Open Geospatial Consortium

Submission Date: 2017-11-27

Approval Date: 2020-05-01

Publication Date: 2020-05-12

External identifier of this OGC® document: http://www.opengis.net/doc/per/FGDC-api-assessment

Internal reference number of this OGC® document: 17-061

Category: OGC® Engineering Report

Editor: Terry Idol

FGDC OGC Application Programming Interface Interoperability Assessment

Warning

This document is not an OGC Standard. This document presents a discussion of technology issues considered in an initiative of the OGC Innovation Program. This document does not represent an official position of the OGC. It is subject to change without notice and may not be referred to as an OGC Standard. However, the discussions in this document could very well lead to the definition of an OGC Standard.

Document type:	OGC® Engineering Report
Document subtype:	
Document stage:	Approved for Public Release
Document language:	English

i. Abstract

The Federal Geographic Data Committee (FGDC) Application Programming Interface (API) assessment was conducted under the OGC Innovation Program with the goal to develop an in-depth understanding of all the components necessary to enable increased coordination and effectiveness of APIs as applied to geospatial information. FGDC customers have been invited to share their experiences with the use of APIs. From those descriptions, recommendations have been derived that help FGDC to better understand how APIs are currently being generated and if using a more standardized approach to APIs might enable a more robust and optimized service offering.

ii. Keywords

ogcdoc, ogc documents, APIs, OGC Essentials, Web services, user experience, usability

1. Introduction

1.1 Scope

Application Programming Interfaces (APIs) have been used for years in complex software systems. Currently, APIs remain popular as organizations can publish their API for use by other organizations to access systems, data and applications. Per the ProgammableWeb website, there are over 17,000 publicly available APIs available for different markets. When searching for "mapping" APIs, roughly 830 Public APIs are available.

The OGC has recently published an OGC Open Geospatial APIs White Paper, which created additional interest in the geospatial community on the state and status of GEO APIs. This Concept Development Study (CDS) is built upon several of the concepts laid out in the White Paper: See http://docs.opengeospatial.org/wp/16-019r4/16-019r4.html

The Concept Development Study (CDS) initiative is sponsored by:

- Federal Geographic Data Committee (FGDC)
- United States Geologic Survey (USGS)

The pace of expansion in the geospatial world highlights the need for nurturing an ecosystem-based approach by enabling the discovery, access and use of data and tools for many applications across a wide variety of stakeholder groups (e.g., commerce, science and decision making).

The question of how geospatial APIs might be developed in a consistent manner across the entire community is the focus of this Study. FGDC and USGS have elected to use the OGC Geospatial APIs White Paper has identified by FGDC and USGS to serve as its foundation.

The project led to increased understanding of the requirements for enhanced interoperability of geospatial APIs, increased commonality of the semantic elements of APIs and reduced effort by software developers who need to use multiple APIs for both the use of APIs and standardized tools for the generation of APIs. In a longer-term goal after the completion of the Concept Development Study, FGDC will embark upon a detailed roadmap that leads to efficient integration of data and information using standard APIs across applications, systems and/or use.

The CDS can be broken down into three major parts. Each part has formed the basis for this evaluation.

- Examine existing geospatial APIs through the release of a Request for Information (RFI).
- Support an FGDC-led API Plugfest and incorporate the major "Lessons Learned" into this CDS results paper.
- Lay the foundation and develop and define the scope of a multi-phase future API interoperability Pilot project to suggest future consensus activities and support implementation.

The purpose of the study is to develop an in-depth understanding of all the components necessary to enable increased coordination and effectiveness of APIs as applied to geospatial information. The future API Pilot plans were also discussed at the FGDC led API Plugfest.

1.2 Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

Name	Organization
Terry Idol	OGC
George Percivall	OGC

1.3 Notice to all

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

2. References

The following documents are referenced in this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

OGC Open Geospatial APIs – White Paper (16-019), http://docs.opengeospatial.org/wp/16-019r4/16-019r4.html, Published 2017-02-23

OGC Request for Information on Geospatial Application Programming Interfaces, Issued March 8, 2017 http://www.opengeospatial.org/standards/requests/157

Programmableweb.com, API Directory (Mapping), 13 June 2017, https://www.programmableweb.com/category/mapping/apis?page=33&search_id=136385&category=19978

3. Conventions

3.1 Abbreviated terms

API	Application Programming Interface
BISON	Biodiversity Information Serving Our Nation

CDS	Concept Development Study
FEWS	Famine Early Warning System
FGDC	Federal Geographic Data Committee
IP	Innovation Program
NSDI	National Spatial Data Infrastructure
OGC	Open Geospatial Consortium
RFI	Request for Information
USGS	US Geological Survey
WFS	Web Feature Service
WMS	Web Map Service
WMSC	Web Map Service Context

4. Summary Conclusions from Open Call for Request for Information

4.1 The API Request for Information Message Background and Questions

The scope of the Request for Information portion of the Concept Development Study was to determine how different software vendors and different infrastructure data consumers can/are using APIs and improve interoperability while doing the below:

- Exchange data between systems without loss of information; and
- Results using different APIs are predictive and similar.

An outcome of the project will be to enable connectivity and interoperability with different distributed or complex systems.

This Concept Development Study and the Request for Information were governed by the OGC Interoperability Program Policy and Procedures[1]. The RFI was open to the general public and to all organizations with an interest in the use of geospatial APIs.

There were several areas of input requested from the community. The public was requested to respond to the following questions.

[1] After following the link provided, see document OGC 05-127r8 for a summary of the OGC Interoperability Program - recently renamed the OGC Innovation Program.

1) There are many who question whether there are issues achieving interoperability with APIs. Please document why you and/or your organization believes there is or is not an issue with interoperability in the geospatial community with the current use of APIs.

2) If you believe interoperability can indeed be improved, how do you think this can best be achieved?

   a) Is it by using a common set of semantics, such as the OGC Essentials as described earlier (or in more detail in the OGC API White Paper)?

      i) If so, would you use and modify the current set of OGC Essentials; or

      ii) Suggest a different common set of semantics upon which to begin?

   b) Please provide other suggestions to improve geospatial API interoperability. Please provide as much detail, including references to the White Paper, or other industry publications, (per the instructions below) as possible.

3) Provide information about APIs that your organization manages or uses to discover, access, manipulate or use geospatial data.

4.2 Summary of the API RFI Results

A total of 19 organizations replied to the Request for Information. There are several major points that were a common theme throughout the different responses. They are as follows.

- The API RFI responses endorse the view that "The proliferation of diversely different APIs degrades interoperability."

- There is a great deal of support for the OGC Essentials. Many of the participants also provided different recommendations on how to improve the initial set of OGC Essentials[2].

- A need was identified for a Best Practice or similar type document that allows an organization to use open standards while writing custom APIs.

    - This subject is discussed later in the FGDC Plugfest section.

- Many custom APIs were listed in the responses. Several of the APIs have been built specific to certain programs. A number of the APIs were built on but then varied from OGC Web Services, making then non-compliant.

    - This subject is discussed later in the FGDC Plugfest section.

- A recurring theme was also the complexity of current specifications. As stated by one Respondent, "WFS is too complex as are several other standards."

- Another common criticism is the term "API". The term APIs is applied at multiple locations in the distributed computing environment. See for example the GEO Secretariat response identifies three different APIs: Javascript API, Server side API,

[2] After the completion of this study, the OGC Essentials were renamed as OGC Building Blocks

RESTful API. Any plan for APIs in OGC should recognize these different uses of the API term.

Detailed information on the responses per organization can be found in Annex B.

5. FGDC Plugfest Overview

5.1 Introduction

The FGDC ran Plugfest with the specific objective of obtaining an increased understanding of the requirements for enhanced interoperability if geospatial APIs and how to reduce the effort by software developers who need to use multiple APIs. The effort concentrated primarily on web APIs, as described in the OGC API White Paper. The goals of the Plugfest included:

- Examining existing geospatial APIs;
- Identify how APIs are used effectively to exchange geospatial information;
- Support planning for increased use of protocols to enhance interoperability;
- Support increased use of essential elements of APIs that can enhance commonly across diverse APIs; and
- Suggest consensus activities that would improve the geospatial API ecosystem.

The participants for the Plugfest came from a diverse group of geospatial users, both within and outside of the USGS and FGDC. From within the USGS, there were representatives from the BISON (Biodiversity Information Serving Our Nation), Water, Earthquakes, FEWS (Famine Early Warning System) and National Map Program. There was also representation from George Mason University as well as from Esri.

The method of engagement was elegant and simple. Three on-line web clients were used to attempt to access as many identified web based APIs as possible, and see what did and did not work.

The first day of testing was through the GeoPlatform along with the GeoPlatform Map Manager and GeoPlatform Map Viewer. ArcGIS Online was also used to create Story Maps.

The remaining time was to be dedicated to using the newly released National Map Viewer with its 'Add Data' function was tested for its support of WMS.

The Geospatial Platform (GeoPlatform) is a strategic national resource that supports the Administration's–Open Government, Open Data and Digital Government strategies to enhance transparency, collaboration and participation. The GeoPlatform provides a suite of well-managed, highly available, and trusted geospatial data, services, and applications for use by Federal agencies—and their State, local, Tribal, and regional partners to meet their mission needs and the broader needs of the Nation. The GeoPlatform was developed by the member agencies of the FGDC through collaboration with partners and stakeholders. The GeoPlatform is being implemented to help agencies meet their mission needs, including communicating with and publishing data and maps to the public. The GeoPlatform focuses on web applications that facilitate participatory information sharing, interoperability, user-centered design, and collaboration on the World Wide Web. The GeoPlatform is a key component connecting many goals of the NSDI Strategic Plan in advancing the NSDI. The portfolio of data, applications, and services provided on the GeoPlatform is stewarded through the use of open licenses and careful review and hosted on cloud infrastructure that maximizes geospatial interoperability. The GeoPlatform provides streamlined access to National Geospatial Data Assets and reduces data duplication. The collaborative GeoPlatform Marketplace helps reduce data acquisition costs. GeoPlatform's many tools and dashboards support the A-16 Portfolio Management process.

