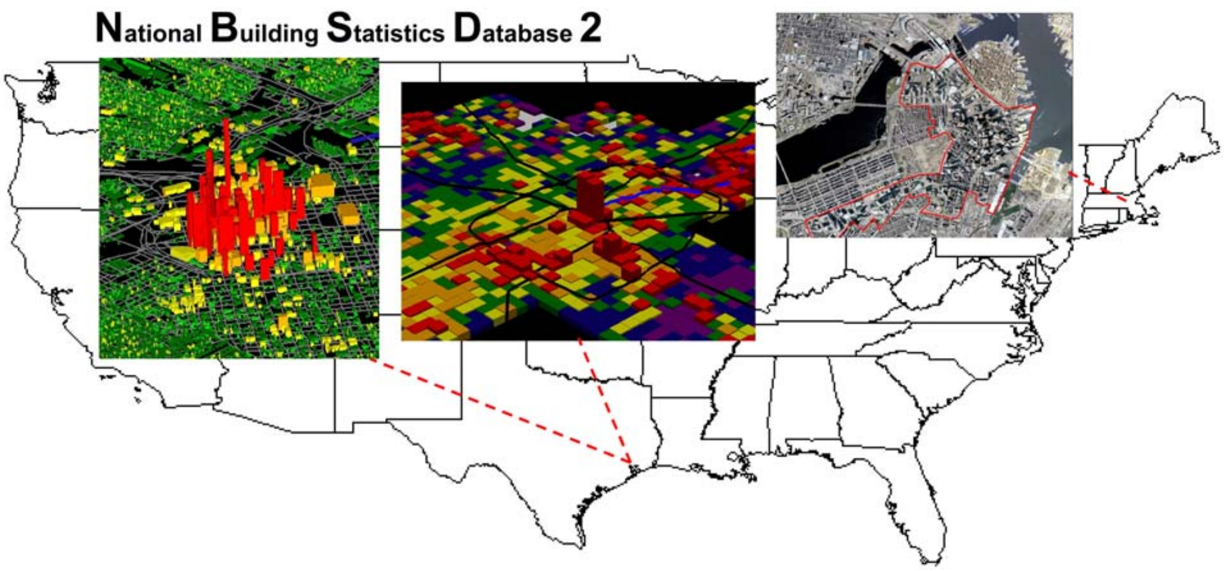
National Building Statistics Database
Version 2



Final Report for the National Building Statistics Database, Version 2 Project

by

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Disclaimer

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Acknowledgments

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1. Introduction

Mesoscale meteorological codes and transport and dispersion models are increasingly being applied in urban areas and numerous challenges exist (Brown 2001; Brown 2004). Representing urban terrain characteristics in these models is critical for accurate predictions of air flow, heating and cooling, and airborne contaminant concentrations in cities. A key component of urban terrain characterization is the description of building morphology (e.g., height, plan area, frontal area) and derived properties (e.g., roughness length, skyview factor) (Burian et al. 2004). In order to improve the quality and consistency of mesoscale meteorological and atmospheric dispersion modeling, a national dataset of building morphological statistics is needed. Currently, due to the expense and logistics of conducting detailed field surveys, building statistics have been derived for only small sections of a few cities. In most other cities, modeling projects rely on building statistics estimated from correlation to underlying land use using intuition and best guesses. There has been increasing emphasis in recent years to derive building statistics using digital building data or other data sources as a proxy for those data. Although there is a current expansion in public and private sector development of digital building data, at present there has not been an accumulation of this information at the national level in a consistent form of derived building parameters that are needed to run meteorological and transport and dispersion models.

This report describes the National Building Statistics Database, version 2 (NBSD2) developed by researchers at the University of Utah in collaboration with researchers at Los Alamos National Laboratory. The NBSD2 is a *second generation* compilation of building statistics derived using consistent methods and it replaces the original NBSD released in 2005. NBSD2 consists of a set of 13 building statistics computed at 250-m and 1-km horizontal spatial resolutions from three-dimensional digital building data for 44 metropolitan areas in the US. In addition, digital datasets of the urban extent of the 46 largest metropolitan areas in the US (based on 2000 Census population) and so-called tall building districts within those metropolitan extents have been derived and are included with the NBSD2. The building statistics combined with the urban extents and the tall building districts provide useful data for setting meteorological and dispersion model parameters. 3D building data for additional cities continues to be processed, methods are being refined to extrapolate the building statistics to metropolitan areas without available building data, and additional building statistics are being computed. These improvements to the NBSD2 will be included in subsequent updates.

2. NBSD2 Development

The NBSD2 is comprised of building statistics computed from three-dimensional building datasets covering parts of 44 cities in the US. Figure 1 shows the distribution of the 44 cities and 12 others that have additional ancillary information contained in NBSD2. The cities are distributed throughout the US, with 27 located west of the Mississippi River and 29 to the east. Regionally, eight cities are on the west coast, seven are in the southwest, three are in the mountain west, four are on the gulf coast, 15 are in the midwest, eight are in the southeast and Florida, and 11 are on the east coast. Table 1 lists the size of the metropolitan area and the population of the 44 NBSD2 cities.

The 44 cities included in the current database rank among the largest 46 metropolitan areas in the US (based on total population according to the 2000 Census). With the core building statistics databases from the 44 cities already compiled and presented in this report and accompanying CD, building statistics may eventually be inferred for any large metropolitan area in the U.S., although extrapolation methodologies currently lack sufficient accuracy.

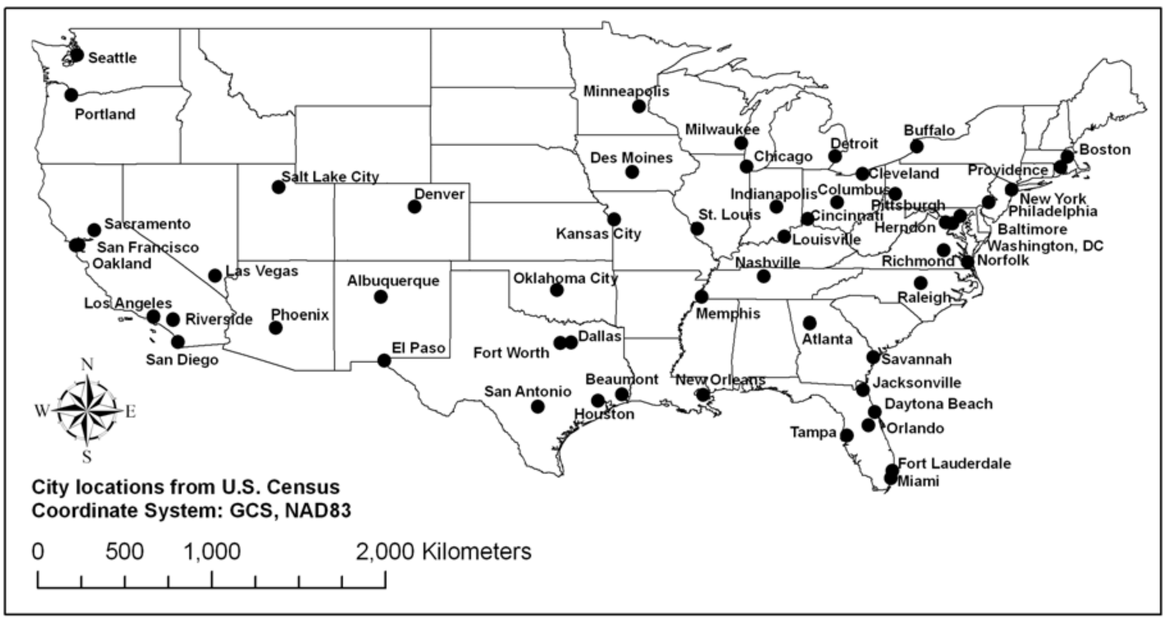


Figure 1. Cities in NBSD2 (Note: not all cities shown have building statistics computed).

Table 1. Characteristics of metropolitan areas *with building data* in NBSD2 (alphabetical).

City	Metro Area (km^2)	Population
Albuquerque, NM	15,461.8*	678,820+
Baltimore, MD	24,917.5*** [1]	2,491,254+++
Beaumont, TX	5,604.6*	376,256+
Boston, MA	16,779.4**	5,667,225++
Buffalo, NY	4,078.3*	1,142,121+
Chicago, IL	18,029.4***	8,885,919++
Cincinnati, OH	9,910.5***	1,960,995+
Cleveland, OH	9,398.3***	2,910,616++
Dallas, TX	23,685.5***	3,280,310+++
Daytona Beach, FL	4,138.7*	474,711+
Denver, CO	23,273.2***	2,417,908++
Des Moines, IA	4,494.5*	443,496+
Detroit, MI	17,080.9***	4,474,614+++
Fort Lauderdale, FL	8,204.0*** [2]	1,535,468+++
Herndon-Dulles, VA	24,917.5*** [1]	4,739,999+++ [1]
Honolulu, HI	1,561.4*	864,571+
Houston, TX	20,048.7***	4,493,741++
Jacksonville, FL	6,856.4*	1,056,332+
Kansas City, MO	14,065.6*	1,755,899+
Las Vegas, NV	102,420.1*	1,381,086+
Los Angeles, CA	88,361.1*** [4]	16,036,587++
Miami, FL	8,204.0*** [2]	2,175,634+++
Minneapolis, MN	15,776.3*	2,872,109+
New Orleans, LA	8,843.4*	1,305,479+
New York, NY	26,445.6***	20,196,649++
Oakland, CA	19,169.1*** [3]	2,348,723+++
Oklahoma City, OK	11,049.7*	1,046,283+
Orlando, FL	9,081.4*	1,535,004+
Philadelphia, PA	15,442.3*	4,949,867+++
Phoenix, AZ	37,913.6***	3,013,696+
Pittsburgh, PA	12,028.9*	2,331,336+
Portland, OR	18,090.0***	2,180,996++
Providence, RI	2,448**	1,125,639+
Raleigh-Durham, NC	9,081.7*	1,105535+
Richmond, VA	7,660.8*	961,416+
Riverside, CA	88,361.1*** [4]	3,200,587+++
Salt Lake City, UT	4,207.9*	1,275,076+
San Antonio, TX	8,654.5*	1,564,949+
San Diego, CA	10,937.8*	2,820,844+
San Francisco, CA	19,169.1*** [3]	6,873,645++
Savannah, GA	3,542.2*	288,426+
Seattle, WA	18,791.6***	3,465,760++
St. Louis, MO	16,631.1*	2,569,029+
Washington, DC	24,917.5*** [1]	4,739,999+++ [1]

* 1990 Metropolitan Statistical Area (MSA) (U.S. Census: www.census.gov/Press-Release/metro05.prn)
** New England County Metro. Area (NECMA) defined as of June 30, 1996; (www.census.gov/Press-Release/metro05.prn)
*** 1990 Consolidated MSA (CMSA) (www.census.gov/Press-Release/metro05.prn)
+ 2000 MSA (www.census.gov/popest/archives/1990s/MA-99-01.txt)
++ 2000 CMSA (www.census.gov/popest/archives/1990s/MA-99-01.txt)
+++ 2000 Primary MSA (PMSA) (www.census.gov/popest/archives/1990s/MA-99-01.txt)
[1] Part of Washington, DC CMSA
[2] Part of Miami CMSA
[3] Part of San Francisco CMSA
[4] Part of Los Angeles CMSA

The characteristics of the building datasets used to derive the NBSD are contained in Table 2. All data extents are smaller than the complete metropolitan area (Table 1), but are centered on the important tall building districts. The majority of the datasets were either obtained from commercial vendors (e.g., i-cubed, Vexcel, Inc., Urban Data Solutions) or extracted from airborne lidar data by the National Geospatial-Intelligence Agency (NGA) using a set of tools created by Science Applications International Corporation (SAIC) in collaboration with the Defense Threat Reduction Agency (DTRA). The Houston dataset is significantly larger than many of the other datasets because it was derived by University of Utah researchers by modifying an existing building footprint dataset available from the city engineering department. The modification involved comparing the existing footprints to high-resolution digital orthophotos and deleting buildings that did not appear in the orthophoto and digitizing buildings that did appear. The building heights were then derived by overlaying the modified footprint coverage onto a 1-m full-feature DEM produced from airborne lidar data. Additional details of each building dataset are included in section 3 of this report.

The following building statistics are included in NBSD2:

- Mean building height
- Standard deviation of building height
- Plan-area-weighted mean building height
- Height histograms (at 5-m height increments)
- Plan area fraction
- Plan area density (at 1-m height increments)
- Building roof area density (at 1-m height increments)
- Frontal area index
- Frontal area density (at 1-m height increments)
- Building surface-to-plan area ratio
- Complete aspect ratio
- Height-to-width ratio
- Sky view factor

The processing of the three-dimensional building datasets is performed using the Urban Morphological Analysis Processor (UMAP) (Burian et al. 2005). UMAP is a tool developed for use with the ESRI ArcGIS 9 geographic information system (GIS) software package. UMAP computes building statistics at a user-defined horizontal spatial resolution. UMAP was designed to derive gridded surface parameter datasets corresponding spatially to an atmospheric dispersion modeling domain. Although effective to compute urban morphological characteristics for large areas, UMAP is a research grade tool. UMAP documentation can be obtained from the research team at the University of Utah (contact: Steve Burian, burian@eng.utah.edu). A brief overview of each building statistic and corresponding calculation method is provided below. Greater explanation of the parameter and explanation of the UMAP approach to computation is included in the documentation.

Table 2. Characteristics of building datasets used to derive NBSD2 (listed alphabetically).

City	Building Data Extent (km^2)	Tall Building District* Extent (km^2)	Number of Buildings**
Albuquerque, NM	48.5	1.1	22,662
Baltimore, MD	383.5	4.6	79,324
Beaumont, TX	362.0	Not defined	64,672
Boston, MA	256.0	3.0	132,007
Buffalo, NY	24.3	3.1	6,133
Chicago, IL	154.1	9.8	47,197
Cincinnati, OH	506.3	2.9	155,408
Cleveland, OH	393.1	4.0	215,339
Dallas, TX	544.3	3.0	120,537
Daytona Beach, FL	439.1	Not defined	91,392
Denver, CO	141.4	5.9	70,209
Des Moines, IA	469.7	Not defined	113,664
Detroit, MI	506.6	10.5	250,900
Fort Lauderdale, FL	65.2	6.6	20,803
Herndon-Dulles, VA	287.7	Not defined	47,986
Honolulu, HI	375.4	Not defined	115,123
Houston, TX	1648.6	3.3	664,861
Jacksonville, FL	478.7	4.3	91,603
Kansas City, MO	357.0	8.9	110,883
Las Vegas, NV	200.0	10.6	85,030
Los Angeles, CA	262.8	2.5	107,864
Miami, FL	129.3	7.7	35,995
Minneapolis, MN	399.4	9.3	203,062
New Orleans, LA	26.1	3.7	13,836
New York, NY	321.2	32.5	43,513
Oakland, CA	54.8	Not defined	22,730
Oklahoma City, OK	27.0	0.7	6,333
Orlando, FL	491.9	Not defined	104,865
Philadelphia, PA	528.0	9.9	134,510
Phoenix, AZ	16.8	1.7	7,997
Pittsburgh, PA	544.8	5.9	183,672
Portland, OR	9.5	1.8	2,000
Providence, RI	503.0	4.2	164,929
Raleigh-Durham, NC	388.4	Not defined	86,389
Richmond, VA	443.8	Not defined	101,139
Riverside, CA	393.4	1.0	162,034
Salt Lake City, UT	140.0	1.6	61,669
San Antonio, TX	770.7	3.2	280,280
San Diego, CA	301.4	3.2	110,432
San Francisco, CA	185.2	4.5	46,935
Savannah, GA	395.1	Not defined	65,015
Seattle, WA	145.9	2.3	60,635
St. Louis, MO	433.9	4.1	149,877
Washington, DC	41.7	13.2	5,756

* Tall building districts were defined using digital orthophotos. The process is described in more detail in Section 4.
** The number in this column represents the number of features in the dataset. The data represent in some cases multiple buildings with a single feature or a single building with multiple features. Therefore, the number of buildings listed in the column is an approximation. Review of the data indicated that the number of misrepresentations is limited and the approximation should be fairly accurate.

Building Height Characteristics

The mean and standard deviation of building height are calculated using the following equations:

$$\bar{h} = \frac{\sum_{i=1}^{N} h_i}{N} \tag{1}$$

$$s_h = \sqrt{\frac{\sum_{i=1}^{N} \left(h_i - \bar{h}\right)^2}{N-1}} \tag{2}$$

where $\bar{h}$ is the mean building height, s_h is the standard deviation of building height, h_i is the height of building i, and N is the total number of buildings in the area. The average building height weighted by building plan area is calculated using the following equation:

$$\bar{h}_{AW} = \frac{\sum_{i=1}^{N} A_i h_i}{\sum_{i=1}^{N} A_i} \tag{3}$$

where $\bar{h}_{AW}$ is the mean building height weighted by building plan area, and A_i is the plan area at ground level of building i.

The building height histograms are simply computed by summing the number of buildings with rooftop height falling within specified height increments. Height increments of 5-m were used.

Building Plan Area Fraction (λ_p)

The building plan area fraction (λ_p) is defined as the ratio of the plan area of buildings to the total surface area of the study region:

$$\lambda_p = \frac{A_p}{A_T} \tag{4}$$

where A_p is the plan area of buildings at ground level, i.e., the footprint area, and A_T is the total plan area of the region of interest, i.e., computational grid cell of UMAP. The computed value of the plan area fraction is dependent on the size of the area or the specific land use types included in the calculation. In most cases the plan area fraction will vary significantly from one city block to the next because of the heterogeneous nature of the urban landscape. The appropriate size of the calculation element should be chosen such that the characteristics of interest in the urban area are homogeneous and discernible.

Building Plan Area Density ($a_P(z)$)

The building plan area density ($a_P(z)$) is defined as the average building plan area within a height increment divided by the volume of the height increment:

$$a_p(z) = \frac{\dfrac{1}{\Delta z}\displaystyle\int_{z-\frac{1}{2}\Delta z}^{z+\frac{1}{2}\Delta z} A_P(z')dz'}{A_T \Delta z} \tag{5}$$

where, $A_p(z')$ is the plan area of buildings at height z', A_T is the plan area of the site, and Δz is the height increment for the calculation. Since A_T is not a function of height it can be brought into the integral in the numerator producing:

$$a_p(z) = \frac{\dfrac{1}{\Delta z}\displaystyle\int_{z-\frac{1}{2}\Delta z}^{z+\frac{1}{2}\Delta z} \frac{A_P(z')}{A_T}dz'}{\Delta z} \tag{6}$$

Knowing $\lambda_P(z') = A_P(z')/A_T$ and assuming that the building plan area does not change appreciably within a small height increment Δz, eq. (6) can be approximated by:

$$a_p(z) \cong \frac{\lambda_P(z)}{\Delta z} \tag{7}$$

Roof Area Density ($a_r(z)$)

The roof area density ($a_r(z)$) is defined as the rooftop plan area per height increment Δz divided by the volume of the height increment:

$$a_r(z) = \frac{A_r(z)}{A_T \cdot \Delta z} = \frac{A_p\left(z - \dfrac{\Delta z}{2}\right) - A_p\left(z + \dfrac{\Delta z}{2}\right)}{A_T \cdot \Delta z} \tag{8}$$

where A_T is the total area within which buildings are contained. The rooftop area within a height increment Δz can be approximated by the difference between the building plan areas at two heights:

$$A_r(z) = A_p\left(z - \frac{\Delta z}{2}\right) - A_p\left(z + \frac{\Delta z}{2}\right) \tag{9}$$

where $A_p(z)$ is the plan area of buildings at the specified height and a flat-roofed assumption has been made. Analogous to the leaf area index used in the plant canopy community, the integration of $a_r(z)$ from a specified elevation above ground (z) to the height of the canopy (h_c) is equal to the building area index ($L(z)$):

$$L(z) = \int_z^{h_c} a_r(z')dz' \tag{10}$$

The integration of $a_r(z)$ from ground elevation to the canopy height (h_c) is equal to λ_P:

$$L(0) = \lambda_P = \int_0^{h_c} a_r(z')dz' \tag{11}$$

Building Frontal Area Index (λ_f)
The frontal area index (λ_f) is defined as the total area of buildings projected into the plane normal to the approaching wind direction (A_{proj}) divided by the plan area of the study site (A_T):

$$\lambda_f\ (\theta) = \frac{A_{proj}}{A_T} \tag{12}$$

where θ is the wind direction. The λ_f value for each grid cell is determined for northerly, northeasterly, easterly, and southeasterly winds.

Frontal Area Density ($a_f(z)$)
The frontal area density ($a_f(z)$) is defined as:

$$a_f(z,\theta) = \frac{A(\theta)_{proj(\Delta z)}}{A_T \Delta z} \tag{13}$$

where $A(\theta)_{proj(\Delta z)}$ is the area of building surfaces projected into the plane normal to the approaching wind direction for a specified height increment (Δz), θ is the wind direction angle, and A_T is the total plan area of the study site. For a specified wind direction, the integral of $a_f(z)$ over the canopy height equates to λ_f.

Complete Aspect Ratio (λ_C)
The complete aspect ratio (λ_C) is defined as the summed surface area of roughness elements and exposed ground divided by the total plan area (Voogt and Oke 1997):

$$\lambda_C = \frac{A_C}{A_T} = \frac{A_W + A_R + A_G}{A_T} \tag{14}$$

where A_C is the combined surface area of the buildings and exposed ground, A_W is the wall surface area, A_R is the roof area, A_G is the area of exposed ground, and A_T is the plan area of the study site. A_C is calculated by summing the surface area of the buildings and the difference between the total plan area of the site and the plan area of buildings at ground level (i.e., the exposed ground surface). For dense urban areas with flat roofed buildings and without much vegetation, A_C can be approximated as the sum of the plan area of the site and the area of building walls (not including rooftops).

The rooftop surface area is calculated assuming the rooftops are flat, which introduces some error. Another source of error is the neglect of the surface area of trees and bushes. Grimmond and Oke (1999) found the surface area of trees and bushes to be an important component of the complete surface area, especially in residential areas. These limitations will be addressed in future revisions of NBSD2.

Building Surface Area to Plan Area Ratio (λ_B)

The building surface area to plan area ratio (λ_B) is defined as the sum of building surface area divided by the total plan area:

$$\lambda_B = \frac{A_R + A_W}{A_T} \tag{15}$$

where A_R is the plan area of rooftops, A_W is the total area of non-horizontal roughness element surfaces (e.g., walls), and A_T is the total plan area of the UMAP grid cell. The computation is based on a flat-roof assumption.

Height-to-Width Ratio (λ_S)

The height-to-width ratio (λ_S) (also called the street aspect ratio) is calculated for two buildings by dividing the average height by the distance between the two buildings:

$$\lambda_S = \frac{(H_1 + H_2)/2}{S_{12}} \tag{16}$$

where H_1 is the height of the upwind building, H_2 is the height of the downwind building, and S_{12} is the horizontal distance between the two buildings (i.e., the canyon width). Figure 2 illustrates the measures used to compute λ_S. The calculation of λ_S is performed for each pair of adjacent elements in a building array, which can be very tedious for the complex building shapes and patterns in a city. For idealized arrangements of buildings, the calculation of an average λ_S can be approximated by taking the average building height divided by the average width between buildings (Grimmond and Oke 1999):

$$\overline{\lambda_S} \cong \frac{\overline{z_H}}{\overline{W}} \tag{17}$$

where $\overline{z_H}$ is the average building height and $\overline{W}$ is the average distance between buildings.

Due to the large number of buildings in real cities, an automated approach is warranted. Because of the complexity of the urban environments and the difficulty in estimating the average distance between two buildings, the simplified methodology described by eq. (17) was not used. Instead, λ_S was computed along linear traverses across the city at different angles using Eq. (16). This calculation strategy involved converting the building database into a raster digital elevation model (DEM – a matrix of numbers representing building height). Then traversing along each row or column of grid cells the height-to-width ratio was calculated between each pair of buildings. Since this approach yields λ_S values in non-preferred directions (e.g., running along a street, not across a street), the matrices of traverses done at different angles were then superimposed, and the largest height-to-width ratio at each grid cell was selected to represent the value of the grid cell. Aggregation to UMAP grid cell resolution is accomplished by simple averaging.

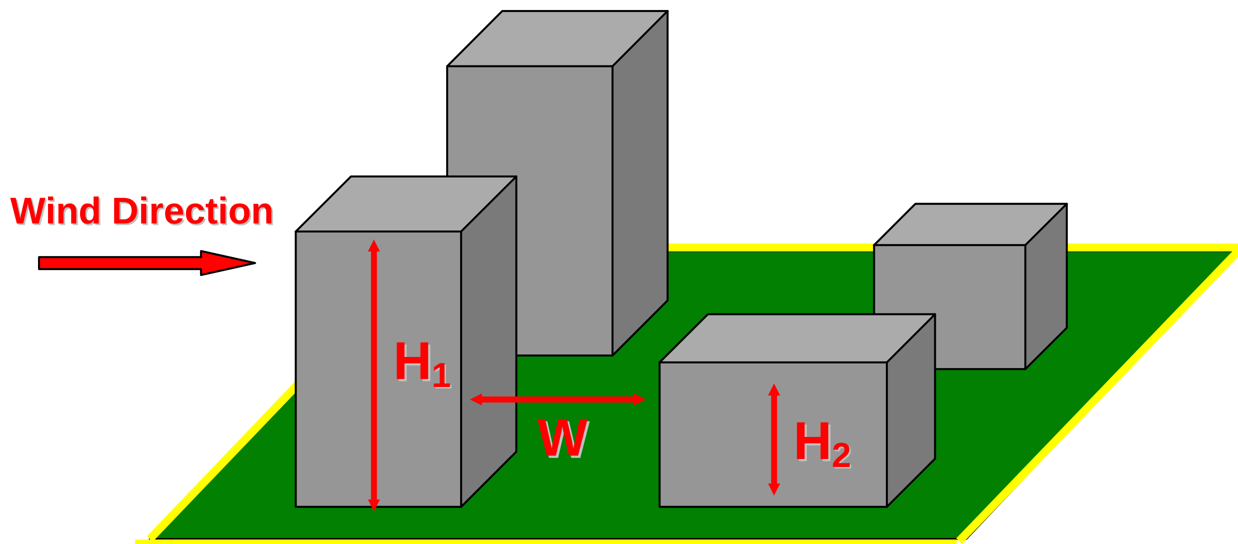


Figure 2. Illustration of height-to-width ratio parameter.

Sky View Factor

The sky view factor calculation involves sending out a ray at ground level searching for buildings. When a building is located, the angle created between the ground level and the top of the building at the point of interest is determined. The ray continues in the same direction encountering other buildings and calculating other angles. The largest angle encountered is selected for inclusion in the sky view factor calculation. Using the largest angle, the component of the sky view factor corresponding to the ray direction is calculated as follows:

$$\Psi_i = (\cos \beta_i)^2 \qquad (18)$$

This equation accounts for the necessary weighting of the incoming radiation based on the angle with respect to the horizon. The sky view factor is then determined by finding the average of the results from equation 18 for a series of rays distributed 360° in the horizontal from the point of interest:

$$\Psi_{sky} = \frac{1}{n}\sum_{i=1}^{n}\left(\cos\beta_i\right)^2 \qquad (19)$$

where i is the ray number, n is the total number of rays included in the calculation, and β_i is the maximum angle between a building top and the ground surface at the point of interest in the direction of ray i. The calculation approach is described in greater detail in the UMAP documentation.

3. NBSD2 Data

The building datasets were processed by UMAP to compute the building statistics at 250-m and 1-km horizontal spatial resolutions. Upon completion of processing, the resulting gridded building statistics were subjected to a rigorous quality assurance/quality control (QA/QC) process. A sample QA/QC summary document is included as Appendix I. The completed QA/QC sheet for each city is included on the NBSD2 CD. Appendix II contains sample plots of the derived building statistics.

Methodology

Digital building data for the 44 US cities containing footprint outlines and height values were processed to compute a set of gridded building statistics. The building data were read into a geographic information system (GIS) and the data were checked for errors and anomalies. After the building database was subjected to quality assurance tests, geospatial data processing was performed using UMAP (Burian et al. 2005) to generate a building statistics database at 250-m and 1-km horizontal spatial resolution. The following UCP's were computed for each grid cell in the data domain: mean building height, standard deviation of building height, plan-area-weighted mean building height, building surface-to-plan area ratio, complete aspect ratio, plan area fraction, frontal area index, height-to-width ratio, and sky view factor. In addition, height histograms, plan area density, roof area density, and frontal area density were determined in height increments of 5-m (histograms) and 1-m (others). These results have been incorporated into the NBSD2 in the form of (1) eight shapefiles (four for frontal area density, one for histograms, one for plan area density, one for roof area density, and one for the remainder of the UCP's) containing the gridded UCP's in the attribute table, (2) raster datasets derived from the shapefiles for all UCP's that are not a function of height, (3) ascii exports of the raster for all UCP's that are not a function of height (spatial reference header included), and (4) Excel spreadsheets containing all UCP's including those that were computed as a function of height.

Data

A majority of the Digital building data were obtained as explained previously, either from commercial vendors (e.g., i-cubed, Vexcel, Inc., Urban Data Solutions), or extracted from airborne lidar data by the National Geospatial-Intelligence Agency (NGA) using a set of tools created by Science Applications International Corporation (SAIC) in collaboration with the Defense Threat Reduction Agency (DTRA) in the form of ESRI 2D shapefiles. The characteristics of the data for each city and specifics of the UMAP processing are contained in Table 3. The data covered a small part of each city's Metropolitan area, focusing on the downtown area, as shown in the example figures in Appendices III and IV. Each building dataset extends over the area specified in Table 3 and as shown in Appendix III. The total number of buildings included in each 2D dataset is also shown in Table 3.

Processing

The 2D shapefile dataset contained the average height of rooftop for each building feature in the attribute table. The average height was used to compute the UCP's described below.

