GNIS-LD: Serving and Visualizing the Geographic Names Information System Gazetteer as Linked Data

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The USGS, BGN, and GNIS

The **U.S. Geological Survey** (USGS) is a scientific agency of the United States federal government that studies the geography, geology, biology and hydrology of the U.S. landscape, including natural resources and hazards.

The **U.S. Board of Geographic Names** (BGN) is a federal body responsible for establishing and maintaining uniform usage of geographic names throughout the country (e.g, names of streets, cities, rivers, mountains, peaks, valleys, etc.).

The **Geographic Names Information System** (GNIS) is an **authoritative, public domain** gazetteer (*a geographic register of place names*) that is the product of the USGS and BGN.

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About the GNIS

Established in late 1800's because of "Inconsistencies and contradictions among many names, spellings, and applications became a serious problem to surveyors, map makers, and scientists who required **uniform, non-conflicting geographic nomenclature**." – geonames.usgs.gov

The data are made available as flat, pipe-delimited text records.

The GNIS is used by, or has been imported by, **all major mapping datasets** covering US: OpenStreetMap, GeoNames.org, LinkedGeoData, Google/Apple/Bing Maps, and so on.

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GNIS Query

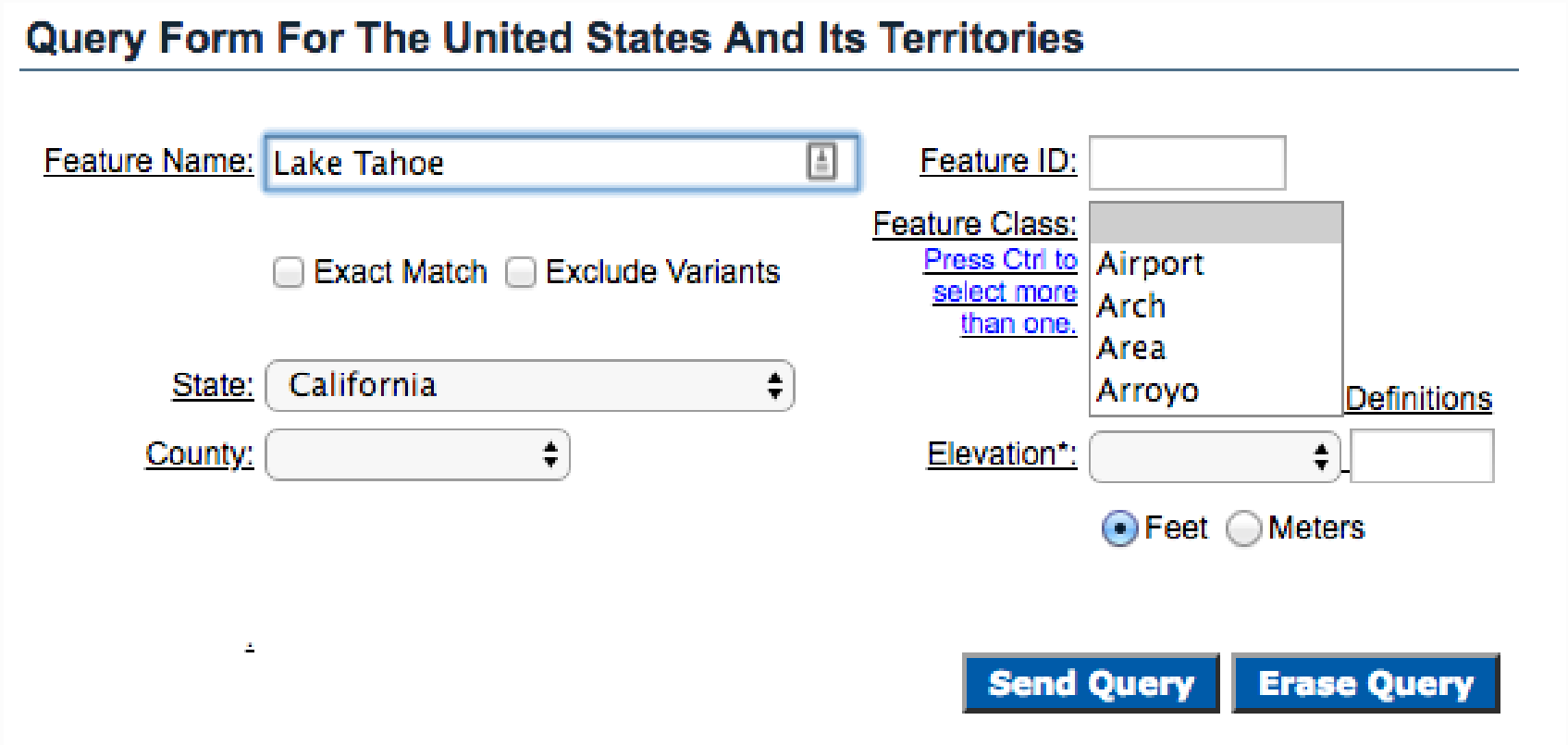

Figure 1: `https://geonames.usgs.gov/pls/gnispublic/`

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GNIS Query

Feature Query Results

Click the feature name for details and to access map services
Click any column name to sort the list ascending ▲ or descending ▼