- **Data Services** - The GeoPlatform delivers trusted, nationally consistent, authoritative geographically enriched social, economic, environmental and other data for understanding and decision making.

- **Applications and Tools** - The GeoPlatform provides a suite of applications and tools for integrating, synthesizing, analyzing, problem-solving and visualizing geographically enriched data to accelerate understanding and decision-making.

- **Shared Services** - The GeoPlatform provides shared hosting infrastructure that allows agencies to publish their geospatial data, applications, and tools in a secure cloud-computing environment at a low cost.

(The preceding paragraphs description is from the FGDC's website and completely describes the purpose and methods of employing standards in the USGS GeoPlatform (https://www.fgdc.gov/initiatives/geospatial-platform. Full credit for the text is given to U.S. Geological Survey Department of the Interior/USGS.).

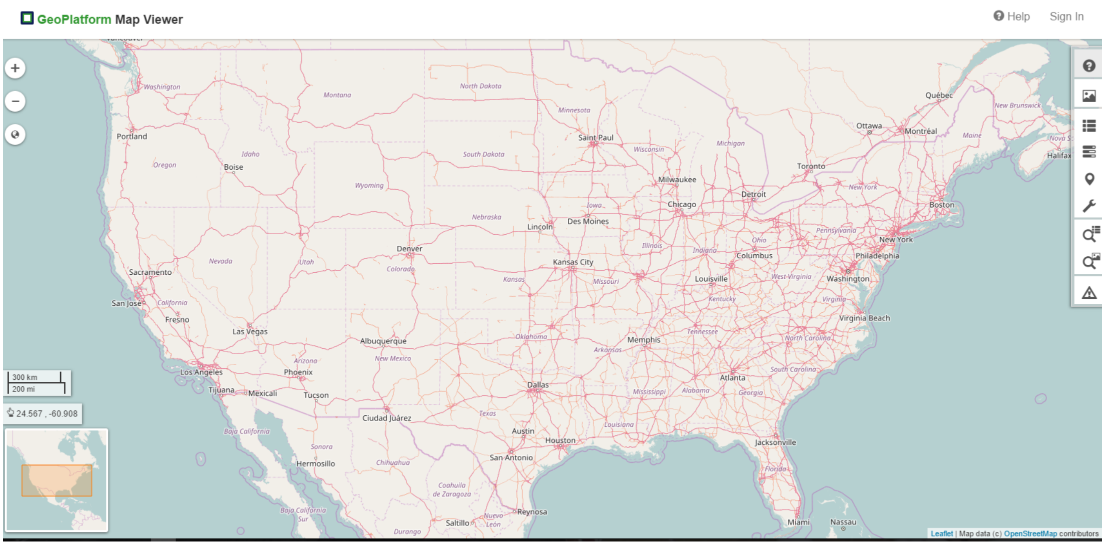

Figure 1 GeoPlatform Map Viewer

As described above, the Plugfest also made use of the Esri ArcGIS Online for the first day. Through GeoPlatform's ArcGIS Online account, all GeoPlatform users have access through their geoplatform.gov login to a suite of hosted ArcGIS applications and services, including Map Viewer, StoryMap Builder, Web AppBuilder and other configurable tools. Any user can upload their own data and map layers to explore in the Map Viewer, as well as quickly add them to other hosted map services provided in OGC standard formats. Users at the Plugfest used ArcGIS's StoryMaps application to combine their authoritative maps with narrative text, images, and multimedia content. Storymaps made it easy to harness the power of maps and geography to tell their story. Further, using ArcGIS's configurable Web AppBuilder, analysts can build intuitive, focused web application that run anywhere, on any device, without writing a single line of code. New maps and applications can be saved and shared for free on the ArcGIS online portal section of the GeoPlatform. Saved maps are then also automatically discoverable through the Geoplatform.gov's Map Manager. (Credit: Esri)

5.2 Plugfest General Results

The first day of the Plugfest, the GeoPlatform portion of the Plugfest was successful in adding the different external geospatial layers. Several different types of data from sites both within and outside USGS could be brought together and create successful maps (Figure 1 and 2). The calls were made via OGC's web map services (WMS).

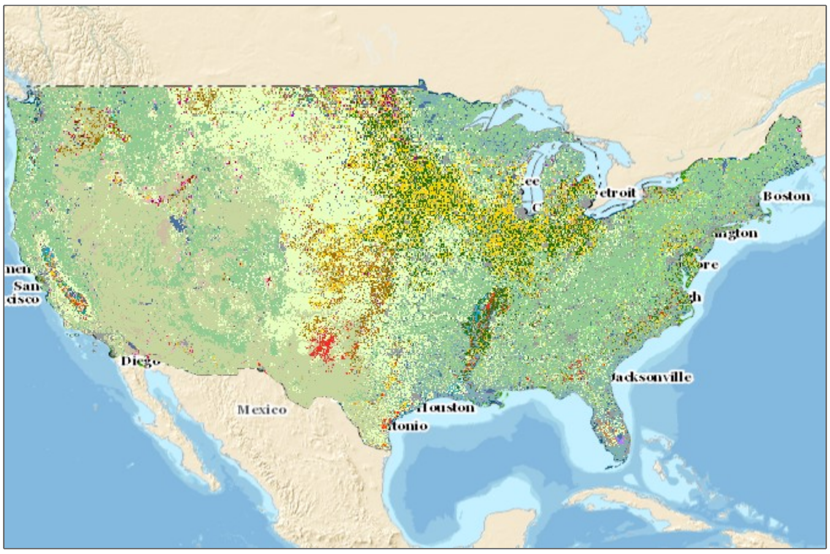

Figure 2 2008 Cropland Data Layer

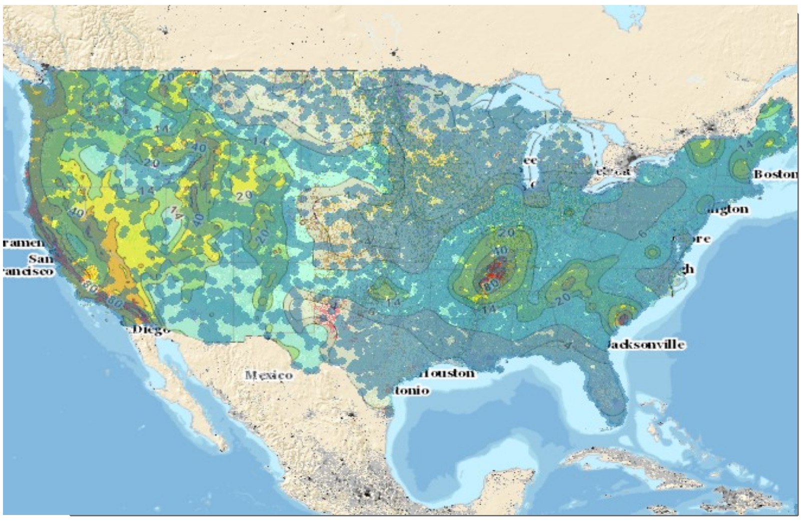

Figure 3 Earthquakes, Crops and Water Layers

A wide range of data was successfully integrated. As shown in the figures, water, crop and earthquake, or hazard data was integrated. Other data sets included selected endangered species using the USGS BISON site.

Unfortunately, the new deployment configuration of the National Map Viewer prevented the WMS capabilities of the Add Data tool from working. No login on to ArcGIS Online required on the National Map viewer, and this also limited the capabilities of the 'Share Map' function.

USGS recently released the National Map Viewer as a standalone version hosted on USGS servers. This switch apparently introduced an undetected configuration issue that prevented adding non-USGS WMS services (or geospatial data layers) via the Add Data tool. It is believed this is a simple fix to add a list of trusted domains for CORS into the standalone configuration.

Work continued with the Geoplatform and the associated Story Map efforts to merge in the different data sources.

5.3 Plugfest Specific Lessons Learned

The following is a list of specific issues that were discussed by the participants during the wrap up sessions held each day. Some issues are large and others might be considered minor, depending on the reader's unique point of view. All are worthy of mentioning for future discussion.

5.3.1 Use of Common Documentation tool

One area of universal agreement from all the participants was the need for all developers to use a standardized method for creating and documenting APIs. All in attendance agreed that Swagger, now named OpenAPI Sec 2.0, should be used to ensure consistency and well documented APIs.

As noted in the OGC API White Paper, Swagger was used in the OGC WaterML2.0 part 2 Interoperability Experiment (https://portal.opengeospatial.org/files/?artifact_id=61224) to document the CSIRO RESTful API. The CSIRO API Report (Annex B) makes the following observation:

- Observation 9: Make use of automated API documentation where possible. These can often be synched directly with an implementation version, which helps to minimize divergence. Some also provide interactive (e.g., Swagger) documentation that allows inline requests to be made. This helps to lower the barrier of entry for developers and quickly builds understanding.

This directly agrees with the comments from the participants in the Plugfest.

5.3.2 Security Issues relating to the Plugfest

An important lesson learned is that security and data access needs to be carefully considered when selecting the site of a Plugfest. Access to certain data layers for some participants was an issue for several participants.

The Plugfest was held at a USGS site. USGS personnel were able to log in using their USGS credentials. Non USGS personnel logged in to the USGS Visitor Network using guest credentials. This is a common and well accepted security practice at many, if not all, government and private facilities that even allow guest access to networks.

The issue was that the guest network severely limited the access of the USGS guests. Most of the internal USGS geospatial data sites, that are widely available to the general public, were not available via the USGS guest network. This greatly limited the work of the non USGS participants during the Plugfest.