Grid Generation

The processing grids were generated with the Southeast corner starting point (UTM coordinates shown in Table 3) and the number of rows and columns arbitrarily selected to cover the building data extent. The grid was generated in the UTM (Zone and Datum specified in Table 3) projected coordinate system to be consistent with the building data. All X and Y coordinates delivered with the data corresponding to the center point of each grid cell projected in UTM with units of meters. The 250-m grid extent is also shown in Table 3 at the largest point with a total number of grid cells corresponding to this extent, although some do not contain buildings. Computations were performed for cells containing building data, while cells without building data or with a small fraction of the surface covered by buildings had their UCP's set to pre-determined values as described following Table 3.

Table 3. Summary of each city's projection, south-east corner grid location, data extent, grid extent and number of buildings. *Note: Some cities contain multiple grid processing sections. The total area and total number of buildings for each of these cities is shown.*

			Location of grid		Data Extent			1-KM Grids		250-m Grids		
City	**Section of City**	**Projection**	**Easting**	**Northing**	**(E-W) Length (km)**	**(N-S) Length (km)**	**Area (km^2)**	**# of rows**	**# of columns**	**# of rows**	**# of columns**	**# of buildings**
Albuquerque	Downtown	NAD83 Zone 13N	348671	3879167	11.6	8.7	100.9	9	12	29	47	22662
Baltimore, MD	Airport & Downtown	WGS84 Zone 18N	352375	4333978	23.75	24.25	575.9	25	24	97	95	79324
Beaumont, TX	Downtown	WGS84 Zone 15N	390320	3297362	27	35.25	951.8	36	27	141	108	64662
Boston	Downtown	WGS84 Zone 19N	319949	4679957	19.5	20.1	392.0	21	20	82	78	132007
Buffalo, NY	Airport	WGS84 Zone 17N	663980	4771985	6.05	4.04	24.4	5	7	17	25	6133
Chicago	Downtown	NAD83 Zone 16N	443520	4629750	7.2	16	115.2	16	8	65	36	27953
	Midway	NAD83 Zone 16N	435775	4624710	3.65	3.32	12.1	4	4	14	15	8617
	Ohare	NAD83 Zone 16N	421990	4642315	6.5	9.5	61.8	10	7	33	26	10623
						Total:	**189.1**				**Total:**	**36570**
Cincinnati, OH	Downtown	WGS84 Zone 16N	699612	4320375	29.6	20.6	609.8	21	30	83	119	155408
Cleveland, OH	Downtown	WGS84 Zone 17N	425988	4581996	34.4	18.5	636.4	19	35	74	137	215339
Dallas, TX	Airport	WGS84 Zone 14N	676620	3633990	13.77	16	220.3	16	14	64	56	18019
	Fort Worth	WGS84 Zone 14N	643380	3621984	16.26	14.02	228.0	15	17	57	66	22139
	Arlington	WGS84 Zone 14N	676640	3612000	16.07	16.01	257.3	17	17	65	65	29122
	Downtown	WGS84 Zone 14N	693990	3623990	18.02	16.01	288.5	17	19	65	73	51257
						Total:	**994.1**				**Total:**	**120537**

Daytona Beach, FL	Downtown	WGS84 Zone 17N	485515	3209215	26.03	34.03	885.8	35	27	137	105	91392
Denver	Downtown	WGS84 Zone 13N	497590	4396540	10.2	14	142.8	14	11	57	42	70209
Des Moines	Downtown	WGS84 Zone 15N	434320	4596005	24.3	27	656.1	27	25	108	97	113664
Detroit, MI	Airport & Downtown	WGS84 Zone 17N	301989	4671990	36.04	24.03	866.0	25	37	97	145	250900
Fort Lauderdale	Downtown	NAD83 Zone 17N	582570	2882218	7.01	9.44	66.2	10	8	38	29	20803
Herndon-Dulles, VA	Downtown	WGS84 Zone 18N	280901	4306499	20.6	19.5	401.7	20	21	79	83	47986
Honolulu, HI	Downtown	WGS84 Zone 4N	591414	2350866	47.5	18.2	864.5	19	48	73	190	115123
Houston	Downtown	NAD83 Zone 15N	244800	3269290	54.55	50.71	2766.2	51	56	204	222	664749
Jacksonville, FL	Airport & Downtown	WGS84 Zone 17N	427940	3337900	24.15	40.13	969.1	41	25	161	97	91603
Kansas City	Downtown	WGS84 Zone 15N	351928	4319700	24.1	20.1	484.4	21	25	81	97	110883
Las Vegas	Downtown	WGS84 Zone 11N	658970	3993417	14.9	15.74	234.5	16	15	63	60	99141
Los Angeles	Long Beach(LGB)	NAD83 Zone 11N	377527	3730066	14.88	10.35	154.0	11	15	42	60	22704
	Anaheim (ANA)	NAD83 Zone 11N	413538	3738279	6.55	4.54	29.7	5	7	19	27	10070
	Airport (LAX)	NAD83 Zone 11N	365238	3752766	9.23	6.93	64.0	7	10	28	37	22686
	Downtown (DWN)	NAD83 Zone 11N	379711	3762380	8.77	11.69	102.5	12	9	47	36	52404
						Total:	**350.2**				**Total:**	**107864**
Miami, FL	Downtown	NAD83 Zone 17N	567000	2846670	21.19	9.43	199.8	10	22	38	85	35995
Minneapolis, MN	Downtown	WGS84 Zone 15N	473966	4961955	23.97	24.09	577.4	25	24	97	96	203062
New Orleans	Downtown	WGS84 Zone 15N	779900	3314900	5.1	5.1	26.0	6	6	22	22	13830
New York City	Downtown	WGS84 Zone 18N	567401	4494080	26.65	33.94	904.5	34	27	136	107	148671
Oakland	Downtown	NAD83 Zone 10N	557991	4179718	9.61	7.74	74.4	8	10	31	39	22730
Oklahoma City	Downtown	NAD83 Zone 14N	633218	3923900	5.3	5.1	27.0	6	6	22	23	6333
Orlando, FL	Airport, Dwntwn, etc.	WGS84 Zone 17N	439808	3128199	32.15	40	1286.0	40	33	160	129	104865

Philadelphia, PA	Downtown	WGS84 Zone 18N	469848	4407842	34.1	34.26	1168.3	35	35	138	137	108245
	Wilmington	WGS84 Zone 18N	444765	4389902	15.32	12.14	186.0	13	16	49	62	26265
						Total:	**1354.3**				**Total:**	**134510**
Phoenix	Downtown	NAD83 Zone 12N	395910	3698361	5.7	5.4	30.8	6	6	22	23	7997
Pittsburg	Airport & Downtown	WGS84 Zone 17N	559769	4458510	42.23	29.61	1250.4	30	43	119	169	183672
Portland	Downtown	NAD83 Zone 10N	522993	5038950	4	3.3	13.2	4	5	14	17	2000
Providence	Dwntwn, navconbat, & newport	WGS84 Zone 19N	291900	4591371	21.09	52.67	1110.8	53	22	211	85	164929
Raleigh-Durham, VA	Downtown	WGS84 Zone 17N	701876	3957934	20.19	12.13	244.9	13	21	49	81	39181
	Durham	WGS84 Zone 17N	681852	3977830	12.25	14.28	174.9	15	13	58	49	35748
	Chapel Hill	WGS84 Zone 17N	669950	3971902	10.11	8.25	83.4	9	11	34	41	11460
						Total:	**503.2**				**Total:**	**86389**
Richmond, VA	Downtown	WGS84 Zone 18N	273936	4147920	26.1	18.12	472.9	19	27	73	105	101139
Riverside, CA	Downtown	WGS84 Zone 11N	445902	3745957	24.14	17.92	432.6	18	25	72	97	89785
	San Bernardino	WGS84 Zone 11N	465853	3769891	14.24	13.44	191.4	14	15	54	57	72249
						Total:	**624.0**				**Total:**	**162034**
Salt Lake City	Downtown	NAD83 Zone 12N	418267	4505224	13.91	15.4	214.2	16	14	62	56	61669
San Antonio, TX	Downtown	WGS84 Zone 14N	529491	3241887	31.12	30.2	939.8	31	32	121	125	280280
San Diego	Downtown	NAD83 Zone 11N	476060	3609693	15.4	19.8	304.9	20	16	79	62	110433
San Francisco	Downtown	NAD83 Zone 10N	548881	4173484	7.81	11.7	91.4	12	8	47	34	19573
	Airport	NAD83 Zone 10N	552083	4160931	4.16	6.1	25.4	7	5	25	17	4632
						Total:	**116.8**				**Total:**	**24205**
Savannah, GA	Airport & downtown	WGS84 Zone 17N	475876	3529892	29.01	32.15	932.7	33	30	129	117	65015
Seattle, WA	King Airport & dwntwn	NAD83 Zone 10N	546016	5262228	8.51	16.44	139.9	17	9	66	35	54055
	Seatac (airport)	NAD83 Zone 10N	549843	5253026	4.62	5.34	24.7	6	5	22	19	6580
						Total:	**164.6**				**Total:**	**60635**
St. Louis, MO	Downtown	WGS84 Zone 15N	733903	4265918	16.16	30.14	487.1	31	17	121	65	149877
Washington DC	Downtown	WGS84 Zone 18N	320114	4303845	6.8	6.1	41.5	7	7	25	28	5756

UCP Calculations

Using UMAP, the following UCP's were computed for each grid cell at 250-m and 1-km resolutions (all height units are meters):

- Mean and standard deviation of building height
- Plan-area-weighted mean building height
- Height histogram (5-m increments)
- Plan area fraction and plan area density (1-m increments)
- Roof area density (1-m increments)
- Complete aspect ratio
- Building-to-plan area ratio
- Frontal area index*
- Frontal area density* (4 wind directions – N, NE, E, SE) (1-m increments)
- Height-to-width ratio*
- Sky view factor*

The 2D building data are provided in shapefile format and UMAP can use the shapefile data directly to compute all the UCP's except those with an asterisk (frontal area index and density, height-to-width ratio, and sky view factor) which require the shapefiles to be converted to ESRI GRID (raster) format. When UMAP requires a raster for computation, the building shapefile is converted internally by UMAP into a raster digital terrain model (DTM) at a user specified resolution. For each city's processing a raster resolution of 5-m was used for all calculations that required raster data. Thus, for the UCP's with an asterisk a value was computed at each 5-m raster cell and then aggregation to the 250-m or 1-km grid cell resolution was accomplished by finding an area-weighted average value in each grid cell. In Appendix 2 at the end of this report, examples of the computed UCP's are shown as gridded fields on maps and as x-y plots. Additional descriptions of how the building data are manipulated by UMAP and how the data are processed to derive the UCP's are available in UMAP documentation available from the contacts listed at the end of this report.

Results

Output Format

The gridded building statistics dataset for all 44 cities was derived at both 250-m and 1-km resolutions and incorporated into the NBSD in shapefile, ESRI GRID (raster), ascii gridded, and Excel tabular format. The file names corresponding to files created for each city are listed in Table 4.

The attribute names in the shapefiles and Excel tables correspond to the UCP's as follows:

- mnHT – mean building height
- sdHT – standard deviation of building height
- awaHT – plan-area-weighted mean building height
- LamP – building plan area fraction
- LamB – building surface-to-plan area ratio

- CAR – complete aspect ratio
- LamF – frontal area index (LamF_0 is for wind direction from north, etc.)
- H2W – building height-to-width
- SVF – sky view factor

Table 4. Summary of output files (*all data projected in UTM, Zone & Datum as previously specified in Table 3*).

File name	File Type	Description
XXX_UCP_250m XXX_UCP_1KM	Shapefile, Excel table, and ESRI GRID raster and ascii export for each attribute	250-m and 1-km grid cells containing X and Y coordinates of center point of cell, mean building height (m), standard deviation of building height (m), plan-area-weighted mean building height, plan area fraction, complete aspect ratio, building surface-to-plan area ratio, frontal area index, height-to-width ratio, and sky view factor
XXX_Histograms_250m XXX_Histograms_1KM	Shapefile and Excel table	250-m and 1-km grid cells containing number of buildings in each 5-m height increment (height histogram)
XXX_PAD_250m XXX_PAD_1KM	Shapefile and Excel table	250-m and 1-km grid cells containing building plan area density in each 1-m height increment (plan area density)
XXX_RAD_250m XXX_RAD_1KM	Shapefile and Excel table	250-m and 1-km grid cells containing building roof area density in each 1-m height increment (roof area density)
XXX_FAD_250m_YY XXX_FAD_250m_YY	Shapefile and Excel table	250-m and 1-km grid cells containing building frontal area density in each 1-m height increment (frontal area density)

XXX – three letter city code (e.g., NYC for New York City)
YY – two digit wind direction (0 = north, 45 = northeast,…)

In addition, the shapefiles and Excel tables will contain X_COORD and Y_COORD, which are the X and Y coordinates of the center point of the grid cell in the projected coordinate space (Table 3). The header to the ascii export file also lists the spatial reference and cell size.

The main UCP shapefile contains a column of codes (named "Code") that have been provided to indicate whether the grid cell lies outside the building data extent and if the grid cell contains no buildings or very few buildings. The codes and their description are listed in Table 5.

Table 5. Explanation of codes found in the "Code" attribute in the UCP results files.

Code	Explanation
NoData	the grid cell is *entirely outside of* the building data extent
NoBldg	the grid cell is *completely within* the building data extent, but no buildings are contained inside its boundaries
LowLambdaP	the grid cell is *completely within* the building data extent, but the plan area fraction of buildings is less than 1% (very low building coverage)

For all NoData cells the UCP values are set to -100 for later identification (different than the -9999 NoData default of ArcGIS). For grid cells that have less than 1% building plan area fraction (assigned LowLambdaP code), the following UCPs were assigned a value of -90 as a marker: mean building height, standard deviation of building height, area-weighted mean building height, and height-to-width ratio, while the following were assigned a value of 1: complete aspect ratio and sky view factor, while building surface-to-plan area ratio and all roof, plan, and frontal area indexes and densities for all wind directions are set to zero. The same is done for all cells that contain no buildings (NoBldg code). If an error was encountered during processing then -99 will appear in the field. The error may be due to data errors, processing bugs, or calculation errors. During QA/QC of results all errors were investigated and many were corrected. However, in several cases the cause of the error was unknown. Therefore, in the datasets that accompany this report some -99 values may remain pending further revision.

4. Tall Building Districts

The 46 largest US metropolitan areas (MA) according to the 2000 Census were identified for additional analysis. The first step was to define the urban extent of the MA's and the second step was to determine the extent of the tall building districts (TBD's) within the MA's. The urban extent was defined using the delineated US Census Bureau Consolidated Metropolitan Statistical Areas (CMSA). Using the CMSA extent dataset is an approximation, but acceptable for this database. Future versions of the NBSD will use a more accurate approach when the building statistics are extrapolated to the full urban extent of the MA. The TBD's were delineated using visual inspection of digital orthophotos. The areas were objectively defined to include concentration of buildings that appeared to be greater than five stories. The analyst identified the location of the concentration of tall buildings, and then identified the contiguous city blocks within the tall building area that contained at least one tall building defined as having at least five stories. The aggregation of all city blocks identified as containing a tall building in the concentrated zone were defined to be a TBD. The minimum size to constitute a TBD was 0.5 km^2. The delineation of the TBD's is simply a way to identify areas of cities that have much different building characteristics that should be noted by atmospheric modelers; they are not used to define building statistics in the database. Table 6 lists the 46 metropolitan areas selected. For each MA, digital orthophotos were downloaded from the USGS seamless data server (seamless.usgs.gov) and the TBD's were digitized. Figure 3 displays the delineated TBD for Boston. The red outline in the figure represents the TBD. The number of TBD's and several summary building statistics are shown in Table 6 for all the cities in the NBSD metro areas database (see Figure 4). Clearly, the delineation of a TBD incorporates subjectivity of the analyst, but general guidelines were set and discussed among the four analysts delineating the TBD's. After one analyst delineated a TBD it was reviewed by the other three and modified in a team format. Alternative ways to systematically derive TBD's using population and satellite roughness information are currently being developed and will be used to produce a more comprehensive national database.

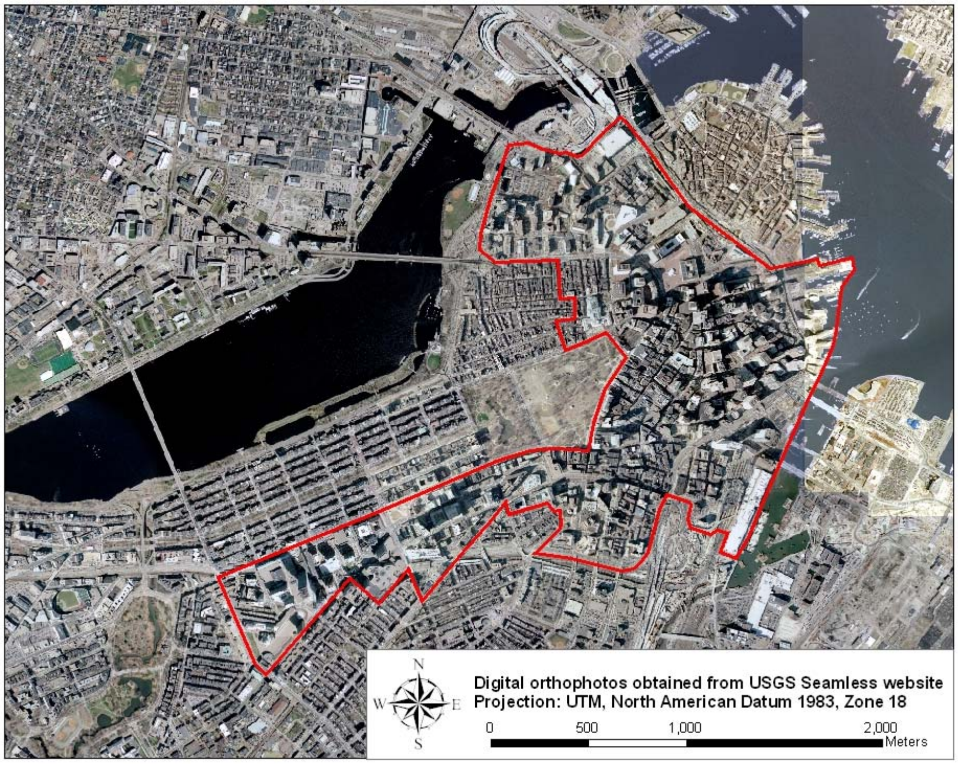


Figure 3. Digital orthophoto and delineated TBD of Boston.

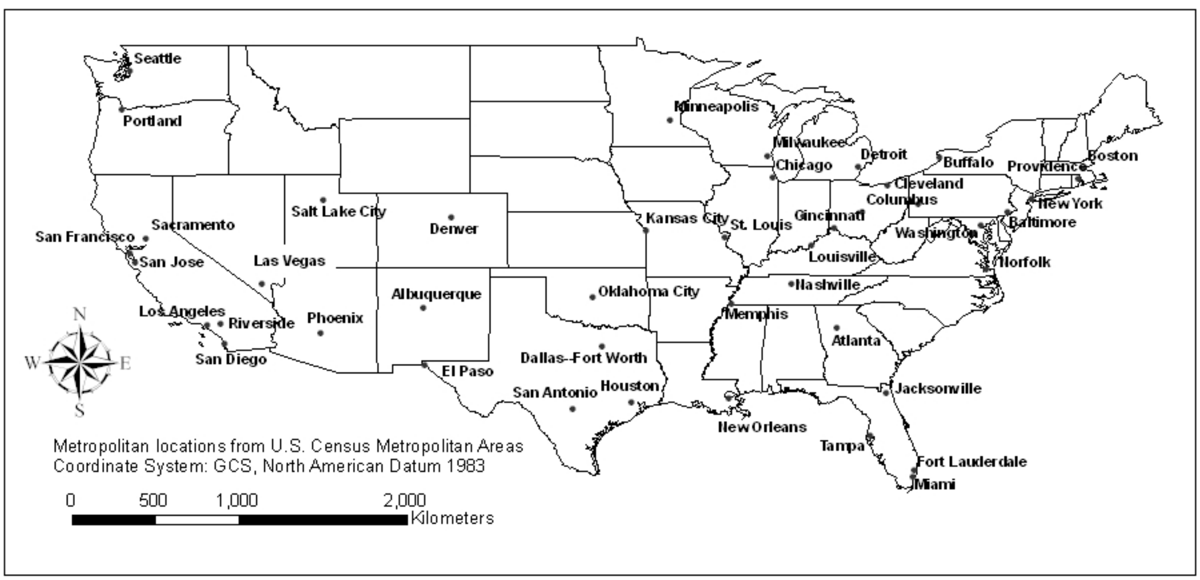


Figure 4. Metropolitan areas included in the NBSD2 TBD dataset.

Table 6. Characteristics of 46 metropolitan areas with population greater than 500,000.

Major City*	# of Tall Building Districts	Area of TBD (km^2)	Mean Height in TBD* (m)	Plan Area Fraction of TBD** (m)
Albuquerque, NM	1	1.1	14.0	0.27
Atlanta, GA	1	4.0	---	---
Baltimore, MD	2	4.6	16.4	0.34
Boston, MA	1	3.0	26.1	0.45
Buffalo, NY	1	3.1	---	---
Chicago, IL	1	9.8	26.3	0.38
Cincinnati, OH	1	2.9	20.5	0.27
Cleveland, OH	1	4.0	16.7	0.29
Columbus, OH	2	13.5	---	---
Dallas-Fort Worth, TX	2	3.5	29.2	0.23
Denver, CO	2	5.9	12.9	0.28
Detroit, MI	1	10.5	10.8	0.22
El Paso, TX	2	2.1	---	---
Fort Lauderdale, FL	2	6.6	< 10	0.25
Honolulu, HI	---	---	---	---
Houston, TX	1	3.3	22.8	0.27
Indianapolis, IN	1	10.2	---	---
Jacksonville, FL	2	4.3	10.8	0.20
Kansas City, MO	1	8.9	< 10	0.21
Las Vegas, NV	4	10.6	< 10	0.23
Los Angeles, CA	1	2.5	45.0	0.29
Louisville, KY	1	3.5	---	---
Memphis, TN	1	4.9	---	---
Miami, FL	3	7.7	11.6	0.24
Milwaukee, WI	2	21.1	---	---
Minneapolis, MN	2	9.3	11.8	0.28
Nashville, TN	1	5.2	---	---
New Orleans, LA	1	3.7	17.4	0.42
New York, NY	1	32.5	30.0	0.39
Norfolk, VA	1	2.7	---	---
Oklahoma City, OK	1	0.7	19.4	0.34
Philadelphia, PA	1	9.9	15.9	0.38
Phoenix, AZ	1	1.7	16.2	0.32
Pittsburgh, PA	2	5.9	16.9	0.33
Portland, OR	1	1.8	18.1	0.35
Providence, RI	1	4.2	10.7	0.21
Riverside, CA	1	1.0	< 10	0.20
Sacramento, CA	1	3.2	---	---
Salt Lake City, UT	1	1.6	13.8	0.34
San Antonio, TX	1	3.2	11.0	0.28
San Diego, CA	1	3.2	12.5	0.32
San Francisco, CA	2	4.5	26.2	0.49
San Jose, CA	2	3.7	---	---
Seattle, WA	1	2.3	21.2	0.36
St. Louis, MO	3	4.1	19.4	0.35
Tampa-St. Petersburg, FL	2	8.3	---	---
Washington, DC	5	13.2	15.6	0.27

* In some cases the metropolitan area is defined by several major cities – only one recognizable city is included in the table for identification purposes
** The building statistics can only be determined for metropolitan areas with building data

5. Accompanying CD

The accompanying CD includes directories for each city that contains the building statistics (provided in ESRI shapefile format, ESRI GRID raster format, Excel tables, and ascii text). The naming convention was provided in Table 4.

In addition, the CD contains the final report, shapefiles of the extent of all 46 metropolitan areas, the TBD's delineated in the metropolitan areas, and the polygons representing the building data extents for the 44 cities with derived building statistics in the NBSD.

6. Summary

The NBSD is being released in phases. The *first generation* NBSD was released in 2005 and included the derived building statistics for 17 cities, a report for each city containing descriptions of the building data and calculations, the delineated metropolitan areas and the delineated tall building districts for the 46 largest metropolitan areas in the US. The *second generation* NBSD (NBSD2) accompanies this report and contains building statistics for 27 additional cities (44 total) at 250-m and 1-km resolution (NBSD only contained 250-m). Updates to the NBSD will be released after substantial improvements have been made. Scheduled improvements include (1) more building data/cities, (2) use of models relating building statistics to land use and/or population to extrapolate building statistics beyond the data extent for each city and to cities without building data, (3) additional building statistics, and (4) revisions requested by users (e.g., data format). Other features may include incorporating greater non-building urban canopy parameters and providing web-based access to the database.

To be included in the NBSD distribution list and to obtain future releases please contact Steve Burian at the University of Utah (burian@eng.utah.edu) or Mike Brown at Los Alamos National Laboratory (mbrown@lanl.gov). Please report your use of the database and provide feedback so that continued improvements and extensions to the database can be made.

References

Brown, M. (2001). "Urban parameterizations for mesoscale models." In: *Mesoscale Atmospheric Dispersion*, pp. 193-255, Z. Boybeyi, ed., WIT Press, Southampton, UK. LA-UR-99-5329.

Brown, M. (2004). "Urban dispersion – challenges for fast response modeling." Preprint proceedings, Fifth Symposium on the Urban Environment, AMS, 23-26 August, Vancouver, BC, Canada, 13 pages.

Burian, S.J., Brown, M.J., Ching, J., Cheuk, M.L., Yuan, M., Han, W., and McKinnon, A. (2004). "Urban morphological analysis for mesoscale meteorological and dispersion modeling applications: current issues." Preprint proceedings, Fifth Symposium on the Urban Environment, AMS, 23-26 August, Vancouver, BC, Canada, 10 pages.

Grimmond, S. and Oke, T. (1999). "Aerodynamic properties of urban areas derived from analysis of surface form." *J. Appl. Met.*, 38: 1262-1292.

Voogt, J. and Oke, T. (1997). "Complete urban surface temperatures." *J. Appl. Met.*, 36: 1117-1132.

Appendix I. Sample QA/QC documentation

National Building Statistics Database
Processing QA/QC Checklist

City: __________________

Processed by: ______________________ **Date:** ____________

Verified by: ________________________ **Date:** ____________

Complete this form when performing the Quality Assurance/Quality Control (QA/QC) steps during processing of building data for the National Building Statistics Database. Check each item below as it is completed and verified. Any problems or issues should be written beneath the QA/QC check.

- ❑ After UMAP calculation is complete, review results by scrolling through the output tables. Check values closely for reasonableness and completeness. Sort ascending and verify that data make sense.

- ❑ Check that all attributes are included in the shapefiles. The main file should contain the following (if the parameters were selected for computation):

  - ID
  - X_Cood
  - Y_Coord
  - Code
  - LamP
  - mnHT
  - sdHT
  - awaHT
  - LamB
  - CAR
  - LamF_XX (where XX is numeric wind direction)
  - H2W
  - SVF
  - Zo_Y_XX (where Y is the method, S for simple, R for Raupach, and M for Macdonald)
  - Zd_Y_XX

Note: There may be multiple LamF fields corresponding to multiple wind directions. The histogram file should contain multiple fields at 5-m increments increasing to the tallest building height in the dataset. The plan area density, roof area density, and frontal area density should increment by 1 m and also end at the tallest building height.

- ❑ Plot ground level UCPs using the shapefile and raster data. Verify that the values shown align with the location of buildings. For example, the highest plan area fraction (Lambda P) values should be concentrated in the area with the highest building density.

- ❑ Check that all cells with LamP < 0.01 have the following values for the UCPs:
    - -90: mnHT, sdHT, awaHT, H2W
    - 1: CAR, SVF
    - 0: LamB, LamF_XX, Zo, and Zd

- ❑ Check the codes and corresponding UCPs to be sure the following exists:
    - NoData: all UCPs should be set to -100
    - NoBldgs: UCPs should be set to -90, 1, or 0 as listed above (with LamP being 0 as well)
    - LowLamP: UCPs should be set to -90, 1, or 0 as listed above (with LamP being reported as the value calculated)

  Note: UCPs that are a function of height will not have values or the values will be zero. The code provided in the Code field is to be checked to determine grid cells that have acceptable results and those that should be ignored (or addressed with additional analysis) by users of the data.

- ❑ Identify and record the UCPs and grid cells that contain -99. This value is an error and must be brought to the attention of Andrew and Steve.

- ❑ Check the following UCP values closely:
    - For five random grid cells verify that LamP is equal to the PAD value at 0

- For five random grid cells verify that LamF_XX is equal to the sum of the FAD values over the entire height for the same wind direction
- For five random grid cells verify that the LamP is equal to the sum of the RAD values over the entire height

- [ ] Double check values in all derived files – shapefiles, raster, ascii, and Excel with a quick once over. Be sure all files are named correctly and are in correct folder.

- [ ] Verify the names of the shapefiles, raster, ascii, and Excel files are names following the convetion shown below. Note: all files need not be present if the parameter was not determined – verify that is the case if a file is missing.