Feature Name	ID	Class ▲	County	State	Latitude	Longitude	Ele(ft)	Map	BGN Date	Entry Date
Lake Tahoe Airport	1654022	Airport	El Dorado	CA	385342N	1195949W	6256	South Lake Tahoe	-	01-MAR-1994
California Highway Patrol Valley Division - South Lake Tahoe	2770087	Building	El Dorado	CA	385113N	1200107W	6345	Echo Lake	-	28-OCT-2015
El Dorado County Sheriff's Office	2755881	Building	El Dorado	CA	385559N	1195819W	6273	South Lake Tahoe	-	23-JUL-2014
South Lake Tahoe Branch El Dorado County Library	1733873	Building	El Dorado	CA	385631N	1195824W	6260	South Lake Tahoe	-	14-MAY-1997
South Lake Tahoe Fire Department Station 1	2624332	Building	El Dorado	CA	385628N	1195709W	6286	South Lake Tahoe	-	03-FEB-2011
South Lake Tahoe Fire Department Station 2	2624530	Building	El Dorado	CA	385611N	1195840W	6270	South Lake Tahoe	-	04-FEB-2011
South Lake Tahoe Fire Department Station 3	2623872	Building	El Dorado	CA	385456N	1200005W	6266	Emerald Bay	-	04-FEB-2011
South Lake Tahoe Police Department	2755890	Building	El Dorado	CA	385604N	1195820W	6273	South Lake Tahoe	-	23-JUL-2014
Church of Christ of South Lake Tahoe	1733823	Church	El Dorado	CA	385638N	1195732W	6250	South Lake Tahoe	-	14-MAY-1997
First Baptist Church of South Lake Tahoe	1733754	Church	El Dorado	CA	385657N	1195708W	6243	South Lake Tahoe	-	14-MAY-1997
City of South Lake Tahoe	2411938	Civil	El Dorado	CA	385622N	1195858W	6263	South Lake Tahoe	-	11-MAR-2008
Lake Tahoe Division	1935160	Civil	Placer	CA	390911N	1200629W	6227	Kings Beach	-	26-SEP-2001
South Lake Tahoe Division	1935321	Civil	El Dorado	CA	385512N	1200218W	6552	Emerald Bay	-	26-SEP-2001
Lake Tahoe Dam	1664623	Dam	Placer	CA	391001N	1200838W	6237	Tahoe City	-	01-JUL-1994
Lake Tahoe Basin Management Unit Headquarters	1655028	Locale	El Dorado	CA	385458N	1200032W	6273	Emerald Bay	-	01-DEC-1991