5.3.3 Other Items Discovered during the Plugfest

The base map in the National Map gallery is from Esri. The Platform version is different for 3d version of Arc than the map that is supporting the background version. Somewhere there is an issue. National Map is on 10.4 Esri server. On GeoPlatform when one adds it in, they get an OLDER version. The two are no in sync.

Universally, there needs to be life cycle management plan with APIs, by the people hosting the APIs and the data behind the APIs. It becomes obvious that in many cases APIs are build and then languish with old versions. Many are not maintained.

In the case of a program such as the GeoPlatform, it would be very useful to know the different users. Then the users can be notified when or if changes are to be made to the web site. This could include organizations that feed data to the GeoPlatform.

A somewhat confusing point for those using the Esri client version is when adding what is a WMS layer, you actually add a “service” versus the “WMS”. This can lead to confusion.

The BISON site had extremely rich endangered species data that is useful to a large section of the scientific community. However, without the standard implementation of the OGC WMS and the “get” capabilities it is difficult to add to a generic client. This nonconformance of standards is quite common and makes it very difficult to bring in several layers. This raises the questions - How do we make sure the API itself is compliant? As opposed to the client? Vendor parameters in get capabilities are allowed, and there is no easy way to really document this clearly.

The above discussion led quickly to the next discussion: Are there compliance checkers for APIs? 1 - How do we get APIs validated and 2 – how do we extend special parameters? In some cases, such as Web APIs, there are OGC verification tests that can take place by the developer. But what about all the other APIs?

Discoverability of geospatial data is still a major challenge. Geoplatform.gov might be able to help. It might be able to be a tool that can register data services (or WMS) and ask certain questions when registering services so the service can be well understood. This might be as simple as displaying extra information when layers or data is pulled up in the viewer.

A similar issue is that, as novice, how does one make his or her geospatial data layers discoverable? There’s no guidebook on how to expose your resources. For example, Cropscape is hard to find. As validator, can’t this be registered via different catalogues automatically?

A common issue that occurred what that when adding layers, the user couldn't see some layer automatically. The system should at least zoom to bounding box or area that has been added.

There needs to be a community discussion on creating a sandbox for testing APIs. FGDC is interested in having this discussion with OGC members and Staff.

5.4 Plugfest Way Forward

There is a six-month target to get ready for a first run of a follow on Plugfest or to start a complete Pilot. The Pilot will be covered in the following section.

The overall results of this initial Plugfest was a part of larger picture road map. The long-term goal of FGDC is bringing standards and data together! FGDC will be developing a Roadmap over the next few of months on how they intend to proceed.

There is also a recognition that a much greater effort needs to be made to publicize the FGDC SDI Cookbook. The FGDC Cookbook, first developed in the year 2000, provides guidelines on how to develop a Spatial Data Infrastructure Platform, amongst other items. Also, FGDC will consider adding a section to the cookbook on APIs.

6. Path Forward – Pilot Plans

It is the goal of a proposed OGC FGDC API Pilot to demonstrate the power and efficiency of distributed online environments using Open APIs to exchange geospatial data. The Pilot as outlined below will be able to address and begin to answer the issues that have been identified in this API Concept Development Study. Its primary intent is to demonstrate that a software architecture using open APIs, based on the API Essentials as defined in the OGC API White Paper Web, allows for an efficient and powerful working environment that supports processing, visualization, and representation of geospatial data in distributed systems. At the same time, this pilot helps gathering further insights into experienced obstacles and difficulties when using available web based geospatial APIs and systems to develop system-wide improvements and adaptations to specific users' needs (Arctic Pilot RFQ 2016).

An OGC pilot initiative orchestrates the activities of multiple agencies, researchers and software implementers in an agile development process. There are three main outcomes of a pilot.

1) Running software code from several organizations to be tested to ensure interoperability of the independently developed implementations based on open standards.

2) Demonstration of scientific and policy-oriented scenarios with the deployed code. These scenarios show the previously unavailable capability from a non-technical point of view.

3) Engineering Reports that document the results of the development, testing and demonstration. The reports then become the basis of procurement activities of the operational system.

In order to achieve the objectives of scientific credibility and software modularity ("plug and play") the pilot will be based on open standards.

There are three major areas upon which the Pilot will concentrate.

1) The OGC Open API White Paper will be one of the primary two areas of exploration for Pilot, with the emphasis on exploring the use and possible expansion of the OGC API Essentials. For the future generation of interoperable APIs, both the results from the OGC RDGC API RFI respondents and the participants in the FGDC Plugfest identified the maturation of the OGC API Essentials as one of the key areas. This section is what is normally what is considered a traditional Pilot, like OGC's Arctic SDP and other OGC Pilots. There would be a minimum of two clients needed, and a minimum of two types of scenarios. One scenario would be a predefined scenario where each of the Participants would follow a script and ensure they could all retrieve certain data sets. The other scenario would be more unscripted where each client would be given a minimum set of (lengthy) requirements for data collection to solve real world problems, and the analysis would include analyzing the adequacy of the real-world data and data collection.

2) The second primary area of study for the Pilot will be how to better facilitate the use, discovery, and currency of existing web-based APIs. This includes enabling helping FGDC and USGS develop a long-term plan to allow GeoPlatform users a simple to discover and use both internal USGS and external non USGS geospatial data sites.

3) This section will start addressing what might be done to ensure the sites referred to by the GeoPlatform (or similar sites) are compliant to OGC API web specifications. In addition, an analysis will begin on how to best start looking at the issue of web site AND data versioning for the different web sites. Finally, ideas for how to best review and make sure the web sites listed are up and running are to be discussed. This section is not expected to solve these issues, but rather to create an approach and start generation both discussions and ideas that may lead to solutions.

There are several benefits that can be derived from this Pilot. A few of the more prominent ones are as follows.

- Demonstrate that geospatial data can be integrated from multiple sources efficiently into different clients using open API and other web standards developed by the OGC and other standardization organizations.

- Implement and document the implementation process of use cases addressing needs of the GeoPlatform using new and existing components .

- Demonstrate the value of metadata and how it can be used for Discovery by comparing discovery and integration efforts for data and services with and without metadata.

- Investigate how metadata might be either used or enhanced to assist with versioning issues.

- Demonstrate an approach to allow for easy discovery of data and data sets.

- Start developing a plan to review and update the list of data sites to reduce users frustrations.

- Document the architecture that was developed and demonstrated in the pilot to support future procurements.

- Develop video material and further best practice documentation and presentation material that demonstrate all the functional requirements defined above.

The OGC FGDC API Pilot has three very distinct and different scopes as described above. The overall size of a fully funded and staffed initiative can be made to FGDC and USGS in a separate, nonpublic cover letter.

Upon confirmation from FGDC and USGS that the Pilot would be funded, OGC would proceed to identify potential additional sponsors and identify common interests and requirements for the pilot. Potential sponsors include government agencies, foundations and forward-looking companies.

Annex A   Call for Participation

The call for participation for the OGC Application Development Interface Concept Development Study is available online at
http://www.opengeospatial.org/pressroom/pressreleases/2557

Annex B API Request for Information Results

The detailed analysis of the Request for Information is below.

B.1 Major Issue(s) with Existing APIs:

Organization:	Response:
Ecere	Some organizations in the geospatial community surely are having interoperability issues with APIs, as that will arise as soon as you do something they were not meant to do, such as using them together with different APIs, programming languages or data formats they do not support.
FEMA	FEMA agrees with the conclusion that API proliferation adds to the complexity for the user and publisher. Lack of consistency with regard to standards in the documentation of capabilities, formatting, and standards used to publish data through various vendor APIs decrease usability between platforms. Data API standards for geospatial data are not consistently implemented across the various COTS and Open Source products. This has resulted in the need to duplicate resources to provide complete set of geospatial API functionality for the user. For example it may be necessary to publish data through a COTS and an Open Source software solution to achieve interoperability. Additionally, inclusion of standards for attribute types for date formatting, defining guidance for string and integer formatting, and including projection and coordinate systems for the data source are not always available. Assumed projection and coordinate systems for most geospatial data services are that data is published in WGS84 format. This is not always the case and metadata and API attribution are not enforced as part of the API reference. Data standards for date and time attribution are not commonly understood or specified.
FGDC Service Status Checker	• resources discovered through our catalog systems often reference non-existent or non-functioning services. • Even when services are discovered through a catalog, it they are not reliable, a user often gets quickly frustrated with not being able to find "healthy" and "usable" services. • The Status Checker is current testing the health and reliability of many OGC and ArcGIS REST services. We should poll the user community for other known types of services that should also be tested by the Status Checker.

GeoScience Australia	1.1. The biggest problem with WMS is how the minimum specification is not fully featured enough to be usable for a reasonably simple web mapping application. GeoServer and ESRI implementations differ for GetFeatureInfo request. Achieving interoperability is difficult. 1.2. I would raise the point regarding the implementation of the OGC standards and API implementations across different vendors. Esri implements OGC in a certain way whereas Geoserver does it in another. What we end up with is a requirement for vendor specific code in use of their API's (the opposite of interoperability). More needs to be done regarding specification to remove this difference in implementation.

George Mason University	It is extremely laborious to prepare the incoming and data information in right status from which analysts/decision-makers can actually use in their analysis or decision. There are many interoperation issues, such as format difference, projection displacement, operation incompatibility, and semantic mismatch.

NOAA IOOS	To achieve interoperability with API endpoints, they need to be tested to ensure that they act as advertised and meet the API specification. Non-standard enhancements need to be encouraged to be included in future release of standards where possible. Best practices need to be established when standards are not sufficient to ensure interoperability. There are currently many API issues that, if addressed, would enhance interoperability.

NOAA NOS CO-OPS	Overall, the implementation of geospatial API standards, if widely adopted in the user community (vendors and organizations), ultimately will aid in wider usage of an organization’s data. However, at this time, CO-OPS’ user community benefits from having both standards compliant geospatial APIs and custom APIs serving data in simple formats such as CSV.

