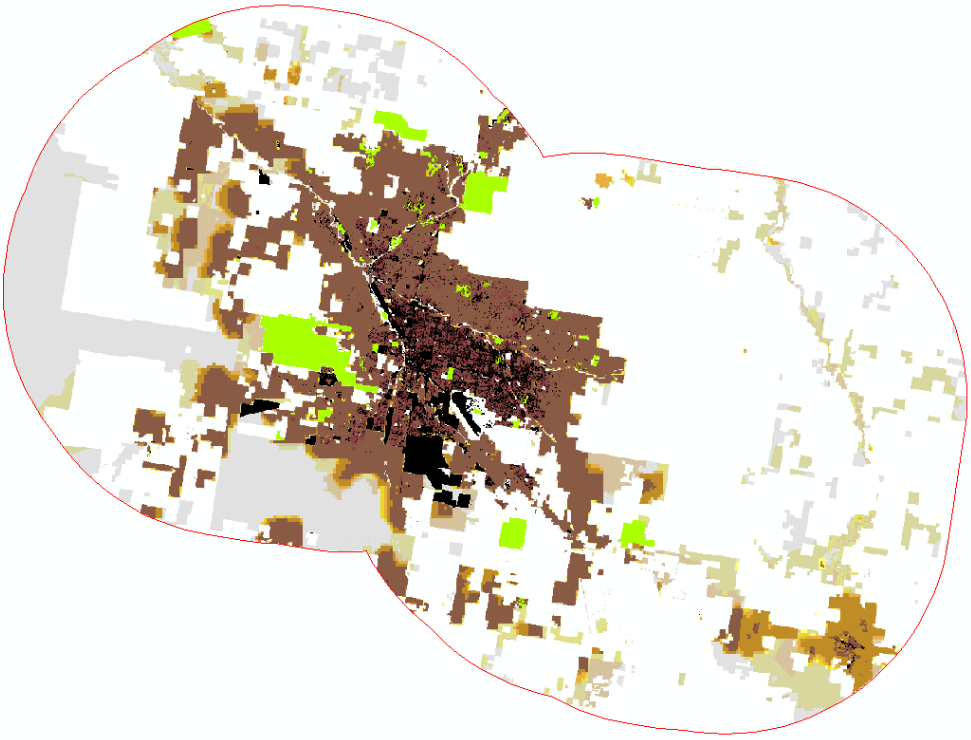
**National Park Service**
**U.S. Department of the Interior**

**Natural Resource Stewardship and Science**

**NOTE: There may be revised processes and documentation available.**

**Check the NPScape methods webpage**
**(http://science.nature.nps.gov/im/monitor/npscape/methods.cfm)**
**for the most current version.**

# NPScape Standard Operating Procedure: Housing Measure – Current and Projected Housing Density



Suggested Citation: National Park Service. 2013. NPScape Standard Operating Procedure: Housing Measure – Current and Projected Housing Density. Version 2014-01-06. National Park Service, Natural Resource Stewardship and Science. Fort Collins, Colorado.

# Contents

**Overview** ..... **3**
**Software Requirements** ..... **3**
**Data Requirements** ..... **3**
SERGoM Housing Density rasters ..... 3
Area of Analysis polygon ..... 4
Input data spatial reference ..... 4
**Input Data Pre-Processing** ..... **4**
Determine AOA polygon ..... 4
Re-project user-defined input datasets (if needed) ..... 4
Download tool input data ..... 5
**Run NPScape Housing Density Tool** ..... **5**
Add toolbox to ArcMap ..... 5
Run the Housing Density Tool ..... 6
**Quality Control** ..... **7**
Verify dataset outputs ..... 7
Verify statistics output ..... 7
**Interpretation Tips** ..... **7**
Output statistics table attributes: ..... 7
**Frequently Asked Questions** ..... **8**
Can/should I use a different spatial reference? ..... 8
I'm having trouble downloading the tool input dataset. Is there another way to get it? ..... 8
My outputs don't show up in my map. What can I do? ..... 9
**Literature Cited** ..... **9**
**Appendices** ..... **9**
Appendix 1: Known issues ..... 9
Appendix 2: Using custom AOAs and/or local input data ..... 10
Appendix 3: Reclassification Table ..... 10
Appendix 4: Tool scripts ..... 10
Appendix 5: Tool input data/metric data processing details ..... 10