row(s) 1 – 15 of 27

Figure 2

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The National Map

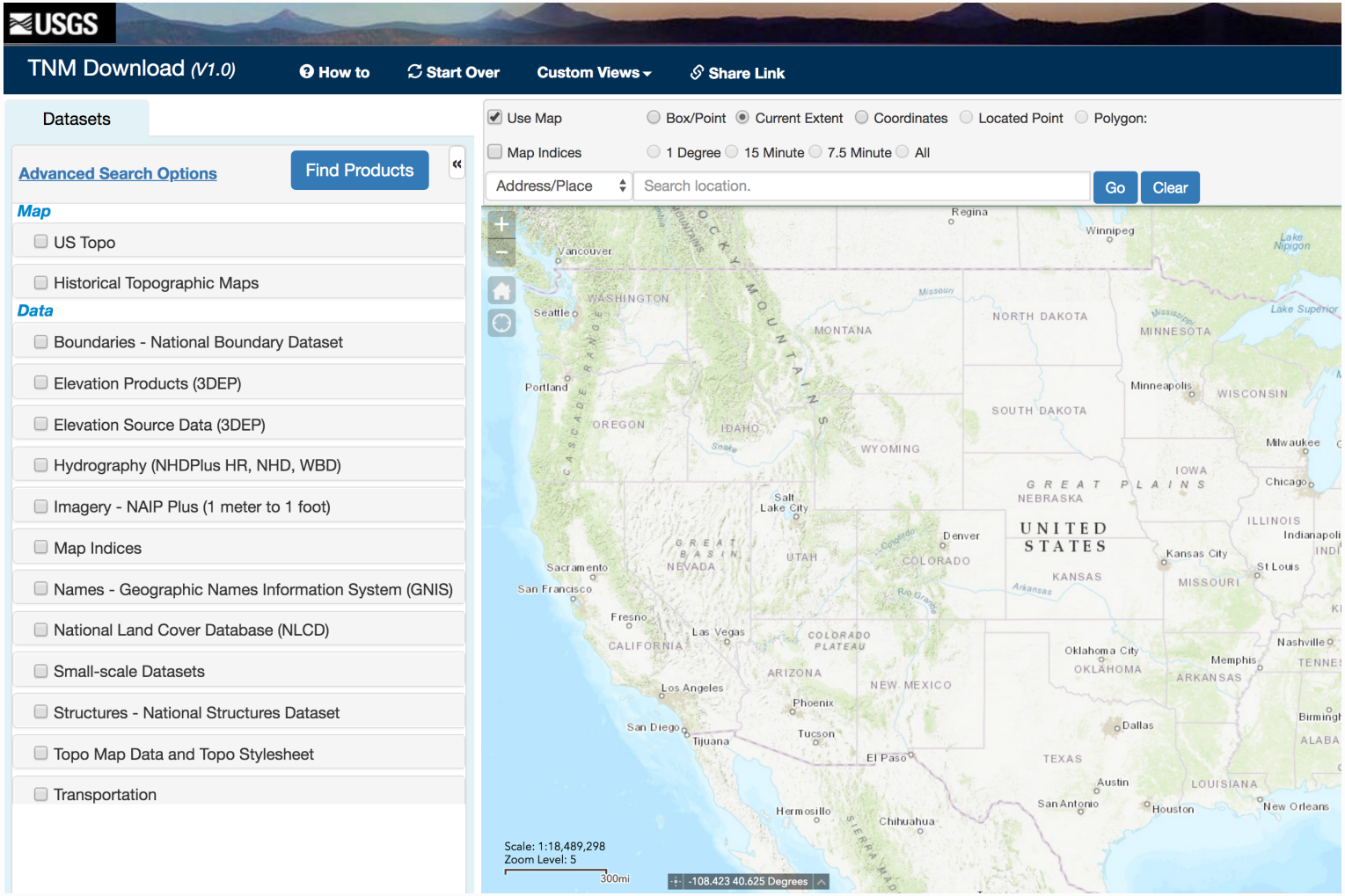

Figure 3: https://viewer.nationalmap.gov/basic/

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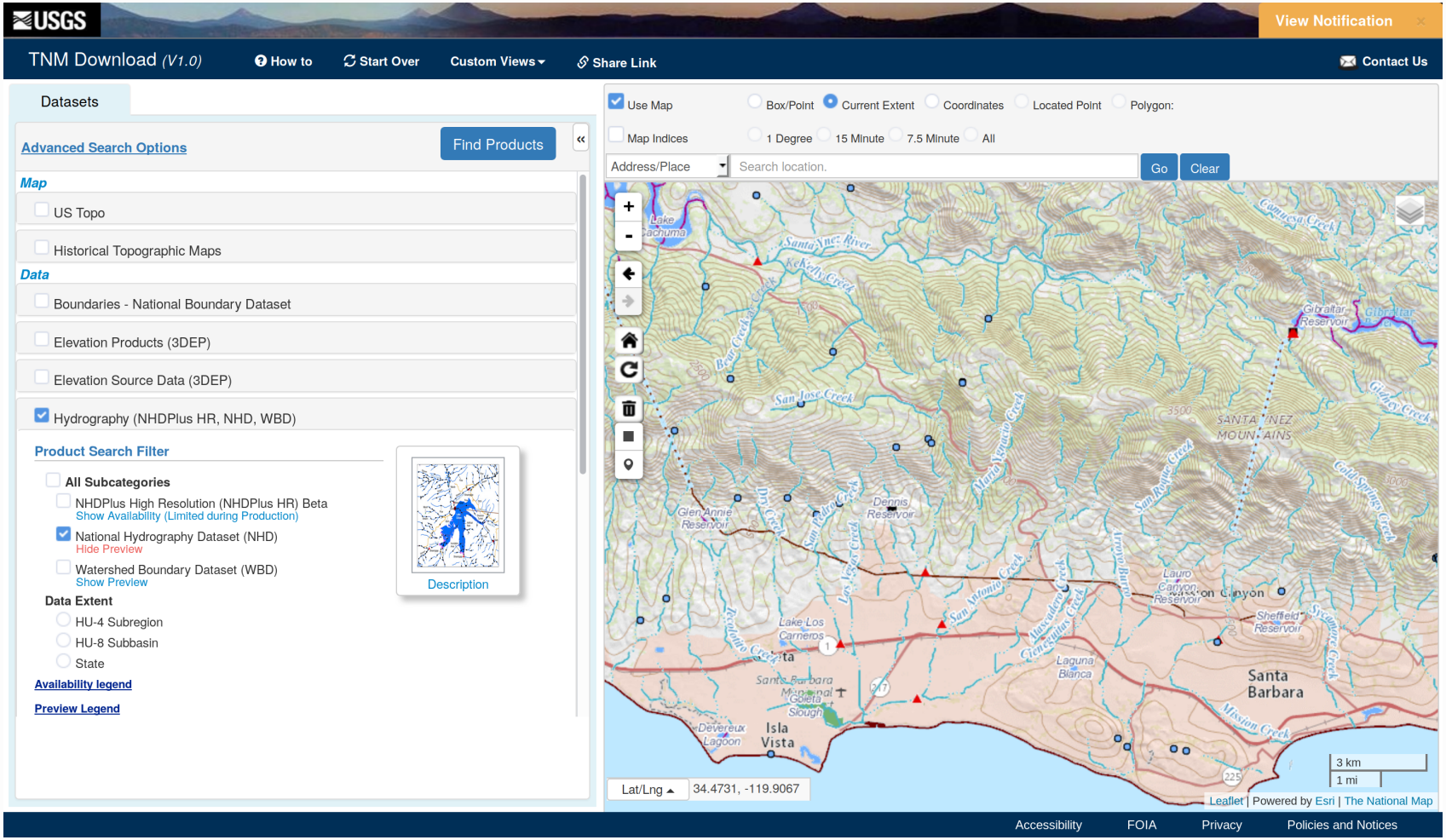

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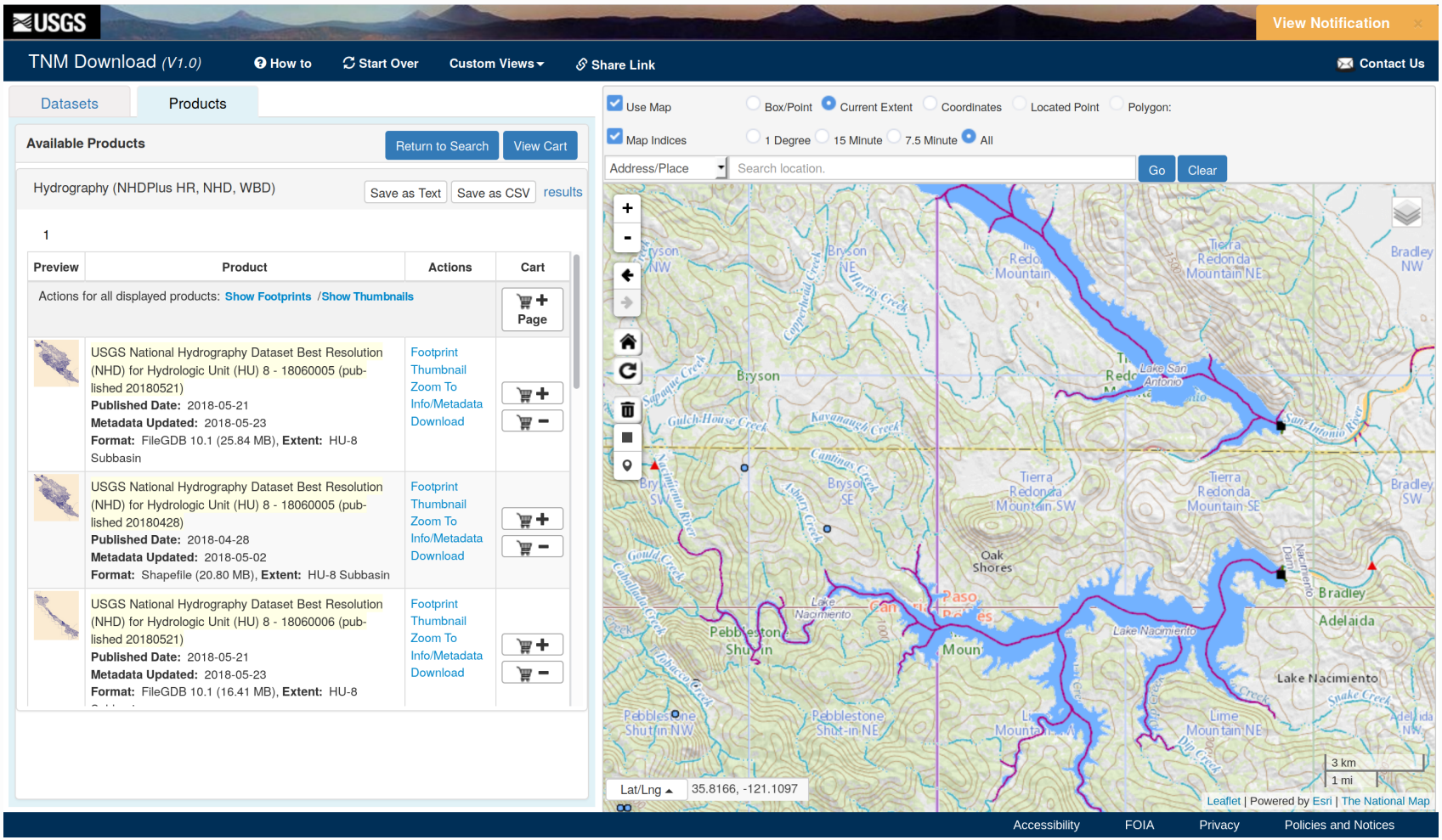

