Stormwater Public Education Target Audience Identification

Yakima County

City of Yakima

City of Union Gap

City of Sunnyside

Feb. 16, 2010

Purpose

The Eastern Washington Phase II Municipal Stormwater Permit section S.5.B.1.a.iii requires that all permittees identify and characterize target audiences within their jurisdiction to meet education and outreach goals described in the permit by Feb, 16, 2010. The City of Yakima, City of Union Gap, City of Sunnyside, and Yakima County formed a Regional Stormwater Group to meet this and other permit requirements as co-permittees (Figure 1). Stormwater management is a relatively new effort in Yakima County, so typical target audience selection methods such as complaint history cannot be used. As an alternative, target audiences can be identified by modeling relative pollutant loads from different types of land use and differing concentrations of impervious surface, then focusing public education messages in areas where the potential pollutant load is the highest. The Stormwater Center's Simple Method (http://www.stormwatercenter.net) in combination with Geographical Information Systems (GIS) software was used estimate stormwater runoff pollutant loads for watersheds within the permit area.

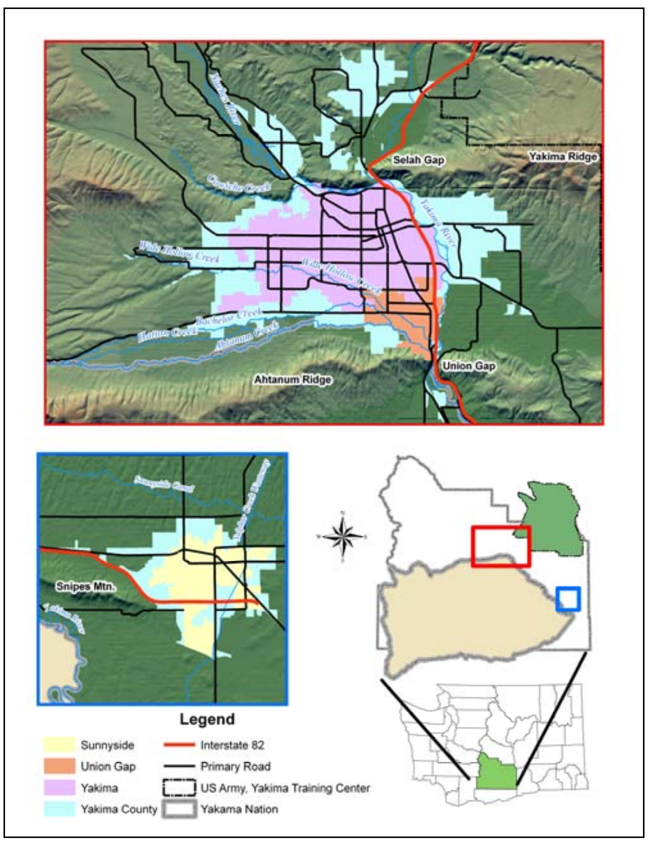


Figure 1. Regional Stormwater Group permit areas.

Methods

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration. The Simple Method equations listed below were input into ArcGIS Model Builder. ArcGIS Model Builder creates a spatial representation of the annual pollutant load. The annual load was estimated for the ten pollutants in question (Table 1). The data input into Model Builder is in raster format where each cell on the map is 100 feet by 100 feet. The pollutant load was estimated for each cell on the map.

Table 1. Chemical Constituents
Biological Oxygen Demand in 5 days (BOD5)
Chemical Oxygen Demand (COD)
Total Suspended Solids (TSS)
Total Copper
Total Zinc
Soluble Phosphorus
Total Phosphorus
Total Lead
Nitrogen (NO_2) and Nitrate (NO_3) as N
Total Kjeldahl Nitrogen

Watershed boundaries were also created from a digital elevation model using the ArcHydro extension of the ArcGIS software. Watershed size was set at <10000 cells per watershed, which resulted in 137 watersheds for the permit areas. The mean pollutant load was then estimated for each watershed by using the Zonal Statistics tool included with the Spatial Analyst extension of the ArcGIS software.

The Simple Method equation for total annual pollutant load is:

$$L = 0.226 * R * C * A$$

Where:

L = Annual load (lbs)

R = Annual runoff (in)

C = Pollutant concentration (mg/l)

A = Area (acres)

0.226 = Unit conversion factor

Median stormwater pollutant concentrations for different land uses including residential, mixed land use, commercial, and open/non-urban (Table 2) were obtained from the U.S. Environmental Protection Agency’s “Results of the Nationwide Urban Runoff Program” publication. The pollutant concentration values were entered into GIS to the corresponding land use. Median stormwater copper and BOD5 pollutant concentration values were not available for the Open/Non-urban land use group which may have artificially increased these annual loads in rural watersheds since this land use was dominant in these areas (Table 2).

Table 2. Median Stormwater Pollutant Concentrations by Land Use

	Residential		**Mixed Land Use**		**Commercial**		**Open/ Non-urban**	
Constituent	**Median**	**COVa**	**Median**	**COV**	**Median**	**COV**	**Median**	**COV**
BOD5 (mg/L)	10	0.41	7.8	0.52	9.3	0.31		
COD (mg/L)	73	0.55	65	0.58	57	0.39	40	0.78
TSS (mg/L)	101	0.96	67	1.14	69	0.85	70	2.92
Total Kjeldahl nitrogen (µg/L)	1900	0.73	1288.8	0.5	1179	0.43	965	1
NO2+NO3asN (µg/L)	736	0.83	558	0.67	572	0.48	543	0.91
Total P (µg/L)	383	0.69	263	0.75	201	0.67	121	1.66
Soluble P (µg/L)	143	0.46	56	0.75	80	0.71	26	2.11
Total lead (µg/L)	144	0.75	114	1.35	104	0.68	30	1.52
Total copper (µg/L)	33	0.99	27	1.32	29	0.81		
Total zinc (µg/L)	135	0.84	154	0.78	226	1.07	195	0.66

COV: coefficient of variation = standard deviation/mean. From United States Environmental Protection Agency (EPA). Results of the Nationwide Urban Runoff Program.

The area of a cell (acres) is represented by A. Each cell is 100 ft. x 100 ft. or 0.2295 acres.

Annual runoff (R) is calculated as a product of annual runoff volume, and a runoff coefficient (Rv). The runoff coefficient is calculated based on impervious cover in the watershed. Impervious cover data originated from the Multi-Resolution Consortium (MRLC) as a 30 meter grid layer based on infrared and red wavelengths from Landsat 5 and Landsat 7 satellite imagery. The National Research Council Yakima County PRISM data resampled from a 1500 ft. grid to a 100 ft. grid was used for the precipitation input. The equation for R is:

$$R = P * P_J * Rv$$

Where:

P = Annual rainfall (in)

P_J = Fraction of annual rainfall events that produce runoff (usually 0.9)

Rv = Runoff coefficient

The runoff coefficient (Rv) is defined as:

$$Rv = 0.05+0.9Ia$$

Where:

Ia = Impervious fraction

Results and Discussion

In most cases pollutant loads increased in watersheds where there is more impervious surface (see Appendix). This is consistent with the National Research Council recommendations that suggest impervious surface should be used as a proxy for stormwater pollutant loading (National Research Council, 2008), results from the impervious cover model that suggest more than 25% impervious cover in a watershed impairs many biological, physical, and chemical indicators of stream health (Schueler, et al., 2009); and with runoff reduction strategies proposed to address stormwater pollution of Chesapeake Bay (Schueler, 2008).

There was a small amount of variability between the ranking of loads from different pollutants within the same watershed. In these cases where the given pollutant is known to be more prevalent in residential areas such as phosphorus and nitrogen, the watersheds with the highest pollutant loads included densely populated residential areas and adjacent city center areas (Appendix).

City Center Pollutants Group

Pollutant loads highest in city center and other commercial areas containing the highest concentration of impervious surface:

- Biological Oxygen Demand in 5 days (BOD5)
- Chemical Oxygen Demand (COD)
- Total Suspended Solids (TSS)
- Copper
- Zinc

City Center and Adjacent Residential Pollutants Group

Pollutant loads highest in city center and adjacent densely populated residential areas:

- Soluble Phosphorus
- Total Phosphorus
- Lead
- Nitrogen (NO_2) and Nitrate (NO_3) as N
- Total Kjeldahl Nitrogen

Public education activities associated with the *City Center Pollutants Group* should be focused on commercial and other land use groups found within the city center or other highly impervious commercial area (Valley Mall) watersheds.