Natural Resources Canada	For domain specific workflows, such as for decision support or complex use cases, interoperability can degrade where tools implementing OGC standards are often seen as too complex to sustain by API developers. The tendency in complex use cases, is the closer the workflow gets to core business functions, the more rigid the infrastructure environments.

OMS Tech	NOTE: ATTRIBUTION REQUESTED: Some of the key issues that exist with respect to the achievability of interoperability are the inconsistent and variable application of the various dimensions of interoperability, the impacts and burdens that API usage have on developers and users, the incomplete or non-understandability of appropriate documentation, and the lack of appropriate tools. A major impediment to interoperability is that there are multiple dimensions to interoperability and all are not being addressed with the same level of importance. Some of these are data interoperability, semantic interoperability, administrative or institutional interoperability, legal interoperability, and security interoperability.

Swedish NMA: Lantmäteriet	WFS is too complex, we have experienced difficulties for the vendors to implement it, both on server and client side, interoperability is poor.

USGS FEWS	The FEWS project has been using its own API for the time series data charting. The FEWS project would be interested to know how many other users / communities are doing similar activities and if anything has been standardized in this area. Another area of interest is how to extend the FEWS WMS layers for its satellite imagery. Since FEWS provides a new WMS layer every 10 days for each dataset, there are more than 35,000+ layers. Even though they are publicly available, the FEWS project adopted their own naming convention which is probably difficult for other to adopt. FEWS is interested in learning if standards or best practices exist for these time based services and how FEWS could improve their sharing of these resources.

USGS GHRC	• Many interoperable data formats are not practical for large volumes of data; and sacrifice efficiency for interoperability. For example OMJSON https://github.com/peterataylor/om-json/blob/master/examples/timeseries-points.json does not handle large sample volumes efficiently (1 day of 1Hz timeseries data, for multiple channels). • Quakeml (https://quake.ethz.ch/quakeml) creators explicitly avoided standards like GML because it was considered too verbose, and not relevant to seismology data. • From a geospatial point of view, interoperability can be an issue with some mapping tools and API's. This is becoming less of a problem however with tool's more standardized use of interchange formats like JSON and XML.

USGS Masaki	We believe that OGC provides excellent guidance for development of geospatial APIs. Our problem has been incomplete compliance with existing standards due to resource constraints and limited ability to enforce standards compliance during development.

USGS Science Base	There are several issues with API interoperability: • Esri APIs vs OGC APIs -- Esri users expect Esri map services. Delivery of OGC map services (WMS) to this subset of users is not useful, so data portals are forced to generate Esri and OGC map services to serve a broad user base. • Versions -- There are many versions of WMS, WFS and WCS to keep track of, and many are not backwards compatible. Some API changes between version cause significant user concern, include reversing the order of coordinates and altering parameters ('layer' changed to 'coverage'). • Common APIs -- Many data stores deliver WMS, but few actually provide data (WFS, WCS, OPeNDAP, GeoJSON). It is very difficult to convince data portals to actually provide data. Without data services users are left with non-API options (downloads). • Bundled information -- Even within WMS the information you need is often bundled with information that you do not care about. It is not easy to pick out the data you need from some map service offerings. • Abstraction layers -- Many APIs work against internally referenced keys, requiring users to build multiple calls into their implementations. A common set of semantics that are supported by major data stores would let users reduce the number and complexity of calls.

6.1 What is RIGHT with APIs and Interoperability:

Organization:	Response:
CEOS WGISS Integrated Catalog (CWIC) Team	The CWIC API leverages OGC and other geospatial API standards to facilitate the granule-level EO data search. To the clients, the standards-based API hides the complexities of heterogeneous data discovery API from different data providers. To the data providers, the common API facilitates broader access to distributed EO data assets.
Ecere	We believe in the interest of flexibility and innovation the API developers should not be imposed how to structure their APIs. Still, we do believe interoperability could be improved.
Esri	Using the ArcGIS API for JavaScript you can deploy your app anywhere a compatible web browser runs. Solutions can be built with no code for non-developers, and minimal coding for developers (Web AppBuilder, AppStudio), and SDKs that allow developers to build one codebase and deploy it to multiple platforms (Qt, .NET, Java, JavaScript).
FEMA	
FGDC Service Status Checker	The OGC Web Service (OWS) Standards have made the discovery and sharing of spatial data standardized and easy.

GeoScience Australia	OGC standards are used extensively at Geoscience Australia to provide interoperable access to its geospatial and geoscience data holdings, in accordance with Australian Government Public Data Policy Statement requirements. OGC web services have been effective in enabling intergovernmental data sharing and collaboration, and have ensured the lowest common denominators within the community can access the services. OGC standards provide open access to data for all without proprietary limitations, and afford the consistency and stability of standards developed by an international standards body using a consensus process.

Natural Resources Canada	From the perspective of public APIs, there are numerous applications that demonstrate interoperability.

Swedish NMA: Lantmäteriet	The use of existing standards have been a strategy in the development, primarily those with geo-focus. But if these standards doesn't fulfill our requirements, we have used general IT standards and de-facto standards. OGC standards are often supported out of the box in GIS clients, so a non-developer can get easy access to services/APIs.Our experience is that WMS and WMTS have good interoperability, they are easy to understand and implement both on server side and in the clients. WCS have also worked well, but there may be an issue with the later version due to added complexity that will make interoperability harder.

USGS Masaki	We need to find ways to increase the rewards to developers and product owners for compliance with existing interoperability standards and for using supported interoperable platforms.

6.2 How can interoperability be improved (General - Specific details in Examples below):

CEOS WGISS Integrated Catalog (CWIC) Team	
example a	To improve the interoperability of granule-level EO data search, CWIC provides federated search of the granule-level EO data to WGISS agency catalog systems through standard-based query APIs (i.e., CSW 2.0.2, OpenSearch) along with standard metadata information models (i.e., Dublin Core, ISO19115-2).

Ecere	2. We have our own ideas on how geospatial APIs could be improved: • Facilitating support for multiple programming languages • Supporting the development of highly modular and light open-source libraries to handle core aspects used all across the community (native libraries with C API) • Suggesting efficient & flexible data structures to represent geospatial data and concepts
example a	**API Bindings Generator.** At Ecere, we are currently developing a bindings generator which will be capable of automatically generating bindings for a number of programming languages from any given eC library. The list currently includes C, C++, C#, Java and Python.
example b	**eC Object Notation** We have developed an object notation defined as a superset of JSON: ECON (http://ec-lang.org/econ/). ECON includes some additional features, and some identifiers naming restrictions to be respected in order to be used with the ECON profile.
example c	**Defining and handling projection definitions** If one thing needs to be standardized for geospatial APIs, we believe it is how to define projection and datum. A stand alone C API library, or additional support in libproj4, would be very beneficial here
example d	**JSON** (or our ECON super-set of it) is in our opinion a much better choice to structure data in a text- based format.

Esri	When choosing an approach for creating applications with ArcGIS capabilities, it's helpful to understand the general differences between native and web apps as well as differences in ArcGIS capabilities. • Native strategies offer the best device integration and the most out-of-the-box functionality for connected and offline workflows, but they require native development skills. You can use ArcGIS Runtime SDKs to create native apps. • Web strategies use HTML, JavaScript, and CSS hosted on a web server and delivered to the user's device or desktop using its web browser. This strategy is best if you don't know the devices your users have and you need to reach a wide audience. You can use ArcGIS API for JavaScript to create web client solutions.

FEMA	FEMA has some basic perspectives that can be used to evaluate the utility of interoperability APIs. Utility, as used in this discussion, is a measure of how much the use of an individual API makes things simpler, easier, or useful.
example a	Data Publisher: This perspective seeks to transmit information to others with minimal loss of semantic or contextual information. It seeks to minimize the burden on itself when providing such information. It seeks to minimize the effect other IT system changes, including upgrades, will have on the publishing process. It seeks to reuse as much as possible existing software, software libraries, and standards known by both the publisher and the consumer.
example b	Data Consumer: This perspective seeks to receive information from others with minimal loss of semantic or contextual information. It seeks to expend minimal effort to ingest received information. It seeks to minimize disruptions due to IT systems changes on either the consumer’s or producer’s side.
example c	Solution Builder: This perspective seeks to build systems and solutions that are resilient, secure, well known, well tested and easily maintained. It seeks to reuse components as much as possible and to de-couple IT system upgrades from publish or consumed data.
example d	Data quality and documentation (metadata) are critical to the utility of any published data set. It is especially important that documentation of the coordinate or projection are always included as a standard data element. Understanding of the defined coordinate system allows the user to properly transform the data specific to their use case. It would be beneficial to have broader support for API requests to return data within defined parameters for projection and coordinate system within the data set itself.

FGDC Service Status Checker	
	Some work has begun in this area related to quality of service information in the OGC Quality of Service and Experience DWG (QoSE DWG). This working group will provide a forum for discussing issues related to Quality of Service and Quality of Experience of Spatial Data Services and applications relying on these services for delivering timely and accurate spatial information to the end users. We hope that the QoS will be able to define how quality of service can be well defined by this group, as well as initiative discussions on the standardization of API's for this information sharing.

GeoScience Australia	
	3.3. Geoscience Australia utilises (web) APIs other than OGC web services. Experience from GovHack events, where developers are typically non-experts in geospatial data and need to rapidly develop mashup applications that integrate disparate data sources in new and innovative ways, has shown that the traditional OGC OWS APIs can be cumbersome and time consuming for developers to learn and write code against. The expectation from this section of the user community is for lightweight, semantically less rich RESTful APIs that typically use JSON rather than XML as a data exchange format. Typical examples (that have been used at Geoscience Australia) include the Google Maps API, OpenStreetMap API and Esri's ArcGIS Server REST API. The trade off with adopting these APIs is a lack of formal standardisation (advantages of which described in previous paragraph).
example a	2.1. Technology moves faster than the standards review process and the requirement for 'agile innovation' sometimes gets mixed up with the concept of 'bespoke'. OGC documentation is seen as complex and difficult to navigate for short-term project based developers.
example b	2.2. Vendors interpret the standard differently; it may be possible to 'lock-down' (standardise) the implementation of an API within a specification but perhaps not possible across different specifications.[examples given in Appendix]
example c	2.3. Improvement in the OGC documentation needed to make the core requirements clear; perhaps an appendix showing examples of core requirements as 'best practice'.