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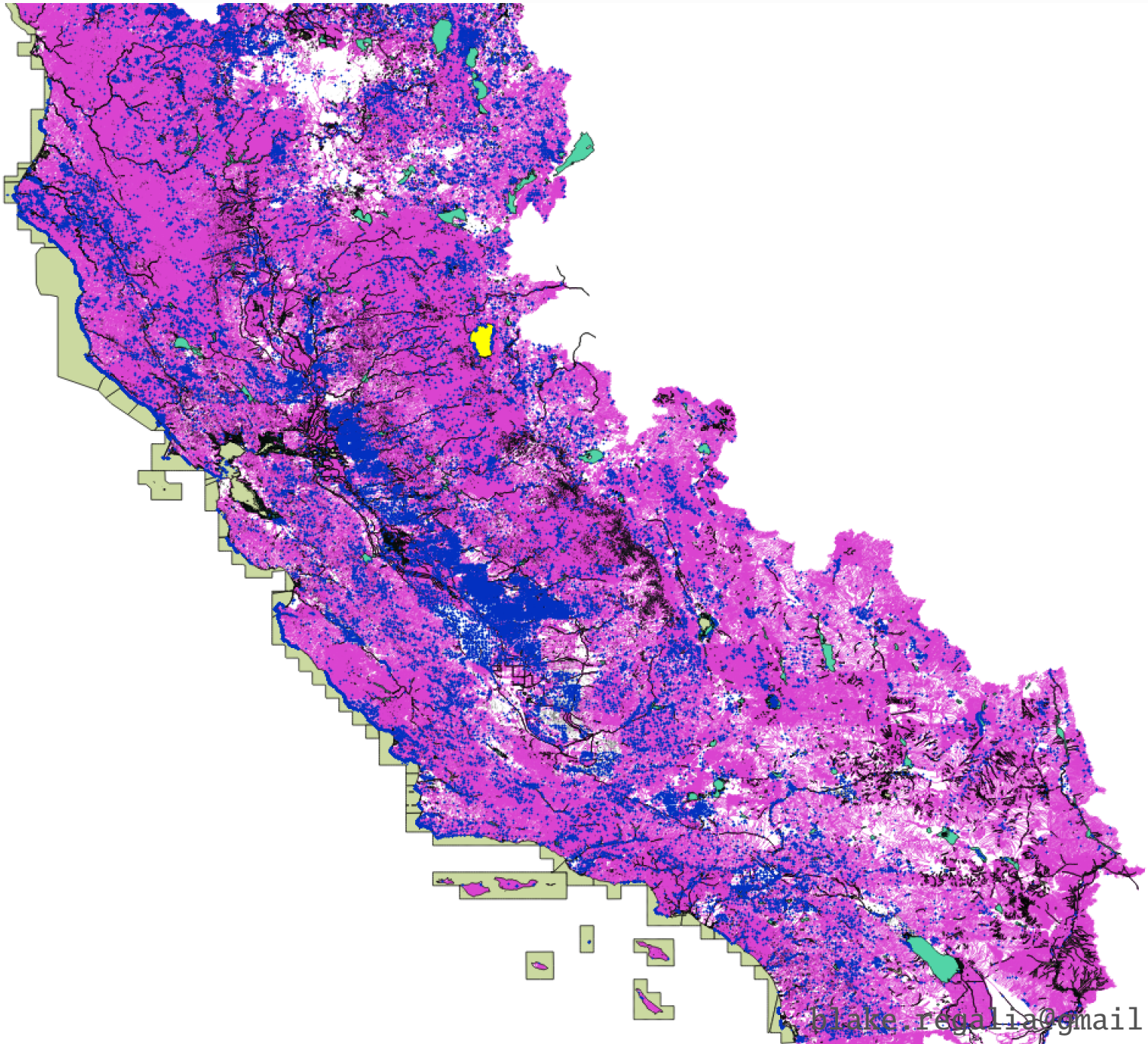

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The National Map as Linked Data

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Summary

Converting **National Map** datasets (i.e., Digital Line Graph data) to Linked Data:

- USGS requires all deliverables (incl. tools, software, and data) to be **open source and based on open standards**.
- The final linked dataset is currently estimated to be upwards of **1.3 billion** triples, and will include **more than 100 GB of geometry data**.
- *May* result in the largest 5-star linked geo-dataset on the cloud

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Objective

This project has multiple phases and this starts with:

- Converting the **GNIS** to Linked Data
- Produce a core **vocabulary and ontology**
- Align with existing repositories such as GeoNames.org, DBpedia, Getty, ADL, ...
- Supply **geo-enabled** user interfaces for dereferencing and browsing

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phuzzy.link

SPARQL endpoint URL:
http://gnis-ld.org/sparql/selec

Prefix JSON-LD context:
http://phuzzy.link/context/gni

Settings:
language: "en"
locale: "en-US"
limit: 256

Plugins:
phuzzy-xsd
phuzzy-language-filter
phuzzy-colored-prefixes: 1 arg
phuzzy-info: 1 arg
phuzzy-geo