**Version History**

| Version | Update Date | Changes |
|---|---|---|
| 20130114 | 20130114 | Initial re-draft |
| 20130213 | 20130213 | Final draft to reflect seamless data and additional reclass (rural, exurban, etc), otherwise data and metrics unchanged |
| 20130315 | 20130315 | Note added regarding an issue in Geoprocessing Options between ArcMap 10.0 and 10.1 that could cause a script to fail in 10.1 |
| 20131223 | 20131223 | Tool optimized for use with ArcMap 10.1, and tested for use with 10.2 |

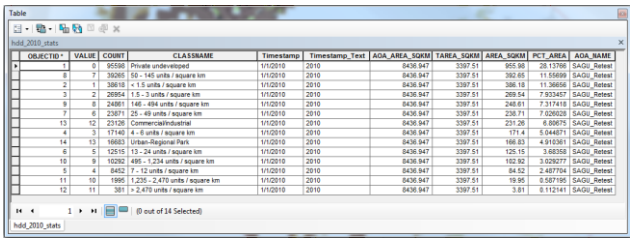
## Overview

NPScape is a landscape dynamics monitoring project that provides landscape-level data, tools, and evaluations for natural resource management, planning, and interpretation (NPS 2013). This standard operating procedure (SOP) provides guidance on how to process current (2010), past (1970-2000), and projected (2020-2100) NPScape housing density metrics from the Spatially Explicit Regional Growth Model, SERGoM (Theobald 2005). Download the tool(s) and a copy of this SOP here: http://science.nature.nps.gov/im/monitor/npscape/methods.cfm

The purpose of this SOP is threefold. First, because these directions were followed in the processing of the NPS dataset, it provides detailed documentation on the methodology used by NPScape to calculate density metrics for the Housing measure. Second, this SOP provides any user with the ability to replicate the creation of these data for custom areas of analysis. Finally, if an I&M park or network has a need to analyze housing density data other than SERGoM, this SOP provides a processing template for recalculating focal metrics associated with the Housing measure.

Metric outputs generated are:

- File Geodatabase (ESRI® format) with 2 or more feature classes and a statistics table (where YYYY = year [i.e., decade]):
  - file geodatabase rasters hdd_YYYY and hdd_YYYY_grouped (for 1970 – 2100)
  - file geodatabase summary statistics tables hdd_YYYY_stats and hdd_YYYY_stats_grouped (for 1970 – 2100)



Table

hdd_2010_stats

| OBJECTID * | VALUE | COUNT | CLASSNAME | Timestamp | Timestamp_Text | AOA_AREA_SQKM | TAREA_SQKM | AREA_SQKM | PCT_AREA | AOA_NAME |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 95598 | Private undeveloped | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 955.98 | 28.13766 | SAGU_Retest |
| 8 | 7 | 39265 | 50 - 145 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 392.65 | 11.55699 | SAGU_Retest |
| 2 | 1 | 38618 | < 1.5 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 386.18 | 11.36656 | SAGU_Retest |
| 3 | 2 | 26954 | 1.5 - 3 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 269.54 | 7.933457 | SAGU_Retest |
| 9 | 8 | 24861 | 146 - 494 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 248.61 | 7.317418 | SAGU_Retest |
| 7 | 6 | 23871 | 25 - 49 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 238.71 | 7.026028 | SAGU_Retest |
| 13 | 12 | 23126 | Commercial/Industrial | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 231.26 | 6.80675 | SAGU_Retest |
| 4 | 3 | 17140 | 4 - 6 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 171.4 | 5.044871 | SAGU_Retest |
| 14 | 13 | 16683 | Urban-Regional Park | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 166.83 | 4.910361 | SAGU_Retest |
| 6 | 5 | 12515 | 13 - 24 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 125.15 | 3.68358 | SAGU_Retest |
| 10 | 9 | 10292 | 495 - 1,234 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 102.92 | 3.029277 | SAGU_Retest |
| 5 | 4 | 8452 | 7 - 12 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 84.52 | 2.487704 | SAGU_Retest |
| 11 | 10 | 1995 | 1,235 - 2,470 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 19.95 | 0.587195 | SAGU_Retest |
| 12 | 11 | 381 | > 2,470 units / square km | 1/1/2010 | 2010 | 8436.947 | 3397.51 | 3.81 | 0.112141 | SAGU_Retest |

