Implementation Details

for

Ground Based Exclusion Zones Tests

**Source:** James (Jody) Neel

Federated Wireless

[james.neel@federatedwireless.com](mailto:Prakash.Moorut@nokia.com)

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# Test Characteristics

|  |  |  |
| --- | --- | --- |
| 1 | **Test ID** | FCC.FT.0.001 |
| 2 | **Title** | Ground Based Exclusion Zone Enforcement Test |
| 3 | **Working Group / Entity** | FCC 96.15 (requirement) NTIA [2] (exclusion zone specifics) |
| 4 | **Test Type** | Functionality |
| 5 | **Test Class** | Certification |
| 6 | **Component / Interface** | SAS |
| 7 | **Report Section** | 8.4 |

# History

|  |  |  |
| --- | --- | --- |
| **Document history** | | |
| V1.0 | 28 September 2015 | Initial Submission to GitHub |
|  |  |  |
|  |  |  |

# Introduction

This document provides implementation details on the tests to verify correct implementation of the Ground Based Radar Exclusion Zones required by 96.15 prior to approval of one or more ESCs used by at least one SAS in accordance by 96.67.

This document includes the following information:

* An overview of the test code
* Parameters for generating test messages

# Test Code for Message Generation

To support this test process, Federated Wireless has provided python code (v 2.7) that accomplishes the following tasks:

* Parsing of the ground based exclusion zone kml files to generate python objects (Shapely objects) for analysis and testing
* Generation of test locations according to the test point generation method specified for each exclusion zone
* Determination of which locations the SAS should allow for CBSD use and which locations should be excluded
* Generation of kml files that can be viewed in Google Maps or another appropriate viewer.

## Code Architecture

A block diagram of this code is shown in . To generate the internal python objects, the test code parses kml files from the NTIA provided Ground Based Radar Exclusion Zone kml file. Then, using configuration information, the code generates test locations (test points) in conjunction with the parsed objects. These test points are then passed through simple exclusion logic that assesses if each test location inside or outside of the polygon(s) that defines the associated exclusion zones to determine if each location is allowable for CBSD use or should be excluded. Finally to facilitate human verification of the generated points, the test code color-codes the locations into allowable locations (green pin) and excluded locations (red pin) and writes them to a KML-formatted file so the points can be visualized against an overlay of the exclusion zones.

A screen capture of an example test points generated for the White Sands Exclusion zone as displayed in Google Maps is shown in , where green pins are allowed locations, red pins are excluded locations, and the Blue Pin shows the centroid location of the polygon. Note that the green pin in the southeast corner of the exclusion zone actually lies just outside of the exclusion, but the resolution of the pin at this zoom level makes it appear to lie inside of the exclusion zone.

|  |  |
| --- | --- |
|  |  |
| Figure : Block Diagram of major components provided by Federated Wireless for Exclusion Zone Testing | Figure : Example visualization of test points generated for White Sands Exclusion Zone according to a 2-D Gaussian distribution from the exclusion zone centroid (blue). |

## Code Implementation

The Federated Wireless provided code consists of the following files, which will be maintained in the GitHub code repository managed by WG4.

* **WG4\_KML.py**
  + Parses KML files to create Shapely objects (polygons)
  + Creates formatted KML for coordinate lists (display points in / out of exclusion zone)
* **WG4\_Area.py**
  + Holds polygon(s) and facilitates geometric operations
  + Generates points
  + Manages determination if collection of points are in / out of the polygon
* **EZ\_test.py**
  + Sample script using libraries above

The code also makes use of the following python packagesnot included in the standard python distribution, all of which are available at the Python Package Index site[[1]](#footnote-1).

* **lxml** and **pykml** - to simplify the kml parsing into Python objects
* **shapely** to perform various geometric operations
* **latlon** - to implement WGS84 distance calculations
* **numpy** - to generate the needed statistical distributions

## Current Remaining Code Development Items

The following remains to be accomplished to use of this code to conduct the automated Ground Based Radar test procedure:

* Creation of the test apparatus (see section 7)
* Integration with the test apparatus and scripting tools instead of via the existing programmatic interface.

# Default Test Parameters for Specific Ground Based Radar Exclusion Zones

The following lists the default test parameters proposed for each Ground Based Radar Exclusion Zone. Note that each zone may include multiple test point generation methods.