George Mason University	1. Multiple levels of compliance: The interoperability relies on compliance to standards with specifications while different use cases may vary on levels of compliance due to the availability of details. This applies to data encoding, metadata encoding, and operations. Explicit declaration of compliance levels would help users to have an understanding of what to expect. 2. Semantic interoperation: An essential set of common vocabularies are necessary to achieve a common ground of defining and describing data, metadata, and operations. This would help in eliminating the semantic confusion of displacing terms out of its original context. 3. Provenance: All geospatial processes should enforce the generation and recording of provenance. Users need to know the quality of the data before they can perform the evaluation of quality. Tracking back to the origin is often necessary for fully understanding the quality of data and service.

NOAA IOOS	One general feeling we share about OGC standards is that the process could be improved to shorten feedback loops and the amount of time it takes to develop new standards or revise existing standards. Bringing the standards discussions and issue tracking into the public and the modern era via tools like Github or Bitbucket would be very valuable. There are also many small issues that negatively impact interoperability among APIs. An excellent way to uncover these issues is to try to use APIs programmatically in end-to-end workflows. As part of the IOOS Program, for example, we generated a number of Jupyter Notebooks as part of a system test to see if we could discover datasets and extract data via web services automatically. In nearly every case, we encountered issues that were easy to overcome, and once fixed, fixed not just the specific workflow, but for everyone in the community. See this paper on Dynamic Reusable Workflows for Ocean Science for more details.

example a	CSW Different CSW implementations represent service endpoints in different ways, for example: a geoportal server instance might represent an OPeNDAP endpoint as: urn:x-esri:specification:ServiceType:odp:url while a pycsw server instance might represent an OPeNDAP endpoint as: OPeNDAP:OPeNDAP We started a community effort on github to address this but this might be better as an OGC effort. This is an analogous problem to the issue raised in Section 2.2 of the white paper, where different popular mapping APIs define 'center' and 'zoomLevel' in similar but slightly incompatible ways. The CSW issue however is more related to ensuring consistent vocabularies are applied within certain sections of the ISO 19115-* metadata standards for content served via CSW. Not all CSW providers honor the bounding box specifications of OGC. Thus we need to use workarounds to ensure that requests to CSW services such as geoportal server and pycsw give the same results. This sorts of interoperability issues could be helped by developing test suites that evaluate and score CSW responses.
example b	WMS WMS extensions provided by ncWMS are critical for working effectively with data with a large dynamic range, where the WMS images are created on the fly with specified color scale limits. Although these features have been embedded in the popular Unidata THREDDS Data Server for more than five years, they have not yet been proposed as part of a WMS specification. If the developers in situations like this were approached with a roadmap for how to proceed, perhaps adoption into the standard could be improved?
example c	UGRID Unstructured grids (e.g. triangular, hex meshes) are being used in next-generation atmospheric, oceanic and groundwater models, and community standards for UGRID have been developed. We have no APIs for efficient extraction of data or mapping of UGRID data.
example d	SOS IOOS had to invest significant resources in order to get SOS schemas for the data responses and metadata mappings to really work for the IOOS community. More complete test suites might have uncovered some of the problems.

NOAA NOS CO-OPS	Interoperability can be improved by having vendors and organizations support a subset of common standards that are open, similar to what is discussed in the OGC Essentials. For example, an organization may choose to implement OGC compliant WMS or WFS services. From CO-OPS perspective, we try to support various users via both common formats (standards) such as OGC WMS and WFS via ESRI REST services, as well as serve up data in simpler formats such as CSV or tab delimited. Not all users wish to make use of “heavier” standards and appreciate the simplicity of simple formats such as CSV. CO-OPS supports various user needs as appropriate. If ESRI Server supports the OGC API essentials, then CO-OPS may use and support the set of OGC Essentials.

OMS Tech	Specifics given for all the bullets above I entire paragraphs
example a	Semantic Interoperability Improvements Semantic interoperability improvements include a transition away from lookup tables to a more generalized semantic environment that utilizes formal vocabularies, taxonomies, and ontologies, and a set of mappings between them. In order for this to work, there must either be a central semantic component that mediates between the semantic resources needed by APIs or a federated solution that decentralizes this and allows for multiple semantic components that understand how to use each other and update each other. In addition, the semantic environment must allow for the curation of the semantic resources by the experts involved. This needs to be done in an open setting so that all APIs can benefit equally. The use of SKOS terms can still be utilized, but may be more meaningful when applied to a more generalized semantic environment as discussed. OGC Essentials can be used, but extension and either alignment or mapping of the OGC Essentials will likely be necessary. Dr. Browdy, in his work with Eye on Earth GNoN, defined a general federation mechanism for components; in particular, semantic components. He also defined a semantic management dashboard that would allow semantic resource managers to openly and properly curate their semantic resources, and have those resources populate the federation of semantic components to ensure semantic interoperability.

example c	Legal Interoperability Improvements The improvements for legal interoperability are based upon the creation of a reusable legal interoperability component that will calculate the proper legal result for a submitted set of resources, and a set of methods to properly associate the correct license or waiver with a resource. The legal interoperability component can either be central or federated as discussed earlier in Section 3.2.1. A federated solution is more scalable and more open. There would also need to be a legal interoperability dashboard for the curation of license types and how their calculus is defined as licenses are updated or new ones defined. Another important improvement for legal interoperability is the proper use of metadata so that resources can be identified with respect to their access and use constraints, meaning licenses and waivers, so APIs can understand what to do. Certain metadata standards, such as ISO 19115, have fields defined for access and use constraints, but the population of these fields is rare. Resource managers need appropriate metadata tools to encourage the proper population of metadata fields without imposing too much of a burden on resource managers.
example d	Security Interoperability The improvements for security interoperability are centered about a security broker. This broker would serve many primary functions. One would be a mediator between the API and the resource provider in terms of the authentication and access protocol used. Another function would be to provide a trust relationship with resource providers in order to authenticate and access the protected resources. These trust relationships can be persistent or temporary, and can be provided dynamically or on a deferred basis. A third function would allow organization or federation security managers to update requirements for trust relationships and protocols to be used. The security broker can be centralized or federated.

Swedish NMA: Lantmäteriet	To increase interoperability and ease the implementation for request-response APIs, it would be useful to standardize a very simple REST API for requests data (features) by geometry (bbox, point, line, polygon...) or by identifier.

USGS GHRC	• Consider the balance between efficiency and explicitness when defining new exchange formats (sometimes the best way to be efficient is to leave little room for interpretation/errors). • Building tools to better leverage efficient data trends more quickly is an area that needs to improve with API interoperability. The adaptation process for many mapping API's is too slow.

USGS Science Base	The reference (http://docs.opengeospatial.org/wp/16-019r4/16-019r4.html) lists the OGC Essentials (OGC Simple Features for SQL, OGC Well Known Text for CRS, Well Known Text for Geometry, Well Known Binary for Geometry, GML Simple Features, OGC Common Query Language, OGC Filter Encoding, OGC WMTS Simple, OGC GeoSPARQL, GeoPackage Features, Simplified GeoPackage Tiles, GeoJSON, GeoRSS Simple, OWS Context) but not analytics on these. How much usage do any of these get, and what locales use specific essential the most? We try to support a number of OGC standards, but cannot afford to support standards that are not being widely used. Ease of use is also a concern. OGC documentation is dense, lacks ready-to-use information, and is often missing useful examples (actual code snippets showing how to use the API). While we are sure there are OGC resources that could address these user's concerns, these materials are not readily available through http://www.opengeospatial.org/.

B.2 Does OGC Essentials play a role in improving API interoperability:

CEOS WGISS Integrated Catalog (CWIC) Team	CWIC utilizes the following OGC API Essentials: - OGC Filter Encoding, - GeoRSS Simple
Why or why not?	

George Mason University	The OGC essentials (described at http://docs.opengeospatial.org/wp/16-019r4/16-019r4.html#_ogc_api_essentials) provide a valuable set of common grounds for the interoperability to be enabled. The Center has used many of these in supporting open access of geospatial data. GML is used to deliver vector-features through OGC WFS. OGC Filter Encoding is used to formulating queries and constraints for different services. OGC Common Query Language (CQL) is used in catalogue services to support user-defined queries. OWS Context is used in keeping user-configuration of views in GeOnAS (http://geobrain.laits.gmu.edu/OnAS/).
Why or why not?	There are gaps identified for the OGC Essentials to function as a common set of consensus for geospatial APIs. It is recommended to expand the Essentials in: (1) common specification for raster features, (2) metadata specifications, (3) multiple levels of explicit compliance declarations, (4) construction of common semantic vocabularies, and (5) enforcement of quality and provenance.

NOAA IOOS	OGC Essentials seems one useful component to improve interoperability. For example, representing CRS in NetCDF as WKT would be very useful. CovJSON (https://covjson.org) should be explored in addition to GeoJSON, which attempts to match the scientific feature types or Discrete Sampling Geometry (DSG) of the Climate and Forecast (CF) conventions, such as point, timeSeries, profile, trajectory. Common representation of these feature types across APIs so that you could round trip a timeSeries through OGC SOS, OPeNDAP with CF Conventions, CovJSON, netCDF-Java library, would be very useful.
Why or why not?	