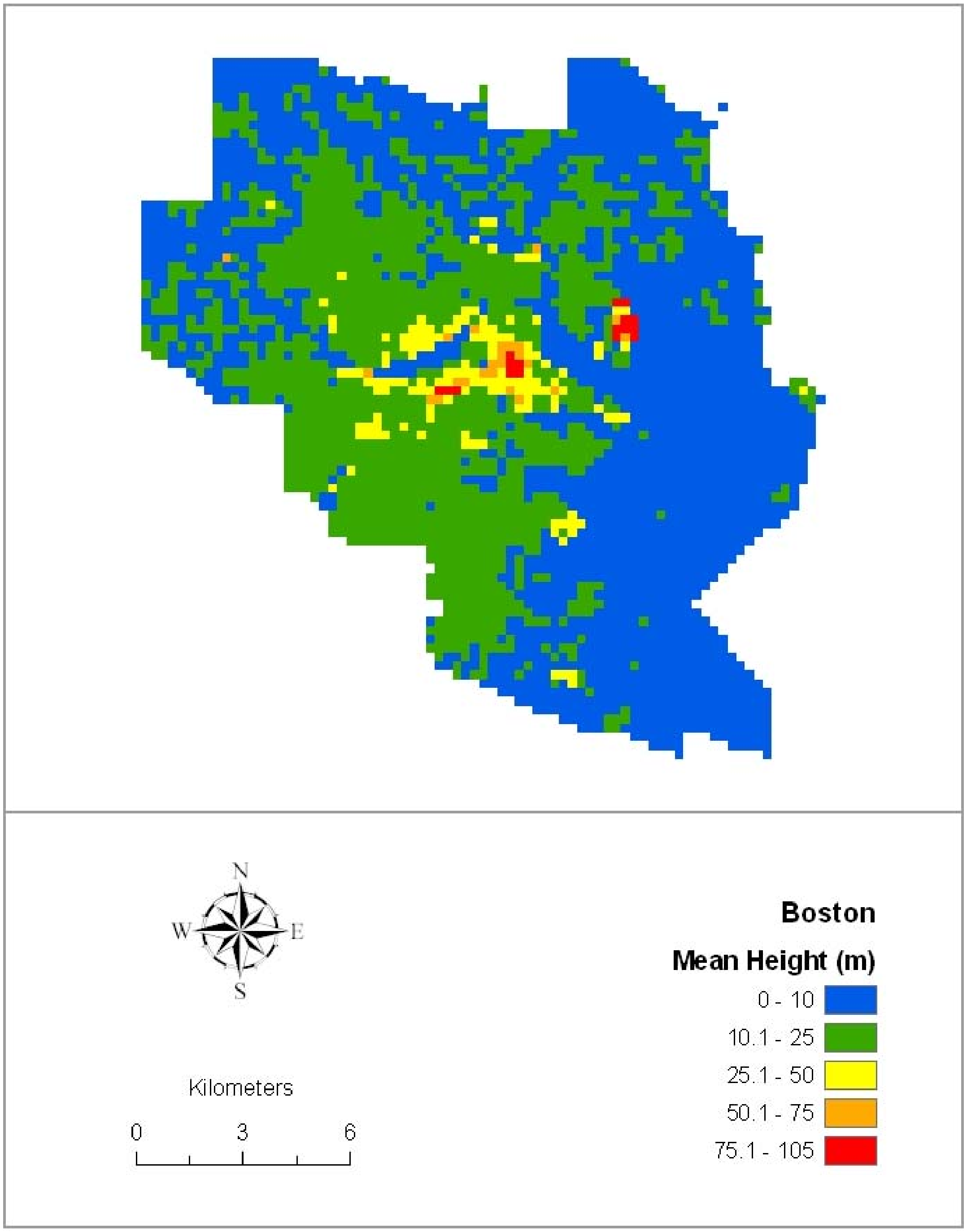
Shapefile	Excel	ESRI_GRID	ASCII_GRID
XXX_UCP_250m XXX_Histograms_250m XXX_PAD_250m XXX_RAD_250m XXX_FAD_250m_DD	XXX_UCP_250m XXX_Histograms_250m XXX_PAD_250m XXX_RAD_250m XXX_FAD_250m_DD	File will be named using the attribute name, e.g., mnHT, sdHT, etc.	File will be named using the attribute name, e.g., mnHT, sdHT, etc.

XXX – three letter city code (e.g., NYC for New York City)
DD – wind direction (0 = north, 90 = east, etc.)

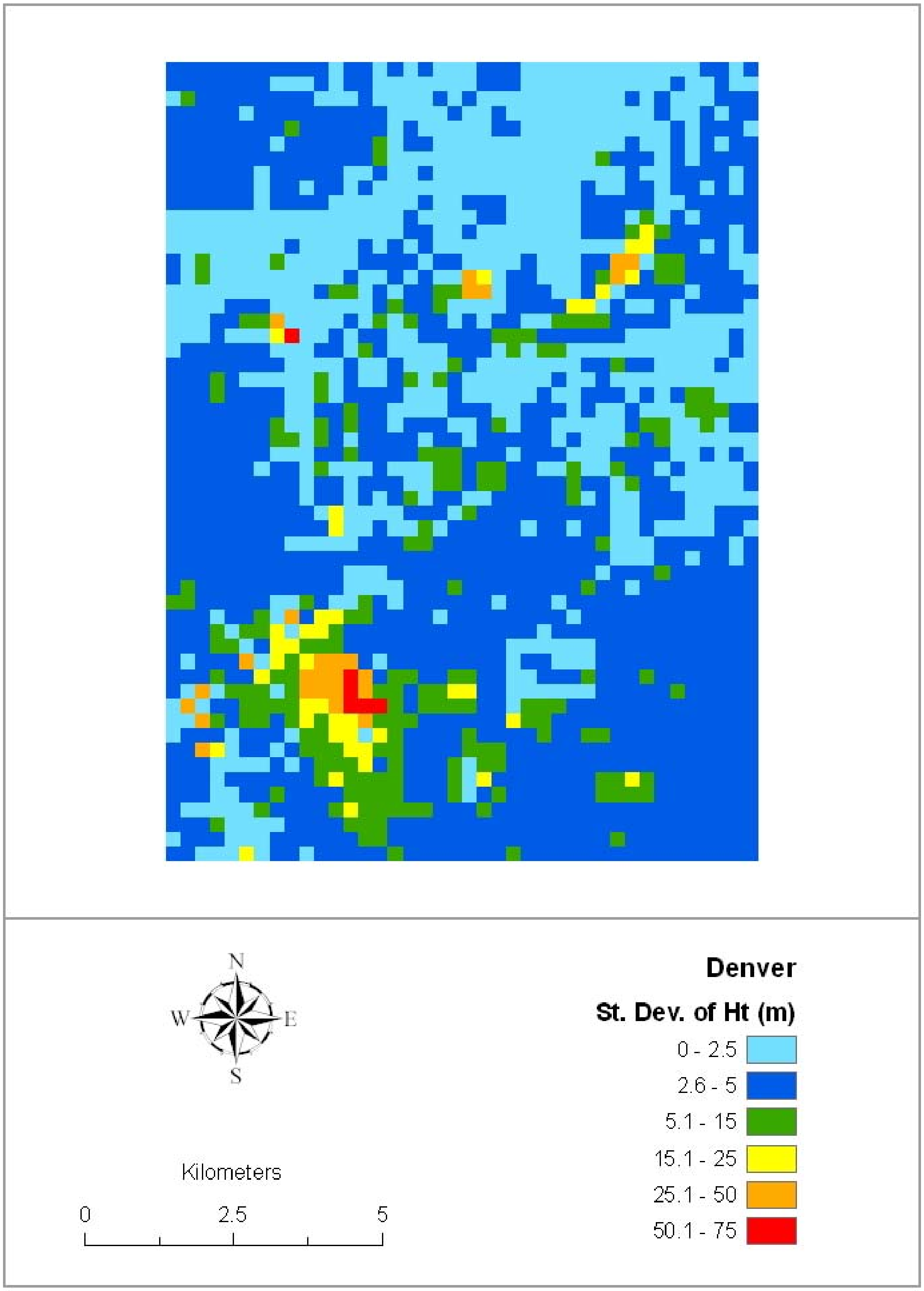
- [ ] Compile report and proofread carefully.

- [ ] Backup distribution package (results and report) and burn to CD.

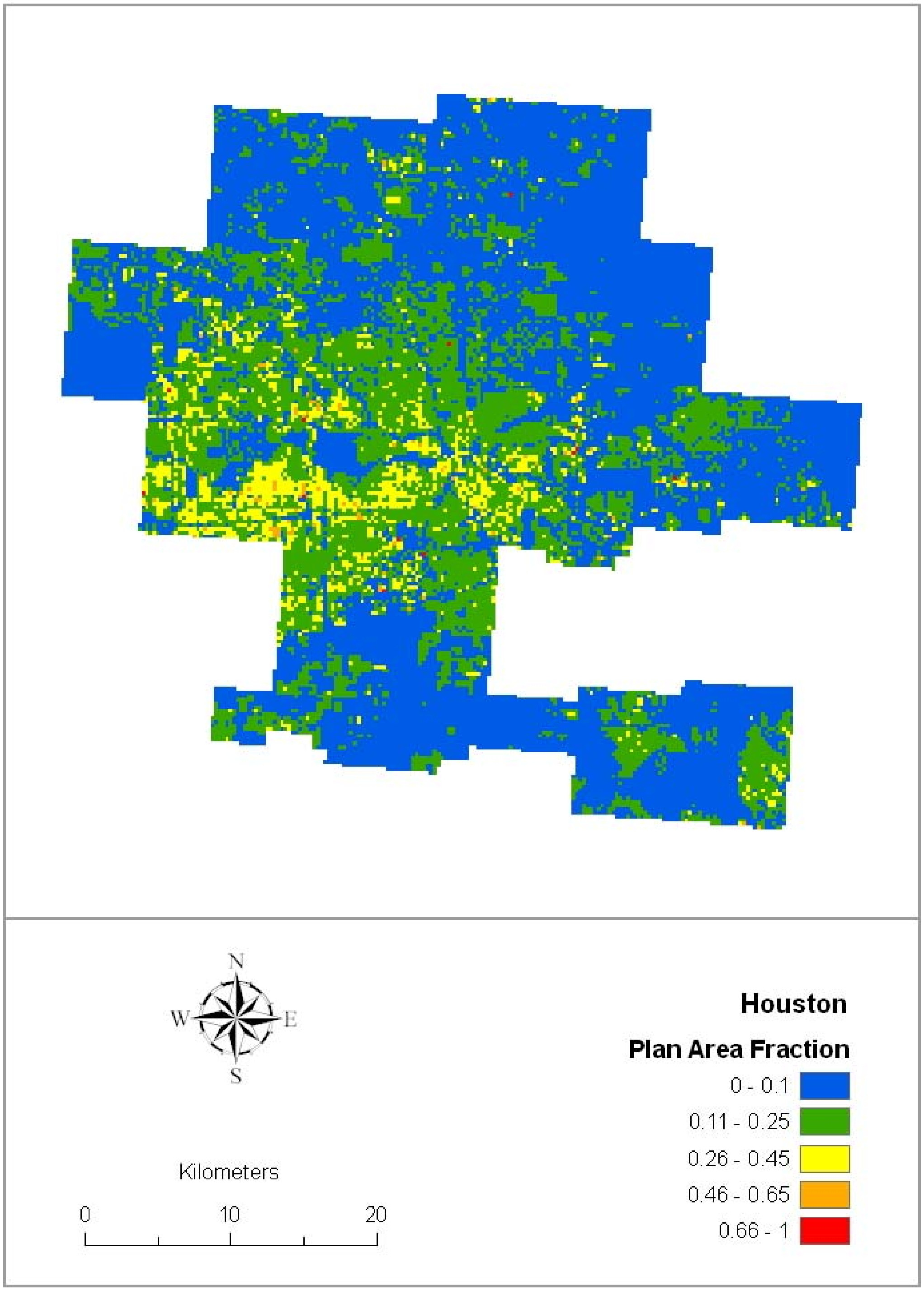
Appendix II. Sample Plots of Derived Building Statistics



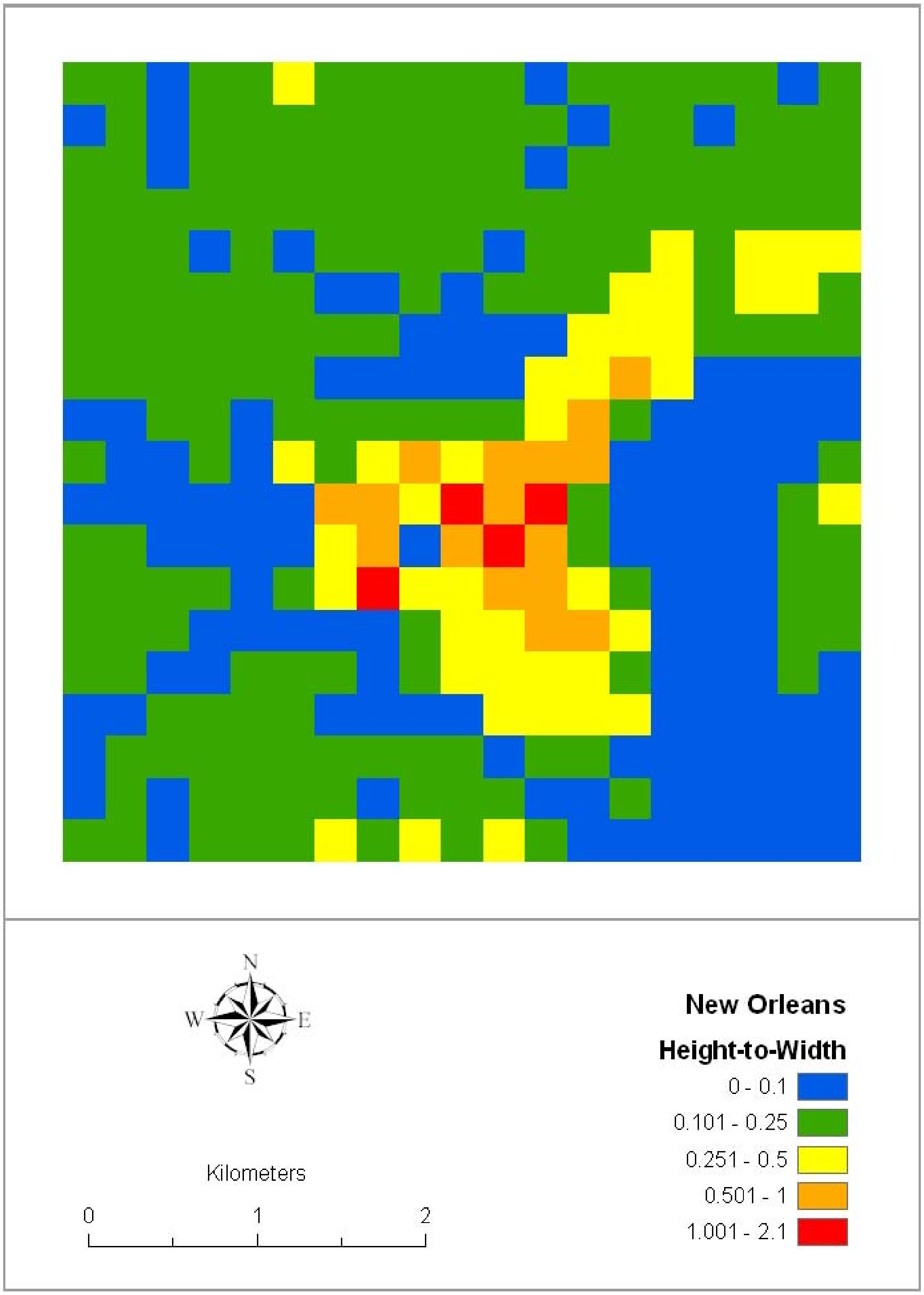
Mean Building Height Distribution at 250-m Grid Resolution for Boston



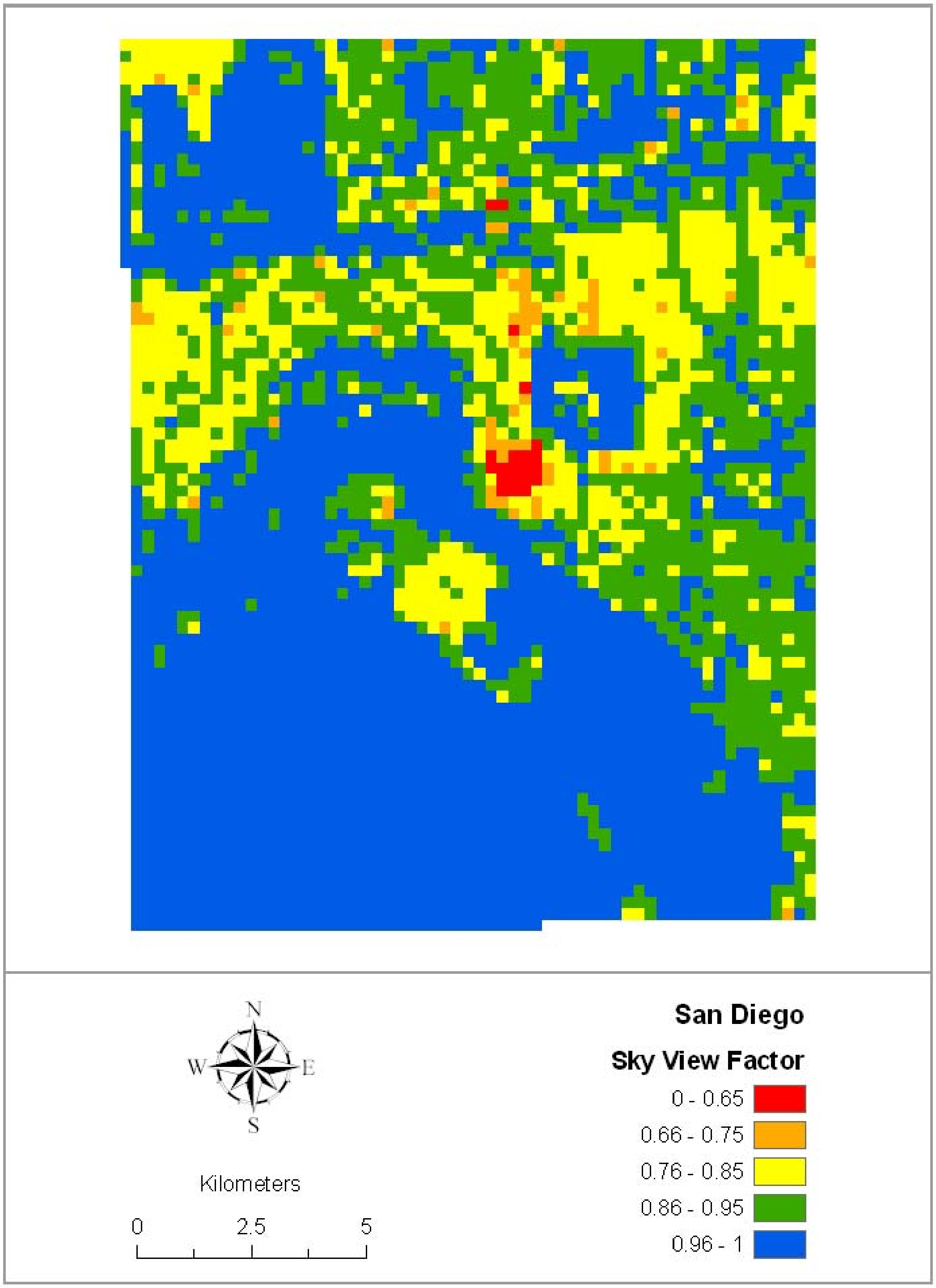
Building Height Standard Deviation at 250-m Grid Resolution for Denver



Building Plan Area Fraction at 250-m Grid Resolution for Houston

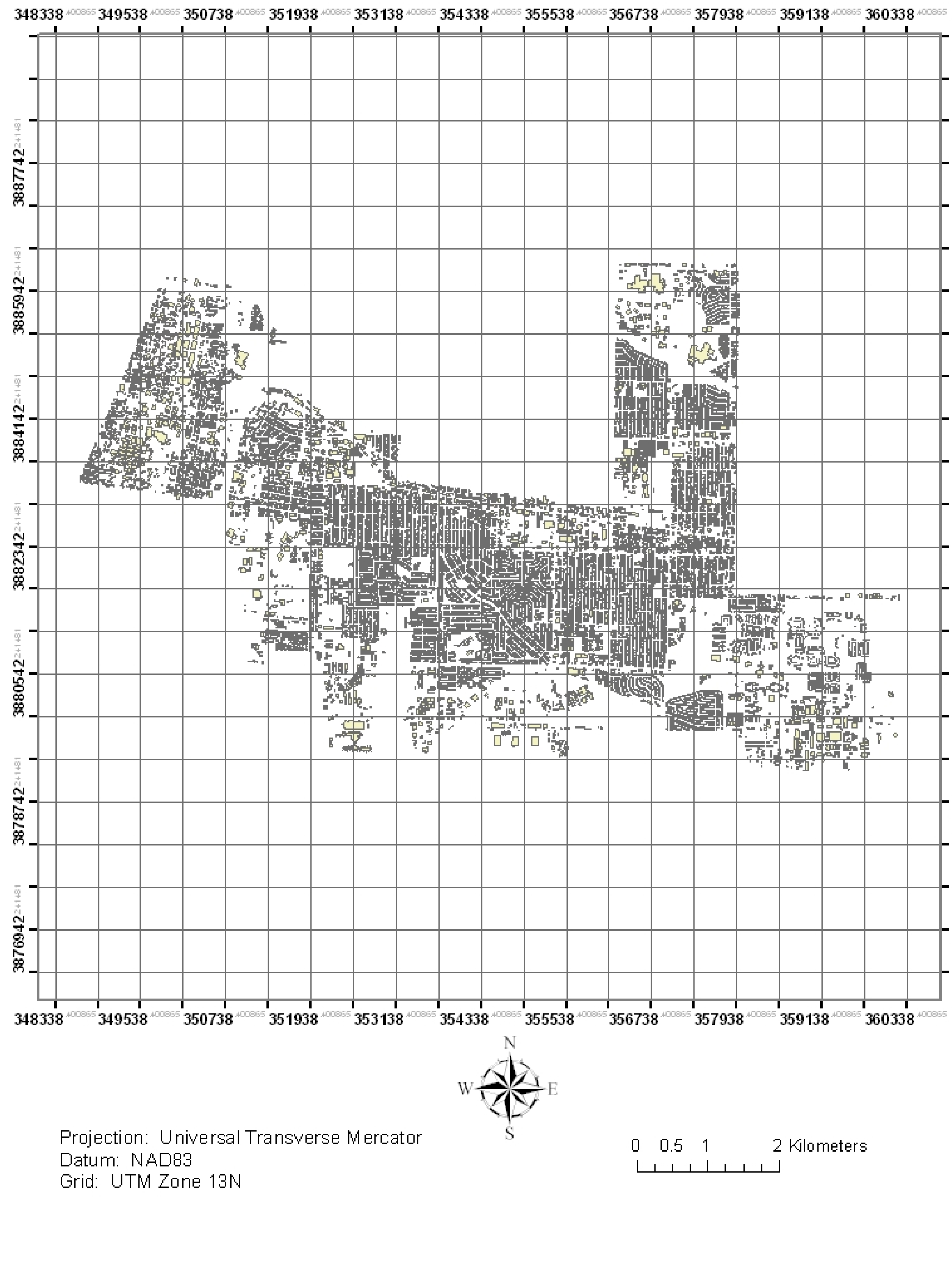


Building Height-to-Width Ratio at 250-m Grid Resolution for New Orleans

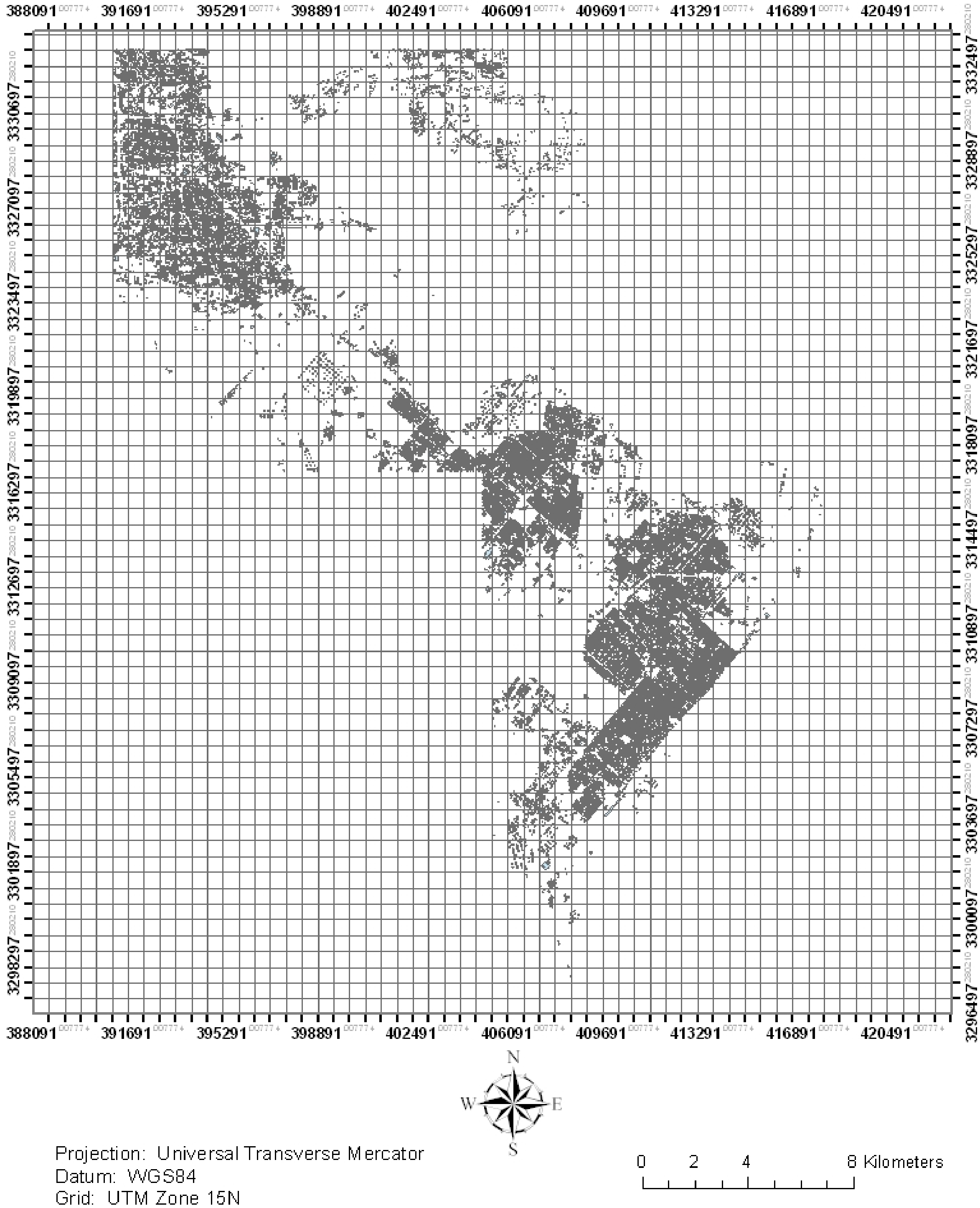


Sky View Factor at 250-m Grid Resolution for San Diego

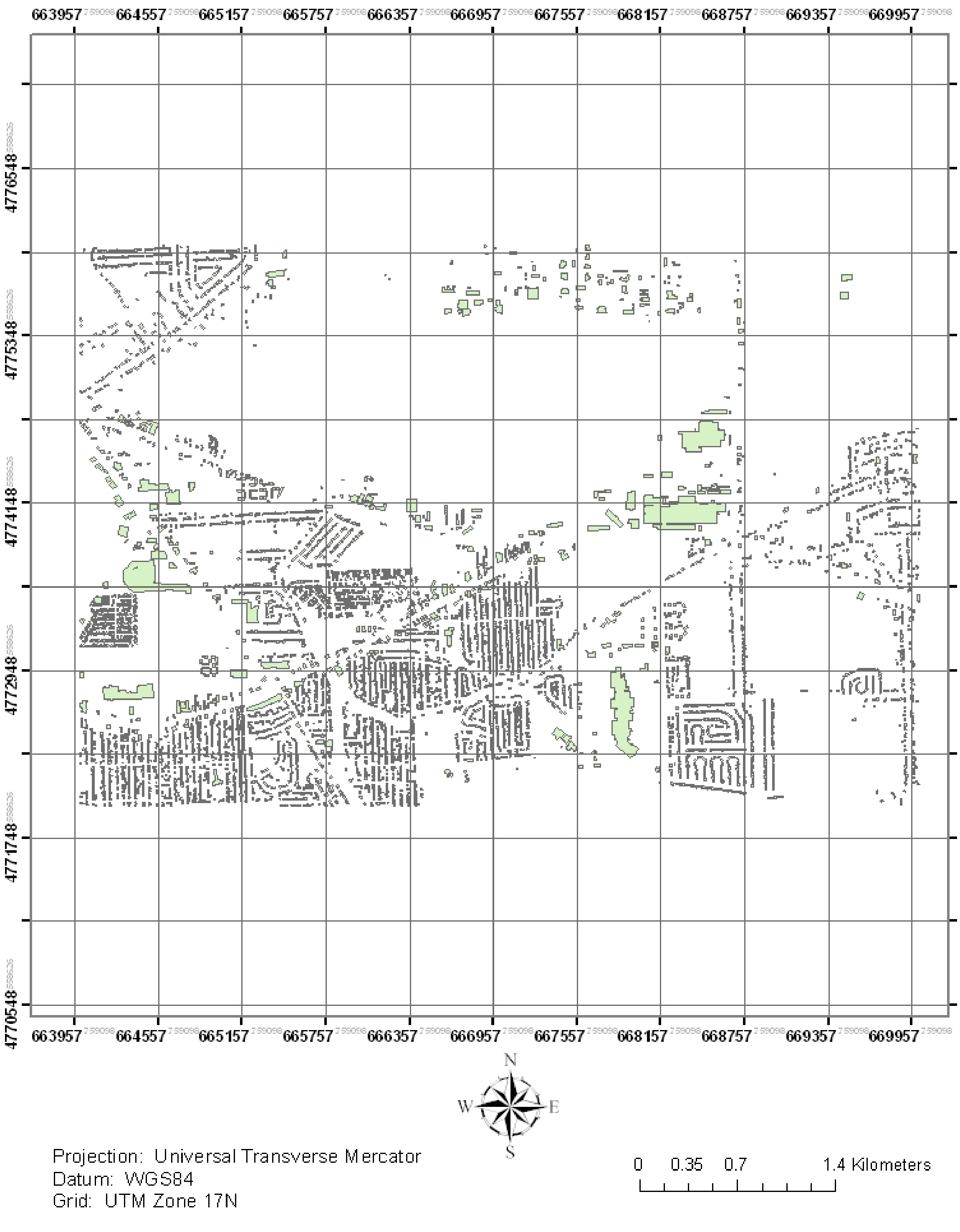
Appendix III: Building Data of Selected Cities