Public education activities associated with the *City Center and Adjacent Residential Pollutants Group* should be focused on not only the city center and other highly impervious commercial area watersheds, but also highly developed adjacent residential watersheds.

A few areas near the permit area boundary did not have watershed boundaries delineated due to constraints used to generate watershed boundaries. Because of this mean loads were not estimated for these areas. The only areas omitted containing high concentrations of impervious surface which correlate to high pollutant loads include the Yakima Valley Mall and Zirkle Fruit north of Selah. Inferring from other watersheds with high amounts of impervious area, it is reasonable to assume these areas would also contribute pollutants in larger amounts than residential or open areas. Zirkle Fruit operates under a NPDES permit from Ecology that mandates stormwater control, so their pollutant load is likely less than that suggested by model results.

Conclusion

Impervious surface seems to be a driving force in the Simple Method that was used to identify target audiences for stormwater public education. Subsequently, pollutant load estimates were highest in the city center watersheds and other highly impervious commercial area watersheds. Pollutant loads for soluble phosphorus, total phosphorus, lead, NO2+NO3asN, and Total Kjeldahl Nitrogen were also nearly as high in densely populated residential watersheds adjacent to the city center watersheds.

Recommendation

Based on modeled relative pollutant load estimates, public education activities concentrating on Biological Oxygen Demand in 5 (BOD5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Copper, and Zinc should be focused on city center watersheds. Public education activities dealing with Soluble Phosphorus, Total Phosphorus, Lead, NO2+NO3asN, and Total Kjeldahl Nitrogen should be focused on both city center watersheds and adjacent densely populated residential watersheds.

References

Environmental Protection Agency (EPA), 1983, Results of the Nationwide Urban Runoff Program. Water Planning Division, PB 84-185552, Washington, D.C.

Stormwater Center, accessed 2010, The Simple Method to Calculate Urban Stormwater Loads, http://www.stormwatercenter.net/.

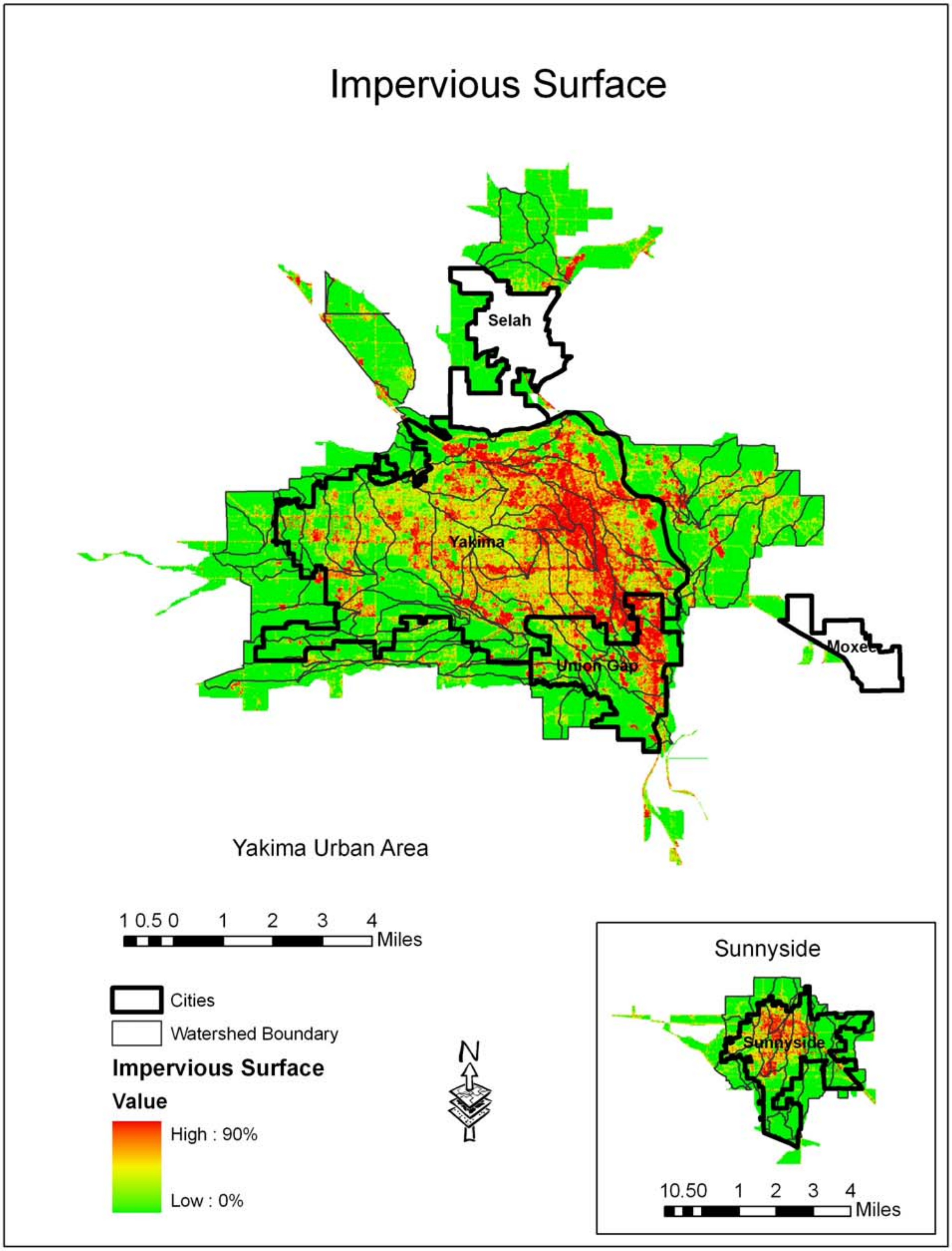
Multi-Resolution Land Characteristics Consortium (MRLC), accessed 2010, National Land Cover Database (NLCD) 2001 Impervious Surface, http://www.mrlc.gov/.

National Research Council, 2008, Urban Stormwater Management in the United States. The National Academies Press, Washington D.C.

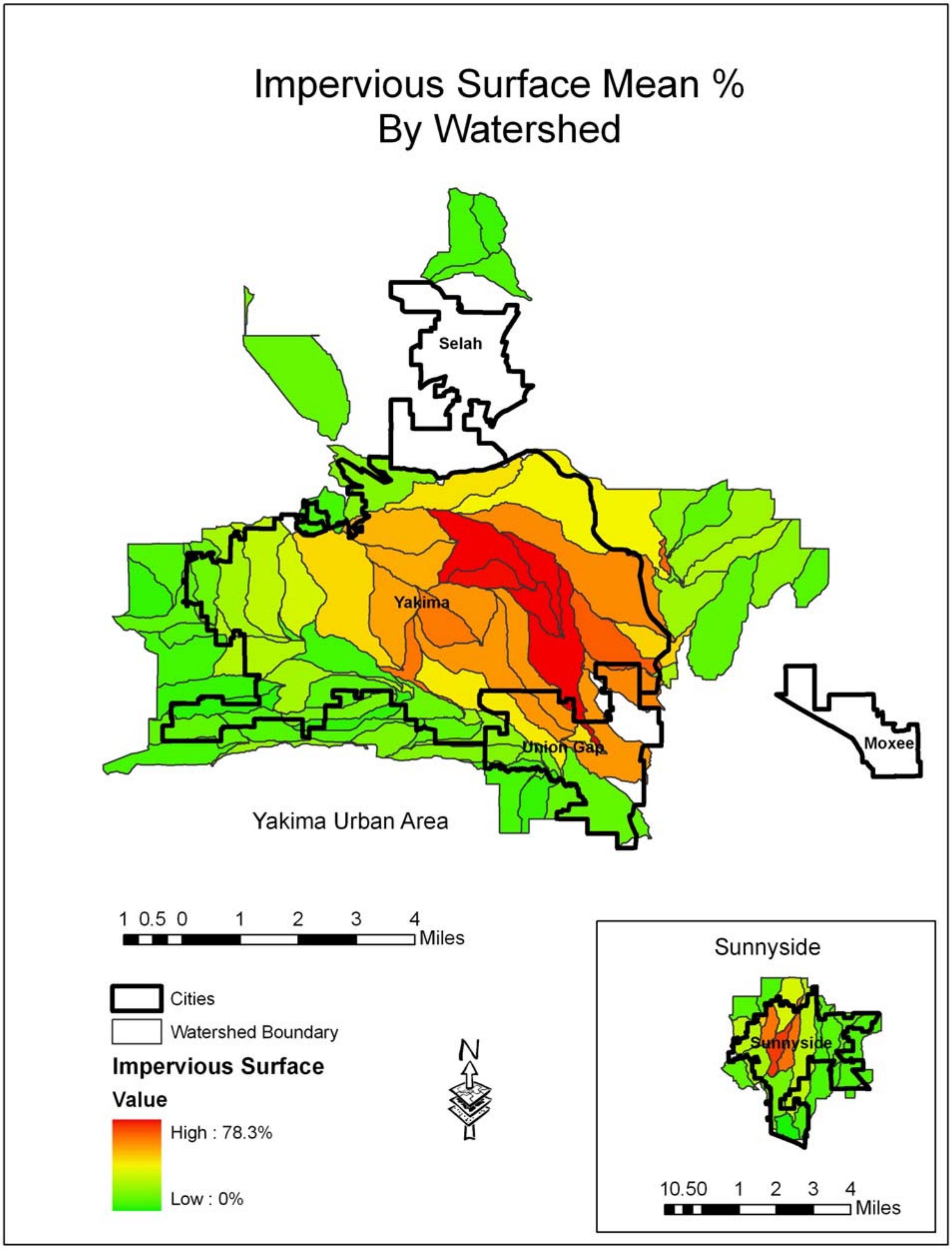
Schueler, T. 2008. Technical Support for the Bay-wide Runoff Reduction Method. Chesapeake Stormwater Network. Baltimore, MD

