OGC Testbed-14

WMS QoSE Engineering Report

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OGC Engineering Report

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Chapter 1. Summary

1.1. Rationale

Quality of Service (QoS) and Quality of Experience (QoE) as they are intended and described at the OGC are two related concepts which require very specific treatment and characterization. Citing the definitions provided by the Domain Working Group (DWG) charter document:

- Quality of Service: Technical reliability and performance of a network service. Typically measured using metrics like error rates, throughput, availability and delay or request response time. This Engineering Report (ER) attempts to handle QoS aspects such as service availability, scalability and speed.
- Quality of (User) Experience: A holistic, qualitative measure of the customers' experience of the application or service. It encompasses both the user experience and the customer support experience of the evaluated applications and/or services.

QoE focuses on the usability of the information that is conceived via OGC services to end users or other client application and therefore is concerned more with qualitative aspects of such services like presence of metadata, proper and descriptive namings, appropriate styling and so on (a more thorough treatment is present in the QoE discussion paper OGC 17-049 entitled "Ensuring Quality of User Experience with OGC Web Mapping Services" available at https://portal.opengeospatial.org/files/?artifact_id=74403&version=1).

QoS focuses on providing reliable (i.e. quantitative) measures of spatial data service metrics which can be used to characterize how a service (one or more specific datasets exposed by a certain service) is performing both in near real-time as well as historically. It touches concepts like availability, scalability (also known as capacity), absolute performance (i.e. speed) and can be used to assess also perceived performance by final clients. As mentioned above, it is typically measured using metrics like error rates, throughput, availability and delay or request response time.

Quite often the QoS and QoE aspects of spatial data services are underestimated if not simply ignored due to lack of resources as well as lack of awareness, resulting in services which are difficult to exploit (i.e. QoE very low) and/or unstable or very slow (i.e. QoS very low). The result is that few users end up using them after the initial launch and this is especially true for services targeting end users who are used to interact with services a-la Google Maps which delivers extreme performance and scalability as well as bullet-proof usability.

1.2. Context

The ability to combine and visualize location-based data using a Web Map Service (WMS) is a key value proposition of the Federal Geospatial Platform (FGP). The FGP is a collaborative online environment where a collection of the government of Canada’s most relevant geospatial information can be found easily and viewed on maps to support evidence-based decision-making, foster innovation, and provide better service for Canadians. The FGP includes the capability of selecting datasets with WMS to view individually or combined with other services in the FGP viewer.

This functionality, as is the general case with a WMS, is provided to allow users to immediately visualize and analyze geospatial data. Unfortunately, user feedback has proven that these geospatial web services are not always easy or intuitive to navigate, combine or understand. Because the FGP's primary end users are government policy analysts who are not always highly familiar with mapping and web mapping technologies, it is important to make WMS, and the content they make available, as user-friendly as possible.

In 2016, to help alleviate this issue, the FGP developed a web service quality assessment methodology that supported WMS, ran an assessment and developed recommendations and best practices to support a user-friendly experience for all employees and citizens using WMS. Assessments to date have shown that key considerations are often very simple, but very impactful on QoE. The results of this study were used as the primary input into an OGC Discussion Paper created by the Quality of Service Experience (QoSE) DWG. The OGC QoSE-DWG has developed a discussion paper (OGC 17-049) entitled "Ensuring Quality of User Experience with OGC Web Mapping Services" [https://portal.opengeospatial.org/files/17-049] that identifies and describes issues often encountered by users of OGC WMS that affect the quality of their experience, and also provides an assessment framework for identifying issues and measuring quality, along with potential solutions and guidance to improve the usability of services.

The assessment framework for measuring QoE and the associated recommendations for improving service quality are intended to benefit human end-users who need to rapidly assimilate and use web mapping visualizations to answer questions or input into analysis. In other words, they need to be able to make sense of the information an OGC WMS provides them.

In addition, Testbed-13 addressed QoS aspects in the aviation domain. Though specific to a particular domain, The Testbed13: Data Quality Specification Engineering Report [http://docs.opengeospatial.org/per/17-018.html] addressed a number of general aspects that apply to this task nevertheless.

1.3. Requirements & Research Motivation

Testbed-14 has addressed the following WMS usability aspects:

1. Develop a revision of the OGC Discussion Paper 17-049: Develop a revision of the OGC Discussion Paper 17-049 as per the review and assessment of the current OGC Discussion Paper 17-049. This revision shall be performed in coordination with OGC QoSE DWG to address potential new requirements such as QoS metadata (Capabilities Extensions) server implementation and monitoring client implementations that allows improved service quality and measurement. The revision is part of this ER.

2. Quality of Service Experience Assessment Framework: The fourteen assessment criteria described in Discussion Paper 17-049 and summarized in Figure 1 are all aimed at assessing the quality of a web service in terms of the degree to which it conveys clearly understood information to the user. The user is assumed to be a non-expert in geospatial web services, but in most cases the criteria are equally valid for all classes of users. A selected number of services in the Testbed will be assessed against the QoSE assessment criteria, and retested once recommendations have been applied. Comparison of results will help to validate the effectiveness of the assessment criteria and the corresponding recommendations to improve usability, and allow for feedback, improvement or correction. Services are provided as Testbed-14 deliverable D115 and, a dedicated client as D116.