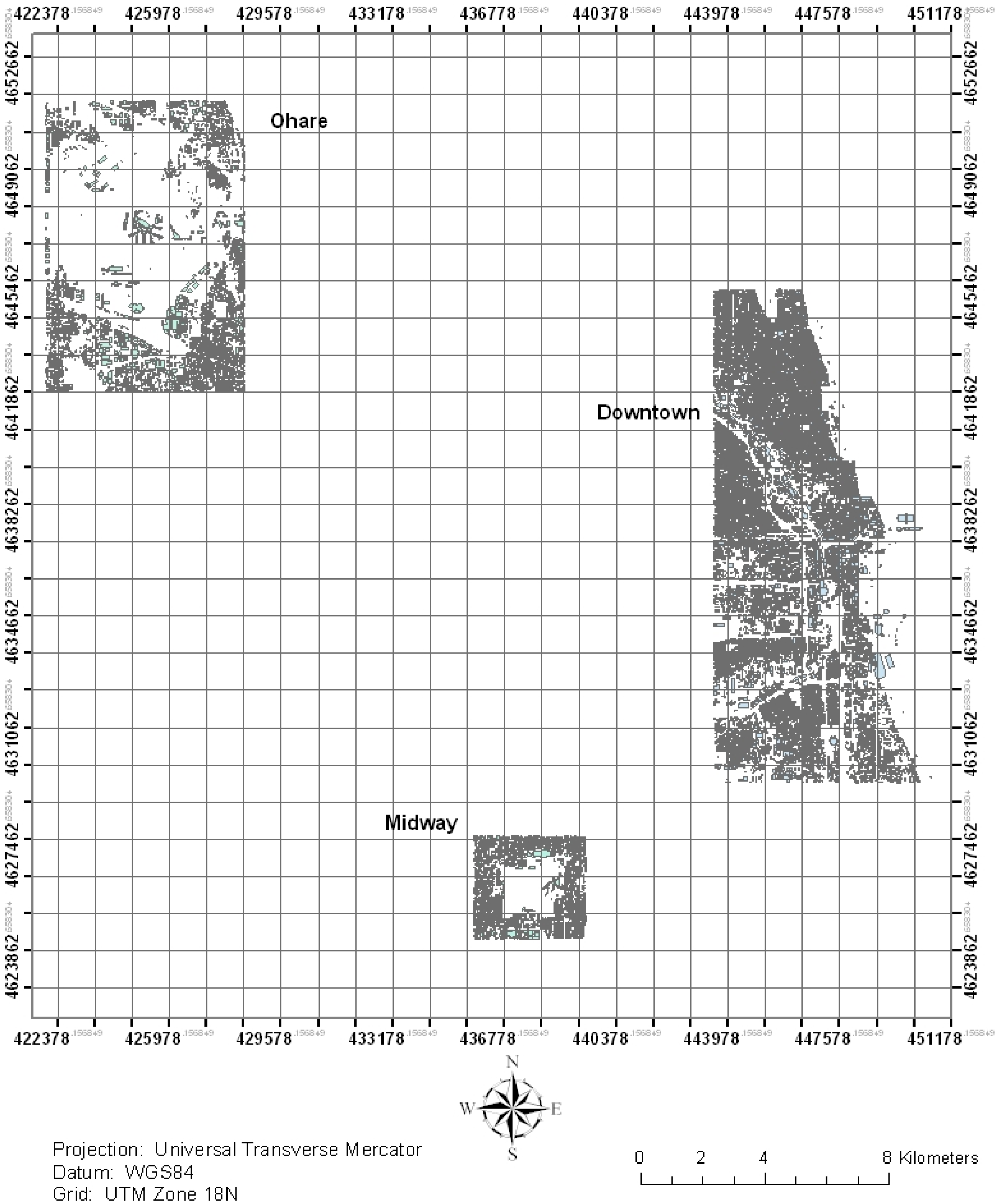
Building Data Extent for part of the Albuquerque Metropolitan Area



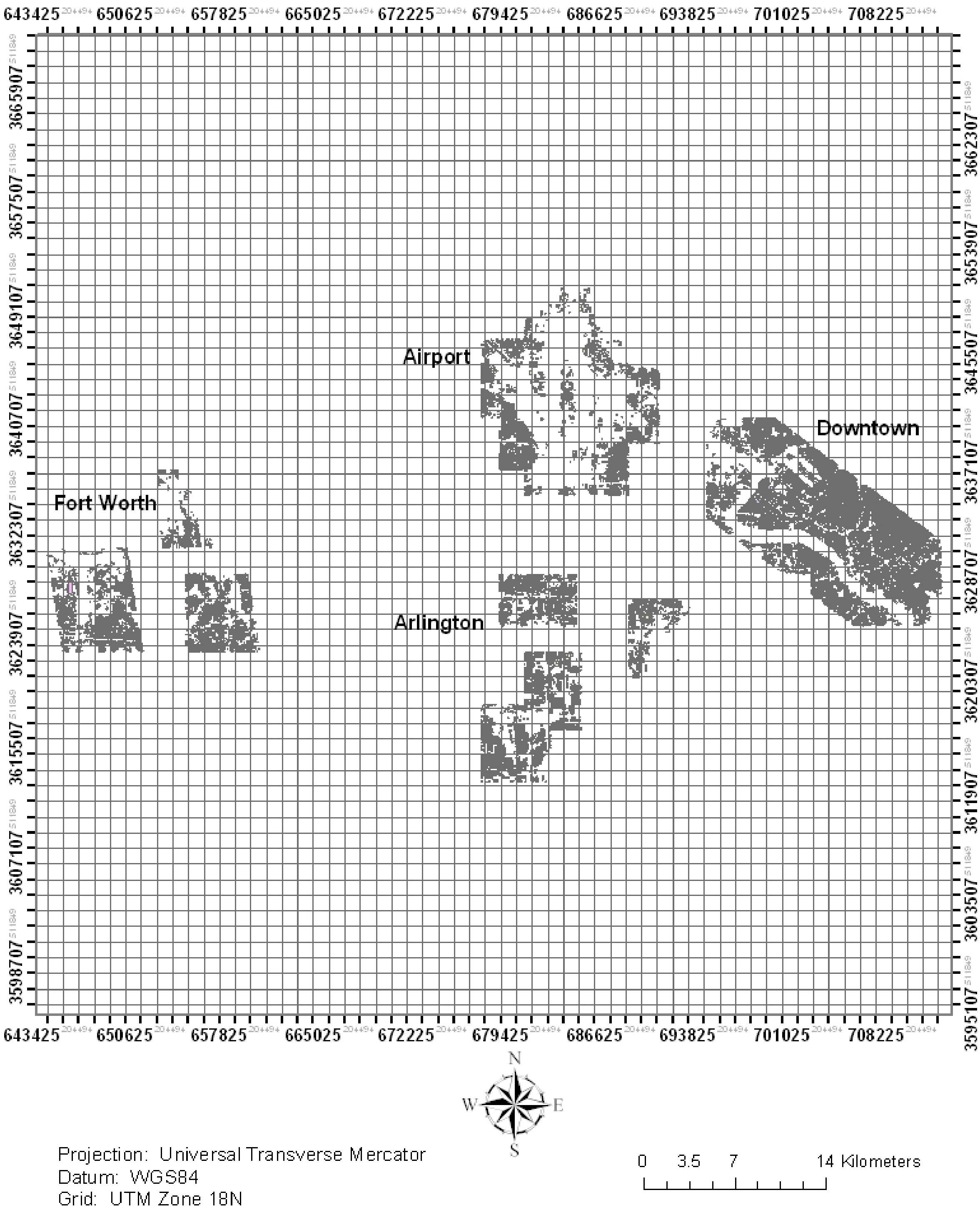
Building Data Extent for part of the Beaumont Metropolitan Area



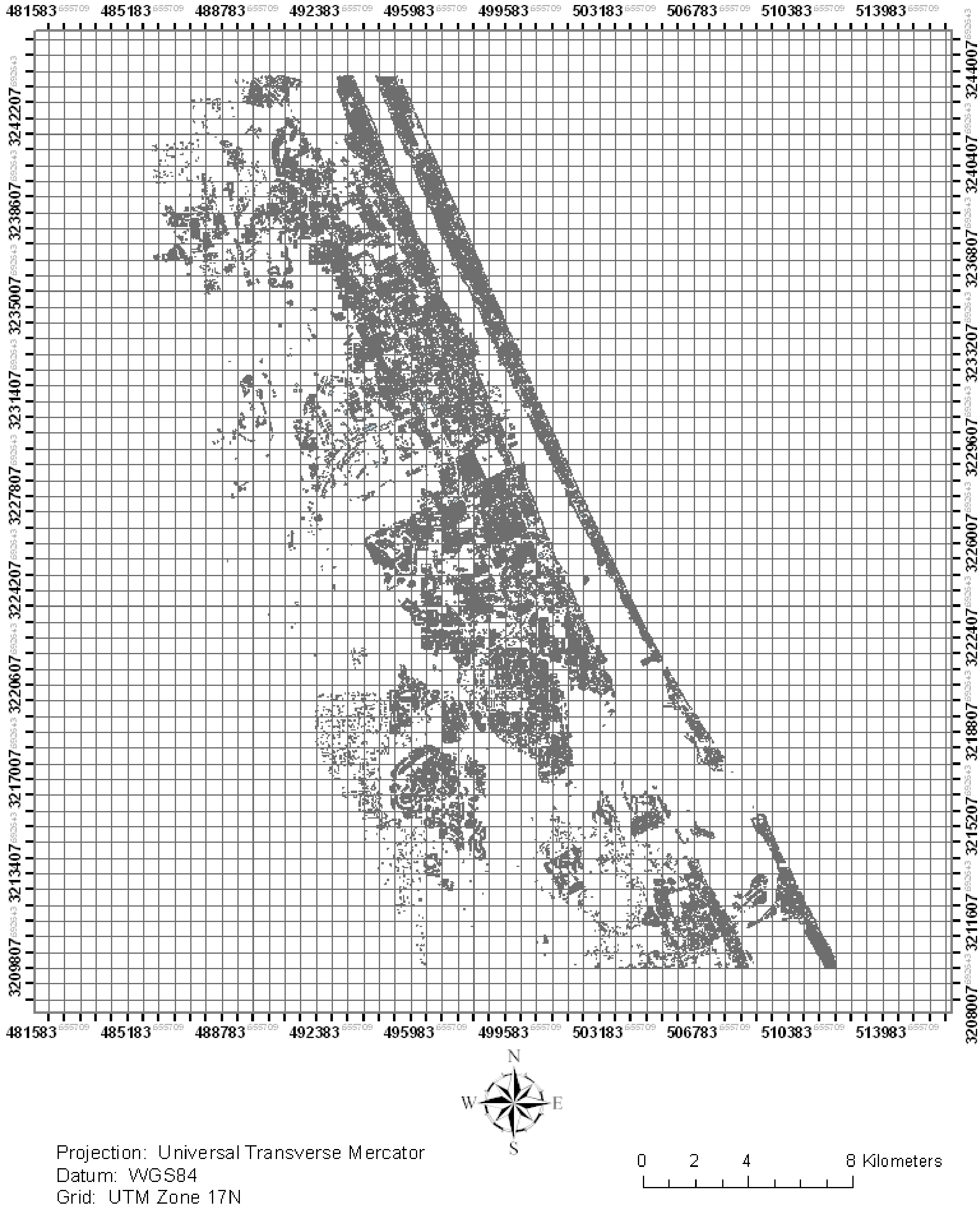
Building Data Extent for part of the Buffalo Airport Metropolitan Area



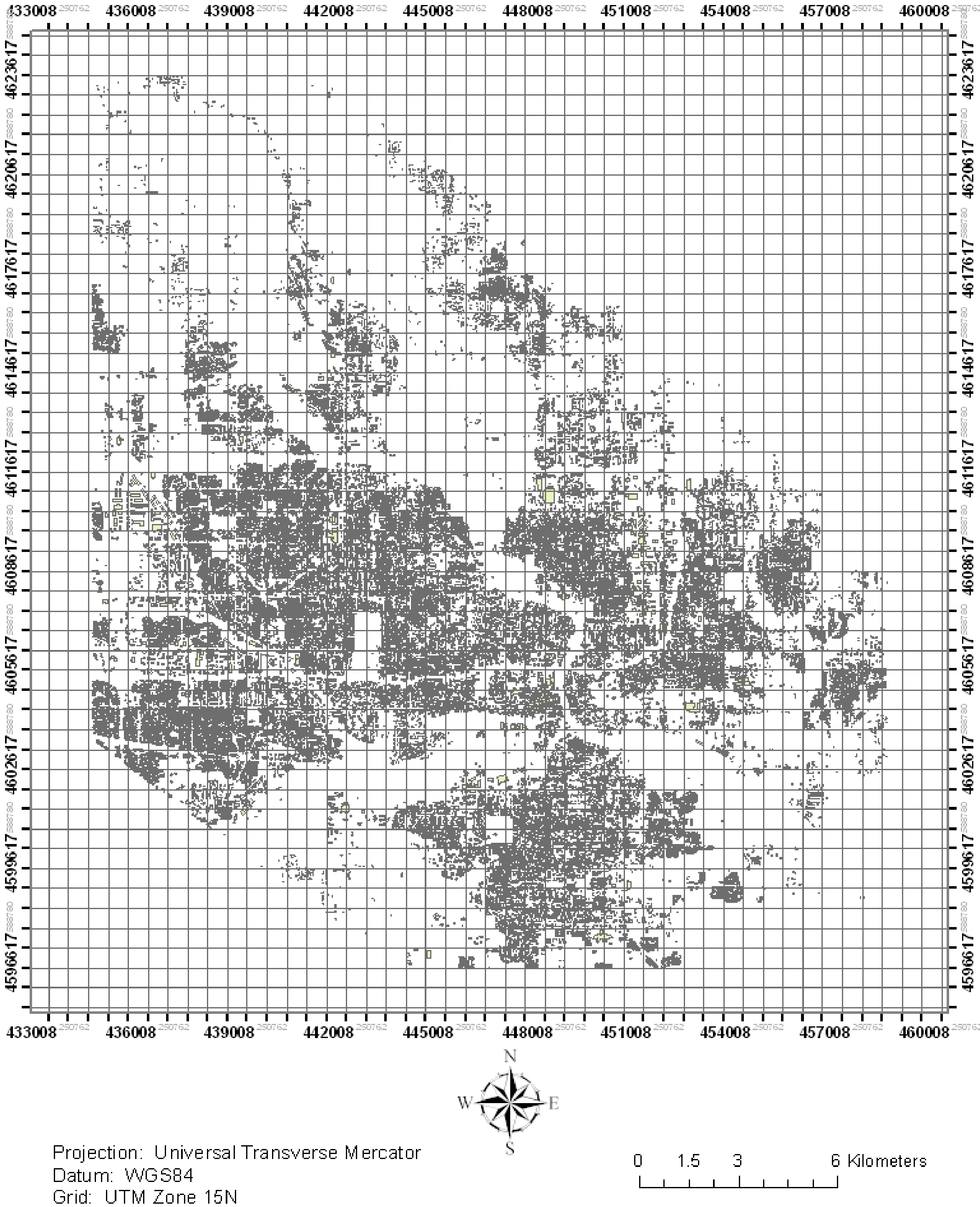
Building Data Extent for part of the Chicago Metropolitan Area



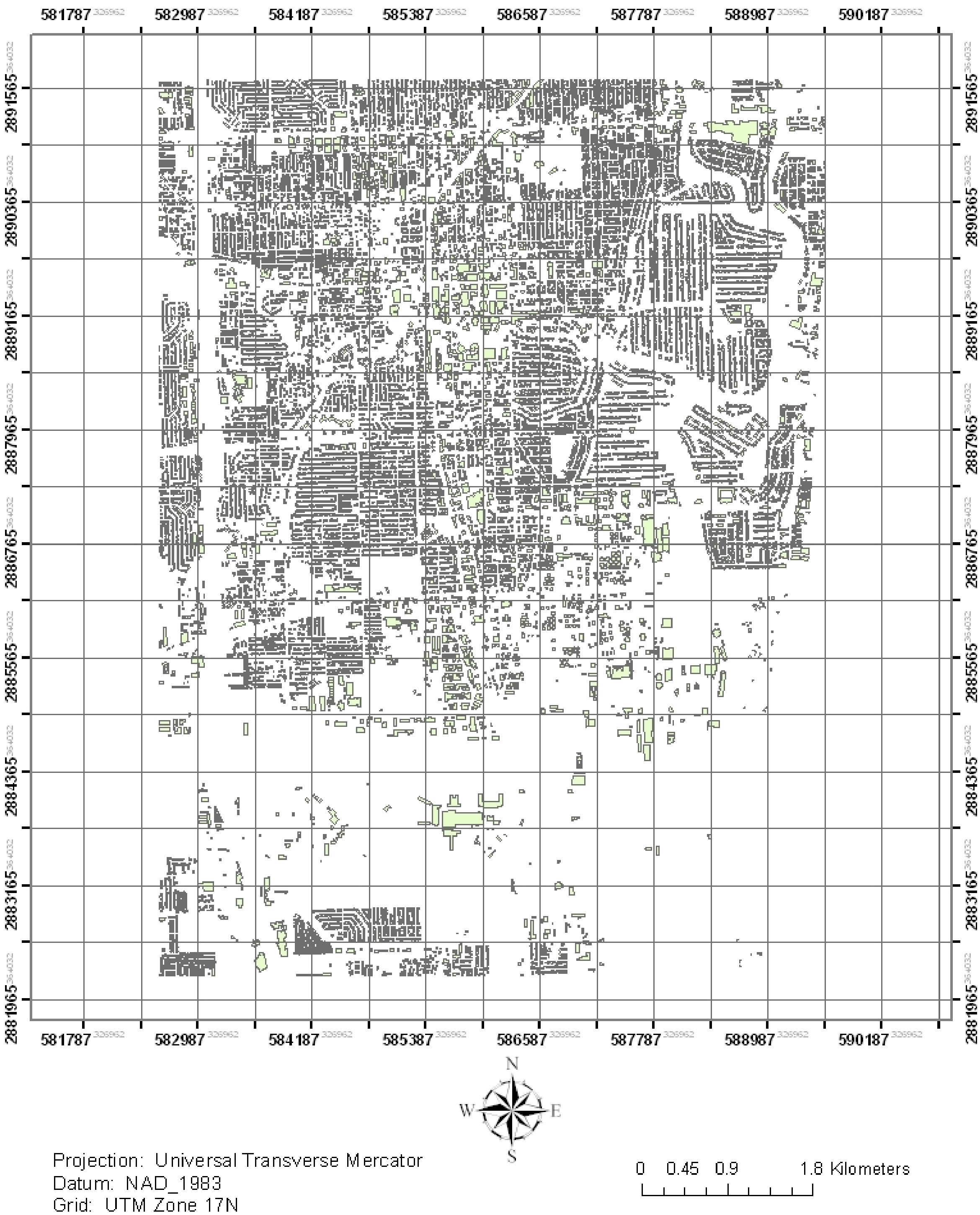
Building Data Extent for part of the Dallas Metropolitan Area



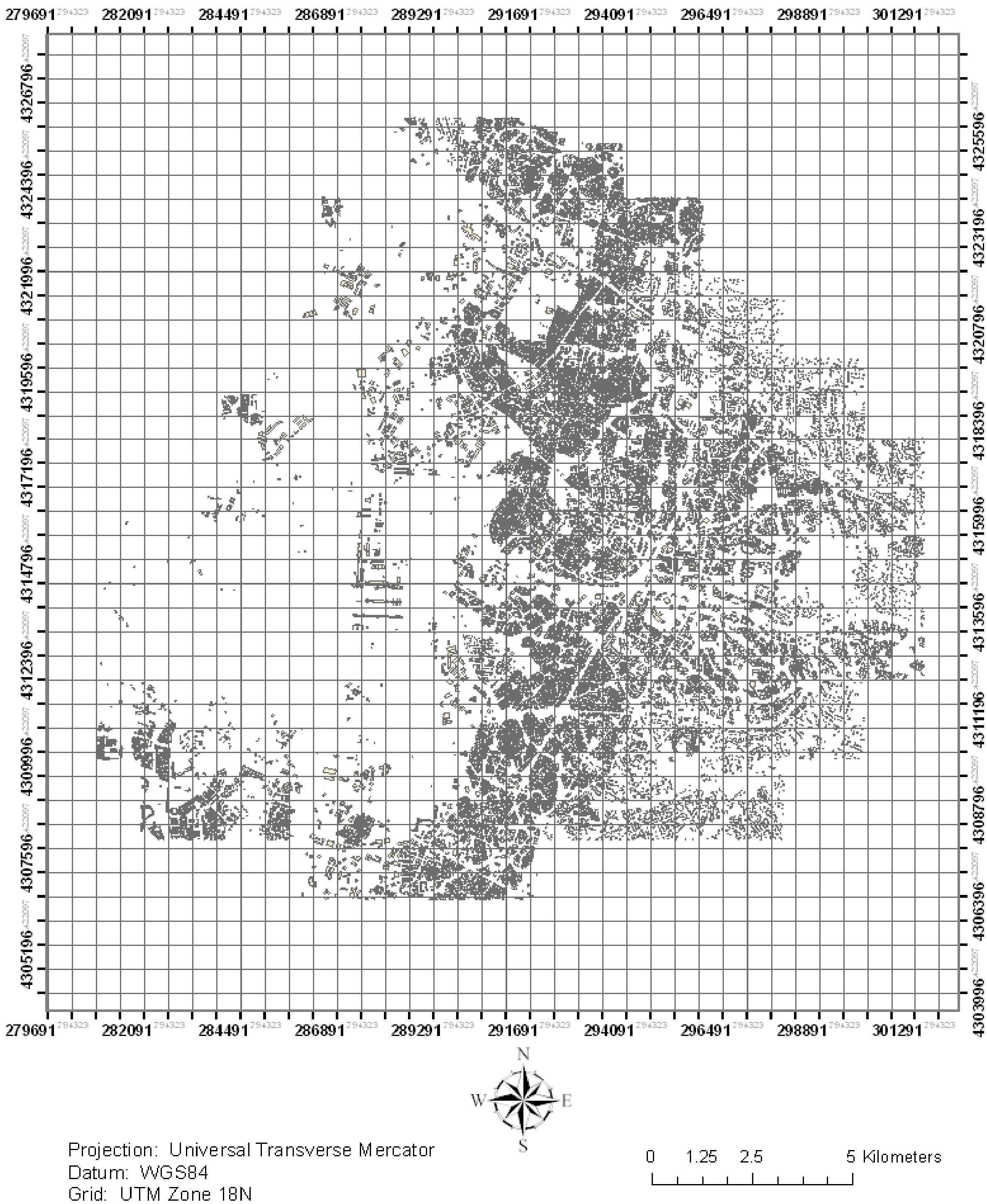
Building Data Extent for part of the Daytona Beach Metropolitan Area



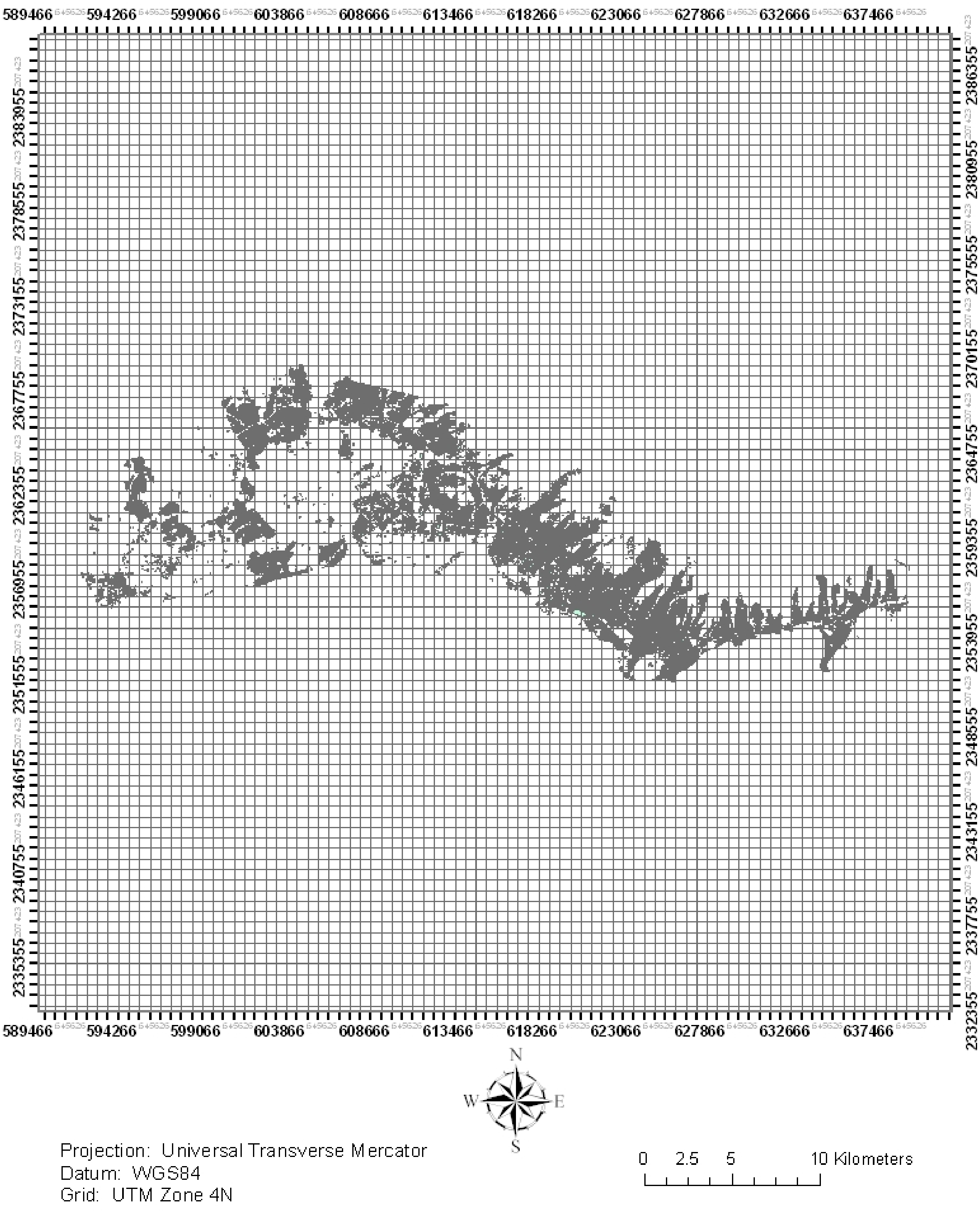
Building Data Extent for part of the Des Moines Metropolitan Area



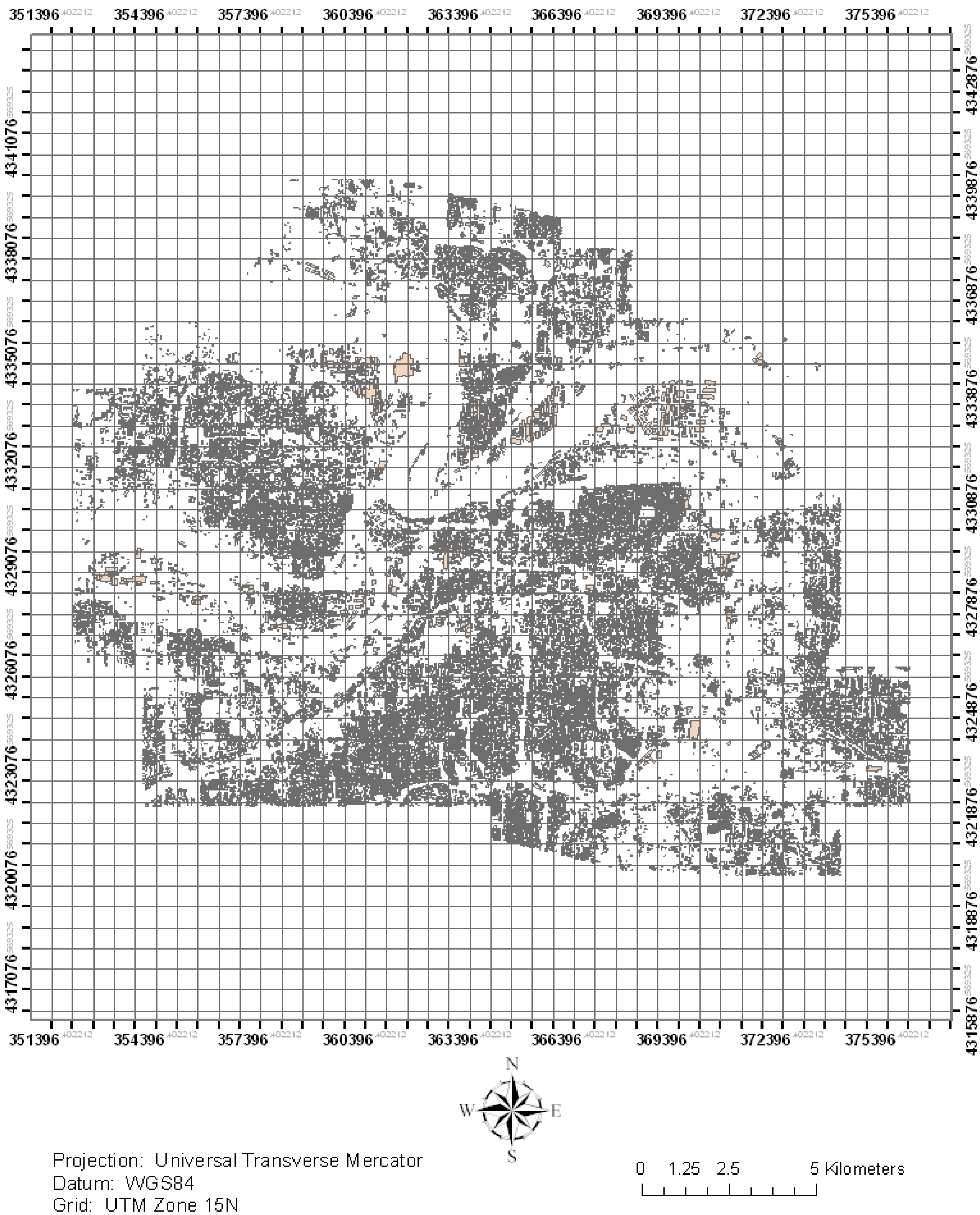
Building Data Extent for part of the Fort Lauderdale Metropolitan Area