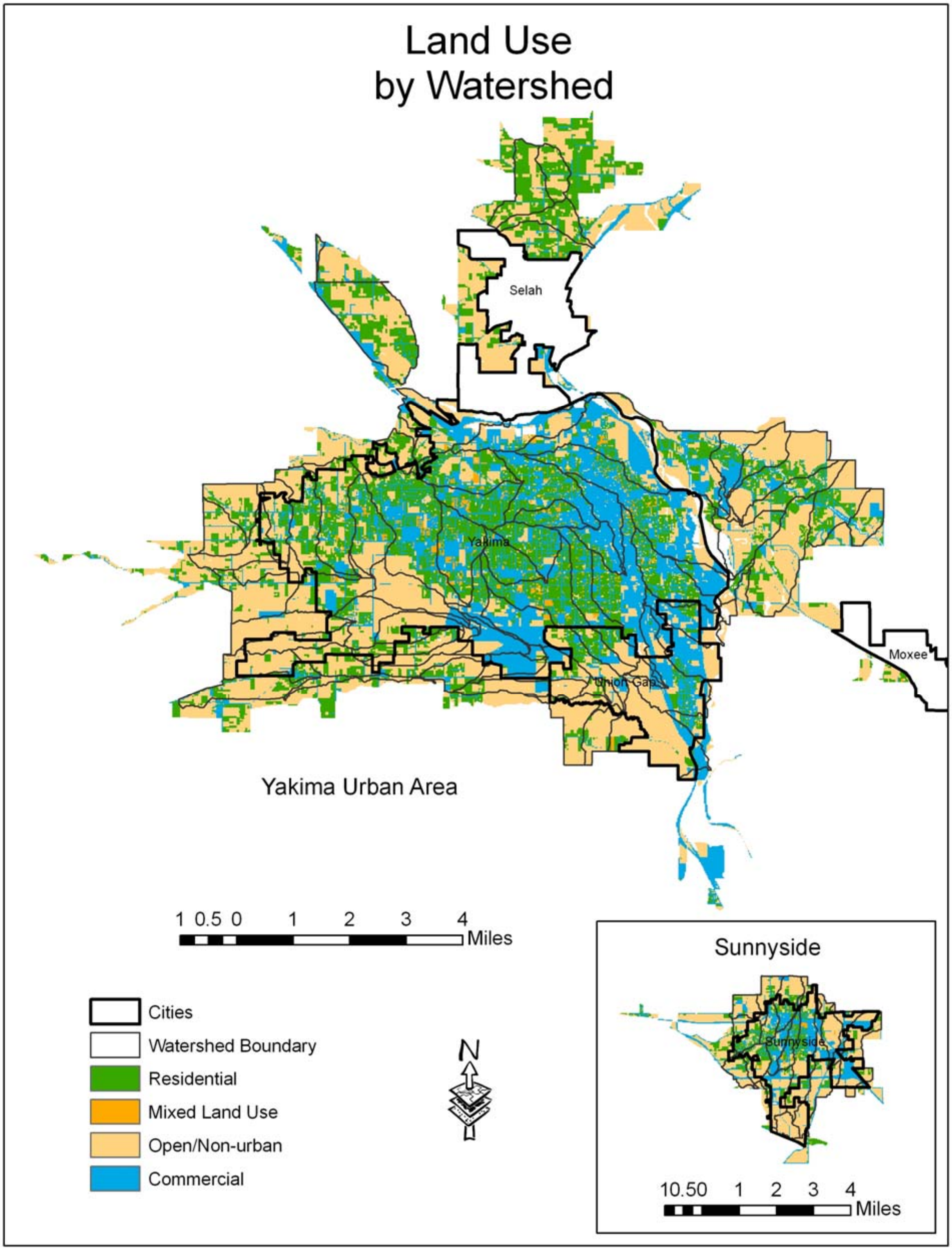
Schueler, T.R., L. Fraley-McNeal, and K. Cappiella. 2009. Is Impervious Cover Still Important? Review of Recent Research., J. Hydrologic Engrg. 14, 309 (2009), DOI:10.1061/(ASCE)1084-0699(2009)14:4(309)

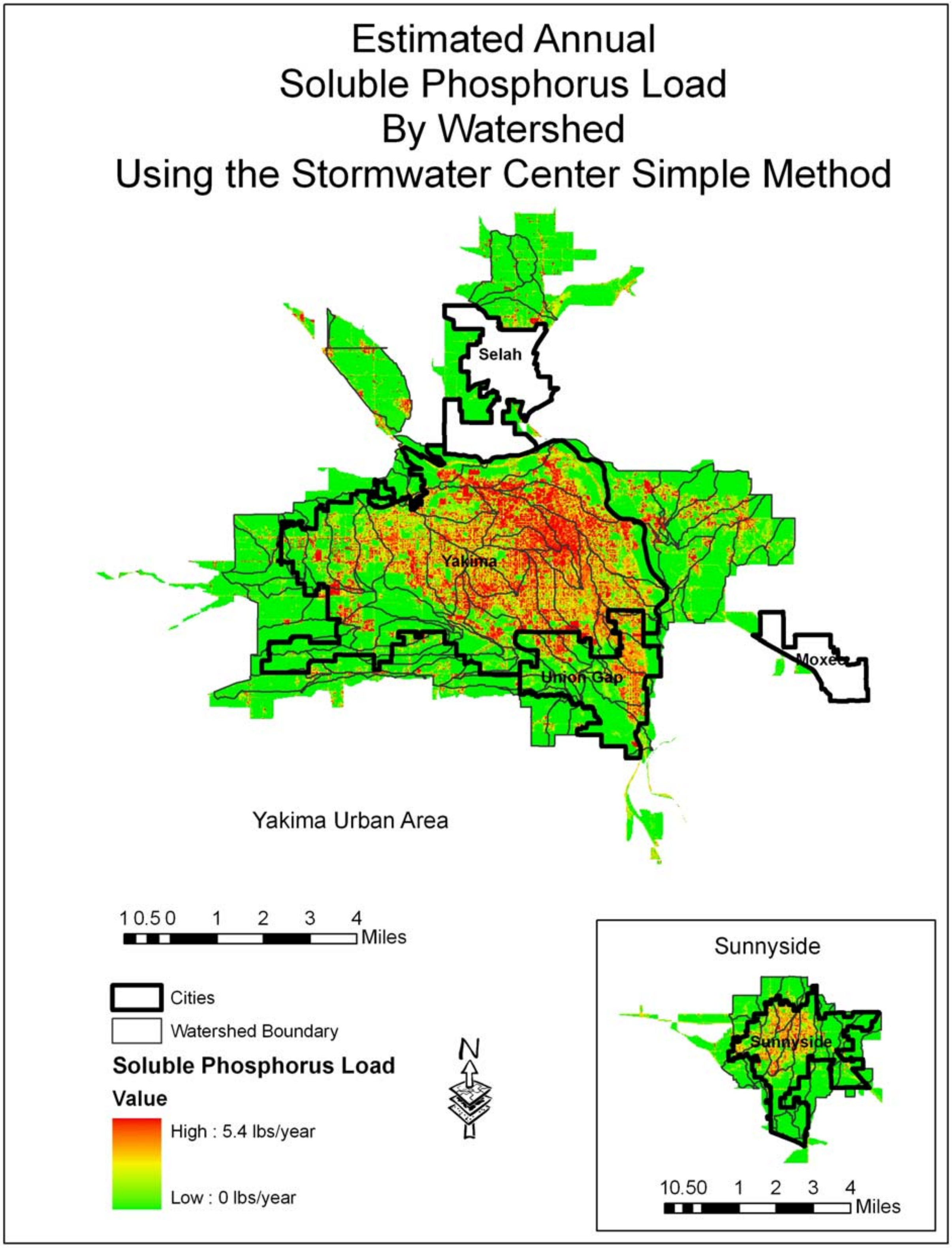
Appendix.



