains demographic data such as total population by age, sex, and race. The U.S. Census Bureau describes census block size as follows: "Census blocks are generally small in area. In a city, a census block looks like a city block bounded on all sides by streets. Census blocks in suburban and rural areas may be large, irregular, and bounded by a variety of features, such as roads, streams, and transmission lines. In remote areas, census blocks may encompass hundreds of square miles." [47]

Since census block sizes differ greatly from urban to rural areas and airports are found in both urban and rural areas, we evaluated uncertainty in the population classified as living near a runway separately for urban and rural airports. We analyzed a subset of California airports: those categorized in Section 2.0 as method I airports (which provides a representative sample of airports in urban areas) and method IV airports (which represent mostly airports in rural areas). We selected California for this evaluation because this state has the second largest number of airport facilities among states in the US (965 airport facilities). Airports were classified as urban or rural based on US Census Bureau urban-rural classification boundaries.[48] The U.S. Census Bureau defines urban areas as densely settled core areas of census tracts with a density of more than 1,000 persons per square mile (ppsm) as well as census tracts that are contiguous to the core area and that have a population density of at least 500 ppsm; all remaining territory not included within an urban area is classified as rural.[49]

For this analysis we calculated the sum of the area for all census blocks intersecting each of the 500 m buffers around the California method 1 and 4 airport runways. We made the simplifying assumption that the total area of the census blocks intersecting the runway buffer is equidistant from the runway.[50] This simplifying assumption allows us to estimate the approximate distance that the population included in this analysis could live from a runway. The total area of a 500 m buffer around a 1,000 m runway is 1.79 km^2. If the summed census block area for a typical airport with a 1,000 m runway is 3.57 km^2, and if the area is equidistant from the runway, then people living in these census blocks reside up to 794 m from the runway. For the analysis presented here, actual runway lengths and their associated buffer areas were used.

Among the 103 airports in urban areas (from method 1 in California), the average summed census block area for those census blocks intersecting 500 m runway buffers is 2.9 times larger than the area of the

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[47] https://www.census.gov/newsroom/blogs/random-samplings/2011/07/what-are-census-blocks.html

[48] "Urban Area Criteria for the 2010 Census" Department of Commerce Bureau of the Census, 76 FR 53030 – 53043 (August 24, 2011).

[49] "Urban Area Criteria for the 2010 Census" Department of Commerce Bureau of the Census, 76 FR 53030 – 53043 (August 24, 2011).

[50] This assumption is more valid in urban areas than in rural areas.

500 m buffers around the runways at these airports. Making the simplifying assumption that the total area of the census blocks intersecting a runway buffer is distributed equidistant around the runway, this average summed census block area suggests that people in these census blocks live within 1,005 m of the runway. This suggests that in urban areas, the method described in this report captures the relevant population living near airports that may potentially experience an increase in lead concentration from aircraft emissions.

Among the 229 rural runways in California (method IV), the average summed census block area for those census blocks intersecting 500 m runway buffers was 23.3 times larger than the area of the 500 m buffer around these runways. Making the simplifying assumption that the total area of the census blocks intersecting a runway buffer is distributed equidistant around the runway, this average summed census block area suggests that people in these census blocks live within 2,441 m of the runway. This suggests that in rural areas, the method used is including people who live beyond the distance at which direct emissions from aircraft emissions may cause elevated concentrations of lead. Since these rural census blocks are sparsely populated, we expect that the misclassification of people imparts a small bias in the analysis. For example, in California, the airport runway that intersected census blocks with the largest summed area contributed 19 people to the analysis results (compared to an average of 1,372 to 1,675 people per runway in the urban airports in methods I and IV, respectively).[51] While there are a large number of rural airports at which the method described in this report might include people who live distant from an airport, comparisons with an alternative approach described below (i.e., dasymeteric data), indicate the approach used here appropriately estimates the number of people who live in rural areas near a runway.

Methods exist to estimate the number of people residing only in the portion of a census block intersecting a runway buffer. For example, one could assume that population density is constant throughout each census block and include only the fraction of a census block population equal to the fraction of the area of the census block that intersected the buffer. An alternative approach for estimating the population near an airport is to include the population of a census block only if the centroid of the block falls within the 500 m buffer. We elected not to use these methods, in part due to the computational burden, but also in recognition that there are multiple approaches to achieve the results desired for the purpose of conducting a national estimate of the population residing near airports.

A second approach for this assessment was evaluated as a sensitivity analysis; this approach involved the use of more spatially refined population data developed by EPA's Office of Research and Development (ORD). EPA's ORD has applied the dasymetric geospatial population mapping technique to 2010 U.S. census block level data by distributing census block population to 30 m square areas based on

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[51] This analysis was based only on California airports in Method IV. At this particular airport the census blocks that intersected the runway buffer had a total area 758 times larger than the airport's runway buffer; the census blocks had an average density of 0.014 people per km^2.

land cover, slope, and ownership data.[52] These data were created for use in EPA's EnviroAtlas[53] which has been externally peer reviewed. In order to further understand the potential uncertainty in population counts using the method described in this report, we conducted a sensitivity analysis using dasymetric data for method I airports (described in Section 2.0) for California. We analyzed the population near airports in urban areas separately from those in rural areas and compared the results to the population counts using the method described in this report.