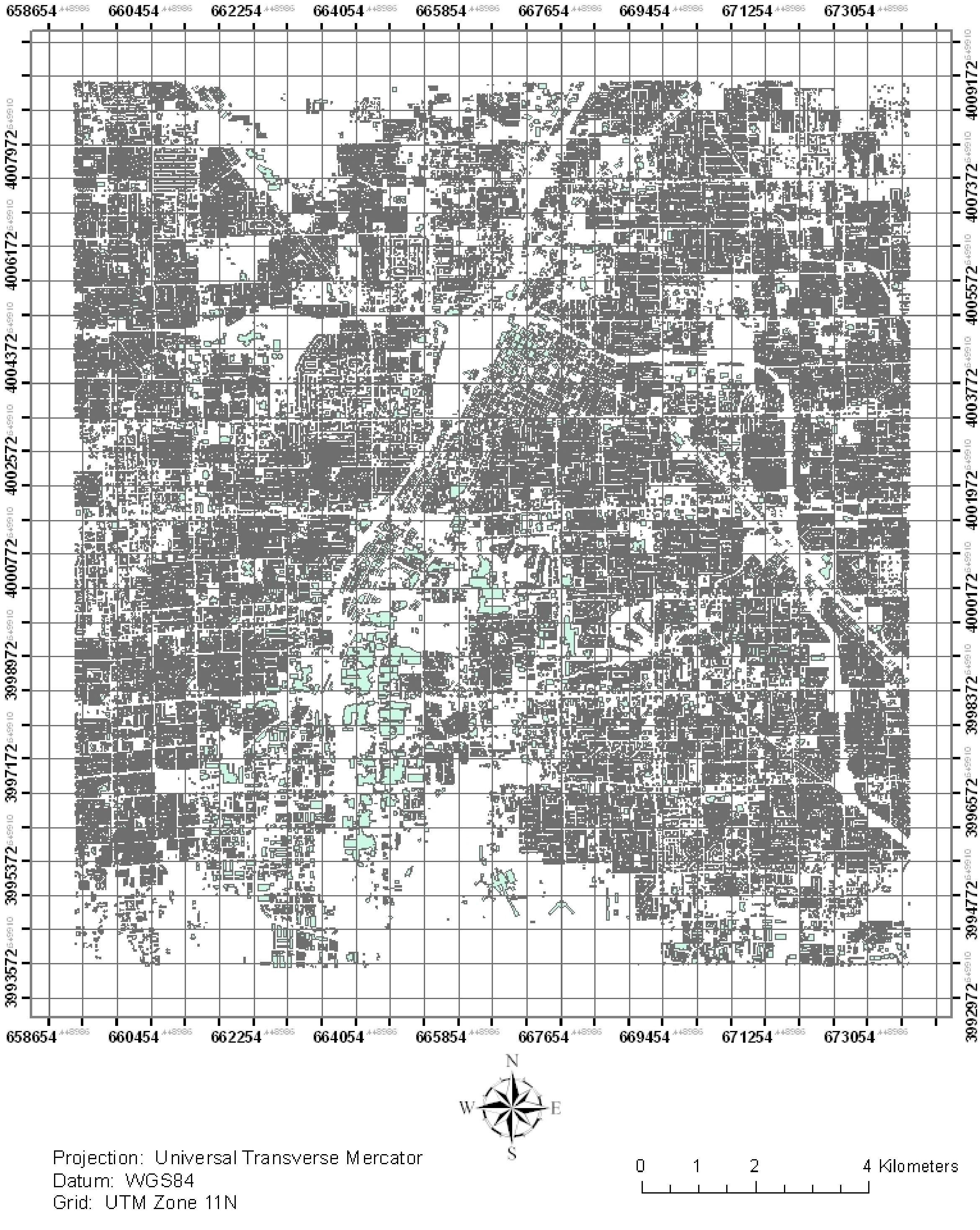
Building Data Extent for part of the Herndon-Dulles Metropolitan Area



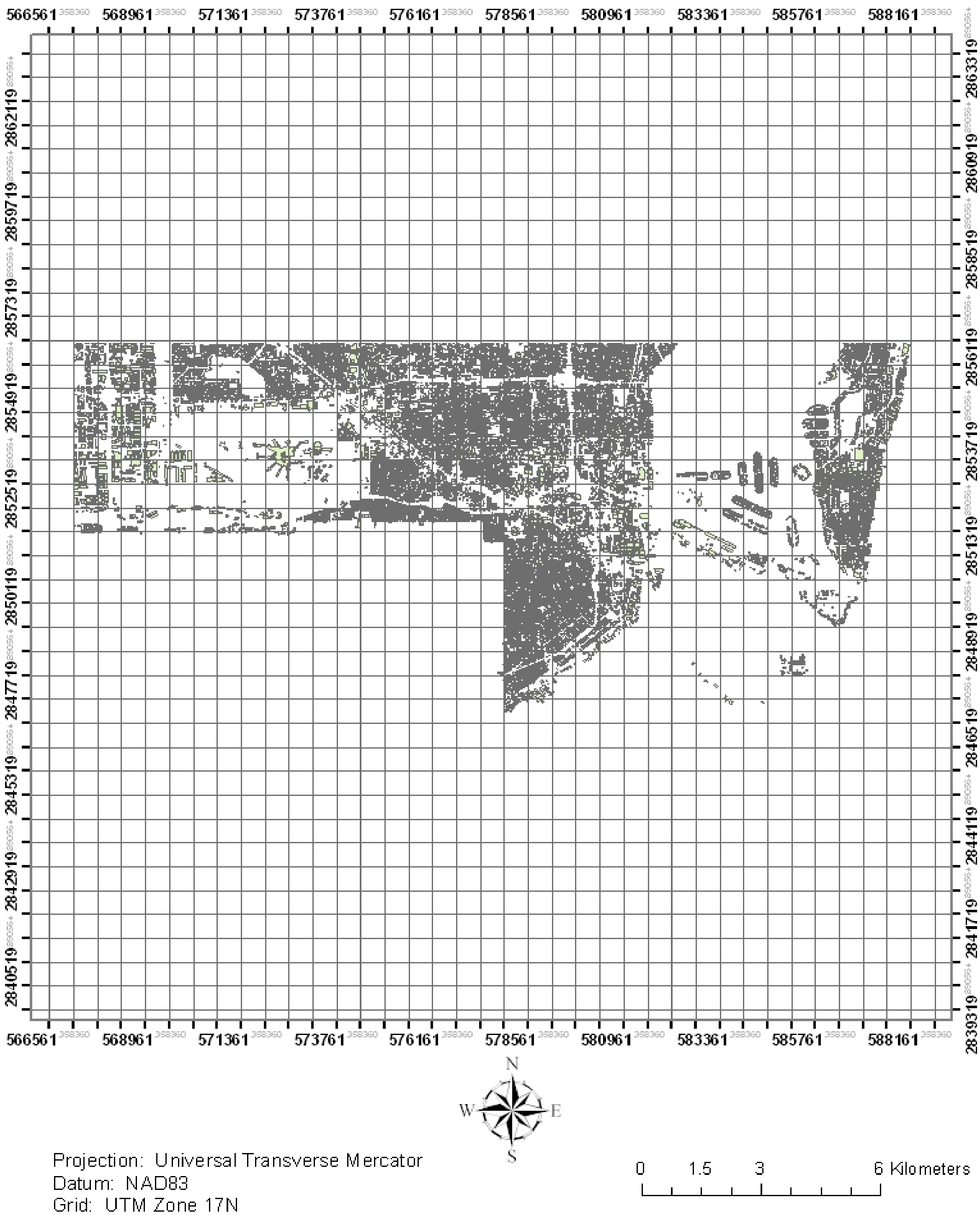
Building Data Extent for part of the Honolulu Metropolitan Area



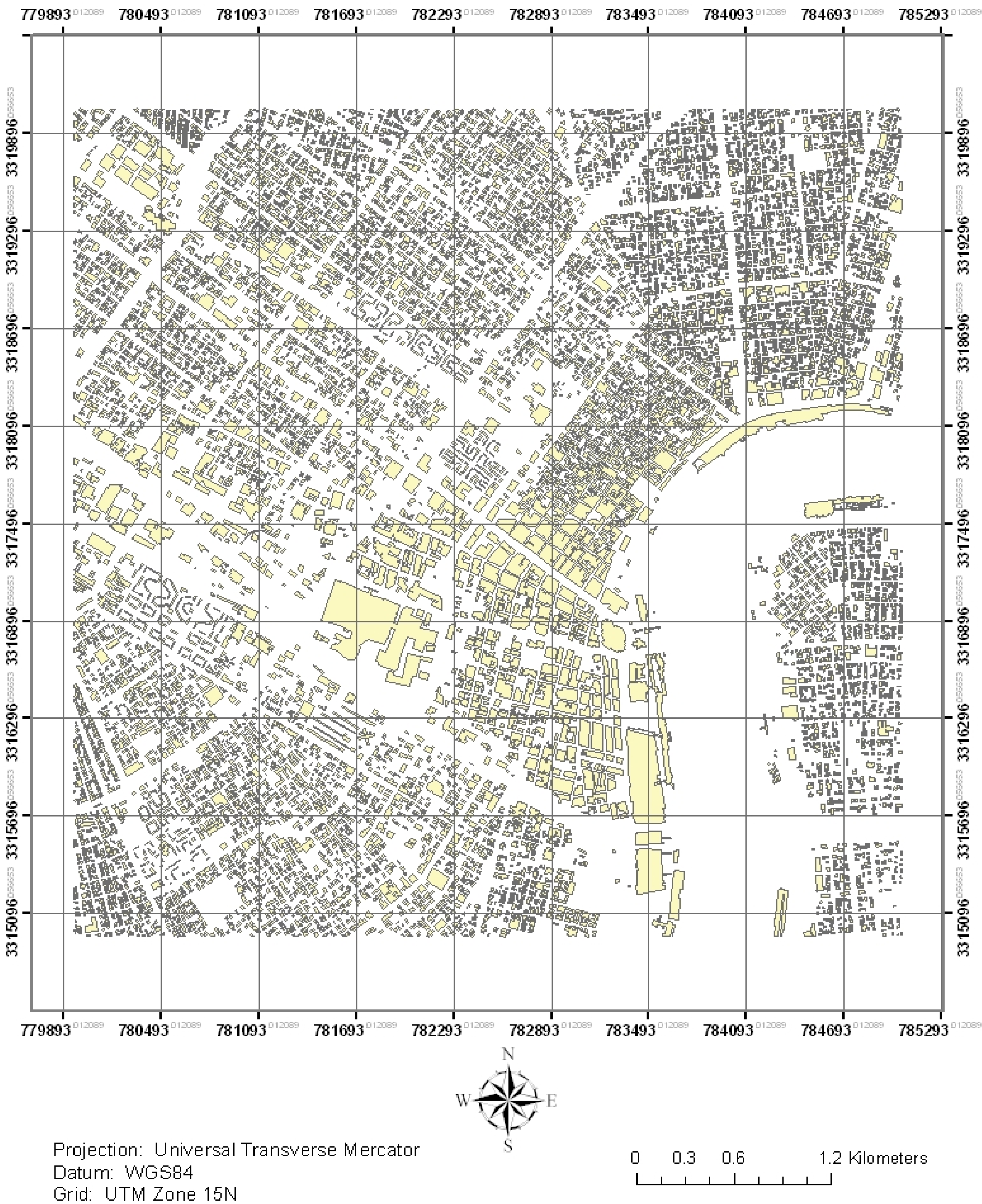
Building Data Extent for part of the Kansas City Metropolitan Area



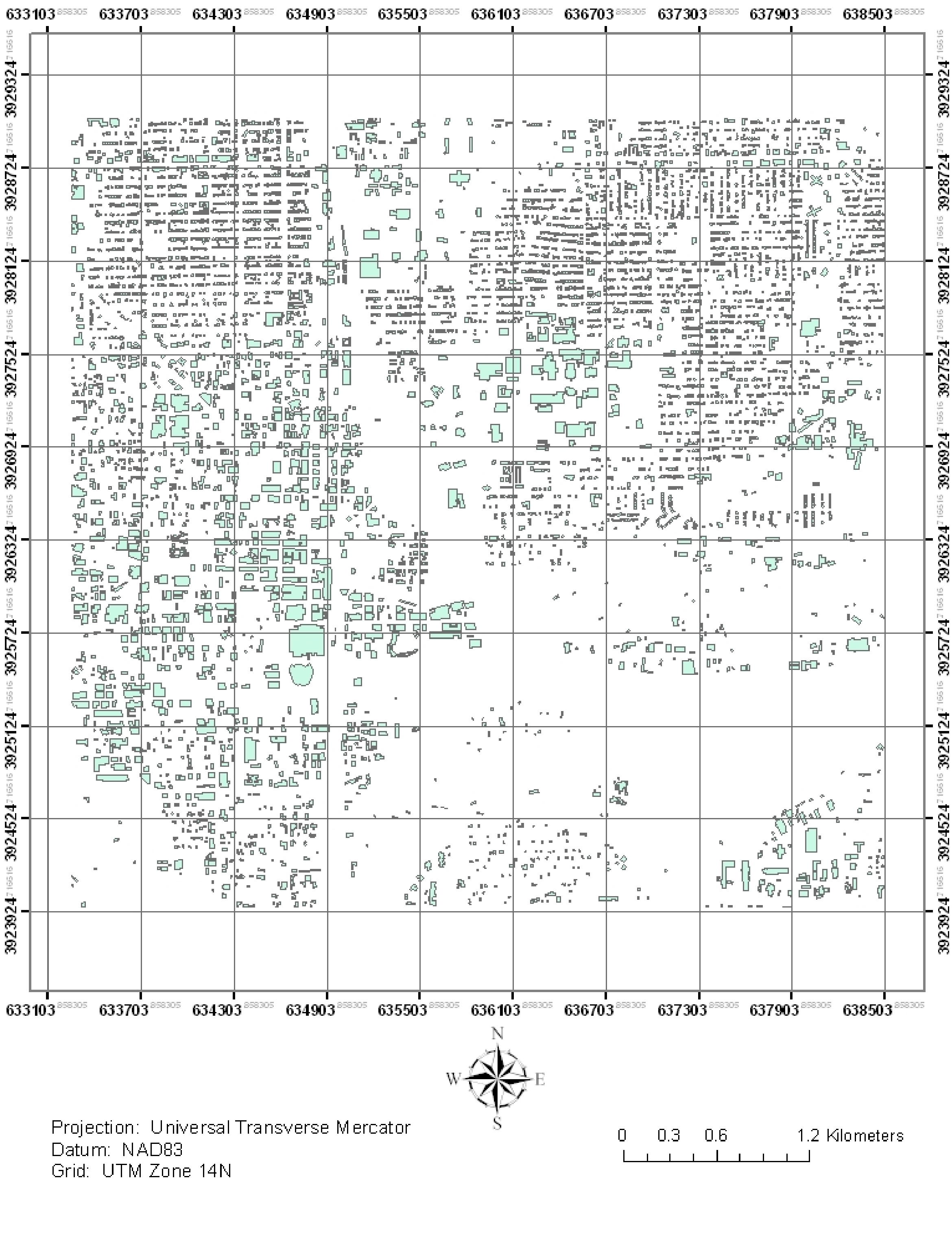
Building Data Extent for part of the Las Vegas Metropolitan Area



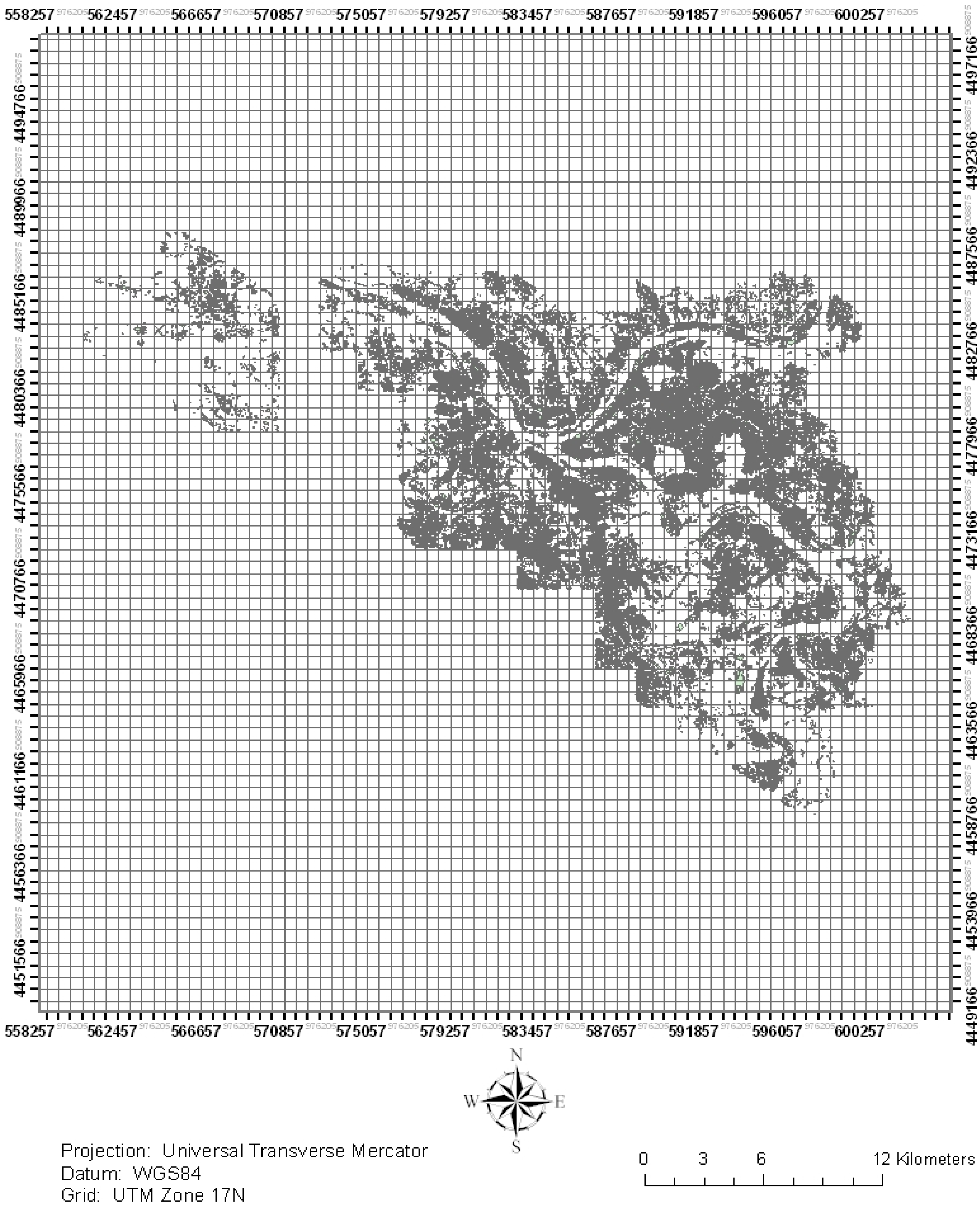
Building Data Extent for part of the Miami Metropolitan Area



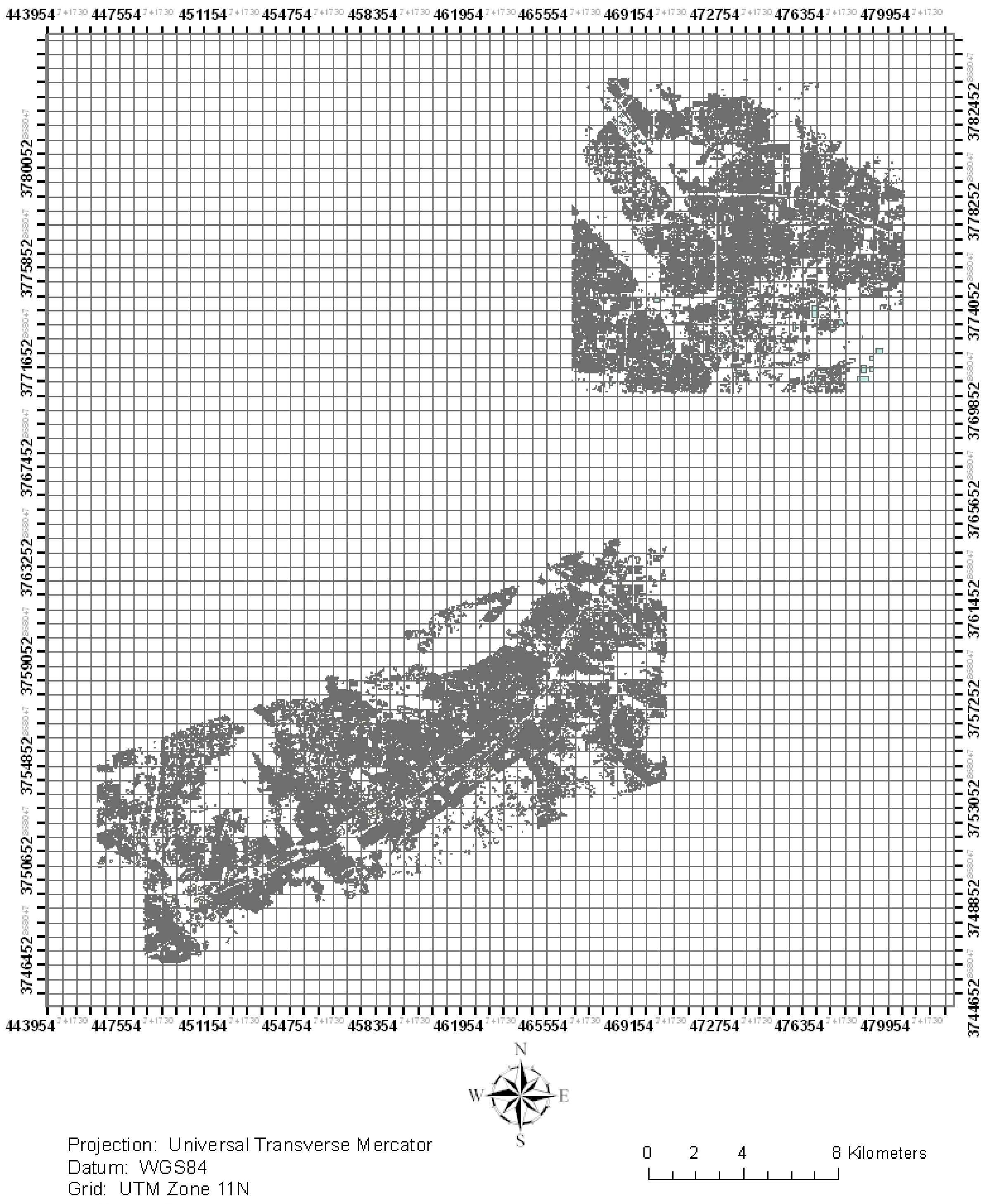
Building Data Extent for part of the New Orleans Metropolitan Area



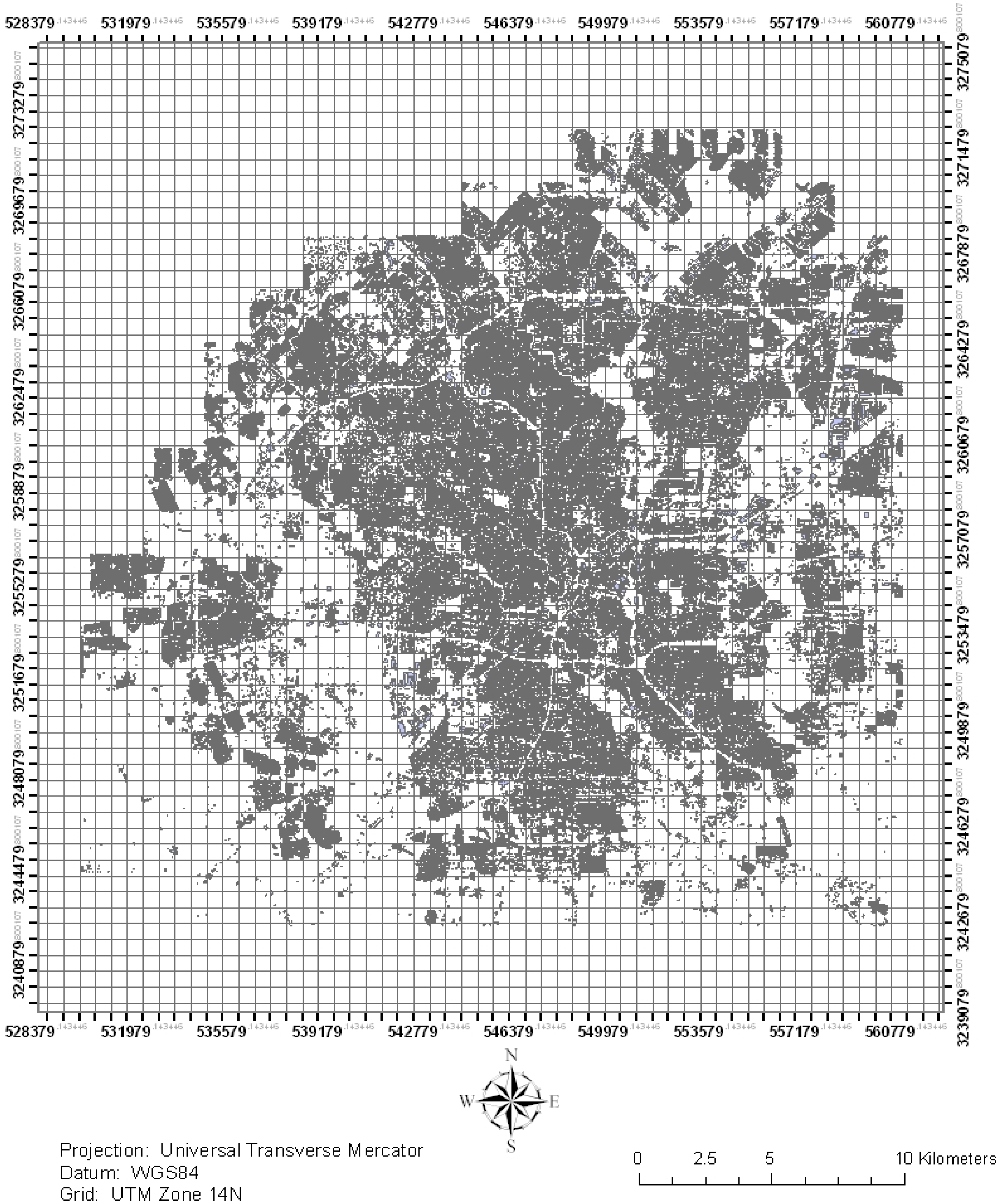
Building Data Extent for part of the Oklahoma City Metropolitan Area



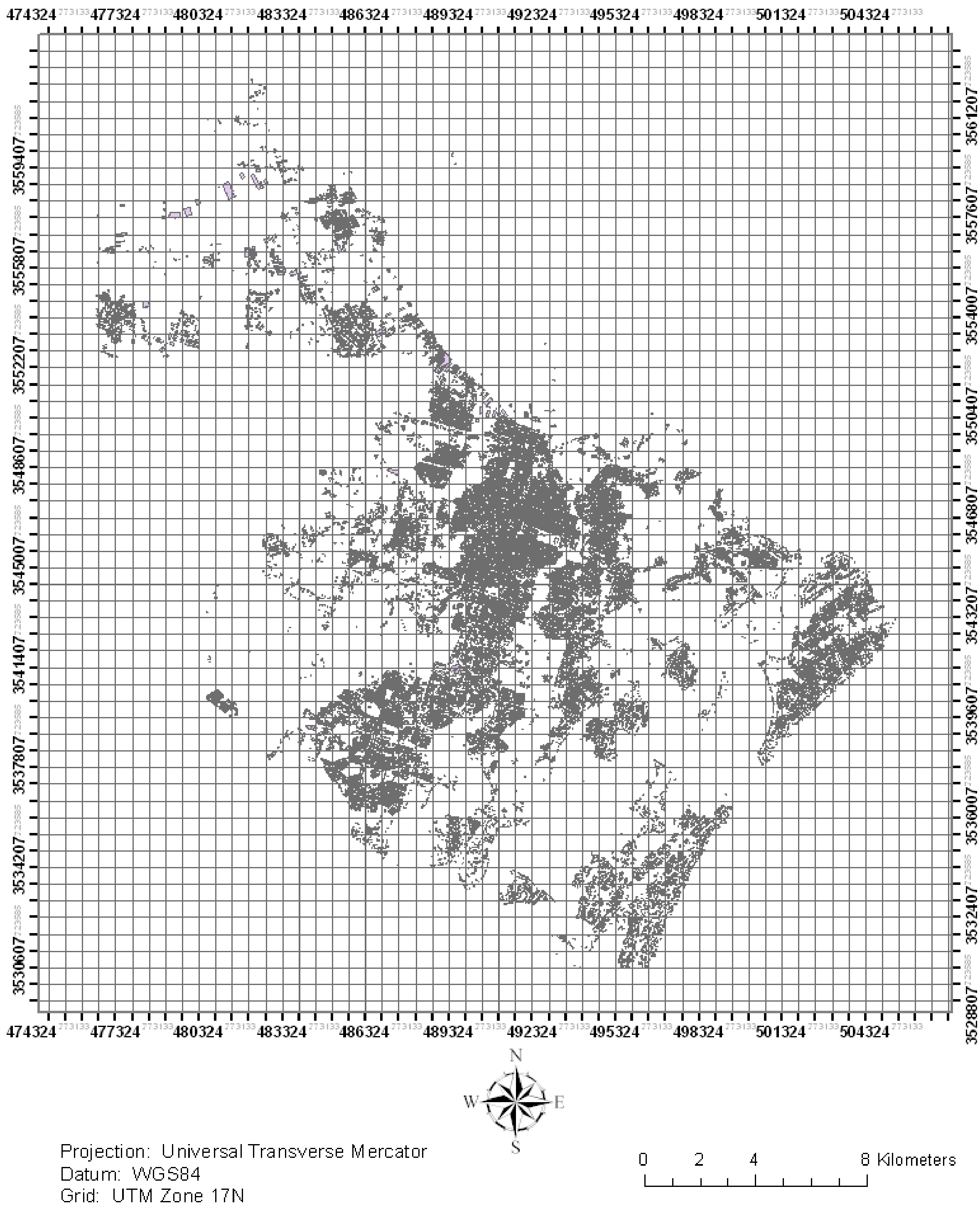
Building Data Extent for part of the Pittsburgh Metropolitan Area