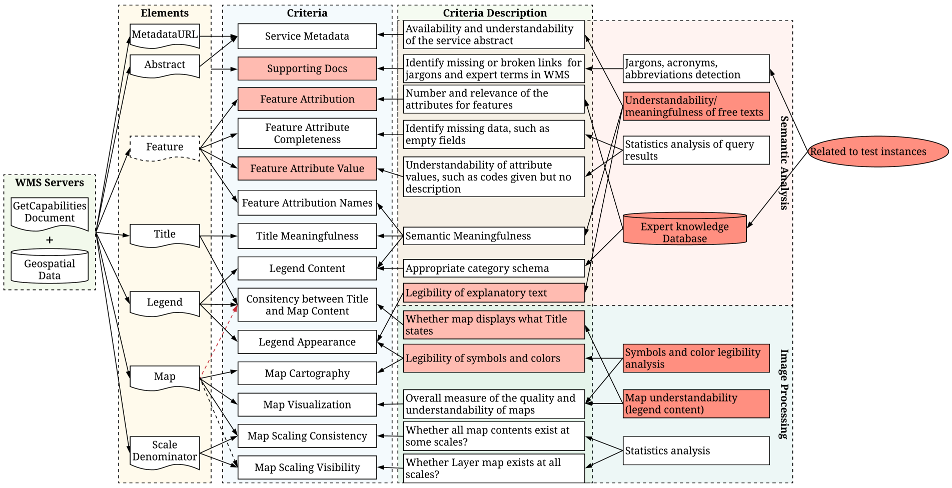

WMS Servers
GetCapabilities Document
+
Geospatial Data
Elements
MetadataURL
Abstract
Feature
Title
Legend
Map
Scale Denominator
Criteria
Service Metadata
Supporting Docs
Feature Attribution
Feature Attribute Completeness
Feature Attribute Value
Feature Attribution Names
Title Meaningfulness
Legend Content
Consitency between Title and Map Content
Legend Appearance
Map Cartography
Map Visualization
Map Scaling Consistency
Map Scaling Visibility
Criteria Description
Availability and understandability of the service abstract
Identify missing or broken links for jargons and expert terms in WMS
Number and relevance of the attributes for features
Identify missing data, such as empty fields
Understandability of attribute values, such as codes given but no description
Semantic Meaningfulness
Appropriate category schema
Legibility of explanatory text
Whether map displays what Title states
Legibility of symbols and colors
Overall measure of the quality and understandability of maps
Whether all map contents exist at some scales?
Whether Layer map exists at all scales?
Jargons, acronyms, abbreviations detection
Understandability/ meaningfulness of free texts
Statistics analysis of query results
Expert knowledge Database
Related to test instances
Semantic Analysis
Symbols and color legibility analysis
Map understandability (legend content)
Statistics analysis
Image Processing

Figure 1. The fourteen assessment criteria for WMS QoSE

3. Quality of Service Experience Practices to Alleviate Usability Issues: The fourteen assessment criteria all have corresponding recommendations that describe practices that, once implemented, should help to alleviate user confusion and improve the usability of WMS as a means of visualizing and simple visual or query-based analysis of geospatial data. Once selected services have been assessed against assessment criteria, all or as many QoSE recommendations will be applied, then services will be subject to retesting.

4. Quality of Service Experience Implementing Best Practices: Man or Machine?: Analysis required here on the making of a geospatial WMS and the opportunities of human operator or programmatic response to make decisions that impact service quality of experience. Assessment of which usability issues are determined/caused by human input or what determined/caused by default via the programmatically generated aspects of the service (not due to direct human input or decisions) via the standard specification implementation. Results are captured in this ER.

5. Quality of Service Experience Test Suite: Develop test suite to programmatically test and validate that best practices have been successfully implemented. The test suite will automatically assess the quality of service according to the assessment criteria and validate or flag services that do not comply to best practices/recommendations. The results of the test suite (D117) are also captured in this ER.

Figure 2 illustrates the QoSE work items as reflected by the OGC Testbed-14 thread.

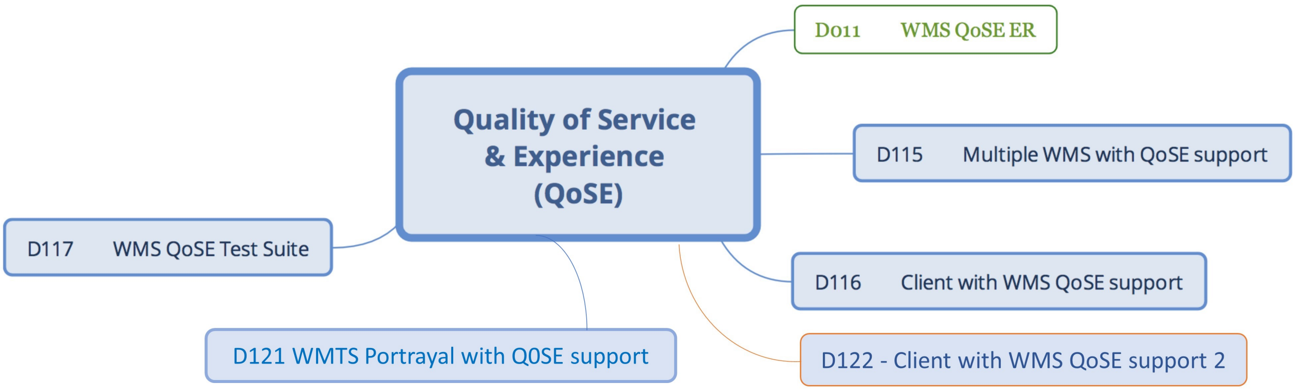

D011 WMS QoSE ER
Quality of Service & Experience (QoSE)
D115 Multiple WMS with QoSE support
D117 WMS QoSE Test Suite
D116 Client with WMS QoSE support
D121 WMTS Portrayal with Q0SE support
D122 - Client with WMS QoSE support 2

Figure 2. Quality of Service & Experience (QoSE) work items

Note: The purpose of D122 is to provide a Client to meet requirements for QoSE and Portrayal as well as measure statistics on response time, number of layers, number of features, error codes generated, etc. within the client. Since subjective measurement criteria, focusing for example on legibility, intuitiveness, consistency of symbology, may be more difficult to automate, participant will gather QoSE statistics manually for those criteria or elements, and then propose recommendations for an automated service for those assessment criteria.

1.4. What does this ER mean for the QoSE DWG and OGC in general

The OGC QoSE DWG provides a forum for discussing issues related to QoS and QoE of spatial data services and applications relying on these services for delivering timely and accurate spatial information to the end-users. Key business goals of the Working Group include the following:

- Sharing implementation experience and ideas in evaluating and improving QoS and QoE of spatial data services.
- Collect best practice, create and promote guidance on evaluating and self-assessing the QoE of spatial data services, and practical means for improving the user experience of these services.
- Identify gaps in the existing standards and guidance related to QoS and QoE of spatial data services, and as appropriate, suggest new standardization activities within OGC to fill those gaps.