1 (0 out of 14 Selected)

hdd_2010_stats

Example hdd_YYYY and hdd_YYYY_stats table for an AOA at Saguaro National Park

Using an ArcGIS™ toolbox, processing steps include extracting housing density rasters for each decade for an area of analysis (AOA), calculating the total AOA area, and the housing density class area and percent area. Any AOA polygon can be used as long as its spatial reference matches that of the tool input dataset.

This SOP is dependent on SERGoM housing density data as the tool input (Theobald 2005).

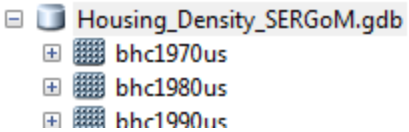
## Software Requirements

ArcGIS software is required to generate the metric outputs. The data sources and tools used are assumed to be in ESRI ArcGIS™ format, version 10 Service Pack 5 or higher.

## Data Requirements

### SERGoM Housing Density rasters

Housing_Density_SERGoM.gdb/bhcYYYYus:
http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm




For this national level effort, Spatially Explicit Regional Growth Model (SERGoM v3) data developed by Dave Theobald (2005) were used to obtain housing density information. Using source Census Bureau housing data, SERGoM methods combined housing data with information on land ownership and density of major roads (interstates, state highways, and county roads) to provide a more accurate allocation of the location of housing units over the landscape. These data were obtained from the author as a series of grids (resampled to a 100 meter x 100 meter cell size) representing housing density classes for decades from 1970 through 2100.

If you are a NPS user, you can contact the NPScape team to request a custom clipped extent: mailto:NRSS_NRPC_NPScape@nps.gov

See the Frequently Asked Questions section for other data access options.

### Area of Analysis polygon

> AOA polygons for boundaries and 3 km and 30 km buffers of parks, CEC ecoregions, FWS LCC polygons, and upstream watersheds (for selected parks) are available as NPScape datasets http://science.nature.nps.gov/im/monitor/npscape/methods.cfm

Alternatively, user-defined AOA polygons can be used if they conform to the input spatial reference.

For local analyses, parks may have access to more detailed, current, and/or accurate housing density information. In most cases, the increased detail would be reflected in a refined spatial resolution (i.e., actual locations of housing units may exist from individual communities' land records or other local entities). Although the current processing logic is depended on the SERGoM format tool input, a simple modification to the model can be made to utilize local alternative housing density tool input data, if they exist. Contact the NPScape team for details (mailto:NRSS_NRPC_NPScape@nps.gov).

### Input data spatial reference

The NPScape project uses USA Contiguous Albers Equal Area Conic USGS as its standard spatial reference. A local (i.e. custom, non-NPScape sourced) area of analysis polygon may be used if its spatial reference matches the NPScape-provided tool input raster or vector data. In this scenario, re-project your local AOA data (if necessary) and run repair geometry on it before running the tool(s). See the Frequently Asked Questions section for more details on re-projecting tool outputs or tool inputs.