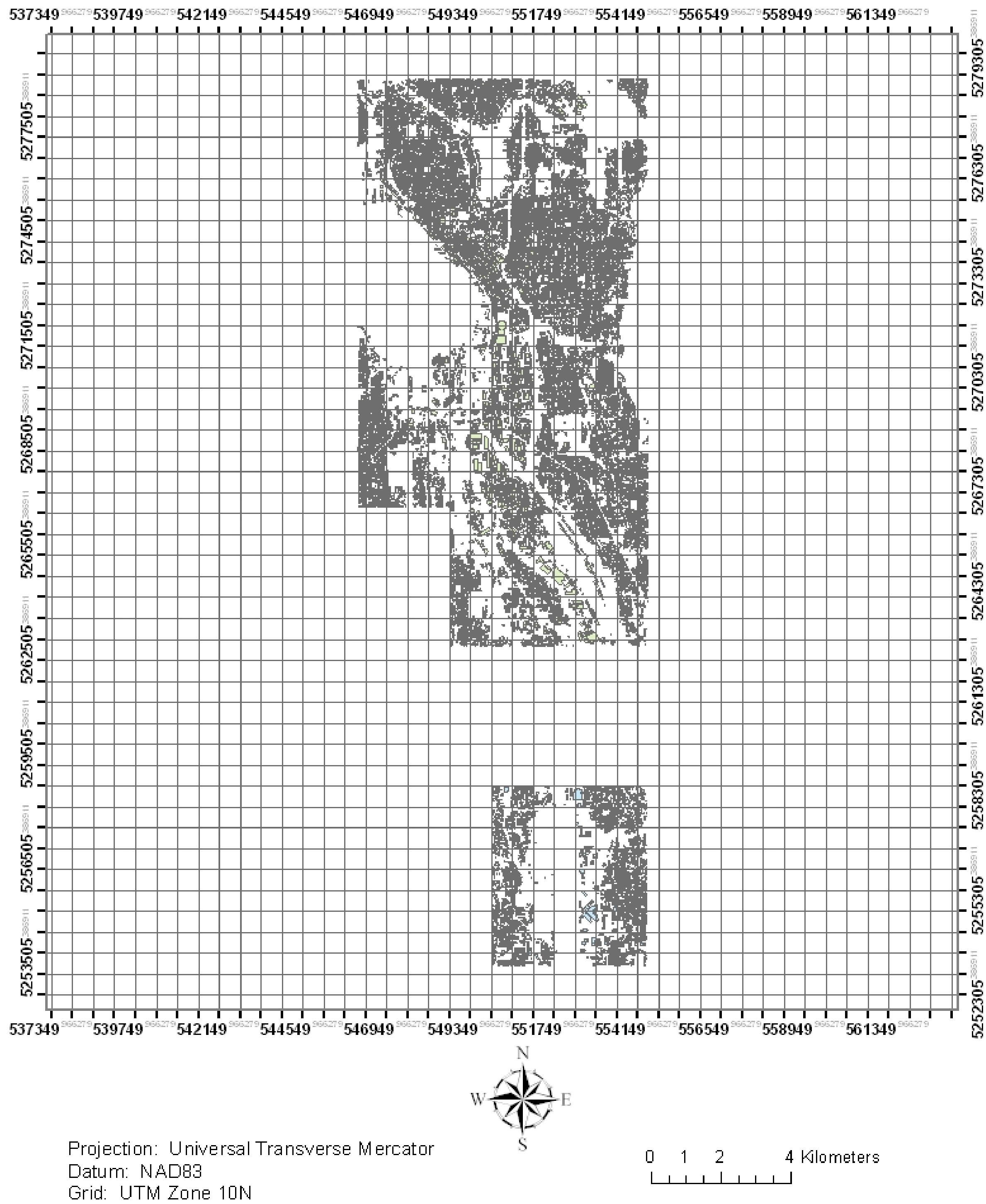
Building Data Extent for part of the Riverside Metropolitan Area



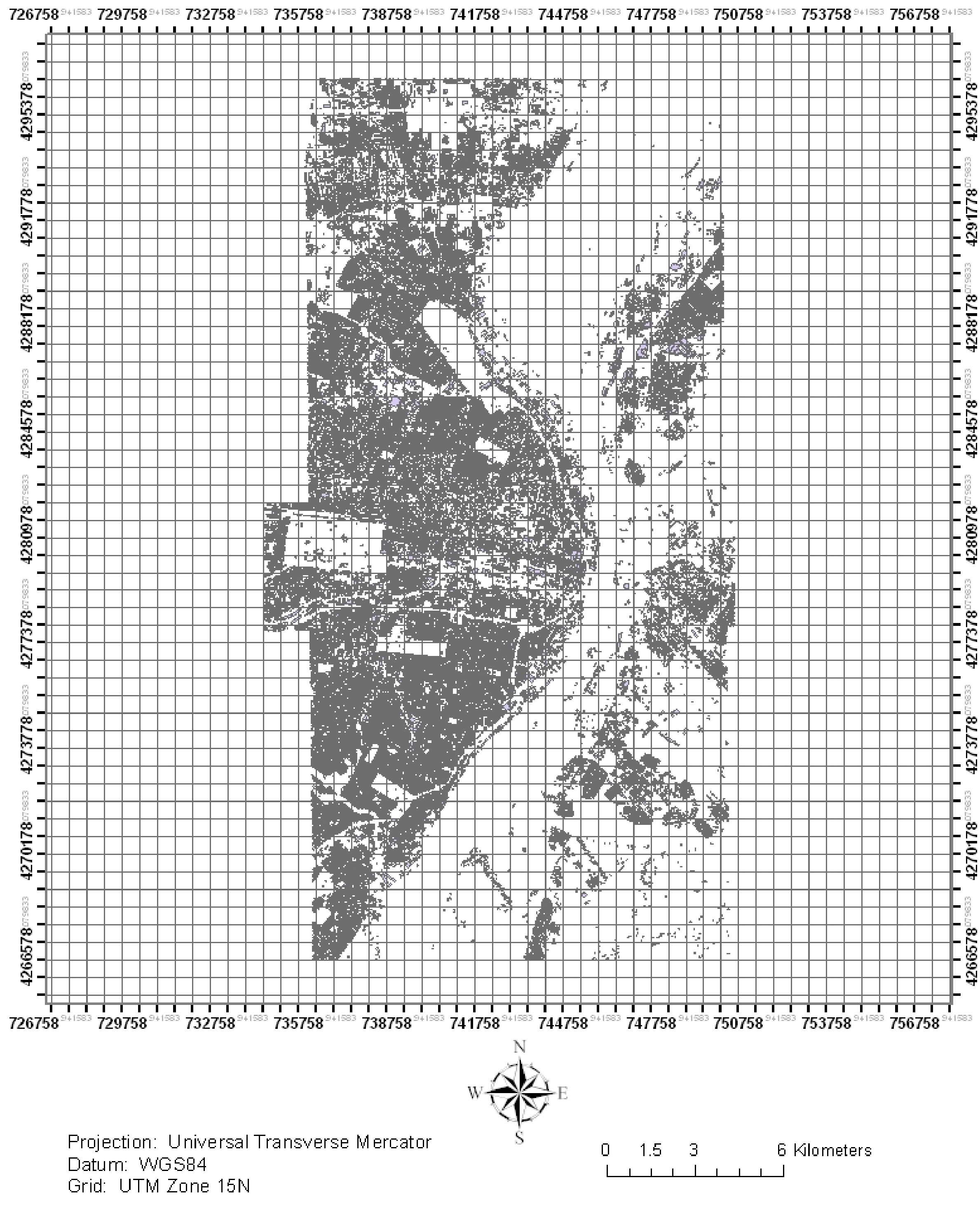
Building Data Extent for part of the San Antonio Metropolitan Area



Building Data Extent for part of the Savannah Metropolitan Area

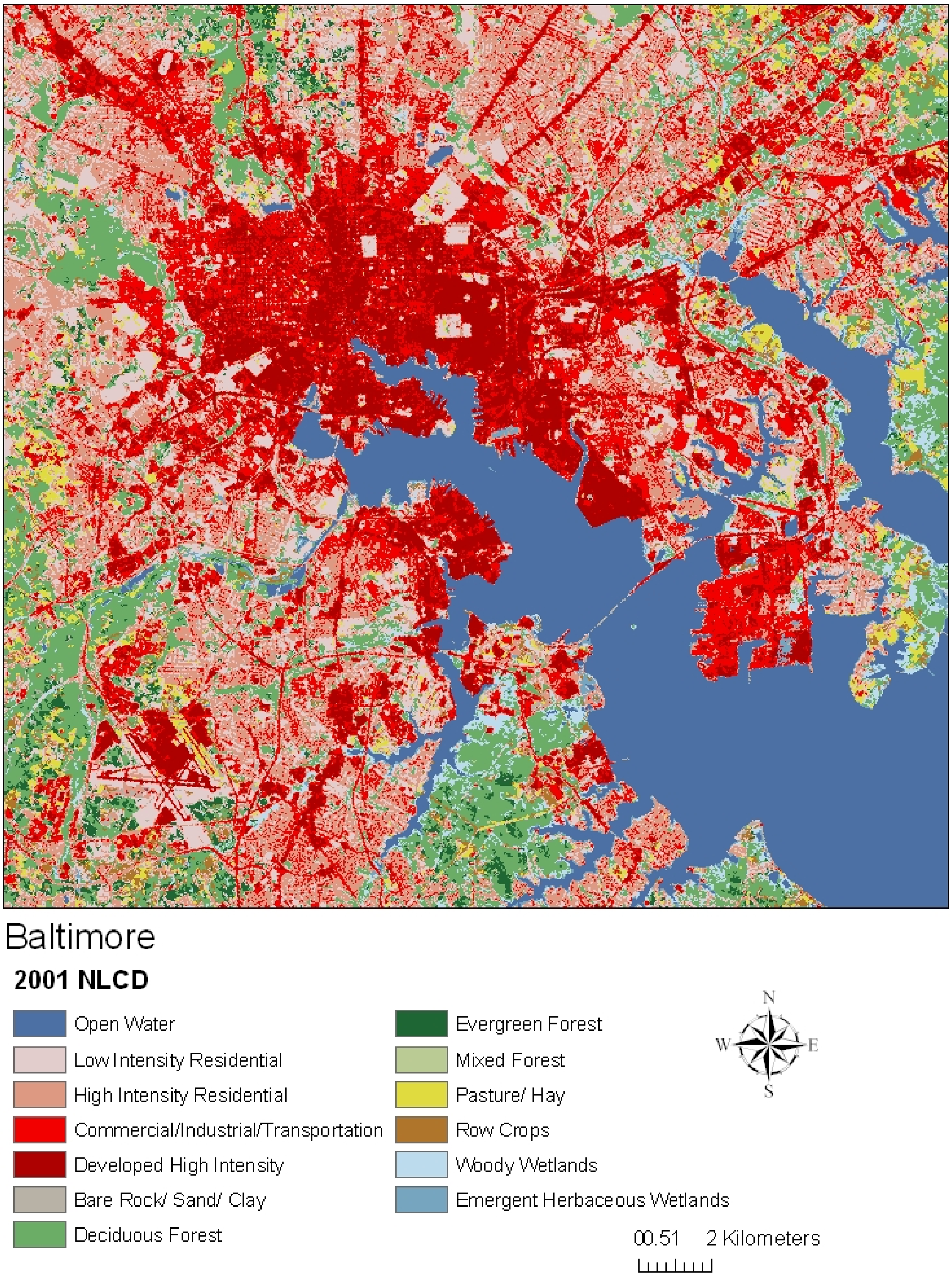


Building Data Extent for part of the Seattle Metropolitan Area

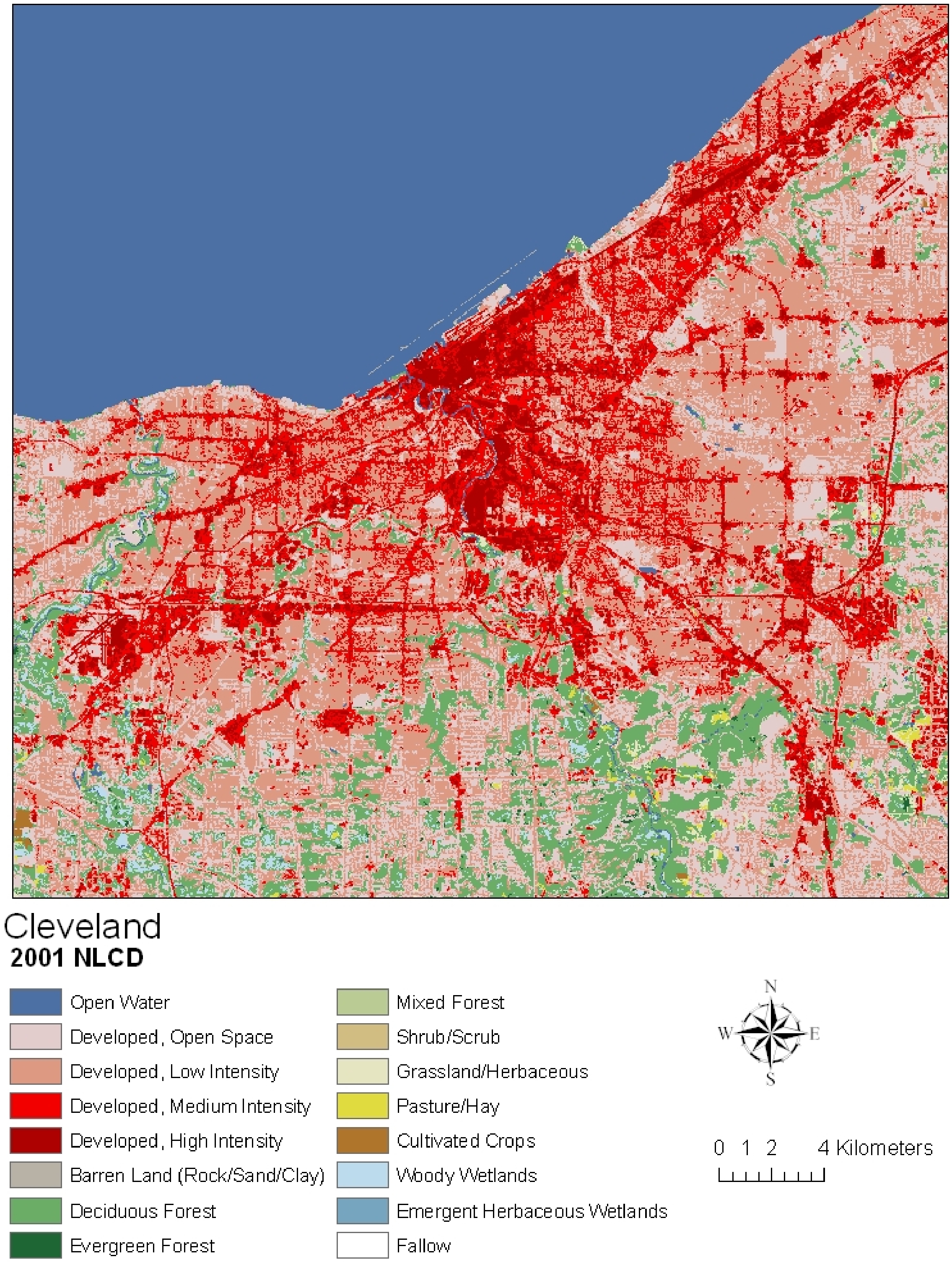


Building Data Extent for part of the St. Louis Metropolitan Area

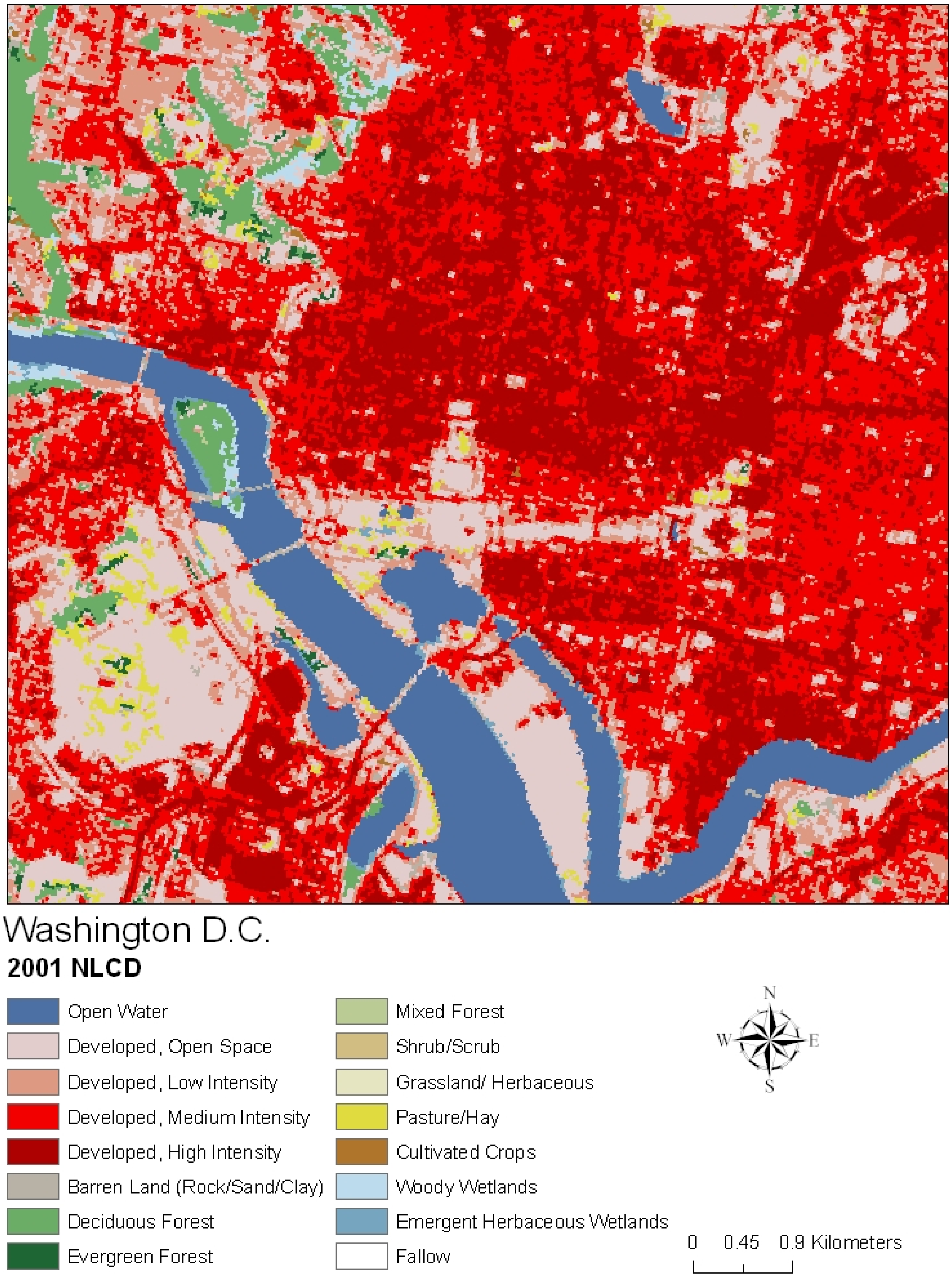
Appendix IV: Land Use/Cover Maps of Selected Cities



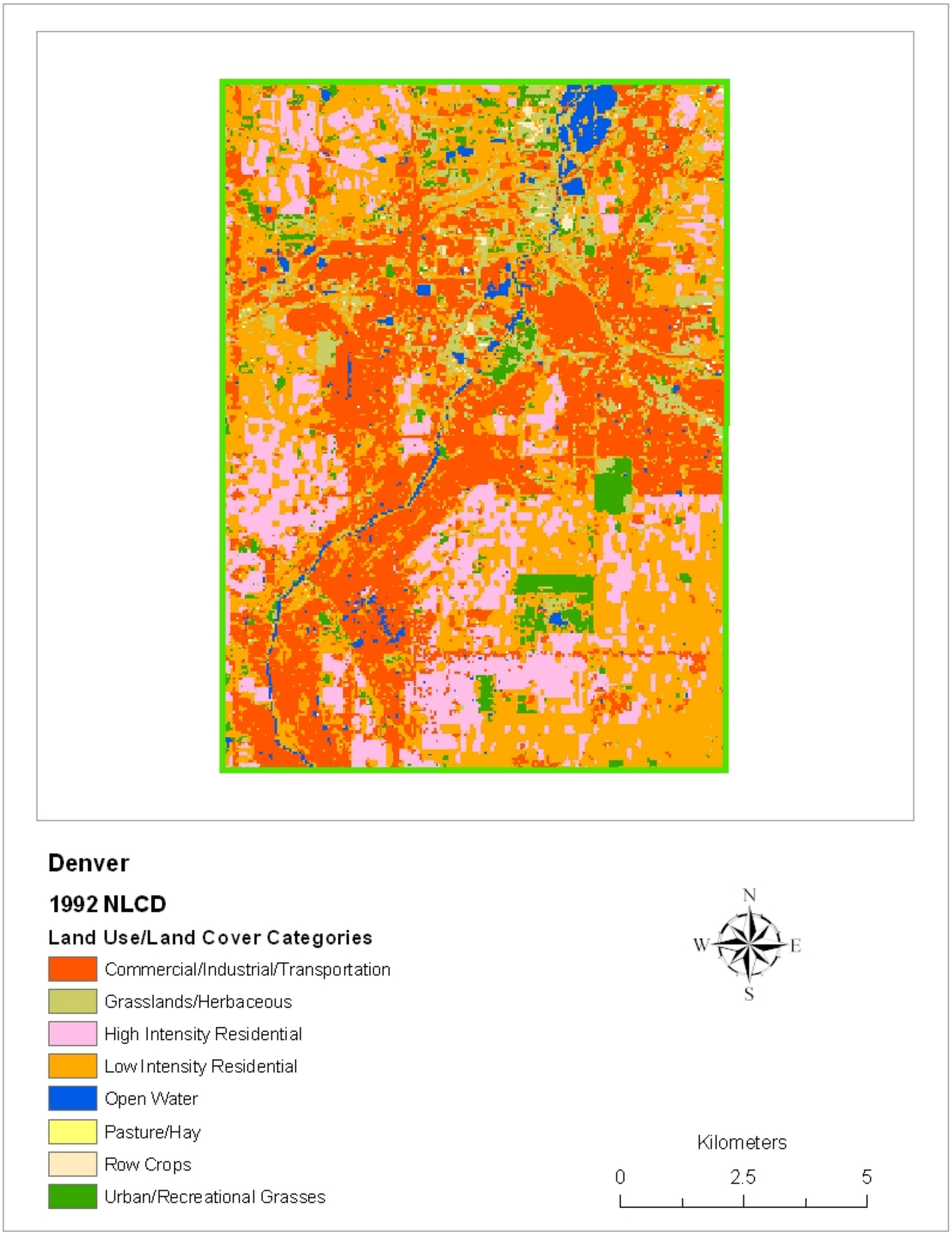
Land Use/Cover for part of the Baltimore Metropolitan Area



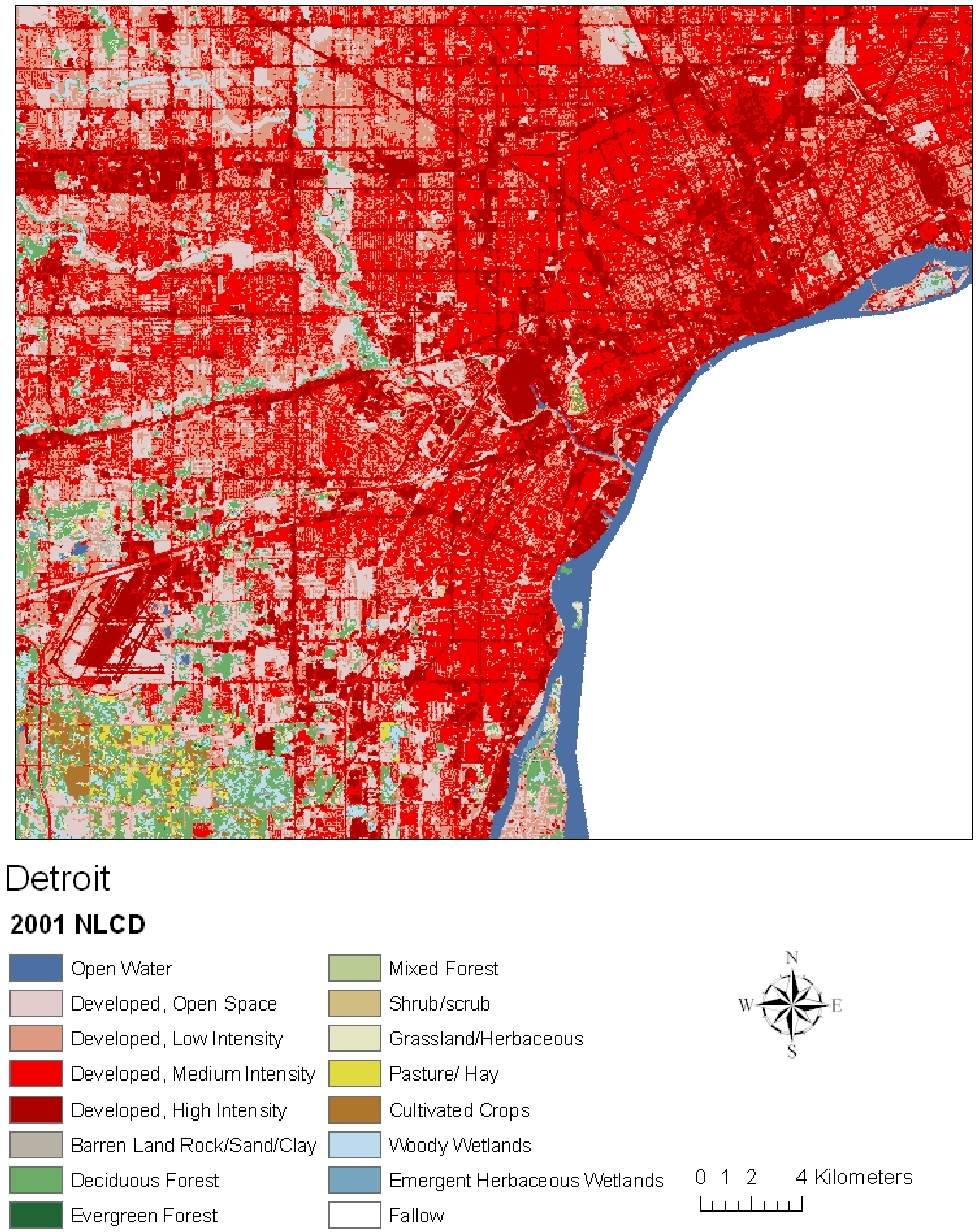
Land Use/Cover for part of the Cleveland Metropolitan Area