1.4.1. QoE specific problem statements from the DWG Charter

- Metadata, such as titles and keywords, is not always written in clear and understandable language considering the end users. Further, metadata does not always describe the provided services and data sets in necessary detail. This makes it more difficult for users to fully take advantage of the provided service and its datasets. There should be better guidance and a checklist to assist data and service providers to record human-readable metadata.
- The ancillary information, such as legends for WMS, is not always clear and human-readable. Missing or ambiguous legend information may easily lead to misinterpretation of the presented data. There should be better guidance for data providers on specifying good and readable legends.
- There is a lack of methods and best practice on evaluating and improving user experience and human interaction of processes involving discovery, initial evaluation of the fitness-for-purpose of spatial data services, as well as access to change records during the services' lifetime.
- There is a need for more accurate understanding of how spatial data services are used and perceived in the larger web service end-user community.
- Evaluating, comparing and improving the QoE of spatial data services is difficult without commonly agreed and well-defined metrics for measuring the QoE.

1.5. Prior-After Comparison

The task described in this ER addressed the QoE assessment criteria laid out in the DWG Discussion paper referred to earlier and also implemented a QoS performance assessment. Specifically, an interactive user-friendly Graphical User Interface (GUI) was developed based on the QoE assessment criteria defined by the DWG. This GUI also lists performance statistics from a WMS server.

1.6. Recommendations for Future Work

A goal of this task and its analysis was also to suggest potential future activity where these results could be investigated through new tasks in future testbeds.

1.6.1. Recommended Future Tasks and Deliverables

Item Related to QoSE Discussion Papers

As per OGC Policies and Procedures, the Discussion Papers are not versioned documents. The option discussed in the QoSE DWG has been that a new document (e.g. perhaps a Best Practice) would be produced based on the original Discussion Paper and the results of the Testbed-14.

Item Related to Future OGC Work

There should be a discussion on how QoS/QoE will fit into next generation OGC service interface specifications (i.e. WFS3, CAT4) given the clean break and move to REST/JSON/etc.

Quality of Experience (QoE) Items

- Extend QoSE evaluation work to test other geospatial services

Although current QoSE indicators are specifically designed for the Web Map Service, some of them could be directly used to measure the quality of other OGC web services (OWS). For example, the title or similar elements in nearly all OWS types could be considered, resulting in the title meaningfulness and related criteria being mapped to the elements. In addition, the feature-related QoSE indicators could be used to evaluate the quality of the WFS. And most of them could be directly used to measure the WMTS.

- Improve current QoSE indicators

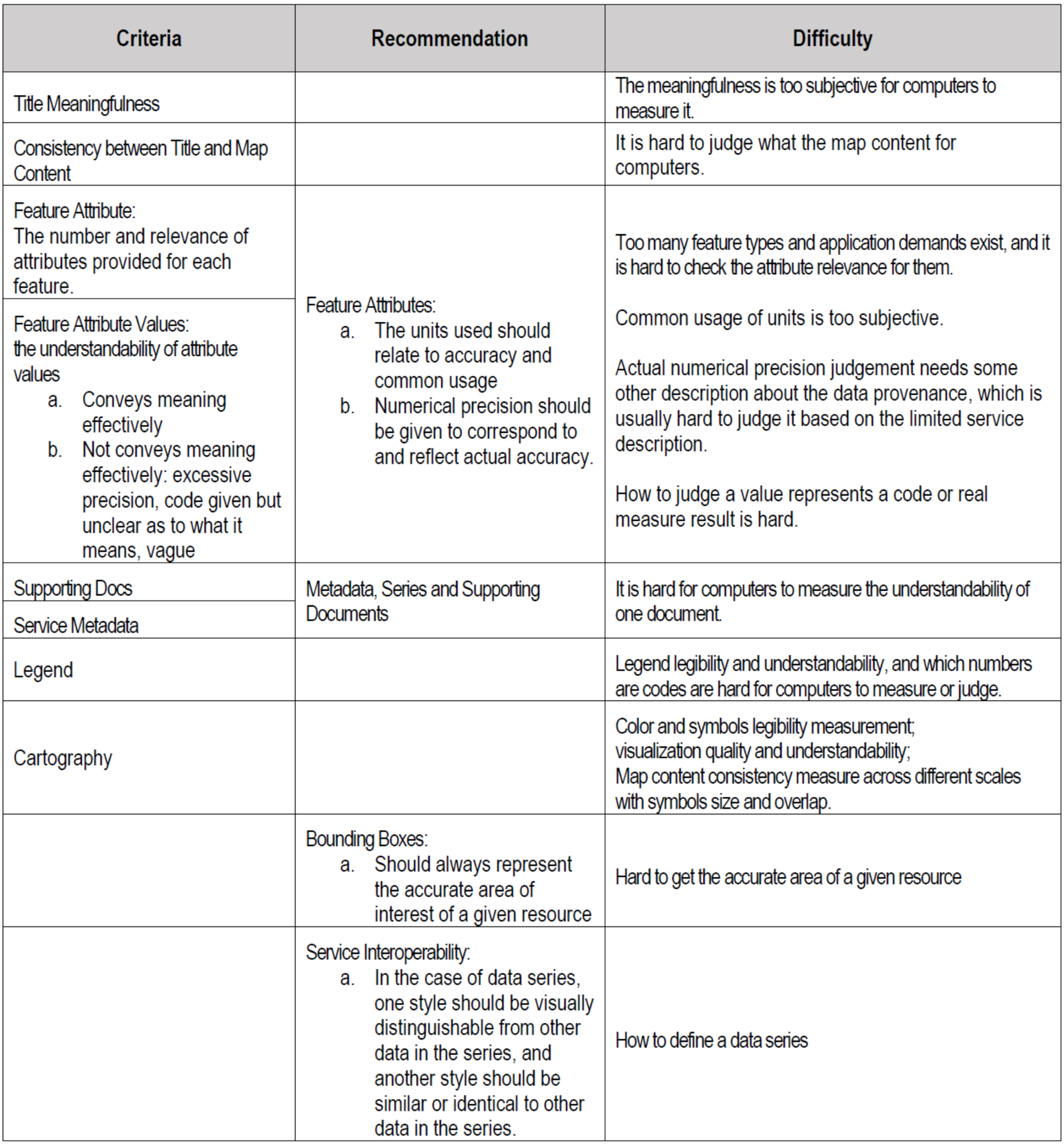
The fifth QoSE criteria is named as Feature Attribution, but its description indicates that it is used to measure the number and relevance of attributes provided for each feature. Besides, the attribution is used to identify the source of the geospatial information. As a result, it might be worth considering to change the Feature Attribution to measures of Feature Attribute.