## Input Data Pre-Processing

### Determine AOA polygon

If using an NPScape-sourced AOA, download the appropriate AOA geodatabase from the link in the Data Requirements section.

### Re-project user-defined input datasets (if needed)

All user-defined, custom, non-NPScape sourced tool inputs (e.g. AOA polygon) must be in the USA Contiguous Albers Equal Area Conic USGS spatial reference if used with NPScape-sourced tool inputs.

1. Open ArcCatalog or ArcMap. Click the search button and search for 'Project'. Open the Project tool and re-project your data to USA Contiguous Albers Equal Area Conic USGS.
2. Search for 'Repair Geometry' and run that tool on your re-projected dataset.
3. See the Frequently Asked Questions section for more details.

**Download tool input data**

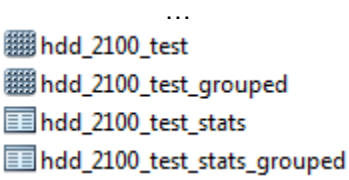
Download the Housing_Density_SERGoM.gdb dataset from the link in the Data Requirements section. These data are seamless across the Lower 48.

## Run NPScape Housing Density Tool

The NPScape Housing Density Tools toolbox contains one tool which outputs date-stamped housing density rasters and summary statistics tables for an area of analysis:

- hdd_YYYY and hdd_YYYY_grouped file geodatabase rasters with housing density classes, clipped to the input AOA
- hdd_YYYY_stats and hdd_YYYY_stats_grouped summary statistics table

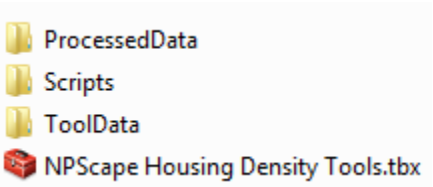
Example tool outputs:




Example thematic classes (standard and grouped):

**Add toolbox to ArcMap**

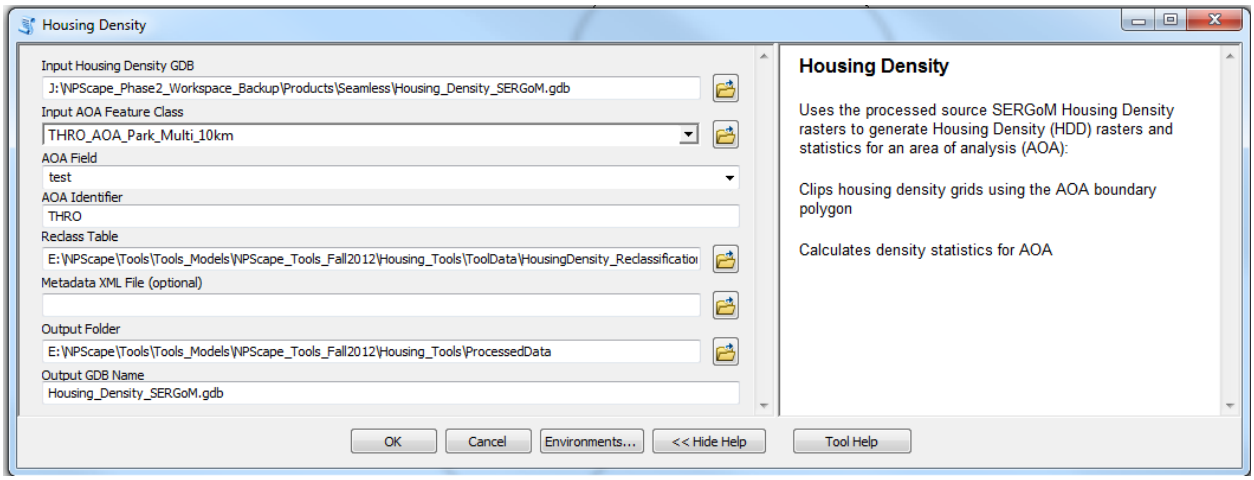
1. Check Geoprocessing Options settings: Geoprocessing → Geoprocessing Options → 'Overwrite the Outputs of Geoprocessing Operations' should be checked. This addresses an issue in ArcGIS 10.1 Service Pack 1 when using feature layers.
2. Extract the tools zip file downloaded from the methods link in the Overview section above. The following folder structure will be created:




   ProcessedData contains ArcMap layer files and is the default tool output folder. Scripts contains the Python code used by the NPScape Housing Density Tools.tbx toolbox.
3. Open ArcMap use the Catalog window to navigate to the folder where the tools were extracted. Open the NPScape Housing Density Tools.tbx toolbox.
4. Double-click on the Housing Density tool to open it.

**Run the Housing Density Tool**

1. Add input data to the map:
   - Polygon feature class for AOA (single or multi-part). If this is a multi-part feature class, summary area will be the total area of all parts, unless one or more individual features is selected.
   - Tool input data: NPScape Housing_Density_SERGoM.gdb
2. Populate values for each of the required parameters in the tool:




Input Housing Density GDB: path to the seamless NPScape Housing_Density_SERGoM.gdb geodatabase
Input AOA Feature Class: feature class used as area of analysis
AOA Field: Text format attribute from Area of Analysis polygon. Used to label output rasters and tables for multi-feature AOAs. If AOA polygon is a single feature, only one output raster and output table will be generated.
AOA Identifier Area of analysis name. For example, ROMO or Upper Lost Creek Watershed. This value is copied to all outputs and summary tables.
Reclass Table: Reclassification table for grouping housing density values. Defaults to \ToolData\HousingDensity_Reclassifications.gdb\HousingDensity_Grouped_Reclass (see Appendix 3)
Metadata XML File (optional): Optional: XML format (FGDC) metadata for output files.
Output Folder: Folder location for output file geodatabase. Defaults to ProcessedData subfolder under tool extract folder. You must have write permission to this folder.
Output Geodatabase Name: File name for output file geodatabase (v10.x); must end in '.gdb'
*Note: if the geodatabase already exists, feature classes and the table will be overwritten*

3. Depending on the extent of the AOA feature class, the tool may take several minutes to run. Processing status will display in ArcMap, either as a popup or as a message in the geoprocessing background bar. The full tool summary is found in the ArcMap → Geoprocessing → Results popup, including error messages.
4. The clipped ungrouped and grouped housing density rasters and summary statistics tables will be added automatically to the map. If single-part AOA polygons were used, only the first 28 rasters and statistics tables from the output geodatabase will be added to the map. Other output rasters and tables can be added manually, and those rasters added manually will have to be symbolized manually using one of the layer files in the ProcessedData subfolder. Default symbology is thematic classes for housing density represented as housing units per $km^2$, ungrouped and grouped:

5. See the Interpretation Tips section for a description of attributes in the output rasters and statistics tables.
6. Running the tool again: open Geoprocessing → Results. Double-click on the Housing Density tool name to open the tool dialog. Change the output geodatabase name if you don't want your original output over-written. Change other parameters as needed.

## Quality Control

### Verify dataset outputs

1. Verify the expected rasters are created and that the AOA_NAME, CLASSNAME, TOTAL_AOA_AREA_SQKM, AOA_FEATURE_AREA_SQKM, TAREA_SQKM, AREA_SQKM, and PCT_AREA fields are present in the raster value attribute tables.
2. Verify that raster edges align correctly with each other. Use the Effects → Swipe tool to help verify this. Note that the NPScape layer files for housing (ProcessedData*.lyr) are used to standardize the raster symbology.
3. Look for the existence of donuts or other spatial errors (note that 'protected lands' are excluded from the tool input density rasters and will appear as NODATA cells within the AOA).