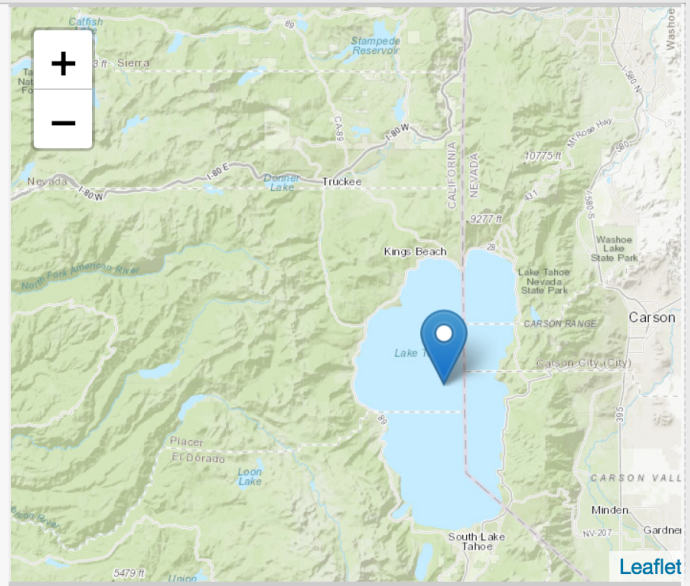
Outgoing properties: 28 triples

Incoming properties: 2 triples

gnisf:1654975

View RDF source </>

rdf:type	→	cegis:Reservoir
rdfs:label	→	"Lake Tahoe" @en
ago:geometry	→	usgeo-point:gnisf.1654975
gnis:alternativeName	→	"Bigler Lake" @en "Bonpland Lake" @en "Daow aga" @en "Lago Beergler" @en "Lake Bigler" @en "Lake Bompland" @en "Lake Bonplan" @en "Lake Bonpland" @en "Lake Teho" @en "Lake Tehoe" @en "Mountain Lake" @en "Taa-oo *" @en "Tah-oo *" @en "Tula Tulia" @en
gnis:citation	→	"U.S. Geological Survey. Geographic Names Phase I data compilation (1976-1981). 31-Dec-1981. Primarily from U.S. Geological Survey 1:24,000-scale topographic maps (or 1:25K, Puerto Rico 1:20K) and from U.S. Board on Geographic Names files. In some instances, from 1:62,500 scale or 1:250,000 scale maps." @en



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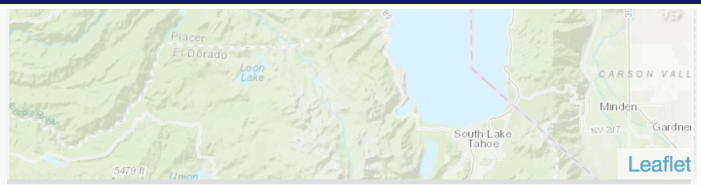
		"Mountain Lake" @en "Taa-oo *" @en "Tah-oo *" @en "Tula Tulia" @en



gnis:citation	→	"U.S. Geological Survey. Geographic Names Phase I data compilation (1976-1981). 31-Dec-1981. Primarily from U.S. Geological Survey 1:24,000-scale topographic maps (or 1:25K, Puerto Rico 1:20K) and from U.S. Board on Geographic Names files. In some instances, from 1:62,500 scale or 1:250,000 scale maps." @en
gnis:county	→	gnisf-alias:California.Placer
gnis:dateFeatureCreated	→	January 19, 1981 ^^ xsd:date
gnis:dateFeatureEdited	→	May 22, 2012 ^^ xsd:date
gnis:dateNameCreated	→	January 11, 2006 ^^ xsd:date
gnis:description	→	"Tahoe is a Washoe Indian word for "much water". Lake Bonpland is an early name Fremont gave Lake Tahoe." @en
gnis:elevation	→	gnis:Elevation.6227ft
gnis:featureId	→	"1654975"
gnis:mapName	→	"Meeks Bay" @en
gnis:officialName	→	"Lake Tahoe" @en
gnis:state	→	gnisf-alias:CA

Incoming Triples

is owl:sameAs	of	gnisf-alias:California.Placer.Reservoir.Lake_Tahoe
is nhd:gnisFeature	of	nhdf:44560536

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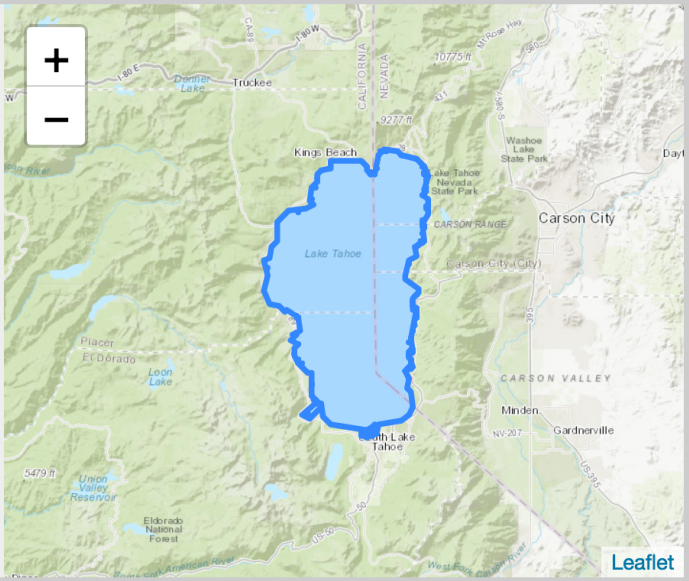
nhdf:44560536

View RDF source </>



rdf:type	→	nhdf:Average_Water_Elevation_Perennial_Lake_or_Pond
ago:geometry	→	usgeo-multipolygon:nhdf.44560536
nhd:area	→	qudt:numericValue 498.1267876 qudt:unit unit:KM2
nhd:elevation	→	qudt:numericValue 6229 qudt:unit unit:M
nhd:gnisFeature	→	gnisf:1654975
nhd:reachCode	→	"16050101000339"
nhd:resolution	→	nhd:High_Resolution
usgs:modified	→	March 12, 2012 ^^ xsd:date

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usgeo-multipolygon:nhdf.44560536

View RDF source </>

rdf:type	→	ago:MultiPolygon
ago:area	→	qudt:numericValue 4.98126787805565E8 qudt:unit unit:M2
ago:boundingBox	→	"<http://www.opengis.net/def/crs/EPSG/0/4326>POLYGON((-120.164012990588 38.9283332062421,-120.164012990588 39.2489710724111,-119.926092324291 39.2489710724111,-119.926092324291 38.9283332062421,-120.164012990588 38.9283332062421))" ^^geosparql:wktLiteral
ago:centroid	→	"<http://www.opengis.net/def/crs/EPSG/0/4326>POINT(-120.033432894877 39.0959954262897)" ^^geosparql:wktLiteral
ago:geometryCount	→	"1" ^^xsd:integer
ago:perimeter	→	qudt:numericValue 159175.518953682 qudt:unit unit:M2
ago:pointCount	→	"9059" ^^xsd:integer
ago:ringCount	→	"225" ^^xsd:integer

Incoming Triples

is ago:geometry	of	nhdf:44560536

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USGS geometry data consists of many high-resolution **polylines and polygons**. GeoSPARQL standards combined w/ spatial indexing, demands geometry in human-readable formats *in addition to* binary formats.