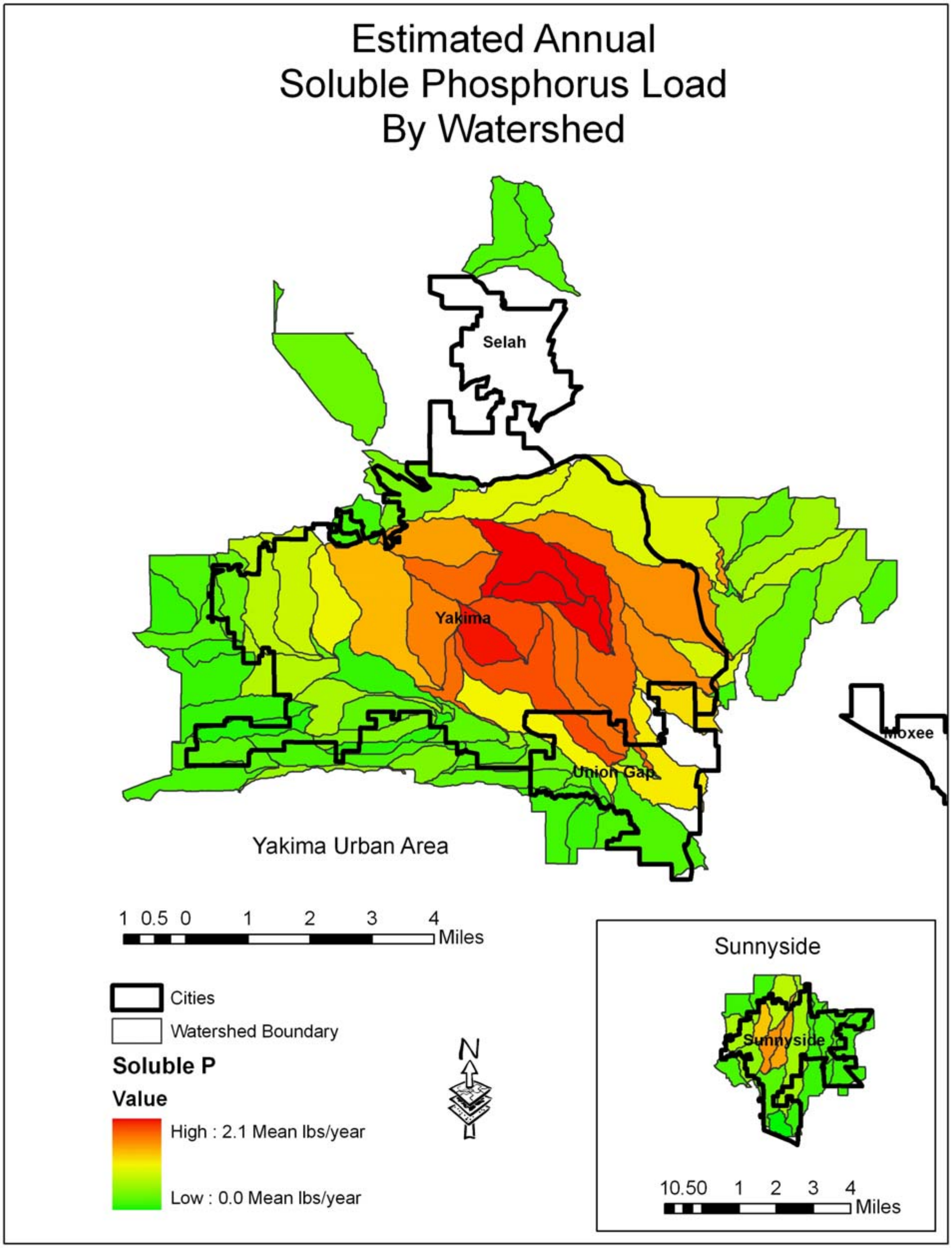
Impervious Surface
Selah
Yakima
Union Gap
Moxee
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
Impervious Surface
Value
High : 90%
Low : 0%
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles

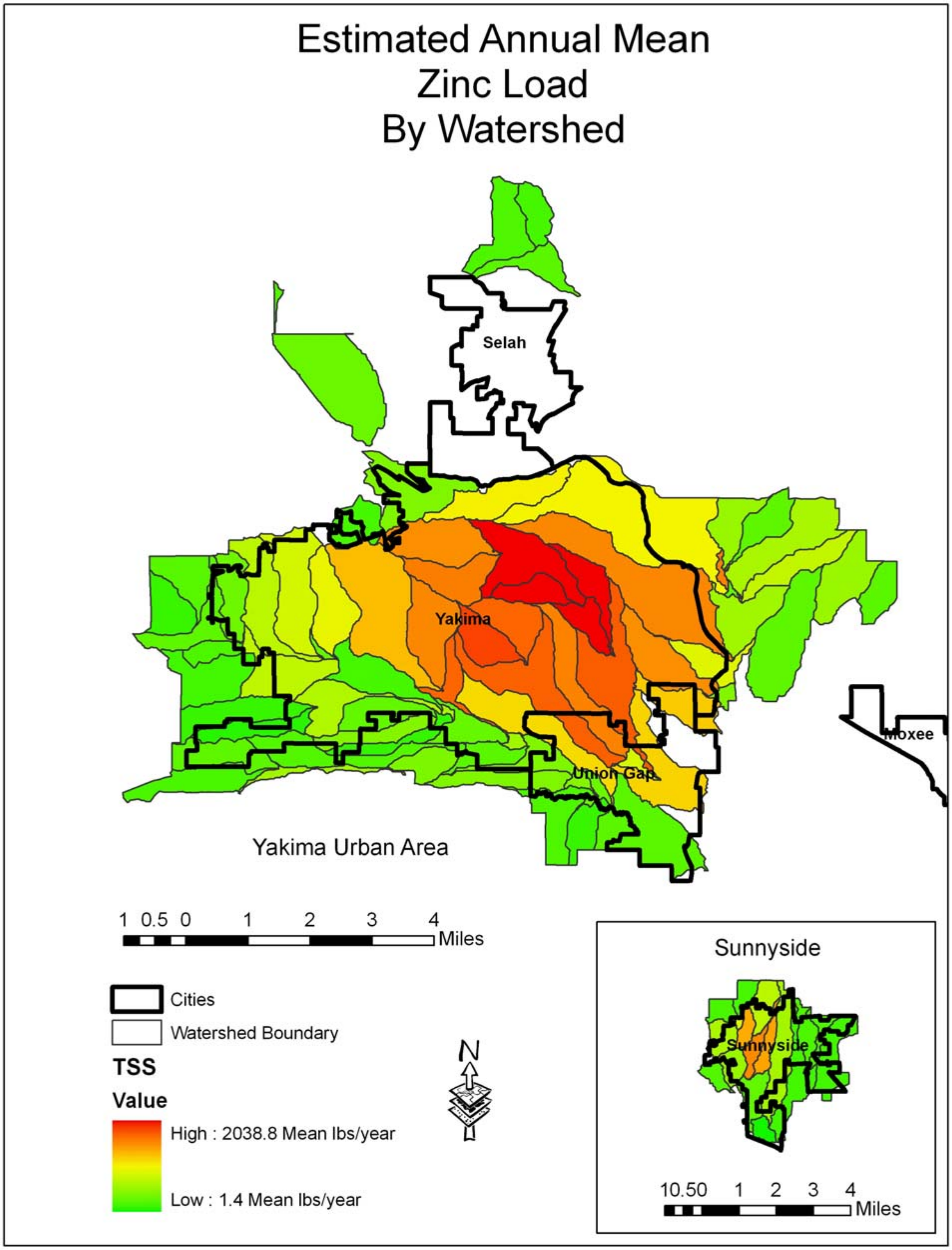

Impervious Surface Mean %
By Watershed
Selah
Yakima
Union Gap
Moxee
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
Impervious Surface
Value
High : 78.3%
Low : 0%
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles

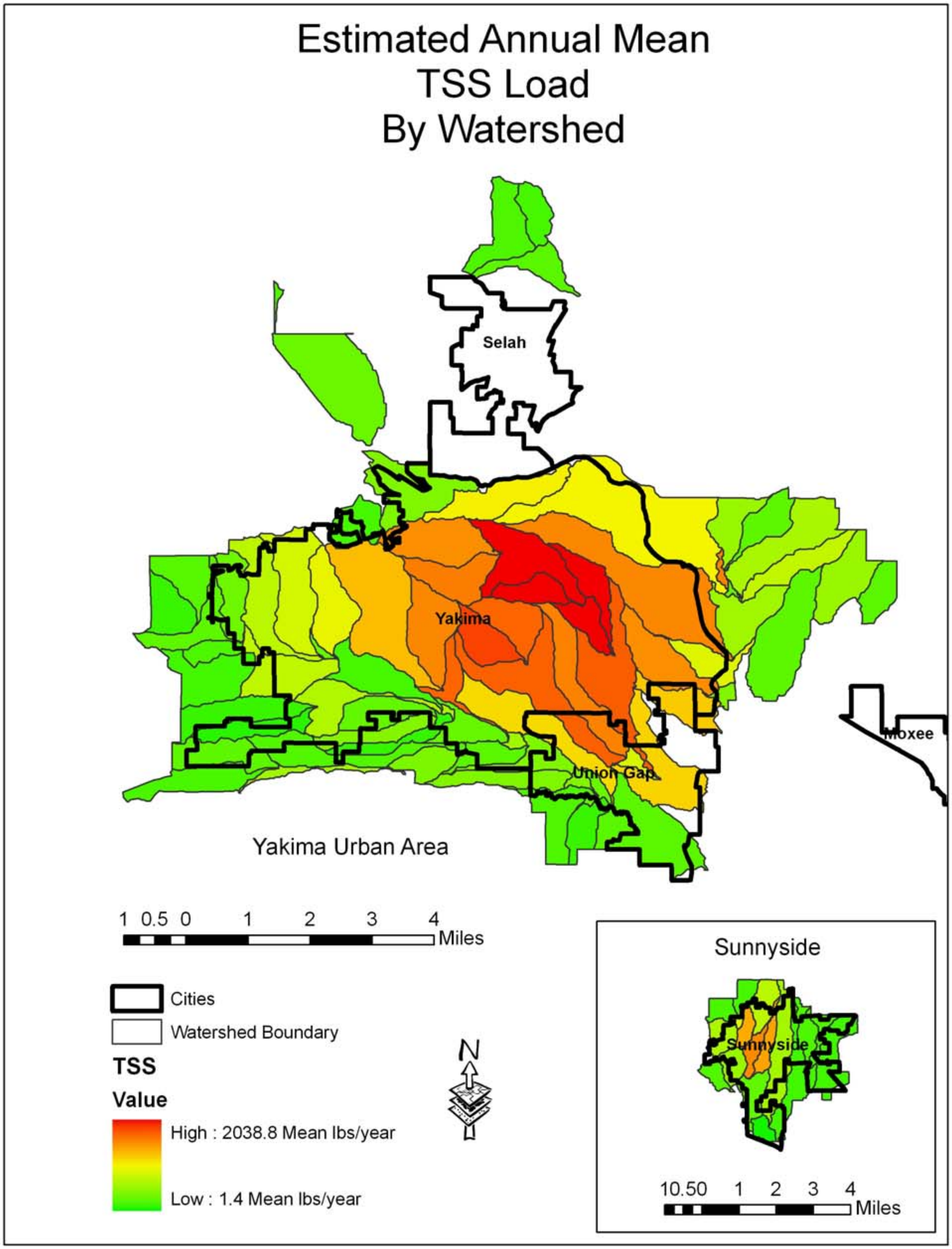

Land Use
by Watershed
Selah
Yakima
Union Gap
Moxee
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
Residential
Mixed Land Use
Open/Non-urban
Commercial
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles

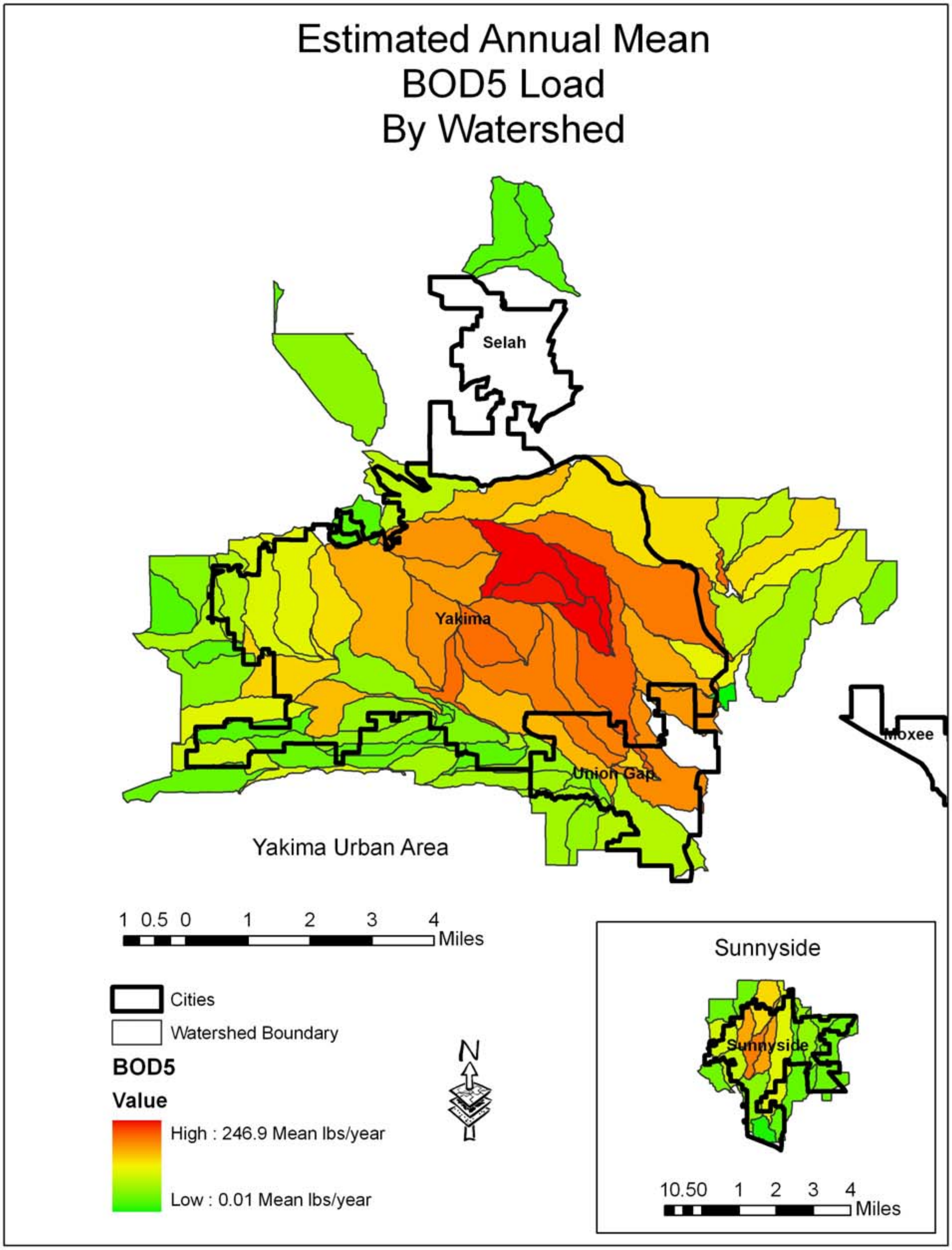


Example of estimated load data that was input into the zonal statistics tool to calculate an estimated mean for the pollutant load per watershed.