The fourteen (14) QoSE criteria only aim at assessing the quality of a web service in terms of the degree to which it conveys clearly understood information to the user. However, QoSE means identifying the usability issues associated with use of OGC web services. Hence, additional indicators beside the information understandability should be developed. For example, the service performance also affects user experience.

In the QoSE discussion paper, the user is assumed to be a non-expert. However, some indicators are difficult for them to understand. In my opinion, the evaluation on feature attribute needs some expert knowledge, since it measures the number and relevance of attributes provided for each feature.

Not all items in the QoSE recommendations could find a matching item in the QoSE criteria, such as fees and access constraints, attribution, bounding box, and service interoperability. Thus, this needs improving.

Some future work related to D117



Criteria	Recommendation	Difficulty
Title Meaningfulness		The meaningfulness is too subjective for computers to measure it.
Consistency between Title and Map Content		It is hard to judge what the map content for computers.
Feature Attribute: The number and relevance of attributes provided for each feature.	Feature Attributes: a. The units used should relate to accuracy and common usage b. Numerical precision should be given to correspond to and reflect actual accuracy.	Too many feature types and application demands exist, and it is hard to check the attribute relevance for them. Common usage of units is too subjective. Actual numerical precision judgement needs some other description about the data provenance, which is usually hard to judge it based on the limited service description. How to judge a value represents a code or real measure result is hard.
Feature Attribute Values: the understandability of attribute values a. Conveys meaning effectively b. Not conveys meaning effectively: excessive precision, code given but unclear as to what it means, vague		
Supporting Docs	Metadata, Series and Supporting Documents	It is hard for computers to measure the understandability of one document.
Service Metadata		
Legend		Legend legibility and understandability, and which numbers are codes are hard for computers to measure or judge.
Cartography		Color and symbols legibility measurement; visualization quality and understandability; Map content consistency measure across different scales with symbols size and overlap.
	Bounding Boxes: a. Should always represent the accurate area of interest of a given resource	Hard to get the accurate area of a given resource
	Service Interoperability: a. In the case of data series, one style should be visually distinguishable from other data in the series, and another style should be similar or identical to other data in the series.	How to define a data series

Figure 3. Recommendations for future items related to D117

Quality of Service (QoS) Items

- Investigate further towards the concept of a status page to report information about availability and status of OGC services endpoints;
- Investigate further, together with the QoSE DWG, the QoS extensions to GetCapabilities operations for WMS and WFS in order to streamline them and propose them as profiles for the respective OGC services;
- Better link the "E" (Experience) of QoSE with QoS since bad performance and/or availability means bad experience for the end-user; meaning that OGC should try and draw a link between checking the famous "14 rules" that are more towards naming and metadata, and that OGC should check for decent performance and decent stability when assigning scores to layers (ideally the score should become dynamic at this stage since performance and availability should be monitored over time).
- Advance performance testing of WMS services by executing the load tests through the containerized architectures: Load testing is crucial for WMS that have to serve many users in real time. Load testing involves simulating similar actions, where computer-generated virtual users mimic real users. In most cases, this kind of testing cannot be generated by a single server due to limited hardware resources. Additionally, physically distributed servers are a must if user behavior is desired from different regions of the world. For these large-scale load tests containerized cloud services offer a good alternative. Cloud services that make use of containerized architectures such as Kubernetes, rkt, etc, offer an alternative to standalone machines, running full virtual machine instances for applications and are well-suited for scaling of simulated clients;
- Extend performance tests by expanding to other geospatial services: There is a variety of open geospatial standards to provide online access to geospatial data, for example, Web Coverage Service (WCS), Web Map Service (WMS), Web Feature Service (WFS), and Web Map Tile Service (WMTS). OGC Testbed-14 focused on performance tests for WMS, but WCS and WFS services are more sensitive to data resolution. For WFS services, due to their verbose nature, transferring large amounts of data might be problematic and lead to higher latencies and lower performance. Extending performance tests to other geospatial services offering data from a sponsor would provide a broader view of how well other geospatial services are provided.

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1.8. Foreword

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.

Chapter 2. References

The following normative documents are referenced in this document.

- OGC: OGC 06-121r9, OGC® Web Services Common Standard: https://portal.opengeospatial.org/files/?artifact_id=38867&version=2
- OGC: OGC 09-025r2, OGC® Web Feature Service 2.0 Interface Standard – With Corrigendum, July 2014
- OGC: OGC 06-042, OpenGIS Web Map Service (WMS) Implementation Specification, March 2006

Chapter 3. Terms and definitions

For the purposes of this report, the definitions specified in Clause 4 of the OWS Common Implementation Standard OGC 06-121r9 [https://portal.opengeospatial.org/files/?artifact_id=38867&version=2] shall apply. In addition, the following terms and definitions apply.

- Quality

```
degree to which a set of inherent characteristics fulfills requirements [SOURCE:
ISO 9000:2005, 3.1.1, modified - Original Notes have been removed.]
```

- Usability

```
The degree to which something is able or fit to be used
```

3.1. Abbreviated terms

NOTE: The abbreviated terms clause gives a list of the abbreviated terms and the symbols necessary for understanding this document.

- DWG Domain Working Group
- QoE Quality of Experience
- QoS Quality of Service
- QoSE Quality of Service and Experience
- WMS Web Map Service

Chapter 4. Overview

This ER describes all the different components that were implemented to advance WMS QoSE. Section 5 describes the following components in detail:

- GUI for WMS Service Quality Assessment
- Test Suite for WMS Service Quality Assessment
- WMS Stress Testing with JMeter
- GeoServer Extension for QoS
- OGC Web Service Landing Pages
- TIE and Scenario for Demonstration

Chapter 5. Components and Component Scenario

5.1. Component Overview Chart

Figure 4 illustrates the connections and interoperability between the various component parts discussed in this ER.