MULTIPOLYGON(((-120.002041 -31.638216, -120.002001 -31.3606135, -120.001995 -31.3215459, -120.001961 -31.2876527, -120.001921 -31.2676681, -120.001918 -31.2633269, -120.001917 -31.2626387, -120.001901 -31.2621424, -120.001906 -31.2614291, -120.001908 -31.1642926, -120.00167 -26.1159182, -120.001672 -28.1159122, -120.001683 -28.9986057, -120.000570 -25.0996057, -120.000022 -25.6972415, -120.000021 -25.7945181, -120.000022 -25.8972415, -120.000019 -25.4864648, -120.000019 -25.3836246, -120.000018 -25.2850012, -120.000018 -25.1781779, -120.000017 -25.0754545, -120.000016 -24.9727311, -120.000016 -24.8700077, -120.000016 -24.8525844, -120.000015 -24.7672843, -120.000015 -24.6645961, -120.000014 -24.5618726, -120.000013 -24.4591492, -120.000013 -24.3683908, -120.000012 -24.2656674, -120.000012 -24.1629440, -120.000011 -24.0602207, -120.000011 -23.9574973, -120.000010 -23.8547739, -120.000010 -23.7520505, -120.000009 -23.6493364, -120.000009 -23.6378272, -120.000009 -23.5351038, -120.000008 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69.9513605, -119.999452 70.0540839, -119.999451 70.1568073, -119.999451 70.2595307, -119.999450 70.3622541, -119.999449 70.4649775, -119.999449 70.5677009, -119.999448 70.6704243, -119.999447 70.7731477, -119.999447 70.8758711, -119.999446 70.9785945, -119.999446 71.0813179, -119.999445 71.1840413, -119.999444 71.2867647, -119.999444 71.3894881, -119.999443 71.4922115, -119.999443 71.5949349, -119.999442 71.6976583, -119.999441 71.8003817, -119.999441 71.9031051, -119.999440 72.0058285, -119.999439 72.1085519, -119.999439 72.2112753, -119.999438 72.3139987, -119.999438 72.4167221, -119.999437 72.5194455, -119.999436 72.6221689, -119.999436 72.7248923, -119.999435 72.8276157, -119.999435 72.9303391, -119.999434 73.0330625, -119.999433 73.1357859, -119.999433 73.2385093, -119.999432 73.3412327, -119.999432 73.4439561, -119.999431 73.5466795, -119.999430 73.6494029, -119.999430 73.7521263, -119.999429 73.8548497, -119.999429 73.9575731, -119.999428 74.0602965, -119.999427 74.1630199, 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-119.999277 99.8438699, -119.999276 99.9465933, -119.999275 100.0493167, -119.999275 100.1520401, -119.999274 100.2547635, -119.999274 100.3574869, -119.999273 100.4602103, -119.999272 100.5629337, -119.999272 100.6656571, -119.999271 100.7683805, -119.999271 100.8711039, -119.999270 100.9738273, -119.999269 101.0765507, -119.999269 101.1792741, -119.999268 101.2819975, -119.999268 101.3847209, -119.999267 101.4874443, -119.999266 101.5901677, -119.999266 101.6928911, -119.999265 101.7956145, -119.999265 101.8983379, -119.999264 102.0010613, -119.999263 102.1037847, -119.999263 102.2065081, -119.999262 102.3092315, -119.999262 102.4119549, -119.999261 102.5146783, -119.999260 102.6174017, -119.999260 102.7201251, -119.999259 102.8228485, -119.999259 102.9255719, -119.999258 103.0282953, -119.999257 103.1310187, -119.999257 103.2337421, -119.999256 103.3364655, -119.999256 103.4391889, -119.999255 103.5419123, -119.999254 103.6446357, -119.999254 103.7473591, -119.999253 103.8500825, -119.999253 103.9528059, -119.999252 104.0555293, -119.999251 104.1582527, -119.999251 104.2609761, -119.999250 104.3636995, -119.999250 104.4664229, -119.999249 104.5691463, -119.999248 104.6718697, -119.999248 104.7745931, -119.999247 104.8773165, -119.999247 104.9800399, -119.999246 105.0827633, -119.999245 105.1854867, -119.999245 105.2882101, -119.999244 105.3909335, -119.999244 105.4936569, -119.999243 105.5963803, -119.

Raw Geometry in RDF

Storing human-readable serializations for geometry:

- Requires approximately 2.5 times the amount of storage space as binary
- Offers no clarity since long strings of coordinates **are not even** human-readable
- Serves no purpose to spatial querying as systems rely on duplicate binary formats of geometry
- Are less suited for transmission because of their size (i.e., a user downloading copies of spatial features)

Instead, our approach (nicknamed **AGO**) is to:

- Eliminate the need to store human-readable representations
- Require each geometry has its own unique, dereferenceable IRI
- Still 100% compatible with GeoSPARQL in practice!

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An Alternative Approach

Beyond simple point features and bounding boxes, raw geometries have little to no function as RDF literals.

```
cegisf:2316598
  geosparql:hasGeometry [
      geosparql:asWKT "<http://www.opengis.net/def/crs/EPSG/0/4326>
      ↪ POLYGON((128.9999986 -14.4290140, 128.9999714 -14.8798443, ...))
      ↪ "^^geosparql:wktLiteral
  ];
  # instead... get rid of blank node and use URI
  ago:geometry ex:LakeTobesofkeePolygon ;
```

This way, geometry can be dereferenced to fetch its data in a variety of formats.

```
curl "http://ex.co/geometry/polygon?id=42" -H "Accept:  $MIME_TYPE"
```

MIME Type	Description	Returns
text/html	Web interface	<!DOCTYPE html><html lang="en">...
text/plain	Well-Known Text	POLYGON((113.1016 -38.062 ...))
application/gml+xml	GML	<gml:Polygon><gml:Exterior>...
application/vnd.geo+json	GeoJSON	{"type":"Polygon","coordinates":...}
application/octet-stream	Well-Known Binary	01 06 00 00 20 E6 10 00 00 01...