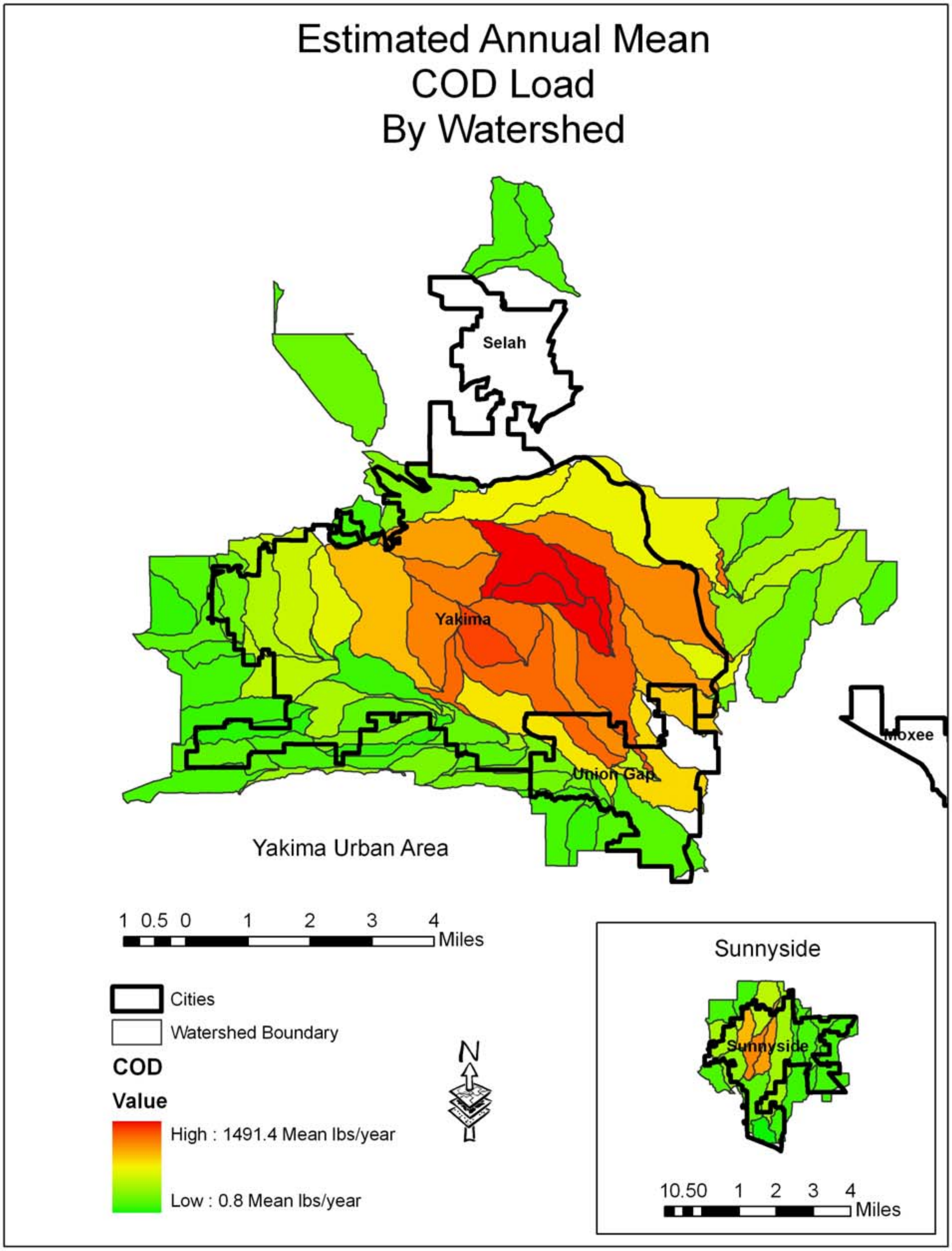

Estimated Annual
Soluble Phosphorus Load
By Watershed
Selah
Yakima
Union Gap
Moxee
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
Soluble P
Value
High : 2.1 Mean lbs/year
Low : 0.0 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles

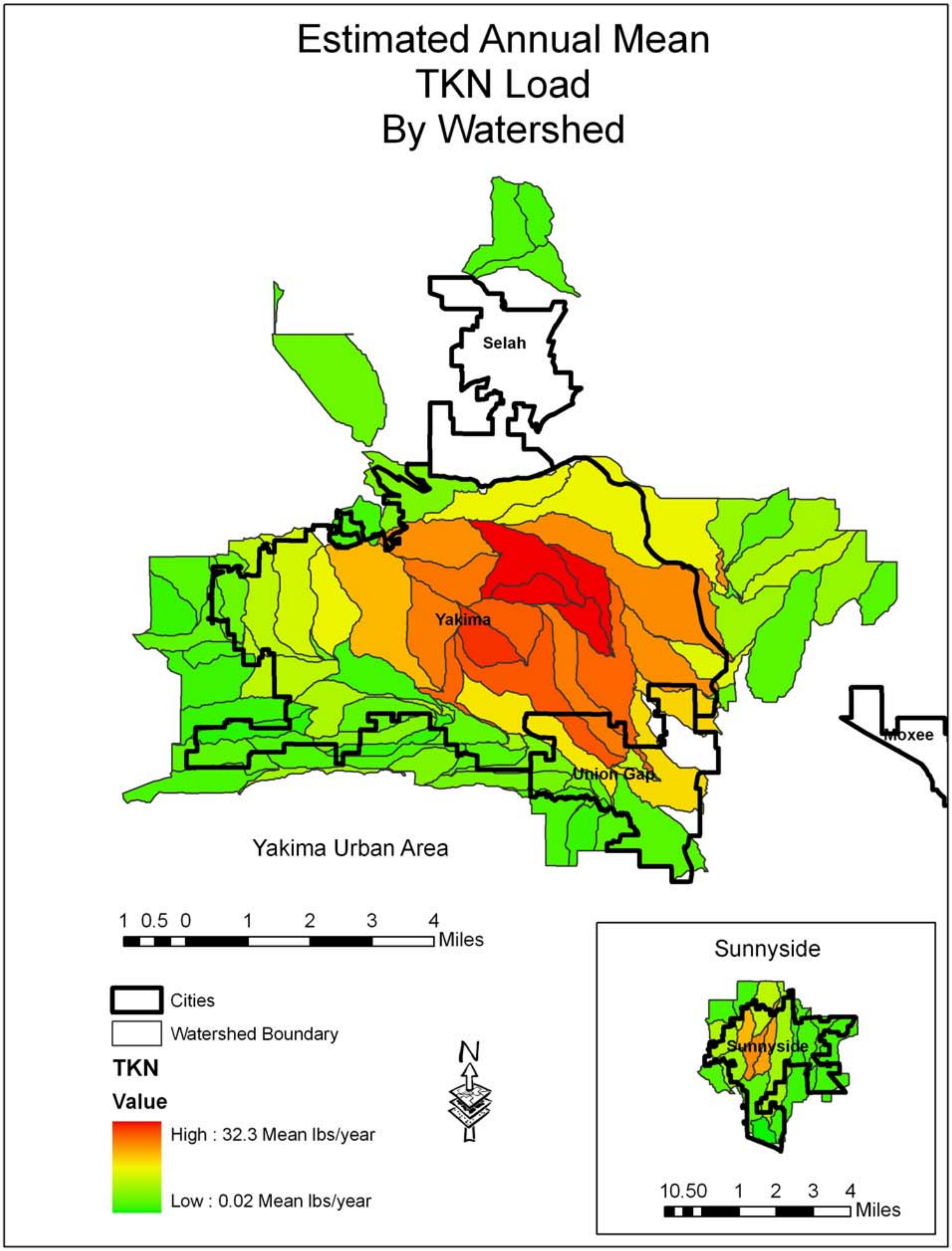

Estimated Annual Mean
Zinc Load
By Watershed
Selah
Yakima
Moxee
Union Gap
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
TSS
Value
High : 2038.8 Mean lbs/year
Low : 1.4 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles

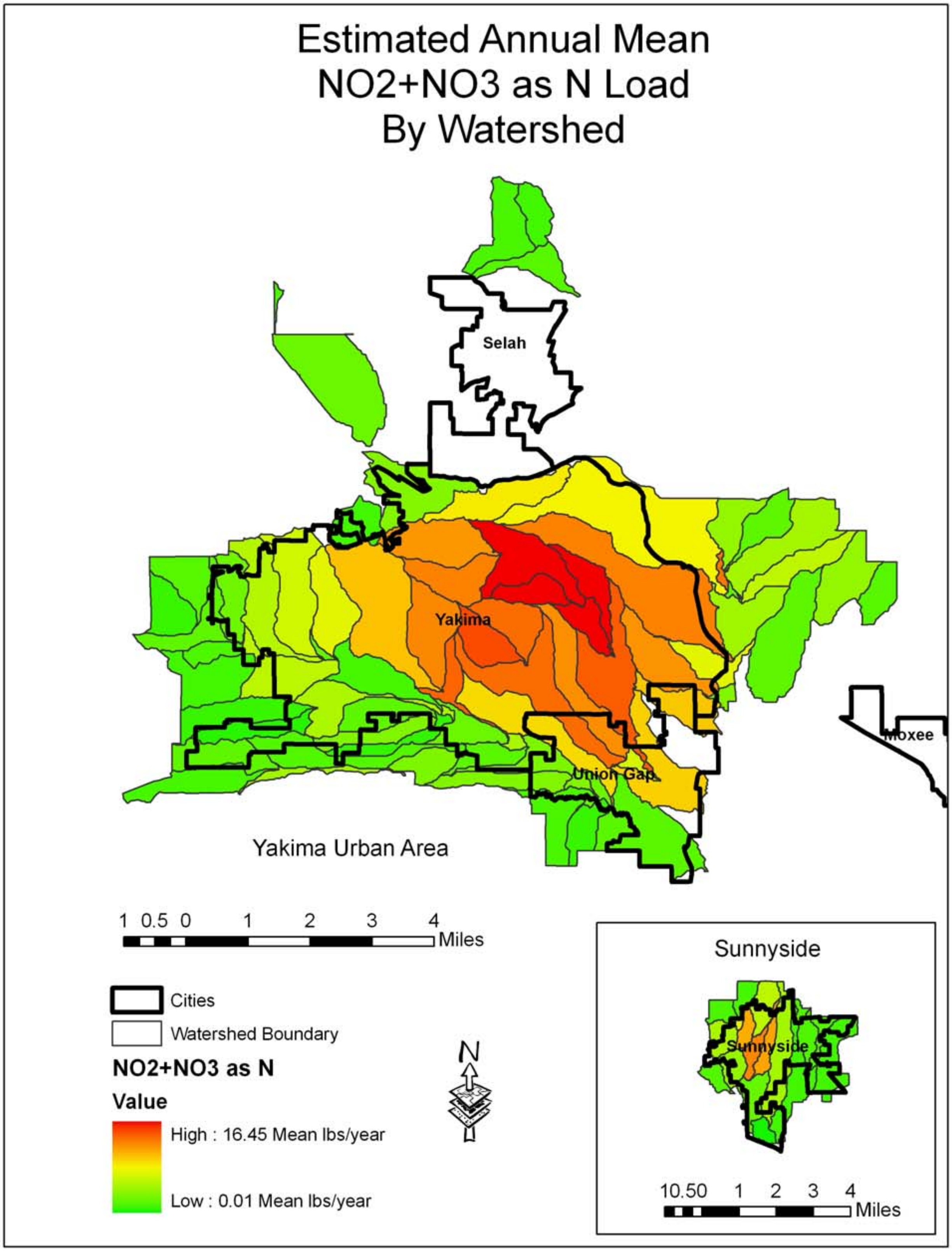

Estimated Annual Mean
TSS Load
By Watershed
Selah
Yakima
Moxee
Union Gap
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
TSS
Value
High : 2038.8 Mean lbs/year
Low : 1.4 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles

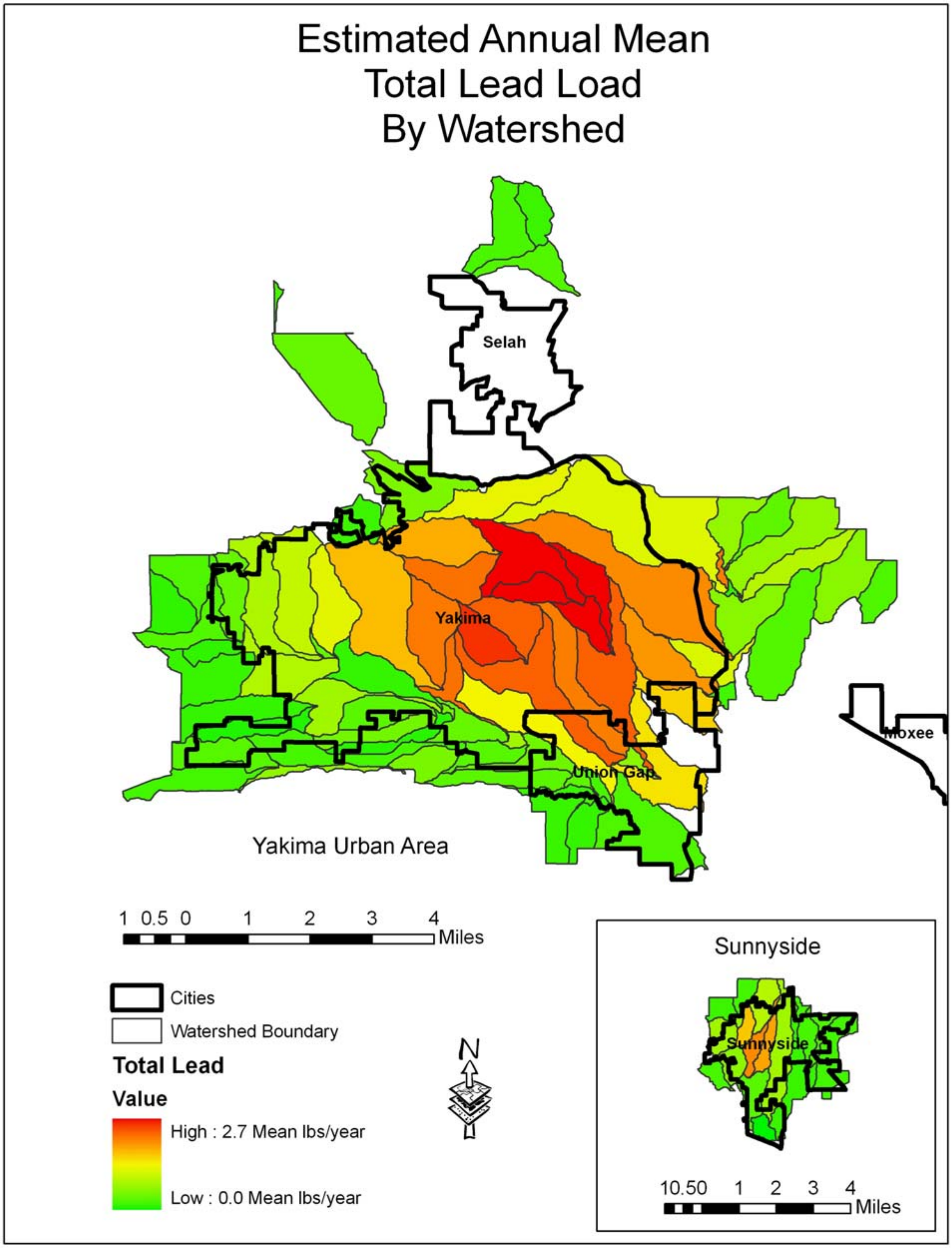


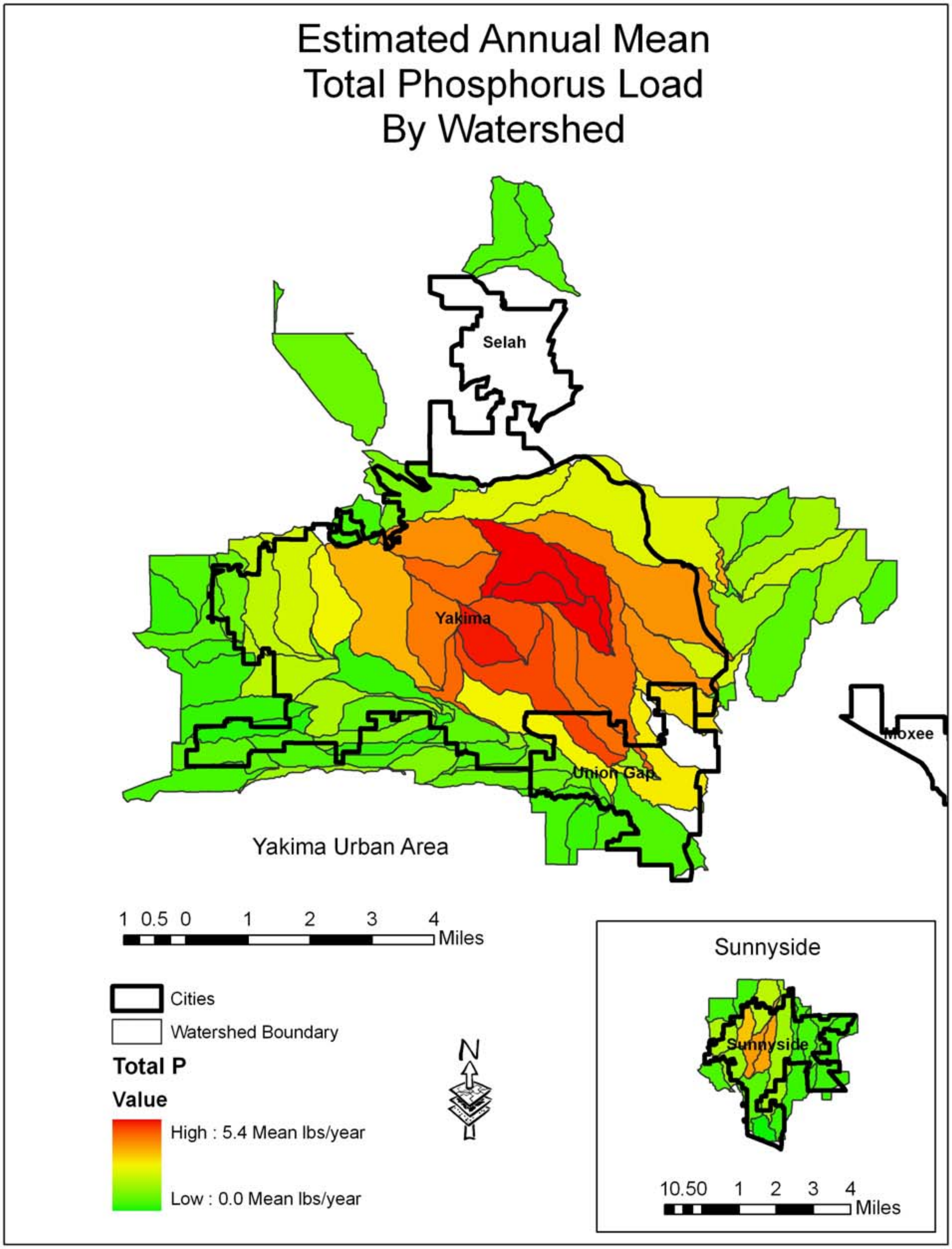
Estimated Annual Mean
BOD5 Load
By Watershed
Selah
Yakima
Union Gap
Moxee
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
BOD5
Value
High : 246.9 Mean lbs/year
Low : 0.01 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles

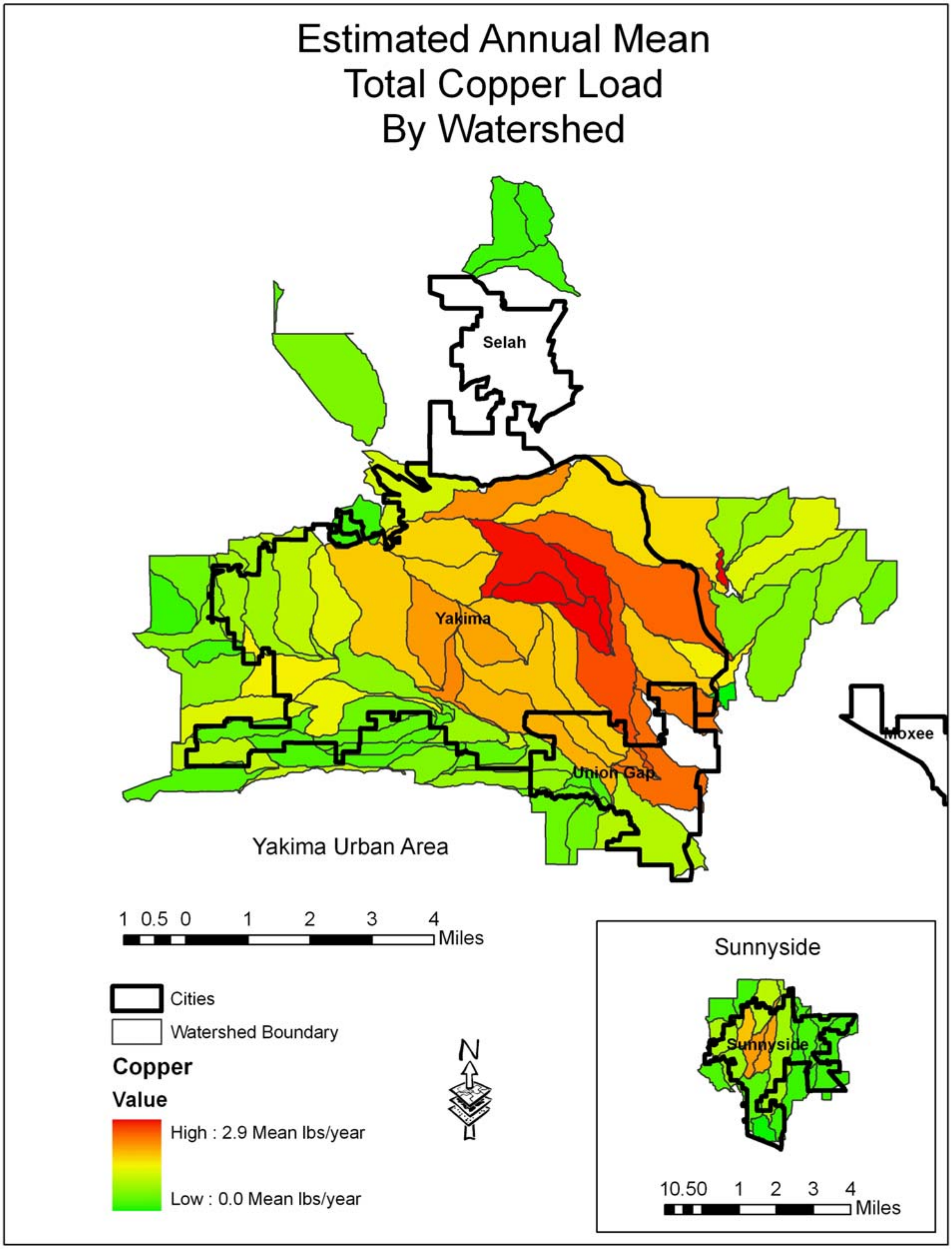

Estimated Annual Mean
COD Load
By Watershed
Selah
Yakima
Moxee
Union Gap
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
COD
Value
High : 1491.4 Mean lbs/year
Low : 0.8 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles


Estimated Annual Mean
TKN Load
By Watershed
Selah
Yakima
Moxee
Union Gap
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
TKN
Value
High : 32.3 Mean lbs/year
Low : 0.02 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles


Estimated Annual Mean
NO2+NO3 as N Load
By Watershed
Selah
Yakima
Moxee
Union Gap
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
NO2+NO3 as N
Value
High : 16.45 Mean lbs/year
Low : 0.01 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles


Estimated Annual Mean
Total Lead Load
By Watershed
Selah
Yakima
Moxee
Union Gap
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
Total Lead
Value
High : 2.7 Mean lbs/year
Low : 0.0 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles


Estimated Annual Mean
Total Phosphorus Load
By Watershed
Selah
Yakima
Moxee
Union Gap
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
Total P
Value
High : 5.4 Mean lbs/year
Low : 0.0 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles


Estimated Annual Mean
Total Copper Load
By Watershed
Selah
Yakima
Moxee
Union Gap
Yakima Urban Area
1 0.5 0 1 2 3 4
Miles
Cities
Watershed Boundary
Copper
Value
High : 2.9 Mean lbs/year
Low : 0.0 Mean lbs/year
N
Sunnyside
Sunnyside
10.50 1 2 3 4
Miles