NOAA NOS CO-OPS	While CO-OPS has not reviewed the OGC API Essentials document in detail, a set of common standards and formats (if implemented by a wide variety of vendors and organizations) can facilitate greater interoperability and simplify data exchange. This does not replace completely the potential need for custom implementations (i.e. simple formats such as CSV); however, it may aid in simplifying access for an organization's data for many users who may be familiar with standards defined in the OGC Essentials.
Why or why not?	

Natural Resources Canada	In general, OGC Essentials will likely improve interoperability especially outside of the traditional geospatial community (e.g. web community) where geospatial tooling and standards are not yet well understood. Empirical evidence gathered through interactions with web developers at Government of Canada sponsored hackathons showed that common geospatial tooling and standards were largely unknown to participants, and in some cases presented barriers to access. The result was minimal re-use of public sector geospatial data at two such events.
Why or why not?	Common semantics are essential, but OGC Essentials potentially go beyond what can be readily achieved by every developer. Interoperability can be hampered by excessive 'degrees of freedom', or complexity, in what is expected to be implemented by platform developers. Furthermore, excessive complexity reduces usability by developers, especially among beginners. In order to target the Web platform as the technology environment, and Web users, authors, and developers as the target audience efforts to minimize complexity should be considered, but to add extensibility where necessary and possible.

B.3 Other (non-OGC essentials) standards used in the organization's APIs

CEOS WGISS Integrated Catalog (CWIC) Team	OGC OpenSearch Geo and Time Extensions (OGC 10-032r8)

George Mason University	To enable the management of geospatial workflows, Business Process Execution Language (BPEL) is used to compose and manage complex processes. SOAP API is used to better facilitate the BPEL-based workflow management system.

B.4 Other comments concerning semantics and APIs?

Ecere	Latitude, Longitude Really, latitude should always go first!

USGS Masaki	We would be more likely to use guidance provided by OGC in the form of an API white paper.

USGS Science Base	We would really like to see OGC track analytics on API use, so systems like ScienceBase can refocus attention on widely used protocols. We also would like OGC to post example implementations (code included) from real-life users that could help communities see the value of these standards. A big challenge with the forward progress and standardization of OGC is the fact that most GIS desktop users only use Esri products. Most everything done in Esri cannot be transferred over to OGC format. One prime example is styling. There needs to be a less steep learning curve for open-source GIS. For example, the SLD (http://www.opengeospatial.org/standards/sld) is supposed to be the authoritative source for OGC styling, but the documentation does not provide a best way to actually create a useable, portable SLD. Many OGC data formats are outdated. Developers prefer the JSON format for content, as opposed to XML (WMC, SLD, etc).

B.5 Information about APIs that the company/agency uses to access...use geospatial data (General - Specific details in Examples below):

CEOS WGISS Integrated Catalog (CWIC) Team	
example a	3.3.3.1 CWIC OpenSearch Description Document: Dataset specific OSDD request URL example: http://cwic.wgiss.ceos.org/opensearch/datasets/Landsat_8/osdd.xml?clientId=cwicClient
example b	3.3.3.2 CWIC OpenSearch request.
example c	3.3.3.3 CWIC OpenSearch response A CWIC OpenSearch response is an ATOM feed with zero or more ATOM entries. Each entry represents metadata pertaining to single granule with submitted query.

Esri	
example a	GeoServices REST API https://github.com/Esri/ArcREST
example b	File Geodatabase API https://github.com/Esri/file-geodatabase-api
example c	geometry-api-java https://github.com/Esri/geometry-api-java
example d	**ArcGIS API for JavaScript** **https://developers.arcgis.com/javascript/latest/guide/index.html** **https://github.com/Esri/jsapi-resources/tree/master/4.x/bower** **ArcGIS API for Python** **http://esri.github.io/arcgis-python-api/apidoc/html/**
example e	**ArcGIS Open Data API API** **http://mjuniper.github.io/presentations/opendata-api.html - /** **https://github.com/ArcGIS/composer-api**

Esri	
example a	GeoServices REST API https://github.com/Esri/ArcREST
example b	File Geodatabase API https://github.com/Esri/file-geodatabase-api
example c	geometry-api-java https://github.com/Esri/geometry-api-java

example d	**ArcGIS API for JavaScript** **https://developers.arcgis.com/javascript/latest/guide/index.html** **https://github.com/Esri/jsapi-resources/tree/master/4.x/bower** **ArcGIS API for Python** **http://esri.github.io/arcgis-python-api/apidoc/html/**
example e	**ArcGIS Open Data API API** **http://mjuniper.github.io/presentations/opendata-api.html - /** **https://github.com/ArcGIS/composer-api**

FEMA	
example a	OpenFEMA API is a representative API FEMA publishes, though it is not primarily geospatial in nature. Additional Geospatial capabilities could be included in the OpenFEMA API but the work necessary to include the geospatial APIs has only been started. FEMA does publish geospatial data in an API format using the native API included within GeoServer. Documentation on use and capabilities are dependent on software version and supporting documentation provided by the software vendor. Examples of each of the APIs documentation can be found at: OpenFEMA https://www.fema.gov/openfema-api-documentation GeoServer http://docs.geoserver.org/stable/en/user/
example b	FEMA APIs: OpenFEMA https://www.fema.gov/data-feeds#APIs GeoServer: https://gis.fema.gov/geoserver/web/?wicket:bookmarkablePage=:org.geoserver.web.demo.MapPreview Page

FGDC Service Status Checker	FGDC Service Status Checker (SSC) provides an API that returns a set of summary and test diagnostic information about the tests performed on each service. SCC API documentation: https://statuschecker.fgdc.gov/documentation#rest-api
example a	Request the latest WMS service test results: https://statuschecker.fgdc.gov/api/v2/results?auth=<API-KEY>&type=wms&limit=1 This URL returns the following JSON response:
example b	Request a live test: https://statuschecker.fgdc.gov/api/v2/liveTest?auth=<API-KEY>&type=wms&url=http://gisweb.unr.edu/ArcGIS/Services/Quaternary_Faults2/MapServer/WMSServer?request=GetCapabilities&service=WMS This URL returns the following JSON response:

GeoScience Australia	3.4. Geoscience Australia also employs the OpenDAP protocol to access its geoscience data holdings, used by in-house scientists and the broader research community to undertake scientific analysis. OGC WCS provides spatial coverages and can provide much of the functionality provided by OpenDAP for accessing georeferenced gridded datasets, but OpenDAP is a lower level protocol than WCS and exposes the complete structure of the underlying netCDF data. This can be advantageous to the scientist (e.g. ability to access all of the metadata and variables in NetCDF files), which can make OpenDAP the preferred method for programmatic data access, especially when accessing complex multidimensional datasets. 3.5. Geoscience Australia uses a number of APIs to programmatically access and manipulate spatial data, including GDAL/OGR, Esri ArcPy and GeoTools. 3.6. Geoscience Australia is a user of FME, and employs the FME API to access FME resources.

Geo Secretariat	The GEO DAB APIs can be used to discover and access GEOSS resources via the GEOSS Common Infrastructure (GCI). The APIs offer simplified means for the development of applications and clients leveraging GEO DAB functionalities for discovery and access. The GEO DAB APIs are addressed to a variety of users/developers. As a matter of fact, not all developers own the same knowledge: they can have different levels of expertise, even in the use of geospatial data and technologies.
example a	**Standard Web Services:** the GEO DAB publishes interfaces for the discovery and access of geospatial data in compliance with de-iure and de-facto standards such as OGC CSW, WCS, WMS, WFS, OAI-PMH, etc. These interfaces allow to interact with the GEO DAB as if it were a single data system, compliant with that particular standard. This type of interaction is useful for advanced users, experts in the use of geospatial data and technologies.

example b	**Client-side APIs**: high level client-side library, designed and developed to facilitate the development of web and mobile applications. These APIs aim to hide the complexity and the low-level interaction with the GEO DAB, enabling developers to work with simple objects representing GEO DAB content. Presently, these APIs are available as a Javascript library; supporting other programming/scripting languages is in scheduling. This solution is indicated for developers with good knowledge HTML5+Javascript+CSS technologies.
example c	**Server-side APIs:** the GEO DAB exposes the main functionalities for geospatial open data discovery and access through a set of server-side APIs, including OpenSearch and RESTful APIs. These allow an easy interaction with the GEO DAB through any programming environment that supports the HTTP protocol and the JSON or XML message encoding.

George Mason University	

example a	3.3.1 APIs for Discovering Geospatial Data GEOSS Registries http://geossregistries.info/geonetwork/srv/en/csw It serves a community catalogue for registering all resources for GEOSS. OGC Filter Encoding, OGC Common Query Language, GML Simple Features Catalogue service libraries used at CSISS CKAN: https://ckan.org/ Purpose Metadata management. Use of OGC Essentials Not applicable. It has its own set of API for harvesting and searching. Plugins can enable OGC catalogue services to be communicated with. GeoNetwork http://geonetwork-opensource.org/ Purpose Metadata management. Use of OGC Essentials OGC Filter Encoding, OGC Common Query Language, GML Simple Features THREDDS http://www.unidata.ucar.edu/software/thredds/current/tds/ Purpose Discover and harvest data from communities of climate and environmental science. Use of OGC Essentials Not applicable. It can be harvested into OGC catalogue services through traversing its hierarchical metadata management and description structures.