Also makes it easier and more efficient for web applications that display geometries on a map.

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In summary, a comparison of strategies to storing and using geometry:

Trait	GeoSPARQL	NeoGeo	AGO
Efficient geometry storage			✓
Geometry can persist externally [1]			✓
Content-negotiation for geometry format		✓	✓
Uniform RDF structure	✓		✓
Composite geometries		✓	✓
Determine geometry type [2]	✓	✓	✓
Access bounding box [2]			✓
Access raw geometry [2]	✓	✓	

1 = Geometry can persist in a local geodatabase or even on a remote system and *without copies*.

2 = From the triples' RDF data alone (e.g., without using SPARQL).

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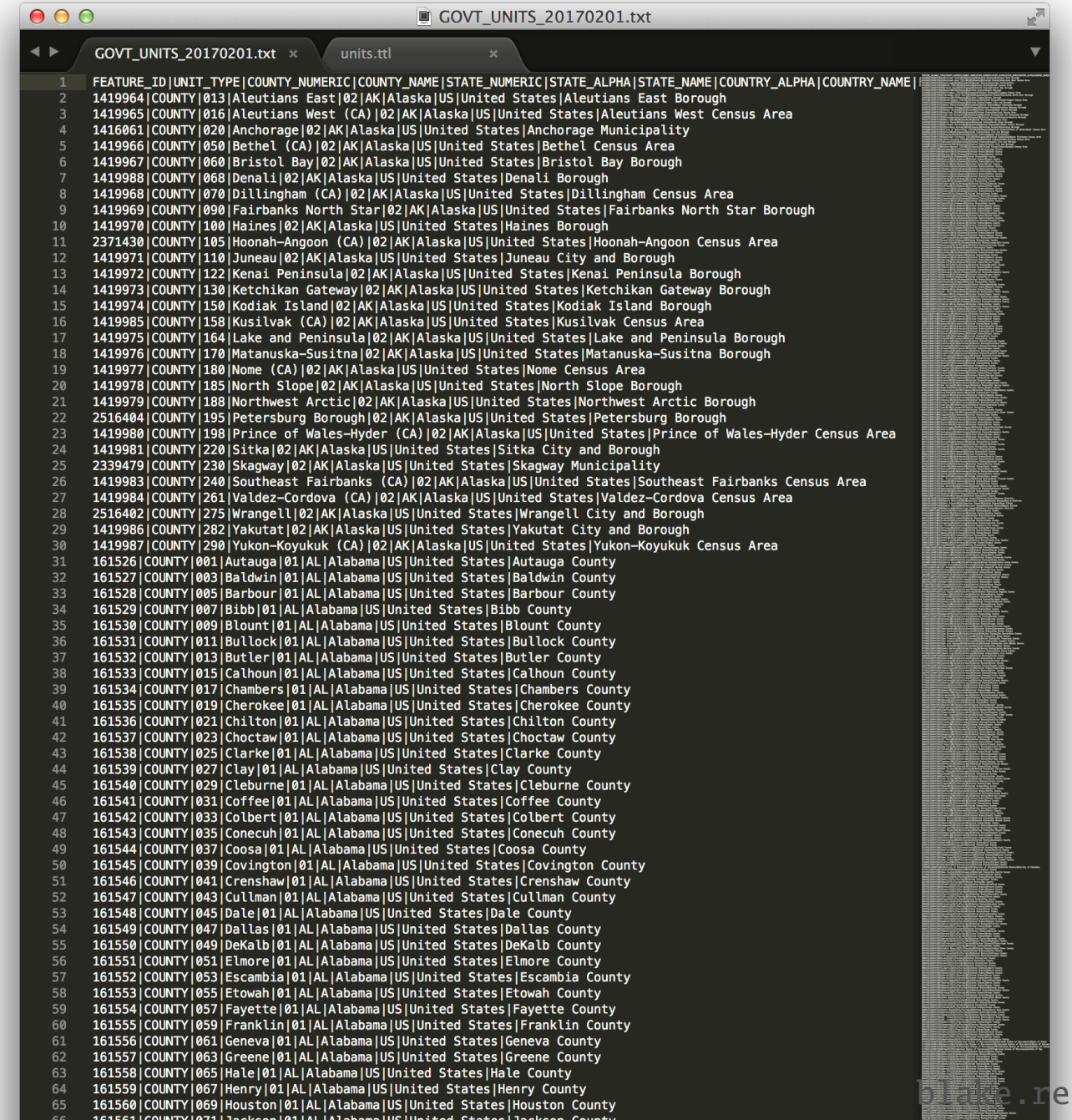

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Triplification

For **GNIS**, mappings are hard-coded in a set of node.js **scripts** that parse text records as input and generate RDF as output.

For other datasets, pipeline includes:

- ogr2ogr (FileGDB to PostGIS)
- more scripts (hard-coded mappings consume geodatabases)
- importing to triplestore (bulk-loading)

```
feature_class: {
    predicate: 'rdf:type',
    object: (s) => {
        s = s.replace(/ /g, '');
        if(s in H_GNIS_CLASS_MAPPINGS) s = H_GNIS_CLASS_MAPPINGS[s];
        return 'cegis:'+s;
    },
},
state_alpha: {
    predicate: 'gnis:state',
    object: s => 'gnisf:'+H_GNIS_STATE_LOOKUP[s],
},
county_name: {
    predicate: 'gnis:county',
    object: (s, h) => 'gnisf:'+(s? H_GNIS_STATE_LOOKUP[h.state_alpha]+`.${clean(s)}`: 'gnis:UnknownCounty'),
    optional: true,
},
```