### Verify statistics output

1. Open each value attribute table and sort the PCT_AREA column in descending order. Look for outlying values (negative values, more than one value near 100, sum of values > 100).
2. Open each statistics table and sort each PCT_AREA column in descending order. Look for outlying values (negative values, more than one value near 100, sum of values > 100).
3. Select one record from each statistics table and double-check the PCT_AREA column values by re-calculating them by hand:

$$PCT_AREA = (AREA_SQKM / TAREA_SQKM) * 100$$

## Interpretation Tips

### Output statistics table attributes:

Statistics table attributes:

| | |
|---|---|
| CLASSNAME | Name of housing density class |
| DECADE | Decade (year) of results |
| TOTAL_AOA_AREA_SQKM | Total area of the AOA in $km^2$, calculated from raster cells |
| AOA_FEATURE_AREA_SQKM | Total area of the AOA in $km^2$, calculated from polygon feature |

| | |
|---|---|
| TAREA_SQKM | Total class area in $km^2$, calculated from raster cells; (COUNT * cell $size^2$) / 1000000 |
| AREA_SQKM | Class area in $km^2$, calculated from raster cells |
| PCT_AREA | Percent area of class, (AREA_SQKM/TAREA_SQKM) * 100 |
| AOA_NAME | AOA name from AOA Identifier tool parameter concatenated with AOA Field value |

Areas of no data represent protected lands (especially publicly-owned, but including some private lands with conservation easements). Check outputs for these areas and account for them in explanatory interpretations of the data. Additional ecological guidance is provided in the NPScape Interpretive Guide (Monahan et al. 2012).

## Frequently Asked Questions

### Can/should I use a different spatial reference?

Any NPScape spatial output can be re-projected to a 'final' local spatial reference. For vector outputs, Repair Geometry should be run after re-projection. This approach should be noted in explanatory or interpretive documentation to avoid misleading the user; re-projection of an output dataset will have no effect on area attributes in the summary table generated by the NPScape script.

All NPScape tools generate area calculations from input data. If tool input data must be re-projected prior to running the tools, care should be taken to use a local spatial reference that distorts area minimally, such as an equal-area projection. For CONUS tool input datasets, NPScape uses USA Contiguous Albers Equal Area Conic USGS (NAD_83) as the spatial reference. Alaska-specific tool input datasets are in Alaska Albers Equal Area Conic (NAD_83) while Hawaii-specific datasets use UTM Zone 5N (NAD_83). UTM WGS84 Zone 55N is used for Saipan and Guam while UTN NAD83 Zone 2S is used for American Samoa.

Re-projecting vector input data:
NPScape tool input vector data can be re-projected prior to use as a tool input. The source dataset should be clipped to an extent larger than the intended area of analysis. Then, after clipping, Repair Geometry must be run to correct geometric errors. Finally, the clipped input can be re-projected to the local spatial reference, followed again with a Repair Geometry operation.

Re-projecting raster input data:
Re-projection to match a local spatial reference is not recommended for raster format NPScape tool input datasets. If re-projection is done, the source tool input raster should be clipped to an area of analysis rectangular extent first. Then, the Processing Extent → Snap Raster environment setting in ArcGIS should be populated with the source input tool raster. Warping will occur but should be less than it would be without the Snap Raster setting.

Alternatively, the AOA extent could be re-projected to the same spatial reference as the NPScape input raster followed by a repair geometry operation. Then, this polygon could be rasterized to a temporary raster dataset with a cell size matching the input raster, setting the snap raster to the input raster to minimize warping. Then, this temporary raster could be used to extract an area from the NPScape tool input raster. Finally, this extracted raster could be re-projected to the desired local spatial reference as described above.

### I'm having trouble downloading the tool input dataset. Is there another way to get it?

Many tool input datasets are very large. Please contact the NPScape team to request a custom delivery and/or a custom clipped extent: mailto:NRSS_NRPC_NPScape@nps.gov

**My outputs don't show up in my map. What can I do?**

The tools use ArcGIS display layers to visualize the metric outputs. If you see a red **!** by the layer name in the map, the layer can't find the raster to which it is linked. The most common reason is that the Output Geodatabase Name parameter differed from what the tool script expected. Fix the problem by clicking the red **!** and navigating to the output geodatabase. Then, select the correct feature class or raster.