Using the dasymetric data, we summed the population in California for method I urban airports using a runway buffer area of approximately 700 m. This summed population of 193,000 people compares closely with the 194,000 people residing in census blocks intersecting the 500 m buffer for method 1 urban airports. However, the two methods differ somewhat in the residences that are counted as being near a runway beyond the 500 m buffer; the analysis using the dasymetric data estimated the population in discreet 30 meter buffer zones from a runway, while the method described in this report includes residences throughout irregularly shaped census blocks, some of which may occupy area that is more than 1,000 m from a runway. One advantage of using the census block data for the purposes of this analysis is the availability of demographic characteristics by census block. The dasymetric data do not include age or racial characteristics of the population.

Using the dasymetric data, the summed population in a runway buffer area of approximately 950 m provided a population estimate equivalent to that from our method for rural Method I California runways (45,484 people using dasymeteric and 45,851 people using our method). Given the analysis described above, at rural runways in California method I the total census block areas were on average 16 times larger than the 500 m buffer area, which suggests that the population in rural areas with a runway tend to live in the portions of census blocks that are in closer proximity to the runway. This sensitivity analysis suggests the method described in this paper provides a reasonable approach for estimating the rural population living near runways.

4.3 Uncertainty Associated with Census Data and School Point Data

In addition to uncertainty in the methods used in this report, there is uncertainty associated with the input datasets. The US Census Bureau recognizes uncertainties inherent to US Census Data reported and US Census Bureau researchers explore approaches to improve accuracy and reduce uncertainty. Sources of error in the census total count and demographics and include omissions, duplications, erroneous enumerations, and errors of geography and demographic characteristics. The Census Bureau employs approaches to measure error including dual-

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[52] The method incorporated the National Land Cover Dataset (NLCD) with the assumption that individuals will not live in areas that are classified as open water, ice/snow, or wetlands. Additionally, public lands and areas with slopes greater than 25% were also considered uninhabitable. Other vegetated and developed areas were considered habitable and were assigned population density probabilities based on land cover class. (from: https://enviroatlas.epa.gov/enviroatlas/DataFactSheets/pdf/Supplemental/DasymetricAllocationofPopulation.pdf)

[53] https://www.epa.gov/enviroatlas

systems estimation and demographic analysis.[54] These uncertainties are not expected to have a significant impact on the results presented in this report.

Since children are a highly susceptible population to the uptake and impacts of lead, we included an evaluation of the proximity of schools and preschools to airport runways. U.S. public and private K-12th grade school data and Head Start preschool data were only available as point data (i.e., represented by a single latitude/longitude pair), which was intersected with the airport buffer layers. However, many school campuses have multiple sports fields and/or playground areas and can cover large areas of land. The results of the intersection analysis, therefore, are subject to uncertainty since inclusion of a K-12th grade school or Head Start preschool is dependent on where the school coordinates fall within the school's actual campus.

In addition, the Head Start preschool data represent only a subset of early education and care programs that serve children and infants. There are additionally the center-based, school-based and in-home preschool facilities for which there is no national database available for this analysis. The absence of information regarding proximity of these facilities to aircraft lead emissions may significantly underestimate this potentially exposed, susceptible population.

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[54] National Academy of Science, Engineering and Medicine (2007) Research and plans for coverage measurement in the 2010 Census. National Academy Press, available at: www.nap.edu/download/11941.

APPENDIX

Table A-1: Airport and Population Data by Method of Analysis

	Number of Runways	Number of Facilities	Description of Available Data and Method of Airport Facility Layer Generation	Description of Buffer Layer Generation	Population[55]
Method I	6,090	4,146	FAA GIS data.	500 m buffer around runway line	1,809,131 (35%)
Method II	414	385	FAA 5010 runway report had latitude/longitude coordinates for both the runway base and reciprocal ends.	500 m buffer around runway line	98,113 (2%)
Method III	4	4	FAA 5010 runway report had latitude/longitude coordinates for either the runway base or reciprocal end. Runway length, the available runway end coordinates, and the magnetic heading of the runway were used to calculate the latitidue/longitude coordinates of the opposite runway end.	500 m buffer around runway line	624 (0.01%)
Method IV	8,597	8,597	FAA 5010 runway report did not have latitude/longitude coordinates for either the runway base or reciprocal end. Theses are facilities with only one runway so runway length, facility centroid coordinates, and the magnetic heading of the runway were used to calculate the latitidue/longitude coordinates of both runway ends.	500 m buffer around runway line	2,195,125 (42%)
Method V	41	41	FAA 5010 runway data report identified the runway ID as "ALL/WAY." Centroid coordinate along with the runway width and length were used to calculate the four coordinate pairs of the rectangle representing this runway area.	500 m buffer around runway rectangle polygon	65,124 (1%)
Method VI	1,881	856	These facilities are multi-runway facilities with no runway specific coordinates. The facility centroid coordinates were used to create this layer.	1000 m buffer around facility centroid	361,577 (7%)
Method VII	5,978	5,589	These facilities are heliports. The heliport centroid coordinates were used to create this layer.	50 m buffer around facility centroid	740,486 (14%)

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[55] Numbers in this column do not sum to the analysis total of 5,179,455 people from Table 1 since the population from a census block that intersects more than one airport buffer is only included once in the Table 1 result but here, the population from a census block that intersects more than one airport buffer is included in the total for each method type in the column 'Population' to which it applies.

Table A-2: Conversion from Runway Heading to θ (degrees)

Runway Heading	θ (in degrees)
01	260
02	250
03	240
04	230
05	220
06	210
07	200
08	190
09	180
10	170
11	160
12	150
13	140
14	130
15	120
16	110
17	100
18	90
19	80
20	70
21	60
22	50
23	40
24	30
25	20
26	10
27	0
28	350
29	340
30	330
31	320
32	310
33	300
34	290
35	280
36	270
NW	135
SE	315
NE	45
SW	225
N	90
S	270
E	180
W	0