Figure 5

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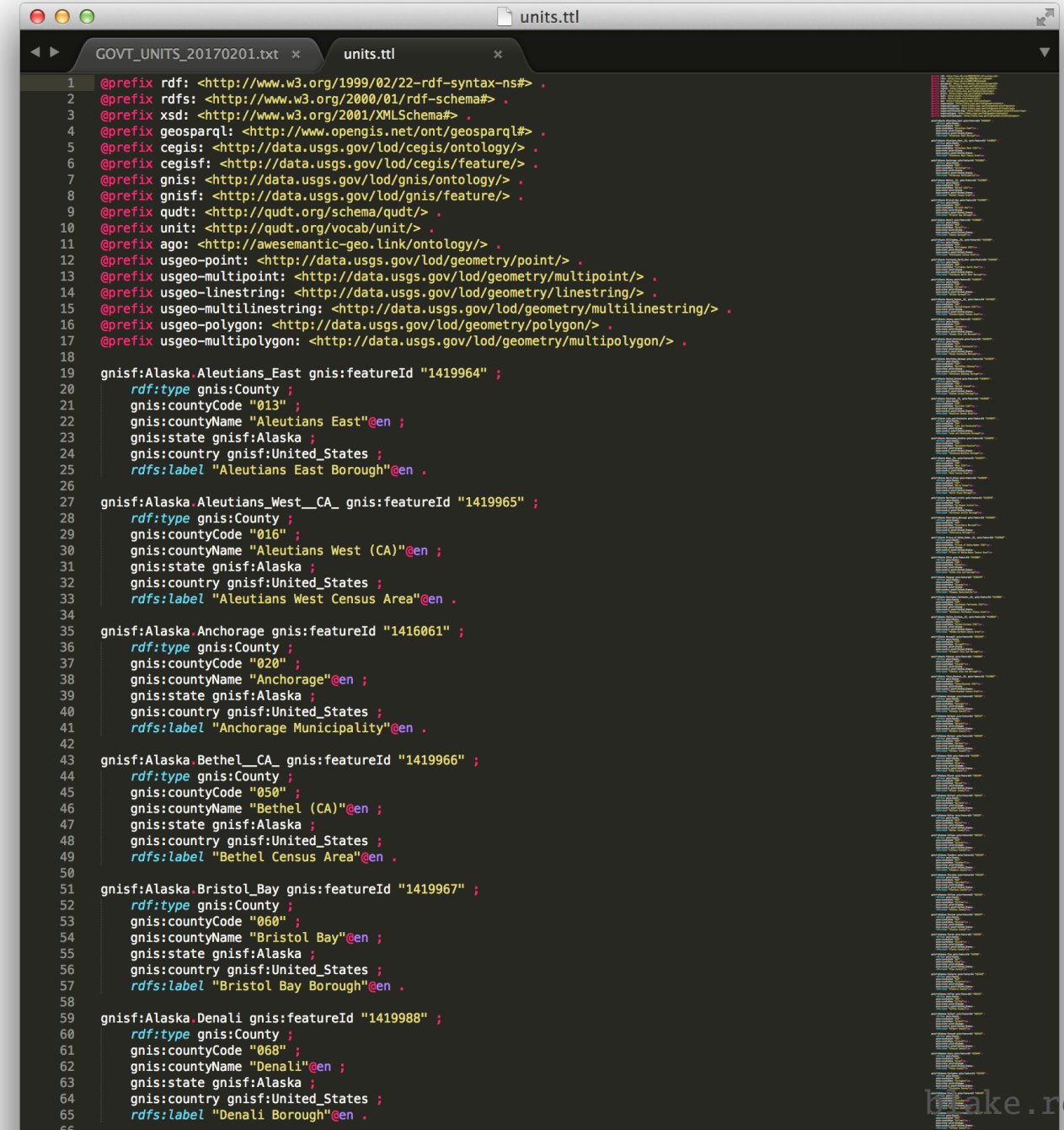

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Quantity	Attribute
37,170,932	triples
6,743,075	named subject nodes
2,276,454	GNIS features
2,014,638	sameAs relations to GeoNames
503,171	sameAs relations to DBpedia
494,757	alternative names
66	feature types
2,537 MiB	worth of Turtle files

(a) General statistics about the GNIS-LD dataset.

Feature Type	Instance Count
231,967	Church
231,508	Stream
216,473	School
201,066	Populated Place
162,509	Locale
160,298	Building
145,534	Cemetery
74,282	Reservoir
70,619	Summit

(b) Top 10 GNIS feature types by instance counts.

Table 1 Dataset statistics

- **VoID description** — Machine readable metadata about the dataset.
- **GNIS feature definitions** — Feature type vocabulary for GNIS.
- **GNIS-LD RDF dump** — The entire GNIS dataset as RDF.
- **USGS-LD SPARQL endpoint** — The SPARQL endpoint for live data.
- **USGS-LD SPARQL service description** — Machine readable metadata about the SPARQL endpoint.

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Software to download, triplify, host and bulk import data, incl. web interface, bundled up as docker compose service:

CLI Usage

From the main directory, use `./run` to manage services:

```
$ ./run --help
Usage: ./run [COMMAND] [ARGS]

Commands:
  download          download data from USGS
  convert           convert USGS datasets into RDF
  triplestore       launch the triplestore as a service
  import            import triples and geometry into the triplestore
  frontend          launch the HTTP web interface frontend as a service

For more information about a specific command, use: ./run [COMMAND] --help
```

Getting Started

To get the entire USGS-LD up and running as-is, the following setup procedure will initialize and load all the data, as well as start the services with default settings:

```
./run download all \
        && ./run convert all
        && ./run triplestore up
        && ./run import all
        && ./run frontend up
```

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Check out **gnis-ld.org**:

Examples

Lake Tahoe

Under the 'Incoming Triples' section, we can see that this is the `nhd:gnisFeature` of an NHD feature, which has a multipolygon geometry node.

Source code

USGS-LD

Bundles the entire pipeline into a Docker Compose file and a helper bash script. Its components are listed out below.

USGS Triplifier

Converts GNIS and other USGS datasets (such as NHD) into RDF.

KiWi Bulk Loader

Loads triples directly into KiWi's PostgreSQL tables in parallel.

Apache Marmotta

The 584 branch of Apache Marmotta supports GeoSPARQL.

GNIS-LD.org

This website which includes dereferencing logic, redirection, and SPARQL query proxying.

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