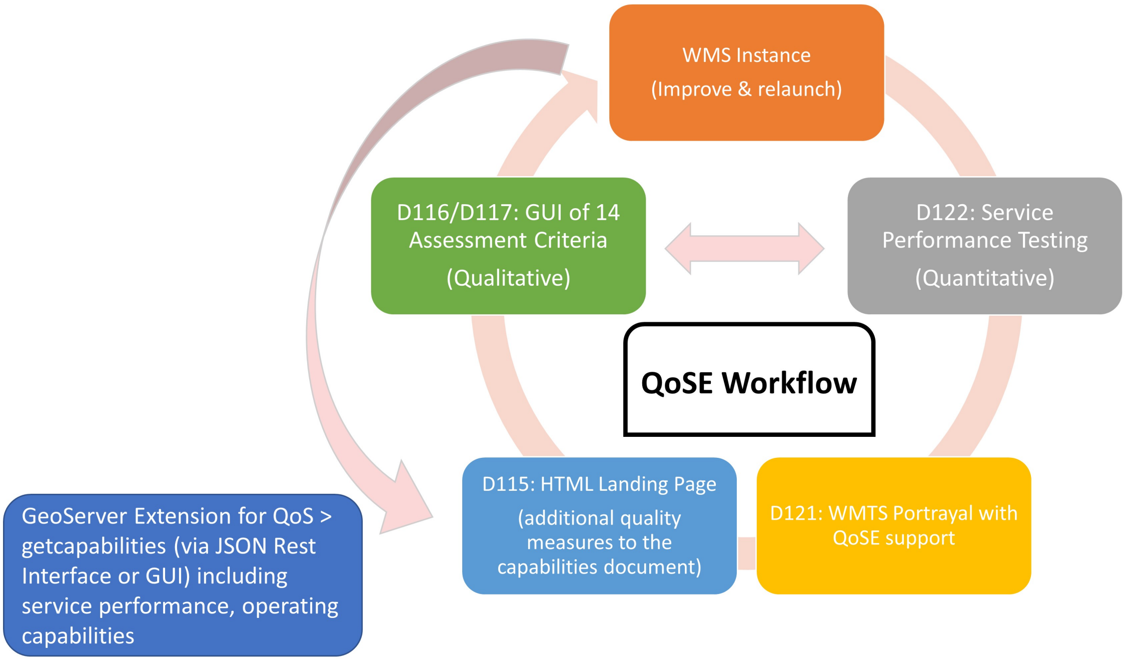

WMS Instance
(Improve & relaunch)
D116/D117: GUI of 14 Assessment Criteria
(Qualitative)
D122: Service Performance Testing
(Quantitative)
QoSE Workflow
D115: HTML Landing Page
(additional quality measures to the capabilities document)
D121: WMTS Portrayal with QoSE support
GeoServer Extension for QoS > getcapabilities (via JSON Rest Interface or GUI) including service performance, operating capabilities

Figure 4. Component Overview Chart

5.2. Quality of Service & Experience (QoSE)

A discussion paper entitled "Ensuring Quality of User Experience with OGC Web Mapping Services" provides an assessment framework for identifying issues and measuring quality, which can be downloaded at public link [https://portal.opengeospatial.org/files/?artifact_id=74403&version=1]. It outlines fourteen criteria to measure QoSE, and recommendations are given for each of them, which are shown as components using a rectangle in Figure 5.