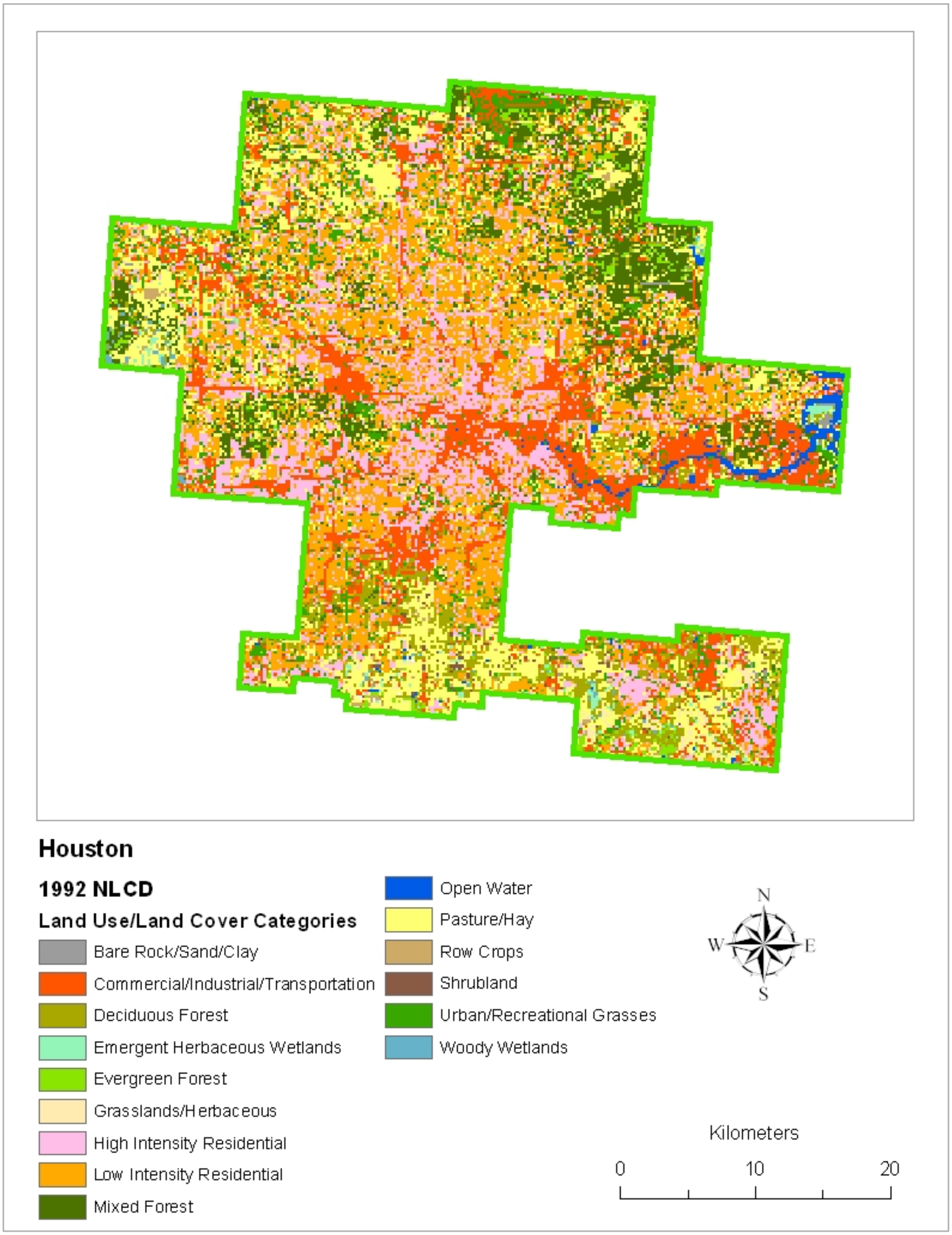
Land Use/Cover for part of the Washington DC Metropolitan Area



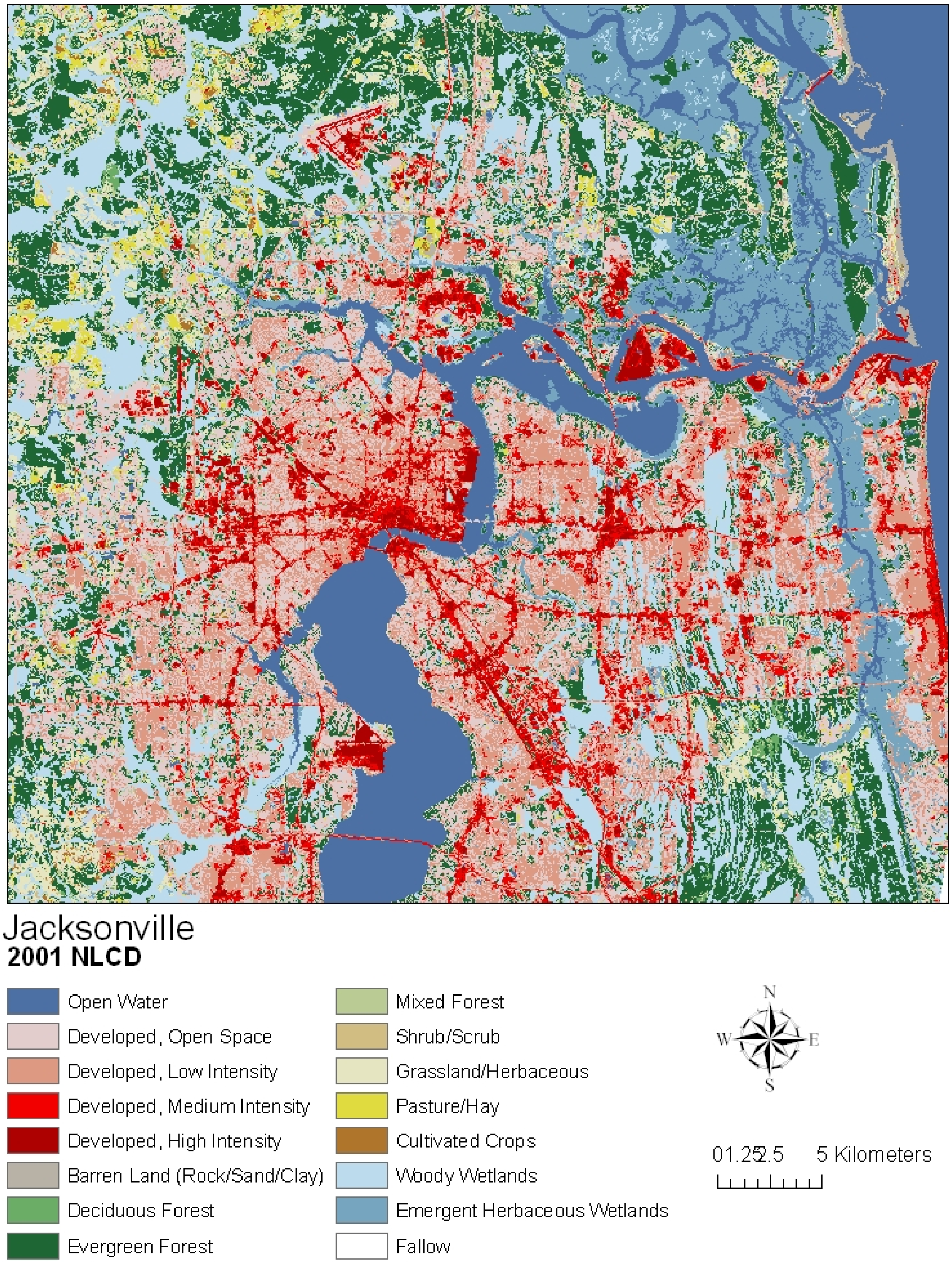
Land Use/Cover for part of the Denver Metropolitan Area



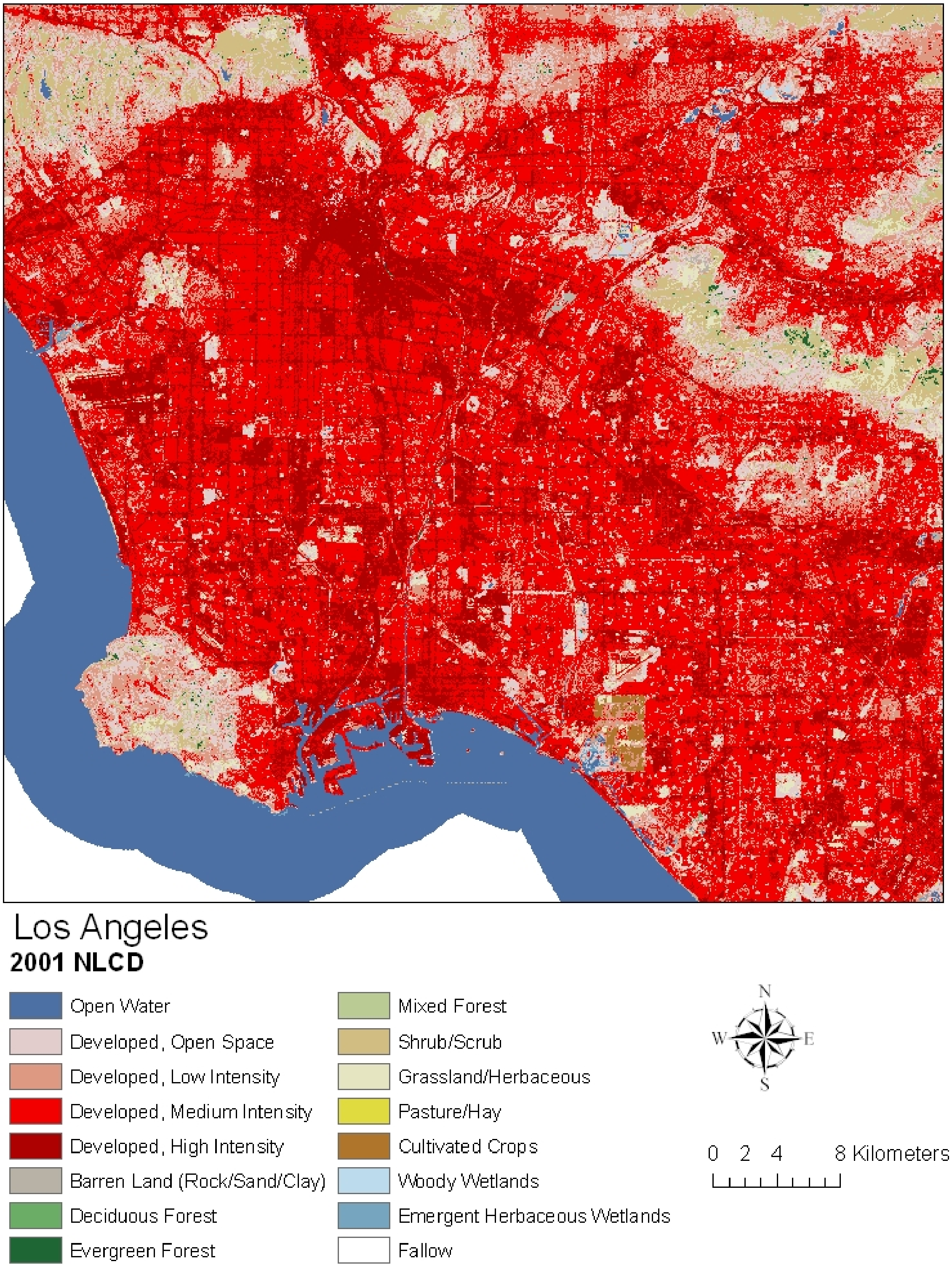
Land Use/Cover for part of the Detroit Metropolitan Area



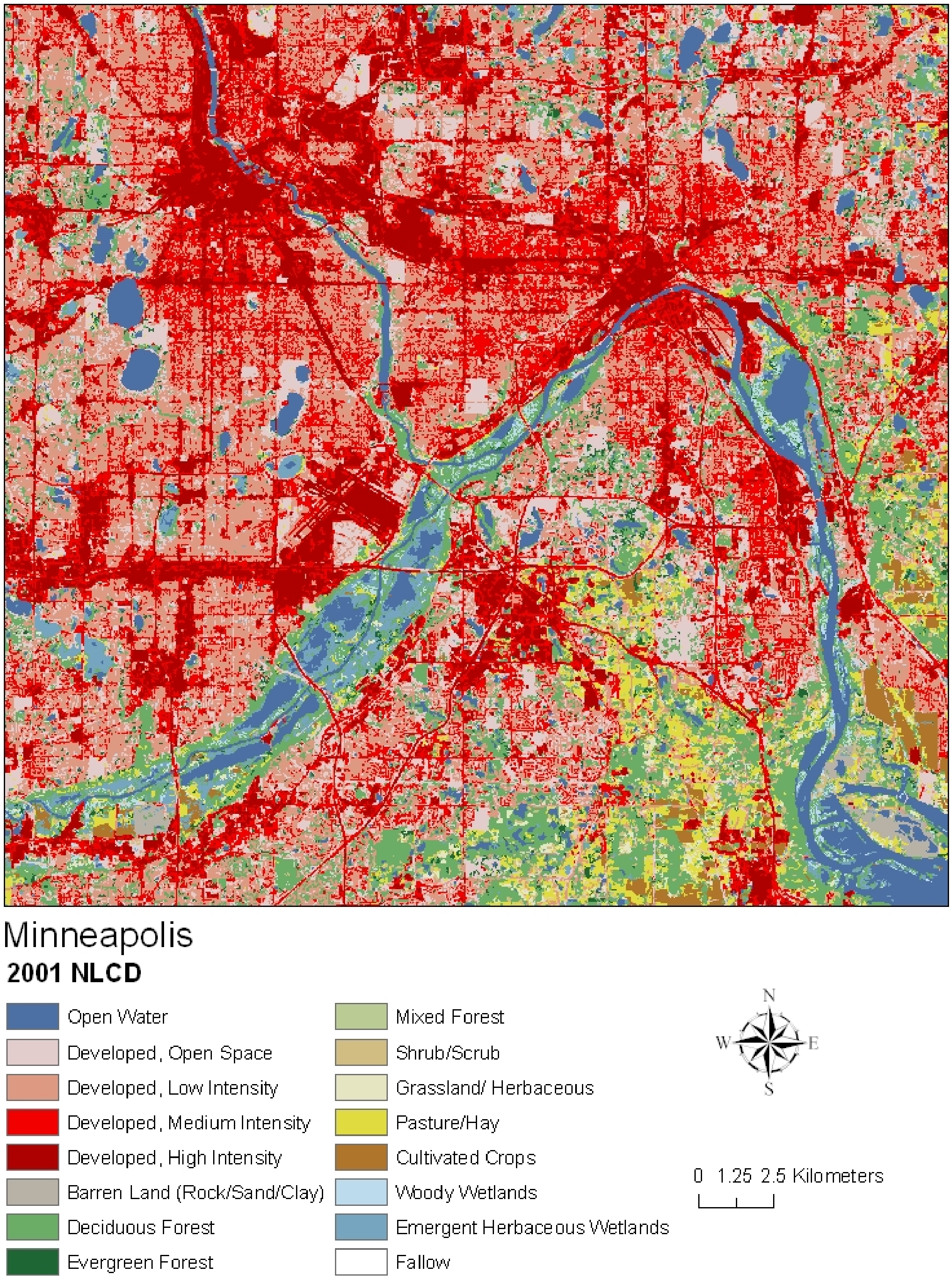
Land Use/Cover for part of the Houston Metropolitan Area



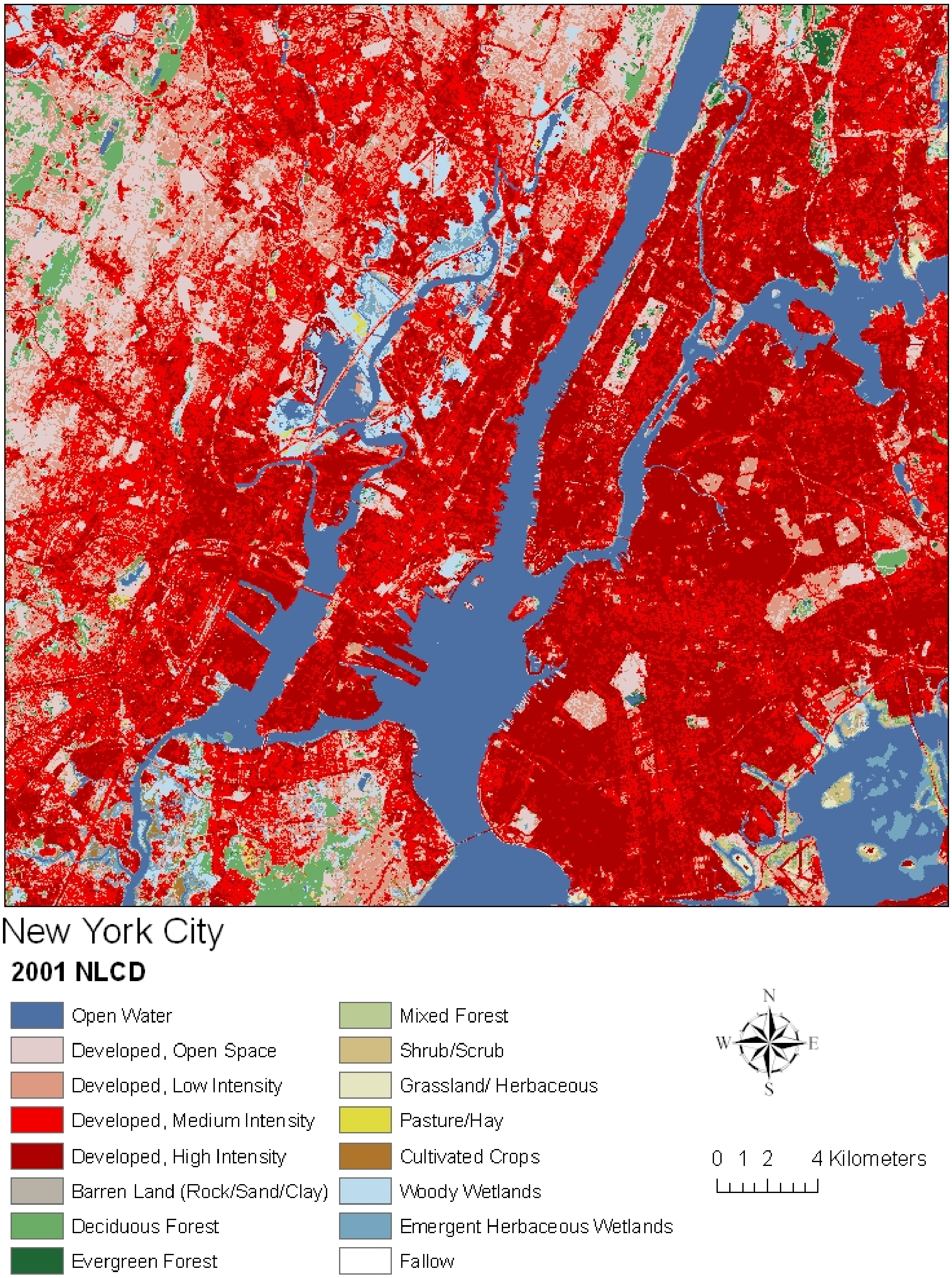
Land Use/Cover for part of the Jacksonville Metropolitan Area



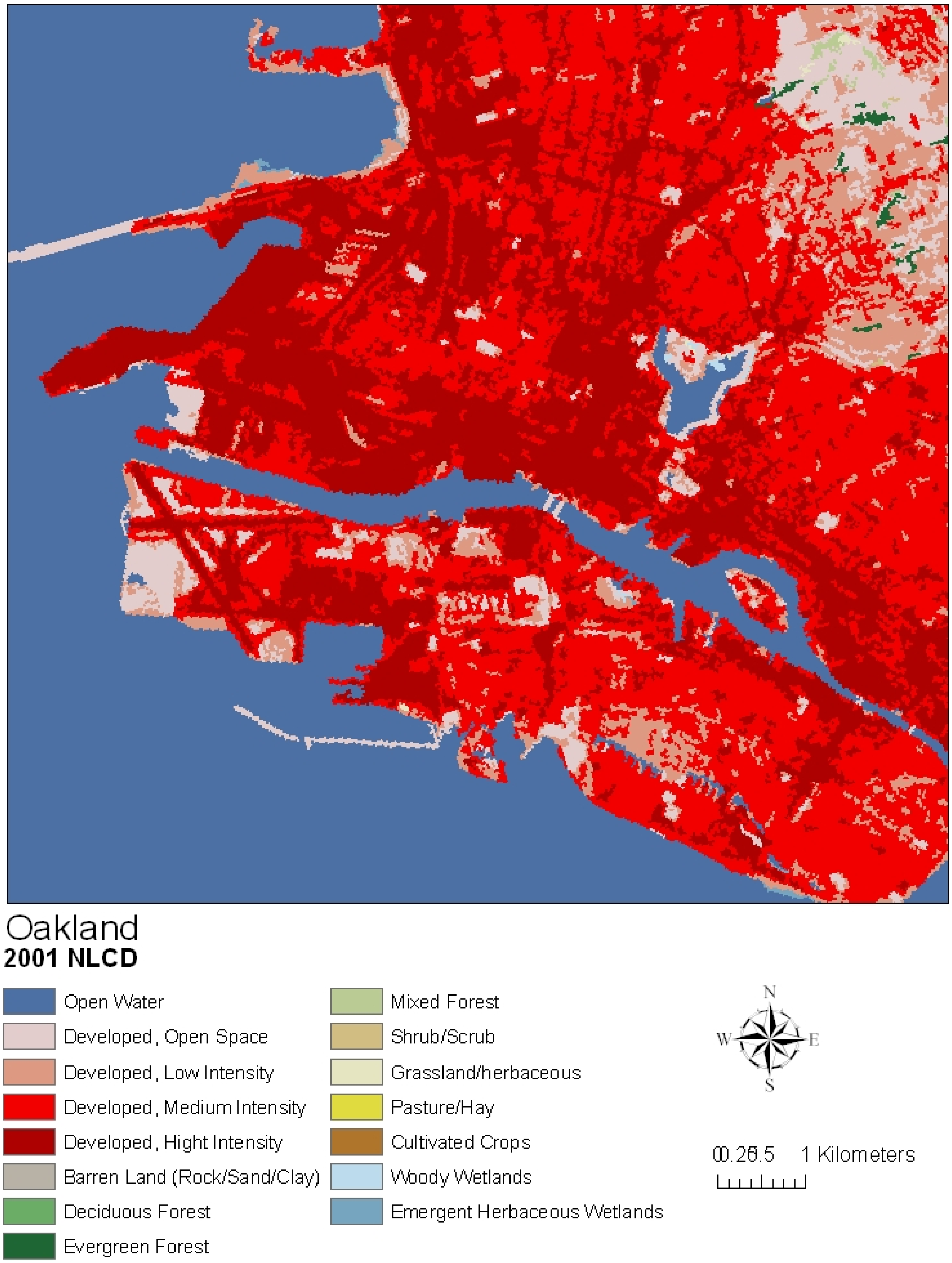
Land Use/Cover for part of the Los Angeles Metropolitan Area



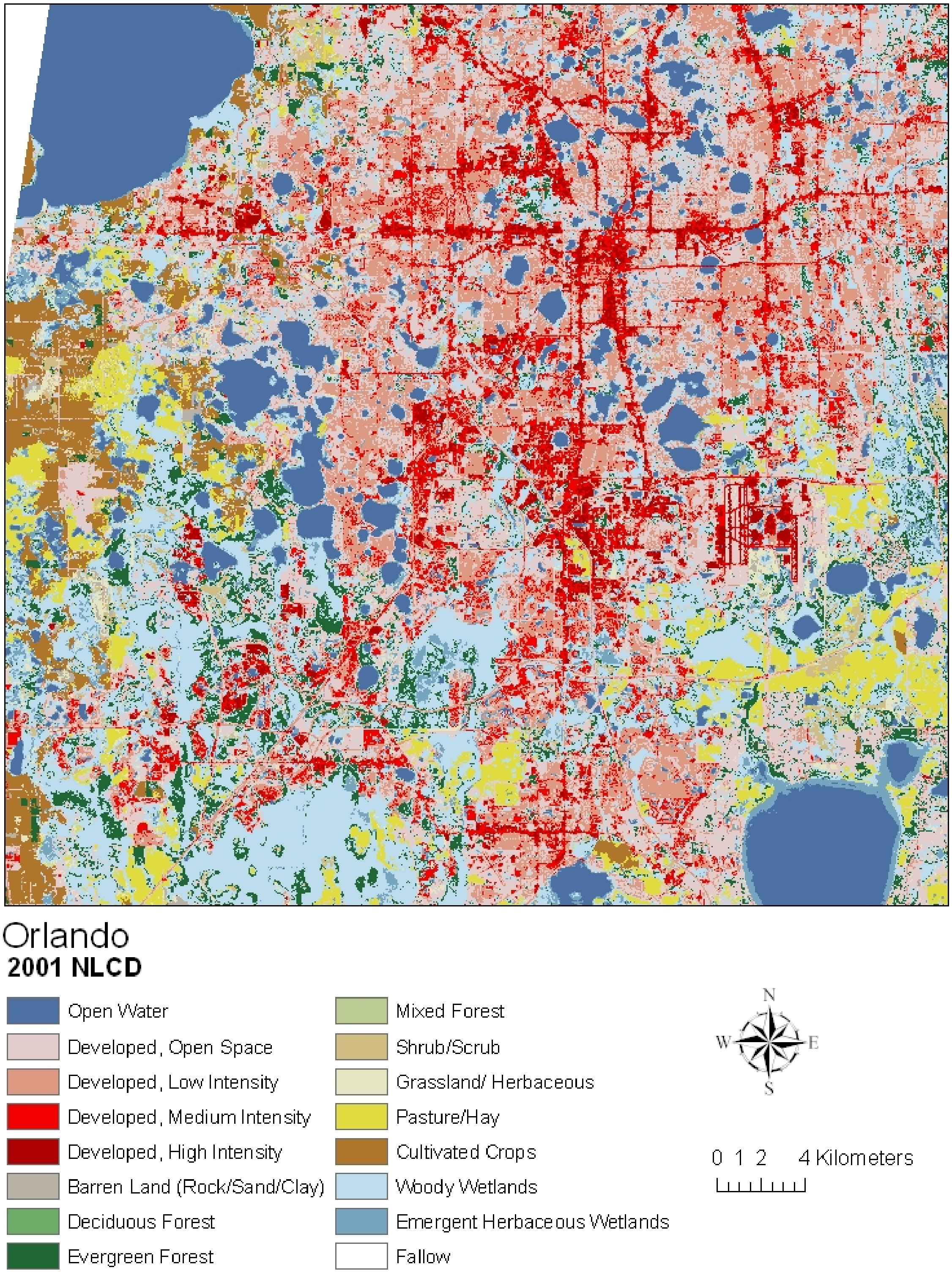
Land Use/Cover for part of the Minneapolis Metropolitan Area



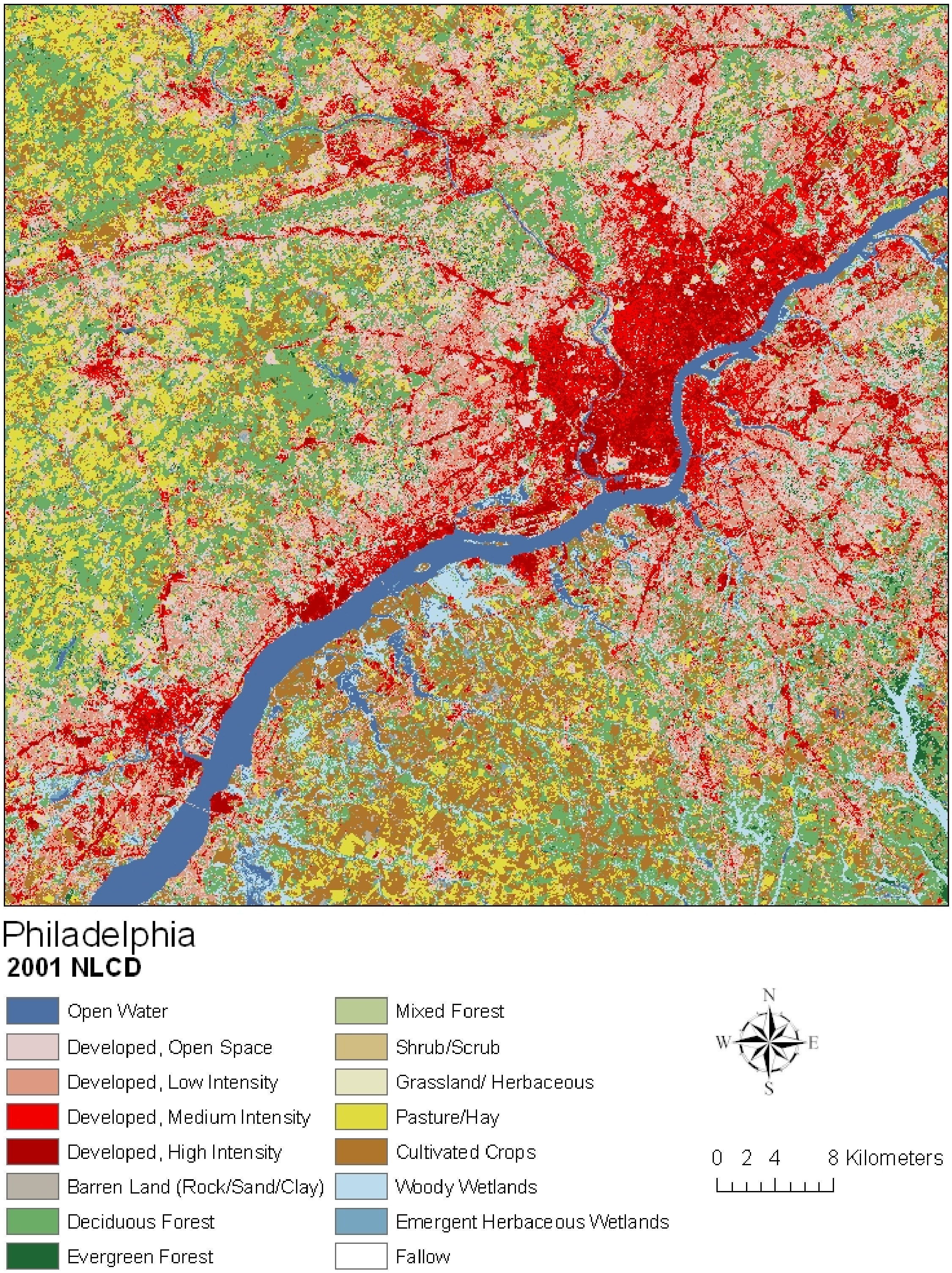
Land Use/Cover for part of the New York City Metropolitan Area