example b	3.3.2 APIs for Accessing Geospatial Data GMUWCS-os https://github.com/CSISS/GMUWCS-os Purpose Implementation of OGC WCS. Use of OGC Essentials OGC Filter Encoding. CropScape API https://ws.csiss.gmu.edu/axis2/services/CDLService?wsdl Purpose Query and report on analysis of CDL data. Use of OGC Essentials GML Simple Features Name GMUWCS-os URI https://github.com/CSISS/GMUWCS-os Purpose Open source implementation of OGC WCS and WFS. Use of OGC Essentials OGC Filter Encoding, OGC Common Query Language, Well Known Text (WKT) for CRS, GML Simple Features Name GeoServer URI http://geoserver.org/ Purpose Open source implementation of OGC WCS and WFS. Use of OGC Essentials OGC Filter Encoding, OGC Common Query Language, Well Known Text (WKT) for CRS, GML Simple Features Name OpenDAP URI http://www.opendap.org/ Purpose Access and disseminate data for the community of climate and environmental science. Use of OGC Essentials Not applicable. It has special capabilities in dealing with data in NetCDF.
example c	3.3.3 APIs for Manipulating or Using Geospatial Data Name GMU GRASS SOAP API URI http://cube.csiss.gmu.edu/grassweb/manuals/ Purpose Complete Web service implementation of GRASS functions in the Web environment. They are published as w3c Web service, i.e. WSDL-described, SOAP-wrapped message, and UDDI-based discovery. Use of OGC Essentials Not applicable. Name BPELPower URI http://geobrain.laits.gmu.edu:8099/bpelasync/ Purpose Implementation of BPEL execution engine. Use of OGC Essentials Not applicable. Name 52°North WPS URI https://www.openhub.net/p/n52-wps Purpose Open source implementation of OGC WPS 1.0 and 2.0. Use of OGC Essentials GML Simple Features

6.3

NOAA IOOS	IOOS relies on: ● OGC Catalog Service for the Web (CSW) ● OGC Web Map Service (WMS) ● OGC Sensor Observation Service (SOS)/Sensor Web Enablement (SWE) ● NetCDF-Java API and OPeNDAP API with ○ Climate and Forecast (CF) conventions for structured grids ○ CF-Discrete Sampling Geometry (DSG) for observational data ○ CF-UGRID for unstructured (e.g. triangular, hex mesh) grids ○ CF-SGRID for staggered structured grids ● ERDDAP GridDAP and TableDAP services Reference: ● IOOS GitHub Organization and Software Repositories

6.4

NOAA NOS CO-OPS	
example a	ESRI FeatureServer ESRI Map Service (OGC WMS and WFS support) ESRI FeatureServer ESRI Map Service (OGC WMS and WFS support)
example b	Custom API (JSON, XML) Custom API (CSV, JSON, XML) Custom API (CSV, TSV, XML, KML) Custom API (XML, HTML, Text ERDDAP installation configured to return CO-OPS data (variety of formats, including ASCII, CSV, NetCDF, JSON, etc.)

Swedish NMA: Lantmäteriet	
example a	1. View Services (WMS, WMTS)
example b	2. Services for Direct Access and consumption (Web services SOAP - GML and REST - GML/GeoJSON)
example c	3. Download Services (FTP, Atom, WCS, REST)

USGS GHRC	

example a	ArcGIS Web Map Link: 30 Day Significant Event Data Feeds; This map displays seismic data products that are contained in near real-time GIS services from the USGS Geologic Hazards Science Center in Golden, CO. Specifically event, ShakeMap, and "Did You Feel It?" data for significant earthquakes over the last 30 days. The services within the map are updated every 15 minutes to display data from recent significant earthquakes. More information on the 3 data products found in this map can be found at: Event: http://earthquake.usgs.gov/earthquakes/; Did You Feel It?: http://earthquake.usgs.gov/data/dyfi/; ShakeMap: http://earthquake.usgs.gov/data/shakemap/ Metadata for these feeds can be referenced at: https://github.com/usgs/hazdev-gis/blob/master/LiveFeedMetadata.zip; http://usgs.maps.arcgis.com/home/webmap/viewer.html?webmap=5555eabe9d65418d8e0b5677b3fe59b5
example b	• Advanced National Seismic System (ANSS) Comprehensive Earthquake Catalog (Comcat) API: https://earthquake.usgs.gov/earthquakes/search/ . The ANSS Comprehensive Earthquake Catalog (ComCat) contains earthquake source parameters (e.g. hypocenters, magnitudes, phase picks and amplitudes) and other products (e.g. moment tensor solutions, macroseismic information, tectonic summaries, maps) produced by contributing seismic networks. ComCat Documentation is available at https://earthquake.usgs.gov/data/comcat/. The API for ComCat is documented at https://earthquake.usgs.gov/fdsnws/event/1/. The ComCat API follows the FDSN Event Web Service Specification (http://www.fdsn.org/webservices/FDSN-WS-Specifications-1.0.pdf).
example c	• LibComcat is a project designed to provide command line equivalents to the ANSS ComCat search API (as previously noted) and is publically available on github. https://github.com/usgs/libcomcat.
example d	GeoServe - https://earthquake.usgs.gov/ws/geoserve/;
example e	Leaflet API - https://github.com/usgs/hazdev-leaflet; General utilities for working with Leaflet, an open-source JavaScript library for mobile-friendly interactive maps.

Natural Resources Canada	Overview data from Natural Earth, place data from GeoNames and baseline data OpenStreetMap are just some examples of APIs that demonstrate interoperability
example a	**Federal Geospatial Platform** (gcgeo.gc.ca) http://csw.open.canada.ca/geonetwork/srv/csw?service=CSW&request=GetRecords&constraintLanguage=FILTER&version=2.0.2&ResultType=results&maxrecords=1000 http://webservices.maps.canada.ca/arcgis/rest/services/ https://github.com/fgpv-vpgf https://github.com/fgpv-vpgf/geoApi
example b	Open.canada.ca (open.canada.ca and open.canada.ca/open-maps) uses a feature-rich registry system called CKAN. CKAN can be accessed via machine-to-machine through the Application Programming Interface (API). While not a geospatial specific API, users can access and manipulate geospatial metadata harvested by Open Canada from the FGP via OGC CSW protocol. CKAN's Action API is a powerful, RPC-style API that exposes all of CKAN's core features to API clients. All of a CKAN website's core functionality (everything you can do with the web interface and more) can be used by external code that calls the CKAN API. Each dataset has a “Link to JSON format” button that uses the API to download the complete metadata record for that dataset, delivering it to the end user in JSON format (JavaScript Object Notation). For example: • Use the API to automate search results: http://open.canada.ca/data/en/api/3/action/package_search?q=geospatial will return all the results with the search term “geospatial”.
example c	Open.canada.ca (open.canada.ca and open.canada.ca/open-maps) uses a feature-rich registry system called CKAN. CKAN can be accessed via machine-to-machine through the Application Programming Interface (API). While not a geospatial specific API, users can access and manipulate geospatial metadata harvested by Open Canada from the FGP via OGC CSW protocol. CKAN's Action API is a powerful, RPC-style API that exposes all of CKAN's core features to API clients. All of a CKAN website's core functionality (everything you can do with the web interface and more) can be used by external code that calls the CKAN API. Each dataset has a “Link to JSON format” button that uses the API to download the complete metadata record for that dataset, delivering it to the end user in JSON format (JavaScript Object Notation). For example: • Use the API to automate search results: http://open.canada.ca/data/en/api/3/action/package_search?q=geospatial will return all the results with the search term “geospatial”.

example d	GeoGratis is a web portal that provides access to a wide collection of Canadian geospatial data, maps, images, and publications at no cost and without restrictions. All distributed data accessed via GeoGratis comes with an Unrestricted Use Licence Agreement that grants users a non-exclusive, royalty-free right and licence to exercise all intellectual property rights in the data including the right to use, incorporate, sub-license, modify, further develop, and distribute the data. At it's core GeoGratis is a RESTful HTTP API that serves geospatial metadata as web resources. Multiple resource representations are supported including JSON, KML, RSS, and CSV making the API easy to consume using lightweight programming models. (http://geogratis.gc.ca/site/eng/api/documentation/sguide)
example e	WET is an open source code library for building innovative websites that are accessible, usable, interoperable, mobile-friendly and multilingual. This collaborative open source project is led by the Government of Canada. It includes an API based on OpenLayers that allows for integration of geospatial data via standards (e.g. OGC WMS, WMTS, GeoJSON, KML, TopoJSON etc.), allowing web developers to easily incorporate geospatial data visualization into a Government of Canada web presence. http://wet-boew.github.io/wet-boew/index-en.html

6.5

USGS Masaki	
example a	National Map API Services https://viewer.nationalmap.gov/help/HowTo.htm
example b	BISON API Services https://bison.usgs.gov/doc/api.jsp

6.6

USGS National Nap	

example a	ScienceBase API ScienceBase is a collaborative environment for communities to document and host their own scientific content. The ScienceBase Catalog provides a fast and flexible data cataloging and discovery mechanism for over 8 million records. It is backed by a REST API for search and update activities. The National Map uses the ScienceBase Catalog to store metadata for all of it's publically available data products. This FGDC metadata includes thesaurus-driven keywords defined by the National Map to aid query and filtering based on: dataset, product extent and product format. By leveraging the existing ScienceBase API , search and filtering capabilities were realized without the need to duplicate these capabilities for the National Map. ScienceBase: - Catalog: https://www.sciencebase.gov/catalog/ - API Documentation: https://my.usgs.gov/confluence/display/sciencebase/ScienceBase

example b	TNMAccess API Interestingly, even though it was adequate for our needs, the ScienceBase API was a non-standard, custom API and we decided to create our own API to address the following issues: ● Simplification - the ScienceBase API handled a much larger problem-set than required by the National Map. This meant that creating anything but the simplest of text queries could require a fairly complex JSON filter construct. The idea of simplifying the API around our much smaller set of use cases had the advantage of making our API more accessible to less technical users. ● Abstraction - The risk of The National map changing backend implementations raised concerns on the impact to users who may have built a dependence on the API. By abstracting our core use cases into a documented API, we could be more assured that even if we changed our backend implementation we could still maintain the same front-end interfaces - greatly minimizing this risk. ● Effectiveness - having an abstraction layer also allows us to add and extend capabilities to enhance the effectiveness of the API without the need to wait for these changes to be adopted by the backend provider which in our case was still managed by USGS but often driven by a different set of priorities. National Map API: - Datasets - Products - Services - Notifications https://viewer.nationalmap.gov/tnmaccess/