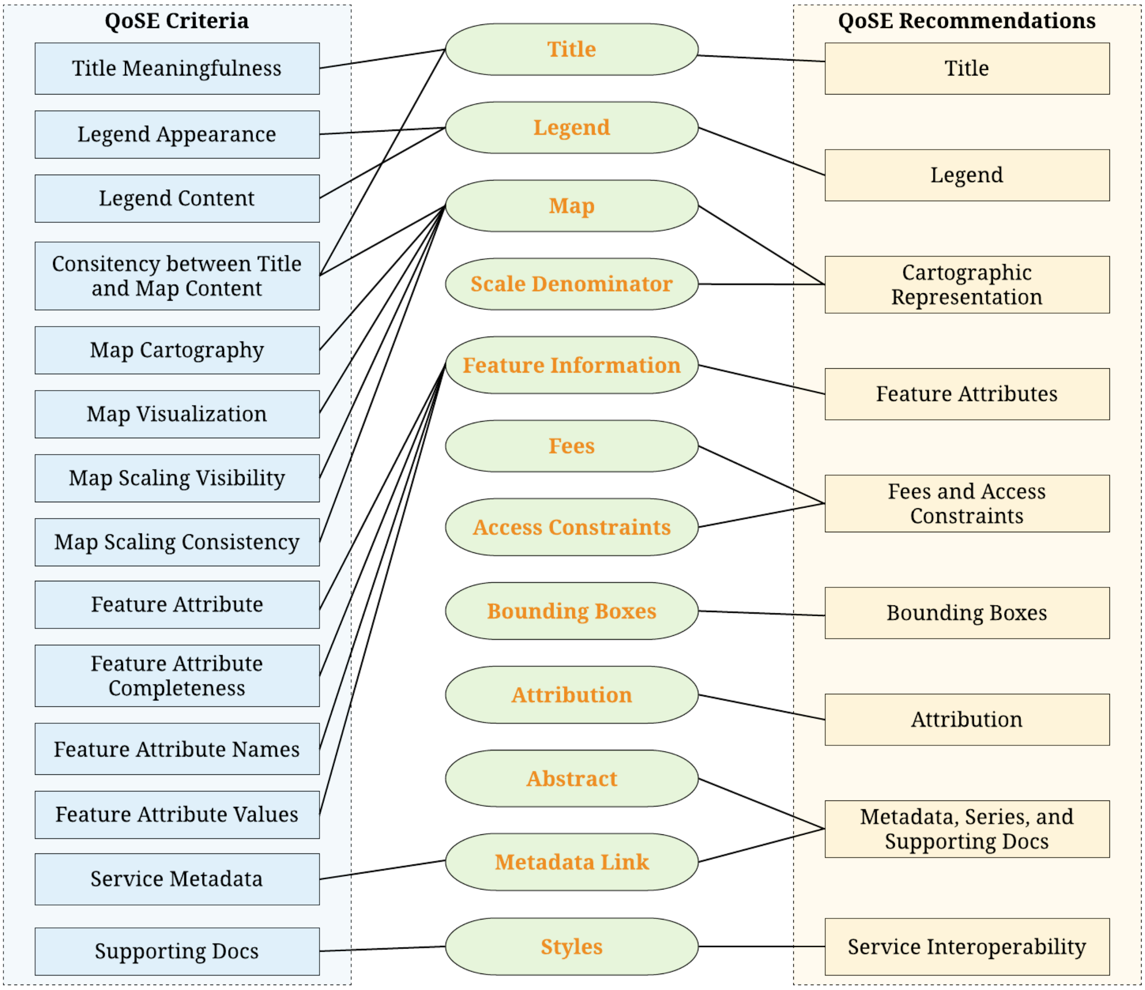
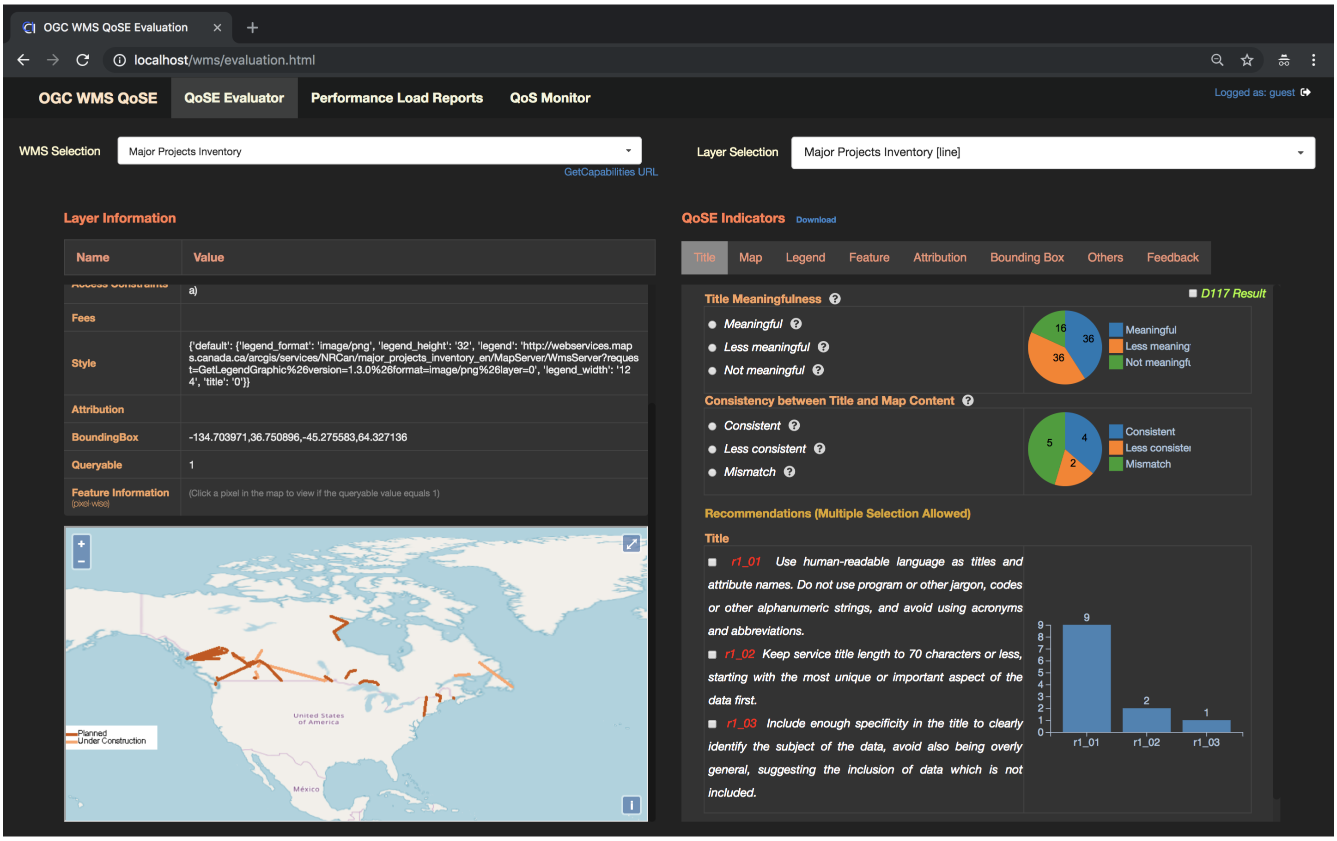


Figure 5. Relationships among QoSE Indicators and WMS Metadata Elements

5.3. Client with QoSE Support

D116 requires implementation of a client dedicated to testing the assessment criteria of WMS instances. Therefore, a Graphical User Interface (GUI) was designed and is shown in Figure 6. It consists of three basic components, including a WMS layer selector, metadata information viewer, and QoSE assessment panel. Users can select a layer of interest from the WMS layer selector. Once a layer is selected, its metadata is loaded and shown in the metadata information viewer, which is located in the bottom-left. Finally, users can give their evaluation for each QoSE indicator based on the layer metadata contents. At the same time, users can also leave feedback about the QoSE framework or the client using the feedback panel.



Name	Value
Access Constraints	a)
Fees	
Style	{'default': {'legend_format': 'image/png', 'legend_height': '32', 'legend': 'http://webservices.maps.canada.ca/arcgis/services/NRCan/major_projects_inventory_en/MapServer/WmsServer?request=GetLegendGraphic%26version=1.3.0%26format=image/png%26layer=0', 'legend_width': '124', 'title': '0'}}
Attribution	
BoundingBox	-134.703971,36.750896,-45.275583,64.327136
Queryable	1
Feature Information (pixel-wise)	(Click a pixel in the map to view if the queryable value equals 1)

□ r1_01 Use human-readable language as titles and attribute names. Do not use program or other jargon, codes or other alphanumeric strings, and avoid using acronyms and abbreviations.

□ r1_02 Keep service title length to 70 characters or less, starting with the most unique or important aspect of the data first.

□ r1_03 Include enough specificity in the title to clearly identify the subject of the data, avoid also being overly general, suggesting the inclusion of data which is not included.

Figure 6. The Client Graphical User Interface (GUI) (http://cici.lab.asu.edu:1080/qose/wms/evaluation.html)

5.3.1. WMS Metadata Elements

In Figure 5, this ER also explains and works out the necessary metadata elements for the QoSE assessment. According to the WMS specifications, all metadata elements could be extracted as shown in Figure 7.