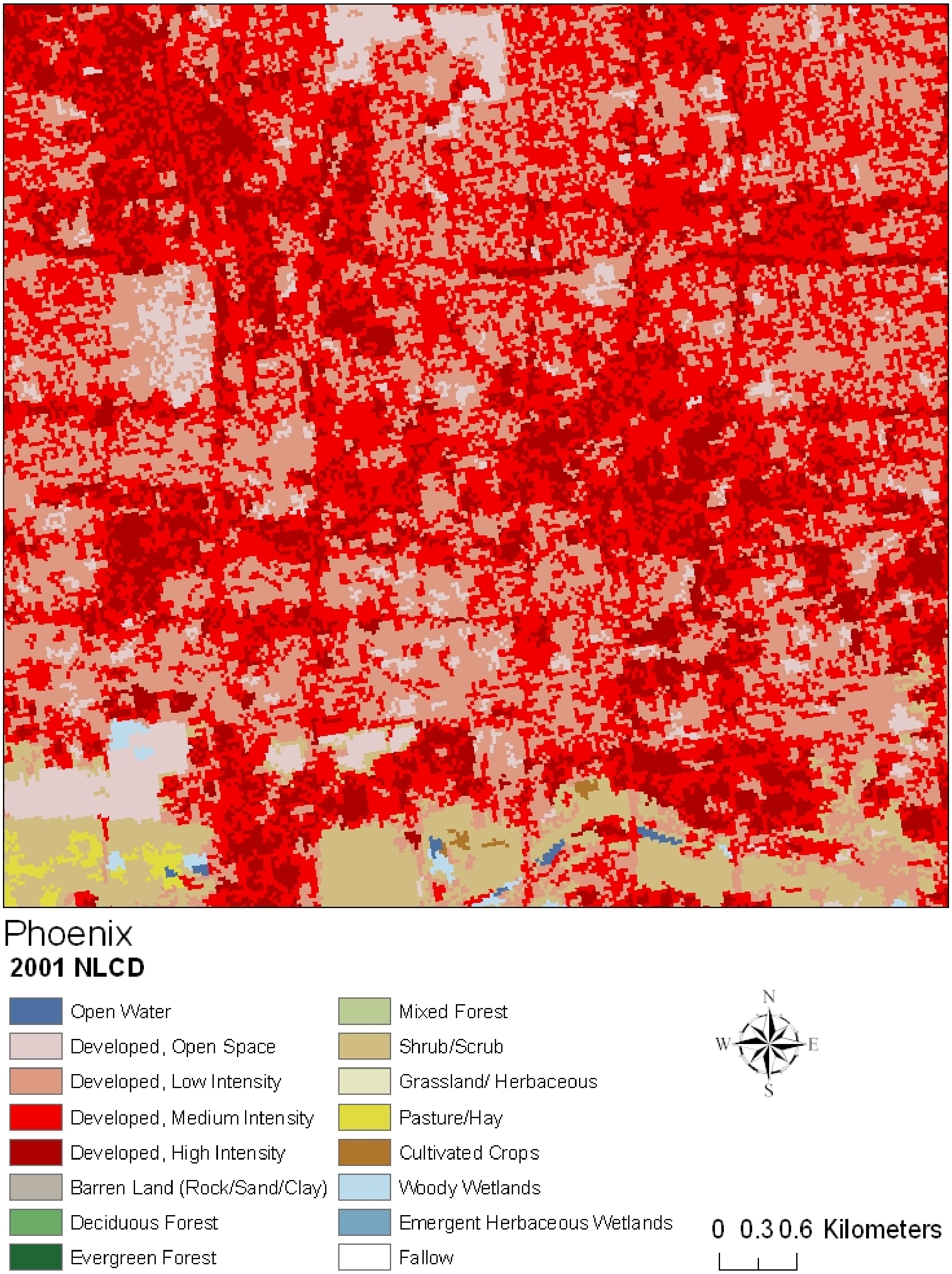
Land Use/Cover for part of the Oakland Metropolitan Area



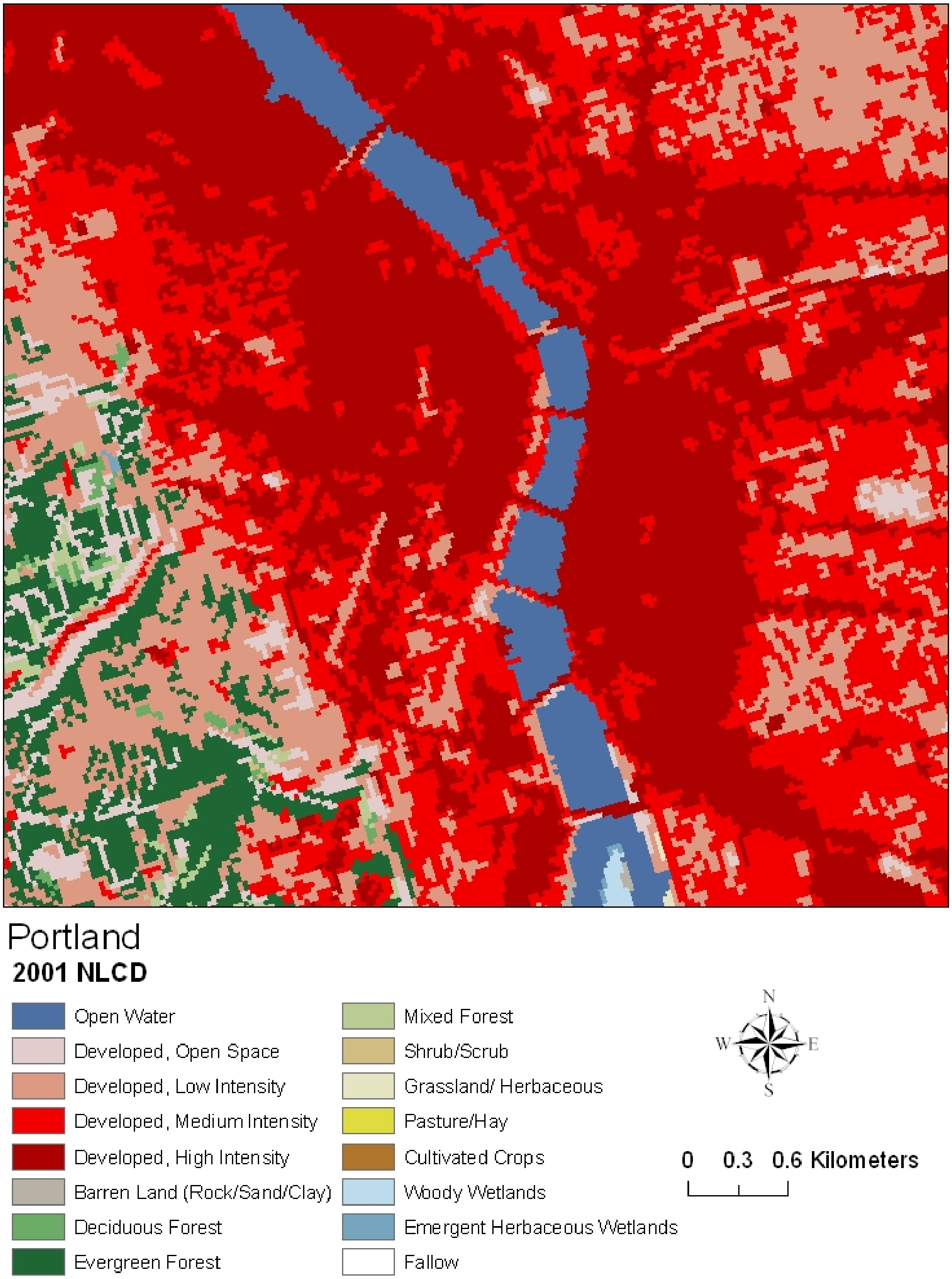
Land Use/Cover for part of the Orlando Metropolitan Area



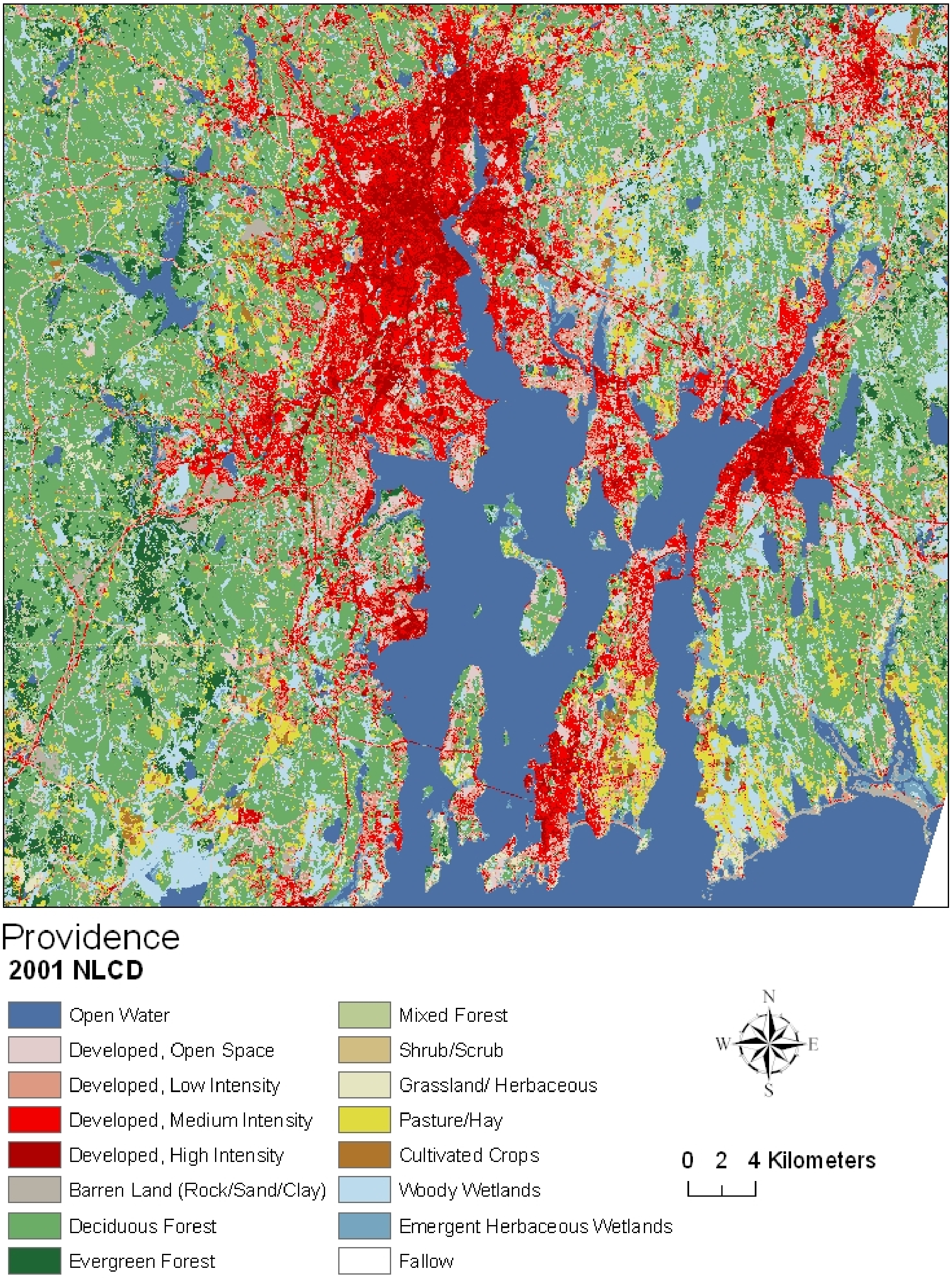
Land Use/Cover for part of the Philadelphia Metropolitan Area



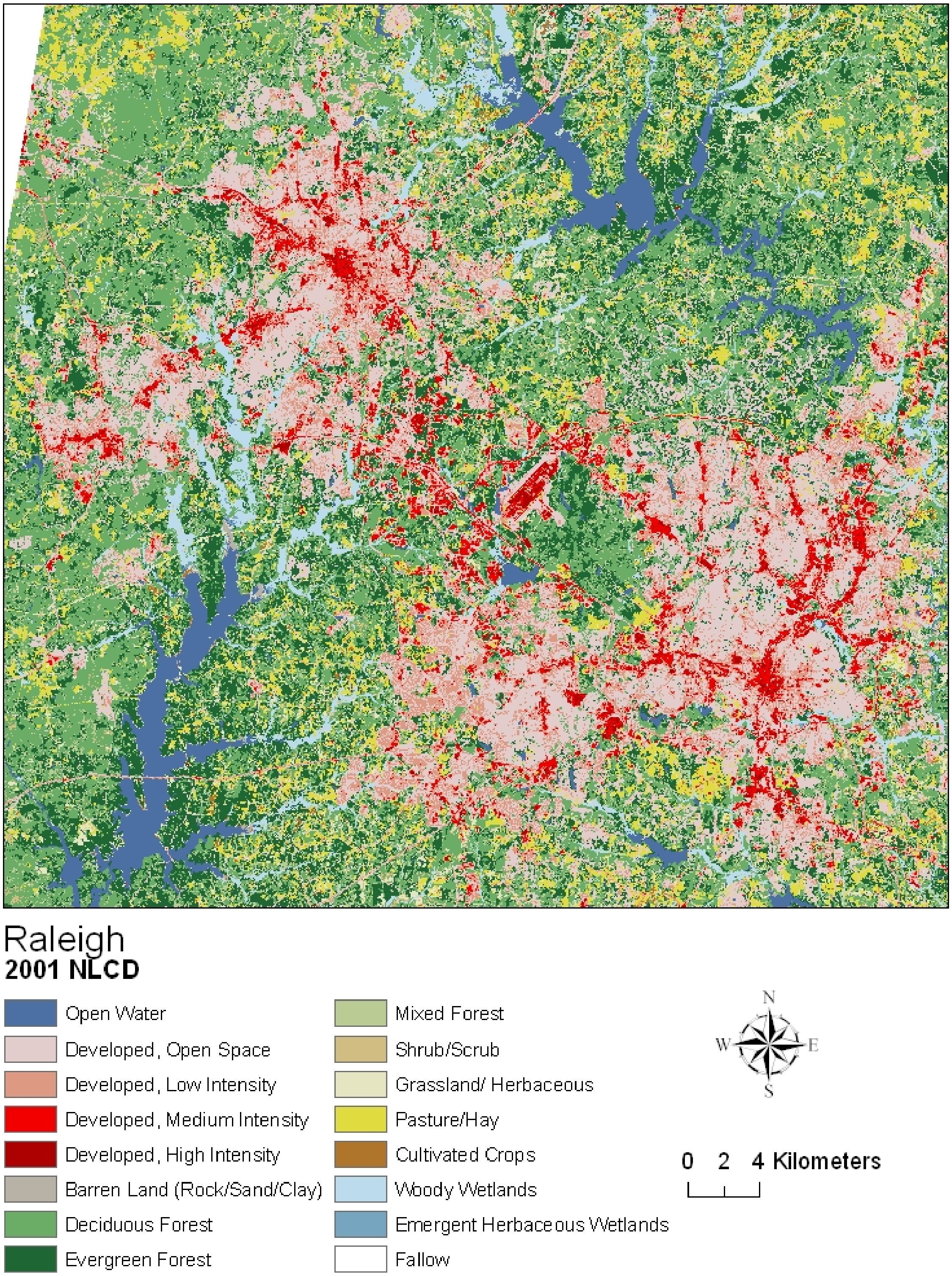
Land Use/Cover for part of the Phoenix Metropolitan Area



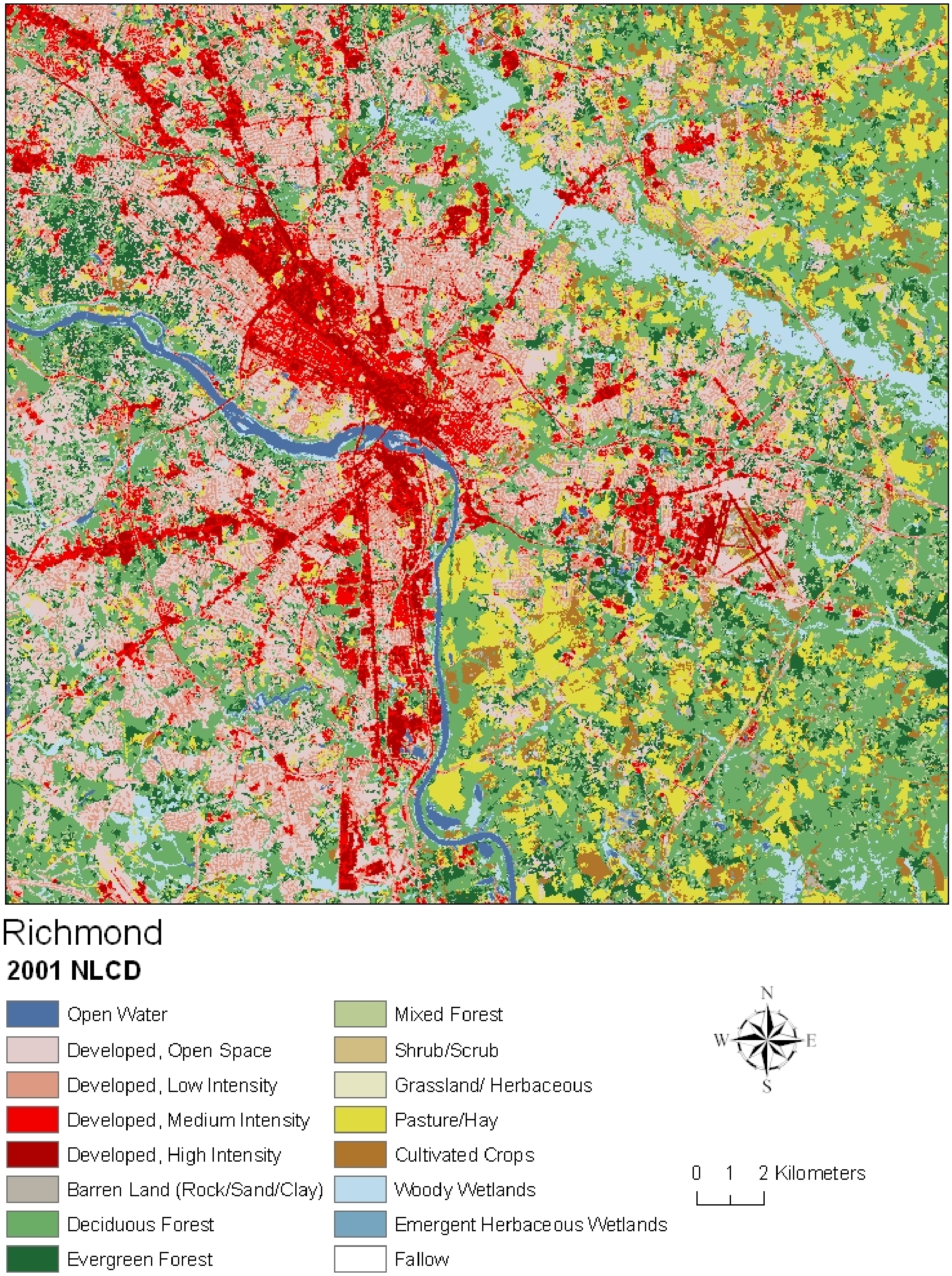
Land Use/Cover for part of the Portland Metropolitan Area



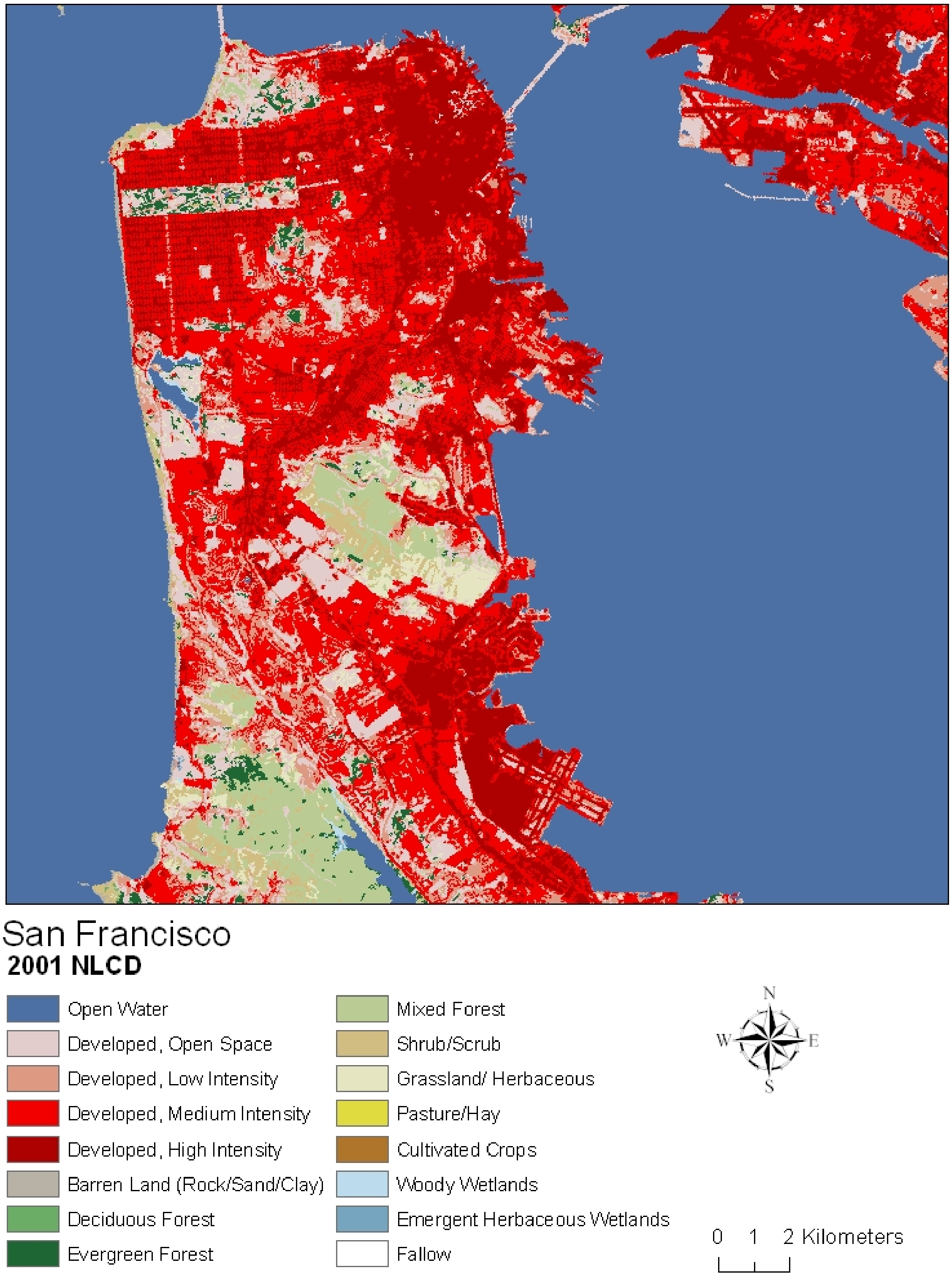
Land Use/Cover for part of the Providence Metropolitan Area



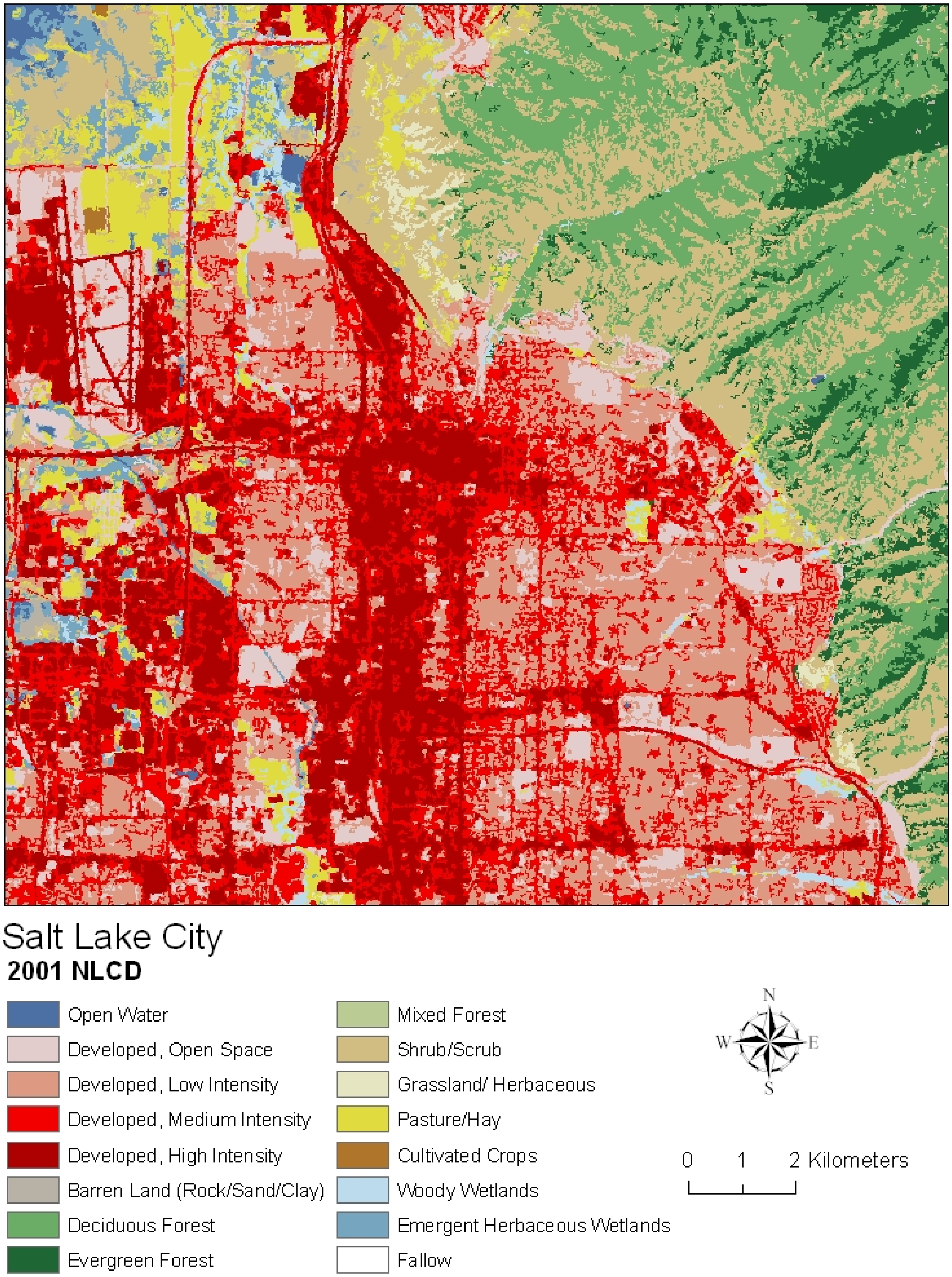
Land Use/Cover for part of the Raleigh Metropolitan Area



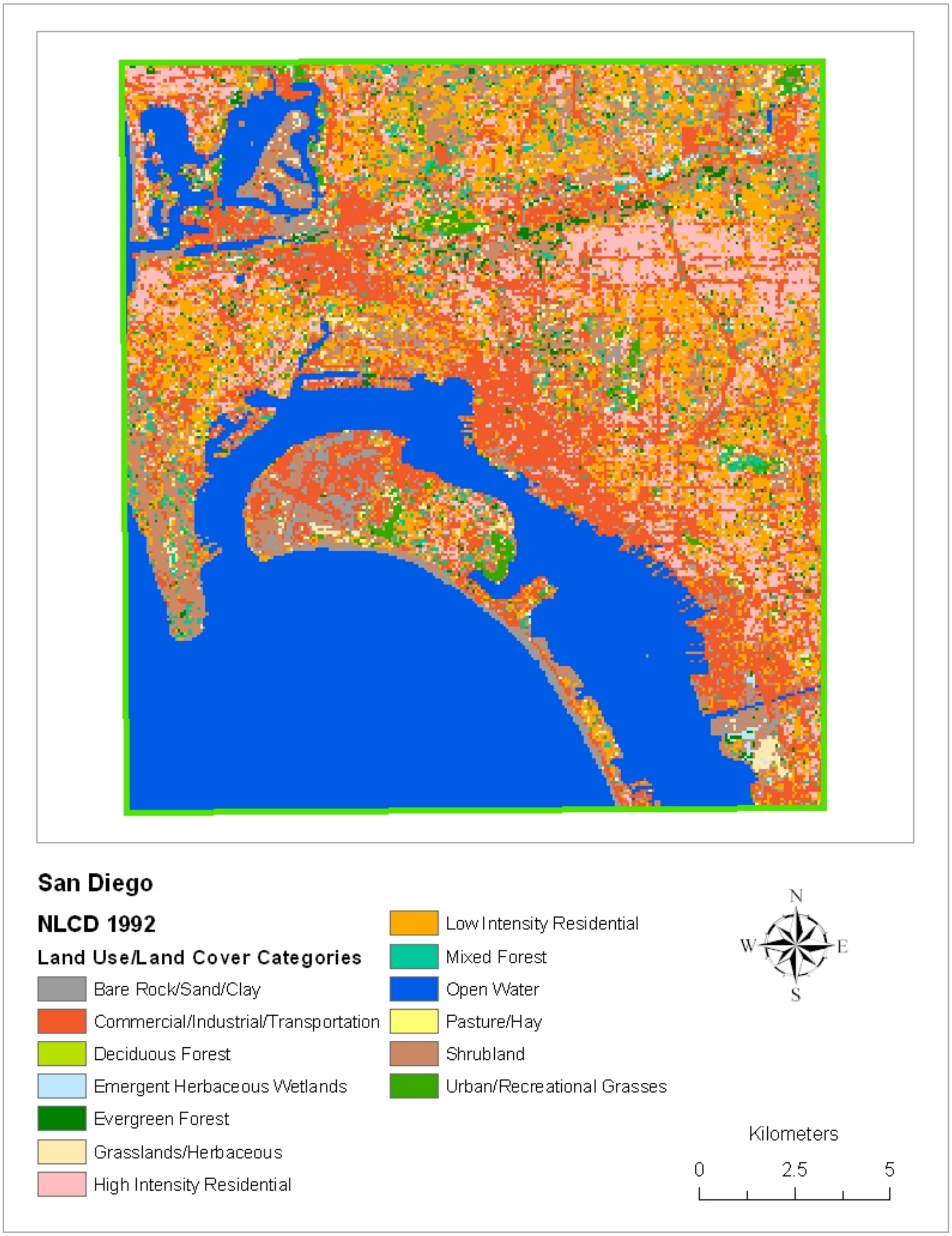
Land Use/Cover for part of the Richmond Metropolitan Area



Land Use/Cover for part of the San Francisco Metropolitan Area



Land Use/Cover for part of the Salt Lake City Metropolitan Area



Land Use/Cover for part of the San Diego Metropolitan Area