USGS Water	
Example a	Web APIs This is a list of the main water Web APIs USGS provides the public, with hyperlinks to their documentation. The list it drawn from materials in [2] and [3], among other places. 1. Water Data for the Nation (WDFN) Site Service [4] - Provides access to a catalog of monitoring locations and important metadata related to the observed parameters, period of data availability, site ownership, and available statistical summaries of observed data. 2. WDFN Instantaneous Values Service [5] - Provides access to high-temporal resolution (15 minute or finer) observational data at sites that can be identified through the Site Service. 3. WDFN Daily Values Services [6] - Provides access to archives of daily statistics and

	observations related to sites and instantaneous values from 1 and 2. 4. WDFN Groundwater Services [7] - Provides access to groundwater level observations for sites found with the site service. These are discrete observations, as opposed to continuously recorded observations which are available from 2 and 3. 5. WDFN Statistics Service [8] - Provides summary statistics for time series data from other services. 6. Water Quality Web Services [9] - Provides unified access to water quality (sample) data from the USGS, US EPA, and USDA. Has sub services for stations, results (data), activities (sampling acts / total field visits), and summaries of activities to provide metrics about the place being sampled.
Example b	7. National Ground-Water Monitoring Network Web Services [10] - Provides an SOS 2.0.0 web service API for groundwater observations available in WaterML2.0 and a WFS 1.1.0 web service API for monitoring features (well lithology and construction). 8. Geo Data Portal Processing Services [11] - Provides a WPS 1.0.0 web service API with processes capable of calculating spatial statistics for large gridded time series datasets. 9. Geo Data Portal data archives - A collection of gridded time series data with OPeNDAP services available via THREDDS. Contents summarized at [12] and [13]. 10. Network Linked Data Index - A system that indexes river-network-attached data and provides a search interface with network navigation capabilities. [14] 11. Publications Data Warehouse [22] - Provides a set of web services to access USGS publications and related metadata. While this project is sponsored by the USGS Libraries, WMA has been the lead for the project for some time. As mentioned, this list is not exhaustive, rather it is a reasonably representative selection of USGS water data APIs. (Links listed bel
Example c	Language Specific APIs The WMA maintains numerous applications that can be used in scientific workflows or as components to construct larger applications. Many of these are written for the R programming language and are maintained at the USGS-R github repository [14] and summarized in [15]. Others are created and hosted as javascript libraries such as in [17], [18], and [19]. There is also a good diversity of python libraries that implement APIs designed for reuse such as [20] and [21]. While these are all intended to support re-use in their respective languages, none of them attempt to implement a pre-existing API specification or have been developed using explicitly Open API development practices. In this context of this RFI response, they are for information only. It is the opinion of the author that APIs with such a domain-specific focus are not good targets for standardization because the use cases addressed are so unique that the number of APIs with similar purpose
Example d	[1] https://waterservices.usgs.gov/ [2] http://onlinelibrary.wiley.com/doi/10.1111/j.1936-704X.2014.03175.x/abstract;jsessionid=4DF93191BACAE24F48E258887291D1C7.f04t02 [3] https://www.researchgate.net/publication/ 287107560_Progress_on_water_data_integration_and_distribution_A_summary_of_

	select_US_Geological_Survey_data_systems [4] https://waterservices.usgs.gov/rest/Site-Service.html [5] https://waterservices.usgs.gov/rest/IV-Service.html [6] https://waterservices.usgs.gov/rest/DV-Service.html [7] https://waterservices.usgs.gov/rest/GW-Levels-Service.html [8] https://waterservices.usgs.gov/rest/Statistics-Service.html [9] https://www.waterqualitydata.us/webservices_documentation/ [10] https://cida.usgs.gov/ngwmn/web-services.jsp [11] https://github.com/USGS-CIDA/geo-data-portal/wiki [12] https://www.sciencebase.gov/catalog/items?parentId=54dd2326e4b08de9379b2fb1 [13] https://cida.usgs.gov/thredds/catalog.html [14] https://cida.usgs.gov/nldi/about [15] https://github.com/USGS-R [16] https://owi.usgs.gov/R/ [17] https://www.usgs.gov/news/usgs-releases-new-javascript-library-plotting-water-data-nation [18] https://txpub.usgs.gov/DSS/streamer/api/3.14/web/index.html#tab1?top [19] https://txpub.usgs.gov/dss/search_api/1.1/doc/index.html#tab1?top [20] https://github.com/USGS-CIDA/pyGDP [21] https://water.usgs.gov/ogw/flopy/ [22] https://pubs.er.usgs.gov/documentation/web_service_documentation [23] http://onlinelibrary.wiley.com/doi/10.1111/jawr.2016.52.issue-4/issuetoc [24] http://onlinelibrary.wiley.com/doi/10.1111/1752-1688.12417/abstract [25] http://docs.opengeospatial.org/wp/16-019r4/16-019r4.html

B.6 General comments not captured above

Organization:	Response:
CEOS WGISS Integrated Catalog (CWIC) Team	CWIC Client **Guide** for OpenSearch (http://ceos.org/document_management/Working_Groups/WGISS/Projects/CWIC/OpenSearch/ CWIC_OpenSearch_Client-Guide.doc)
Esri	**SDG API** **https://github.com/Esri/sdg-api**
Geo Secretariat	Useful Links Online documentation and examples: http://www.geodab.net/apis (alternatively, http://api.eurogeoss-broker.eu) Online GEO DAB View Test: http://www.geodab.net/test-apis
Natural Resources Canada	API developments should address the needs of Northerners and Indigenous communities, including responding to priorities of Northerners and Indigenous Communities, working in zero/low bandwidth regions and considering the realities of frontier economies. Arctic SDI is leading a user needs assessment activity, which is supporting Arctic SDI Strategic Plan objectives 1,2,3,4 and 5.1 (Arctic-SDI.org).

B.7 Other APIs from Natural Resources Canada:

Environment and Climate Change Canada
- MSC GeoMet (https://ec.gc.ca/meteo-weather/default.asp?lang=En&n=C0D9B3D8-1)
- WMO World Ozone and Ultraviolet Radiation Data Centre (http://woudc.org)

- http://woudc.org/about/standards.php
- http://woudc.org/about/data-access.php?lang=en#web-services
- https://github.com/woudc (public)
Provincial
-Open Alberta API
The Government of Alberta is committed to publishing open data to third parties via data feeds through an application programming interface (API). The Government of Alberta encourages developers to deliver and innovate using open data.
The base URL for the API is: http://open.alberta.ca/api.
https://github.com/abgov
British Columbia Data Catalogue API
Published by the Ministry of Jobs, Tourism and Skills Training - DataBC
Licensed under Open Government License - British Columbia
The live published metadata content of the BC Data Catalogue is accessible through an application programming interface (API) available here http://catalogue.data.gov.bc.ca/api/ .
Documentation on the use of the API is available http://docs.ckan.org/en/ckan-2.5.3/api/index.html .
Catalogue content is also available via this record http://catalogue.data.gov.bc.ca/dataset/bc-data-catalogue-content

- British Columbia Geomark Web Service
The Geomark Web Service is a free web service for public and government users to store an area of interest or shape, called a 'geomark'.
https://catalogue.data.gov.bc.ca/dataset/geomark-web-service
- British Columbia Physical Address Geocoding Web Service
The Physical Address Geocoder can be used to resolve physical locations from place names and addresses in British Columbia. This RESTful web service, and corresponding, web application interface can also be used to correct and standardize addresses in British Columbia.
-New Brunswick GeoNB API
Map Viewer:http://geonb.snb.ca/geonb/
Operating under the mandate: find it, map it, share it, GeoNB aims to provide standardized geospatial land data. The repository provides data from multiple sources and uses a REST architectural style to serve users.
http://geonb.snb.ca/arcgis/rest/services
-Nova Scotia Open Data Portal
Portal: https://data.novascotia.ca/browse
GitHub: https://github.com/socrata?page=1

Uses Socrata Open Data API to compile a catalogue from various sources that provide open data sets to the end-user.
-Yukon
Map Viewer: http://mapservices.gov.yk.ca/GeoYukon/
GitHub: https://github.com/Esri/geoportal-server/wiki#welcome-to-the-esri-geoportal-server
Users can use a map viewer feature to preview layers or search data via the catalogue (http://geoweb.gov.yk.ca/geoportal/catalog/main/home.page#). The application makes use of ESRI server REST API.
Municipal
Municipal APIs built around interoperable data management platforms (i.e. CKAN)
-Edmonton (https://data.edmonton.ca/)
-Ottawa (http://data.ottawa.ca/)
-Montreal (http://donnees.ville.montreal.qc.ca/)
-Sherbrooke (https://www.donneesquebec.ca/fr/)
-Surrey (http://data.surrey.ca/)
Public Domain
-OpenStreetMap
OpenStreetMap API provides read and write operations on the raw map data of the OpenStreetMap database.
(http://wiki.openstreetmap.org/wiki/API)
Academic
-Nunaliit

The Nunaliit Atlas Framework aims to make it easy to tell stories and highlight relationships between many different forms of information from a variety of sources, using maps as a central way to connect and interact with the data.
The Nunaliit Atlas Framework was born out of a multi-disciplinary research project led by Dr. Fraser Taylor, a Distinguished Research Professor in the department of Geography and Environmental Studies and director of the Geomatics and Cartographic Research Centre at Carleton University in Ottawa, Canada.
https://github.com/GCRC/nunaliit/wiki/Atlas-Builder-Documentation
-Polar Data Catalogue of the Canadian Cryospheric Information Network
As a pilot project, GeoNetwork is being configured to serve the Polar Data Catalogue Metadata collection as a Catalogue Service for the Web (CSW), to provide additional flexibility and options for metadata interoperability.
http://polardata.ca/geonetwork

Annex C Revision history

Revision Date	Revision Number	Author	Changes noted
6/18/2017	0.1	T. Idol	Major version