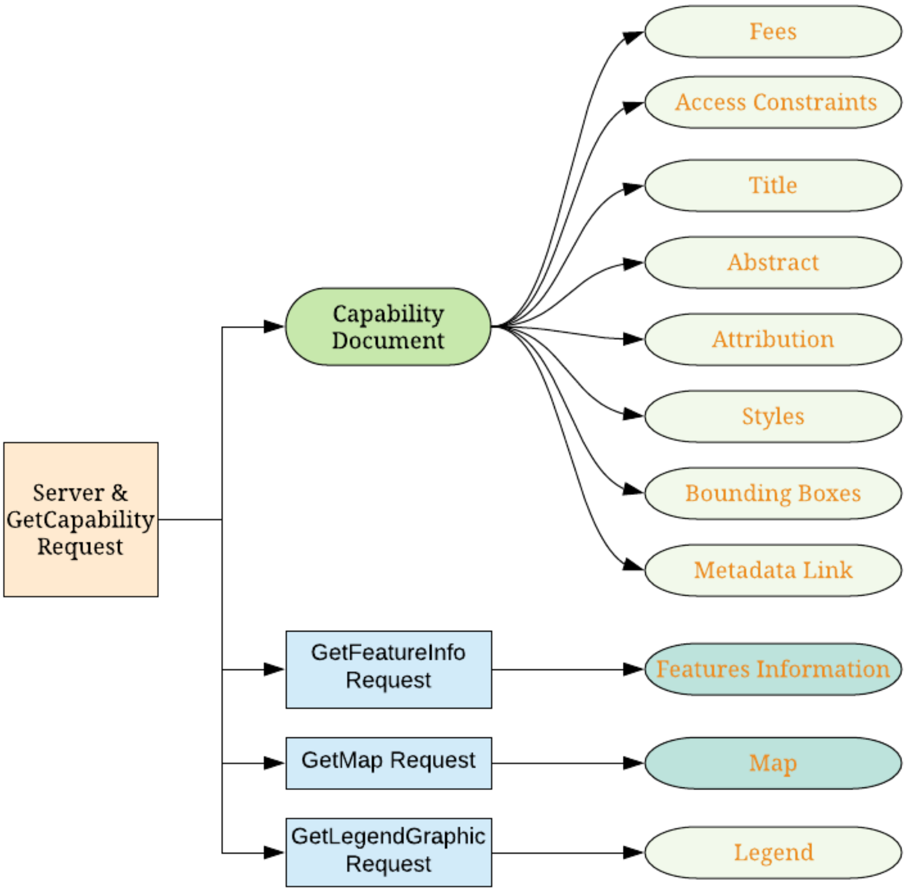


Figure 7. WMS Metadata Elements Extraction

Metadata cache, through pre-parsing the metadata elements and storing them, could enhance the user experience by reducing user wait time. Therefore, some metadata elements contained in the capability documents are pre-parsed and stored in the local database. However, some metadata elements are not suitable for this procedure. For example, the layer map may be configured with different rendering strategies at different zoom levels, but it is difficult to know how many rules exist. Also, the WMS only supports pixel-wise GetFeatureInfo operation, which makes it hard to cache all feature information, and it is also a lot of effort to manage the vector information. For this, the live request operation is provided which will be described in the sections below.

5.3.2. Operations

5.3.2.1. Layer Selection

In the WMS specification, the title element is described as more understandable for humans than the layer name which is designed for computers to identify. Therefore, the layer title is adopted to assist users in layer selection. But layers from different WMS services may share the same title. As a result, our portal requires users to specify a WMS before the layer selection.

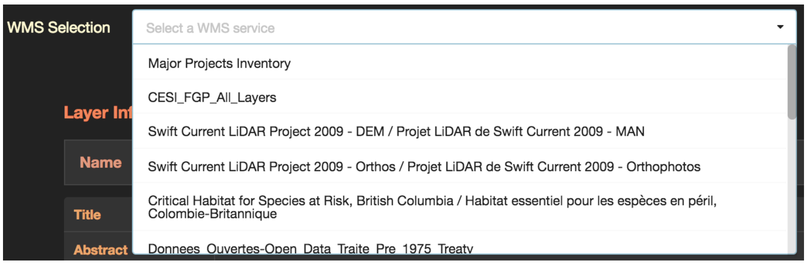

WMS Selection
Select a WMS service
Major Projects Inventory
CESI_FGP_All_Layers
Swift Current LiDAR Project 2009 - DEM / Projet LiDAR de Swift Current 2009 - MAN
Swift Current LiDAR Project 2009 - Orthos / Projet LiDAR de Swift Current 2009 - Orthophotos
Critical Habitat for Species at Risk, British Columbia / Habitat essentiel pour les espèces en péril, Colombie-Britannique
Donnees_Ouvertes-Open_Data_Traite_Pre_1975_Treaty
Layer Inf
Name
Title
Abstract