## Yuma Proving Ground

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Yuma Proving Ground** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 1 mi  #Points = 500 |
| Area: 1821 sq mi  Perimeter: 268 mi  #Coord: 904 | 2-D Gaussian | Center = -114.417851, 33.246524  #Points = 50 Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## Yakima Firing Center

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Yakima Firing Center** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 150 |
| Area: 589 sq mi  Perimeter: 102 mi  #Coord: 604 | 2-D Gaussian | Center = Polygon Centroid #Points = 50  Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## White Sands Missile Range

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **White Sands Missile Range** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 400 |
| Area: 4,283 sqmi  Perimeter: 348 mi  #Coord: 1237  #Coord: 185 | Edge Distribution | Inner Boundary Edge Stddev = 0.5 mi  #Points = 40 |
| 2D Gaussian | Center 1: 33.332926, -106.424012  Center 2: 32.349906, -106.358094  Stddev = 20 mi |
| **Manual Coordinates** | |
| None | |

## White Sands Missile Range

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Schofield Barracks Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 1 mi  #Points = 100 |
| Area: 100 sq mi  Perimeter: 46.8 mi  #Coord: 457 |  |  |
|  |  |
| **Manual Coordinates** | |
| None | |

## Pohakuloa Training Area

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Pohakuloa Training Area** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 150 |
| Area: 268 sq mi  Perimeter: 65.8 mi  #Coord: 594 | 2-D Gaussian | Center = Polygon Centroid #Points = 50  Edge Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## Pinon Canyon Maneuver Site

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Pinon Canyon Maneuver Site** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 150 |
| Area: 369 sq mi  Perimeter: 106 mi  #Coord: 679 | 2-D Gaussian | Center = Polygon Centroid #Points = 50  Edge Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## Letterkenny Army Depot

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Letterkenny Army Depot** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 100 |
| Area: 80.9 sq mi  Perimeter: 33.3 mi  #Coord: 1024 | 2-D Gaussian | Center = Polygon Centroid #Points = 50  Stddev = 5 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Stewart

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Stewart** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 150 |
| Area:616 sq mi  Perimeter: 99.5 mi  #Coord: 797 | 2-D Gaussian | Center = Polygon Centroid #Points = 50  Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Sill Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Sill Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 1 mi  #Points = 150 |
| Area: 300 sq mi  Perimeter: 84 mi  #Coord: 367 | 2-D Gaussian | Center = Polygon Centroid #Points = 50  Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Riley Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Riley Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 150 |
| Area: 295 sq mi  Perimeter: 72.6 mi  #Coord: 556 | 2-D Gaussian | Center = Polygon Centroid #Points = 50  Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Polk Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Polk Military Reservation** |  |  | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 150 |
| Area: 283 sq mi  Perimeter: 71.7 mi  #Coord: 433 | 2-D Gaussian | Center = Polygon Centroid #Points = 50  Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

Technically two placemarks with three polygons total where polygons overlap. This one is a single polygon.

## Fort Polk Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Polk Military Reservation** |  |  | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary(1,2) Edge Stddev = 0.5 mi  #Points = 150 |
| Area: 354 sq mi  Perimeter: 113 mi  #Coord: 390  #Coord: 239 | 2-D Gaussian | Center = Polygon Centroid (1,2) #Points = 50  Stddev = 10 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

Technically two placemarks with three polygons total where polygons overlap. This one is two polygons.

## Fort Pickett Military Reservation (Closed)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Pickett Military Reservation (Closed)** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 100 |
| Area: 142 sq mi  Perimeter: 44.8 mi  #Coord: 358 | 2-D Gaussian | Center = Polygon Centroid #Points = 25  Stddev = 5 mi |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Lewis Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Lewis Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 150 |
| Area: 277 sq mi  Perimeter: 74.9  #Coord: 727 | 2-D Gaussian | Center = <-122.522552, [47.080643](javascript:void(0))> (long, lat)  Stddev = 10 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Irwin

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Irwin** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 1.0 mi  #Points = 200 |
| Area: 1,176 sq mi  Perimeter: 140 mi  #Coord: 605 | 2-D Gaussian | Center = polygon centroid  Stddev = 15 mi #Points = 100 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Indiantown Gap Military Reservation (Closed)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Indiantown Gap Military Reservation (Closed)** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 1.0 mi  #Points = 100 |
| Area: 97.4 sq mi  Perimeter: 40.7 mi  #Coord: 376 | 2-D Gaussian | Center = polygon centroid  Stddev = 5 mi #Points = 100 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Hood

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Hood** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 200 |
| Area: 597 sq mi  Perimeter: 117 mi  #Coord: 1077 | 2-D Gaussian | Center = polygon centroid  Stddev = 10 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Ethan Allen Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Ethan Allen Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | 2-D Gaussian | Center = polygon centroid  Stddev = 10 mi #Points = 50 |
| Area: 54.9 sq mi  Perimeter: 27.2 mi  #Coord: 204 |  |  |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Drum