If a multi-feature singlepart AOA polygon was used, there will be an output raster or feature class and statistics table for each AOA feature, named with the value of the AOA Field attribute. However, only outputs for the last feature processed will be added to the map automatically. Add the remaining output rasters/feature classes and statistics tables. Use the *.lyr files in the ProcessedData subfolder to symbolize the features.

## Literature Cited

Monahan, W. B., J. E. Gross, L. K. Svancara, and T. Philippi. 2012. A guide to interpreting NPScape data and analyses. Natural Resource Technical Report NPS/NRSS/NRTR—2012/578. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/App/Reference/Profile/2184927 (Accessed 20121130).

National Park Service. 2013. NPScape: monitoring landscape dynamics of US National Parks. Natural Resource Stewardship and Science, Inventory and Monitoring Division. Fort Collins, Colorado. http://science.nature.nps.gov/im/monitor/npscape/ (Accessed 20130219).

Theobald, D.M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society 10:32. (online) www.ecologyandsociety.org

## Appendices

### Appendix 1: Known issues

Data availability

Housing density source data are available only for the Lower 48. Housing density from SERGoM is available as 100 m rasters for 1970-2100, by decade.

Completeness of Source Rasters from SERGoM

In certain areas, density values may be missing from the source housing density grids. These areas typically occur across entire counties and are irregularly distributed throughout the dataset.

Also, SERGoM data is not calculated for certain protected area locations across the CONUS. In particular, park polygon areas may be excluded due to their status as protected areas.

Projected Housing Density Values from SERGoM

Projected housing values are based on socioeconomic forecasts. Rates of growth and subsequent projected changes in housing density are reflected in the SERGoM dataset at a local level and will vary throughout the larger nationwide dataset. While projections were based on best-available information, economic changes or geographic patterns could vary considerable from what is forecast in future decades.

**Appendix 2: Using custom AOAs and/or local input data**

Custom AOAs

The AOA feature class should include a text attribute with a name value for the AOA feature(s). This text attribute should not contain '/' or other special characters. The feature class can contain single or multi-part polygons. If single-part polygons are used, an output raster and statistics table will be produced for each feature, named with the attribute value selected in the AOA_Field parameter.

Local input data

The tools are dependent on the specified tool inputs and therefore are not generic.

**Appendix 3: Reclassification Table**

SERGoM housing density classes: standard and grouped

| Housing Density Class | Raster Value | Grouped Housing Density Class | Raster Value |
|---|---|---|---|
| Urban-Regional Park | 13 | Urban-Regional Park | 13 |
| Commercial / Industrial | 12 | Commercial / Industrial | 5 |
| >2,470 units / $km^2$ | 11 | Urban | 4 |
| 1,235 – 2,470 units / $km^2$ | 10 | | |
| 495 – 1,235 units / $km^2$ | 9 | Suburban | 3 |
| 146 - 495 units / $km^2$ | 8 | | |
| 50 – 146 units /$km^2$ | 7 | Exurban | 2 |
| 25 - 49 units /$km^2$ | 6 | | |
| 13 – 24 units /$km^2$ | 5 | | |
| 7 - 12 units /$km^2$ | 4 | Rural | 1 |
| 4 - 6 units /$km^2$ | 3 | | |
| 1.5 - 3 units /$km^2$ | 2 | | |
| < 1.5 units /$km^2$ | 1 | | |
| Private undeveloped | 0 | | |

**Appendix 4: Tool scripts**

See Scripts subfolder for Python scripts used by the metric tool(s).

**Appendix 5: Tool input data/metric data processing details**

Source data

SERGOM grids were imported into a file geodatabase (Housing_Density_SERGoM.gdb).

Processing steps - Summary

None

Update schedule

Undetermined