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Drum** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 150 |
| Area: 302 sq mi  Perimeter: 74.3 mi  #Coord: 384 | 2-D Gaussian | Center = polygon centroid  Stddev = 10 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Dix Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Dix Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 200 |
| Area: 134 sq mi  Perimeter: 49.2 mi  #Coord: 417 | 2-D Gaussian | Center = polygon centroid  Stddev = 5 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Carson Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Carson Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary (1,2) Edge Stddev = 0.5 mi  #Points = 200 |
| Area: 908 sq mi  Perimeter: 179 mi  #Coord: 718  #Coord: 438 | 2-D Gaussian | Center = polygon centroid (1,2)  Stddev = 10 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

Both polygons in kml

## Fort Campbell

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Campbell** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 200 |
| Area: 293 sq mi  Perimeter: 74.3 mi  #Coord: 554 | 2-D Gaussian | Center = polygon centroid  Stddev = 10 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Bragg

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Bragg Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 200 |
| Area: 381 sq mi  Perimeter: 88 mi  #Coord: 668 | 2-D Gaussian | Center = polygon centroid  Stddev = 10 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Fort Benning Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Fort Benning Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 1.0 mi  #Points = 200 |
| Area: 451 sq mi  Perimeter: 92.4 mi  #Coord: 836 | 2-D Gaussian | Center = polygon centroid  Stddev = 10 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Cp Smith

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Cp Smith** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | 2-D Gaussian | Center = polygon centroid  Stddev = 2.5 mi #Points = 50 |
| Area: 25.9 sq mi  Perimeter: 18.2 mi  #Coord: 509 |  |  |
|  |  |
| **Manual Coordinates** | |
| None | |

## Camp Sherman 3 km PD

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Camp Sherman 3 km PD** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | 2-D Gaussian | Center = polygon centroid  Stddev = 2.5 mi #Points = 50 |
| Area: 23.2 sq mi  Perimeter: 17.3 mi  #Coord: 180 |  |  |
|  |  |
| **Manual Coordinates** | |
| None | |

## Camp Shelby 3 km PD

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Camp Shelby 3km PD** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 100 |
| Area: 234 sq mi  Perimeter: 62 mi  #Coord: 233 | 2-D Gaussian | Center = polygon centroid  Stddev = 10 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Aberdeen Proving Ground Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Aberdeen Proving Ground Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 1.0 mi  #Points = 100 |
| Area: 184 sq mi  Perimeter: 63.2 mi  #Coord: 403 | 2-D Gaussian | Center = polygon centroid  Stddev = 5 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

Three Aberdreen placemarks, Four Polygons

## U.S. Army Aberdeen Proving Ground

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **U.S. Army Aberdeen Proving Ground** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary Edge Stddev = 0.5 mi  #Points = 100 |
| Area: 113 sq mi  Perimeter: 41.7 mi  #Coord: 365 | 2-D Gaussian | Center = polygon centroid  Stddev = 5 mi #Points = 50 |
|  |  |
| **Manual Coordinates** | |
| None | |

## Aberdeen Proving Ground Military Reservation

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Aberdeen Proving Ground Military Reservation** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | Edge Distribution | Outer Boundary 1 Edge Stddev = 1.0 mi  #Points = 100 |
| Area:118 sq mi  Perimeter: 60.6 mi  #Coord: 484  #Coord: 234 | 2-D Gaussian | Center = polygon (OB1) centroid  Stddev = 2 mi #Points = 50 |
| 2-D Gaussian | Center = polygon (OB2) centroid  Stddev = 2 mi #Points = 50 |
| **Manual Coordinates** | |
| None | |

One polygon is nearly circular

## Knoxville, TN

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Knoxville, TN** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | 2-D Gaussian | Center = polygon centroid  Stddev = 2 mi #Points = 50 |
| Area:10.9 sq mi  Perimeter: 11.7 mi  #Coord: 123 |  |  |
|  |  |
| **Manual Coordinates** | |
| None | |

## Tupelo, MS

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Tupelo, MS** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | 2-D Gaussian | Center = polygon centroid  Stddev = 2 mi #Points = 50 |
| Area:10.9 sq mi  Perimeter: 11.7 mi  #Coord: 123 |  |  |
|  |  |
| **Manual Coordinates** | |
| None | |

## Morristown, NJ

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Visualization** | **Test Coordinate Data** | |
| **Morristown, NJ** |  | **Automatically Generated Coordinates** | |
| **Type** | **Parameters** |
| **Stats** | 2-D Gaussian | Center = polygon centroid  Stddev = 2 mi #Points = 50 |
| Area:10.9 sq mi  Perimeter: 11.7 mi  #Coord: 123 |  |  |
|  |  |
| **Manual Coordinates** | |
| None | |

1. https://pypi.python.org/pypi [↑](#footnote-ref-1)