Figure 8. WMS Selection

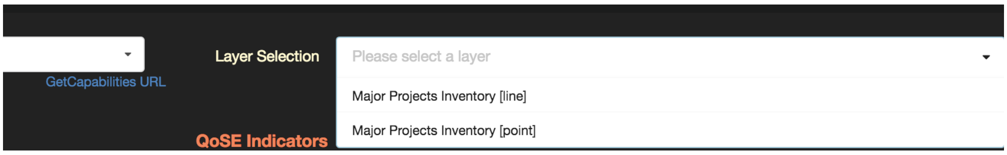
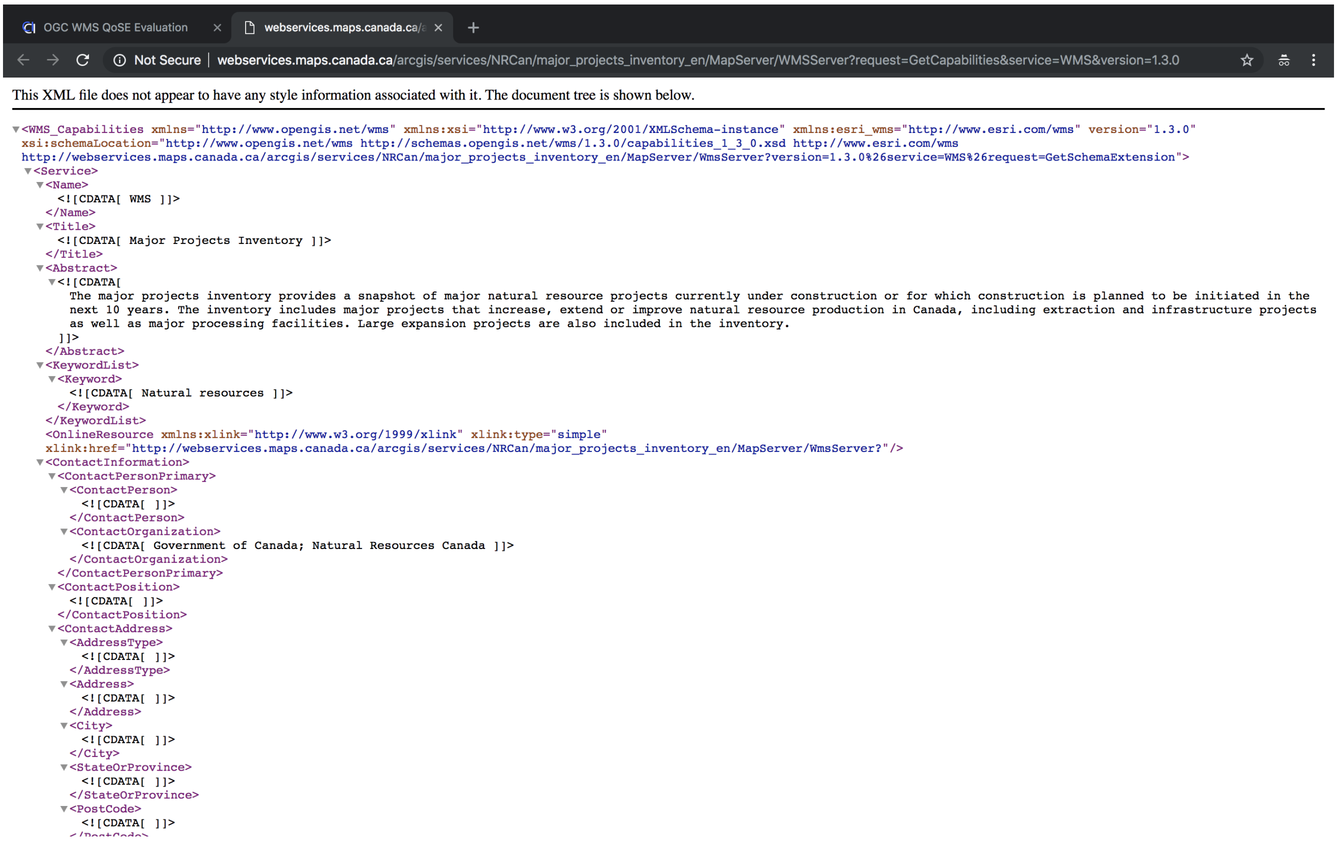


Figure 9. Layer Selection

Users can also view the native WMS capability document (Figure 10) using the hyperlink shown in Figure 9.


OGC WMS QoSE Evaluation
webservices.maps.canada.ca/a
Not Secure
webservices.maps.canada.ca/arcgis/services/NRCan/major_projects_inventory_en/MapServer/WMSServer?request=GetCapabilities&service=WMS&version=1.3.0

This XML file does not appear to have any style information associated with it. The document tree is shown below.

```
▼<WMS_Capabilities xmlns="http://www.opengis.net/wms" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:esri_wms="http://www.esri.com/wms" version="1.3.0"
 xsi:schemaLocation="http://www.opengis.net/wms http://schemas.opengis.net/wms/1.3.0/capabilities_1_3_0.xsd http://www.esri.com/wms
 http://webservices.maps.canada.ca/arcgis/services/NRCan/major_projects_inventory_en/MapServer/WmsServer?version=1.3.0%26service=WMS%26request=GetSchemaExtension">
  ▼<Service>
    ▼<Name>
       <![CDATA[ WMS ]]>
     </Name>
    ▼<Title>
       <![CDATA[ Major Projects Inventory ]]>
     </Title>
    ▼<Abstract>
      ▼<![CDATA[
         The major projects inventory provides a snapshot of major natural resource projects currently under construction or for which construction is planned to be initiated in the
         next 10 years. The inventory includes major projects that increase, extend or improve natural resource production in Canada, including extraction and infrastructure projects
         as well as major processing facilities. Large expansion projects are also included in the inventory.
       ]]>
     </Abstract>
    ▼<KeywordList>
      ▼<Keyword>
         <![CDATA[ Natural resources ]]>
       </Keyword>
     </KeywordList>
     <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
     xlink:href="http://webservices.maps.canada.ca/arcgis/services/NRCan/major_projects_inventory_en/MapServer/WmsServer?"/>
    ▼<ContactInformation>
      ▼<ContactPersonPrimary>
        ▼<ContactPerson>
           <![CDATA[ ]]>
         </ContactPerson>
        ▼<ContactOrganization>
           <![CDATA[ Government of Canada; Natural Resources Canada ]]>
         </ContactOrganization>
       </ContactPersonPrimary>
      ▼<ContactPosition>
         <![CDATA[ ]]>
       </ContactPosition>
      ▼<ContactAddress>
        ▼<AddressType>
           <![CDATA[ ]]>
         </AddressType>
        ▼<Address>
           <![CDATA[ ]]>
         </Address>
        ▼<City>
           <![CDATA[ ]]>
         </City>
        ▼<StateOrProvince>
           <![CDATA[ ]]>
         </StateOrProvince>
        ▼<PostCode>
           <![CDATA[ ]]>
```

Figure 10. WMS Capability Document

5.3.2.2. Map Window

The map window consists of a background map from OpenStreetMap (OSM), the layer map, and the layer legend. It supports some basic map operations including roam, zoom in/out. In addition, the map click operation is valid for queryable layers with a crosshair cursor shape. If the layer is not queryable, the click operation will be hidden, and the mouse cursor on the map will be changed to a move shape. If it is too small for users to view or operate, a full screen operation is implemented like that in Figure 11.

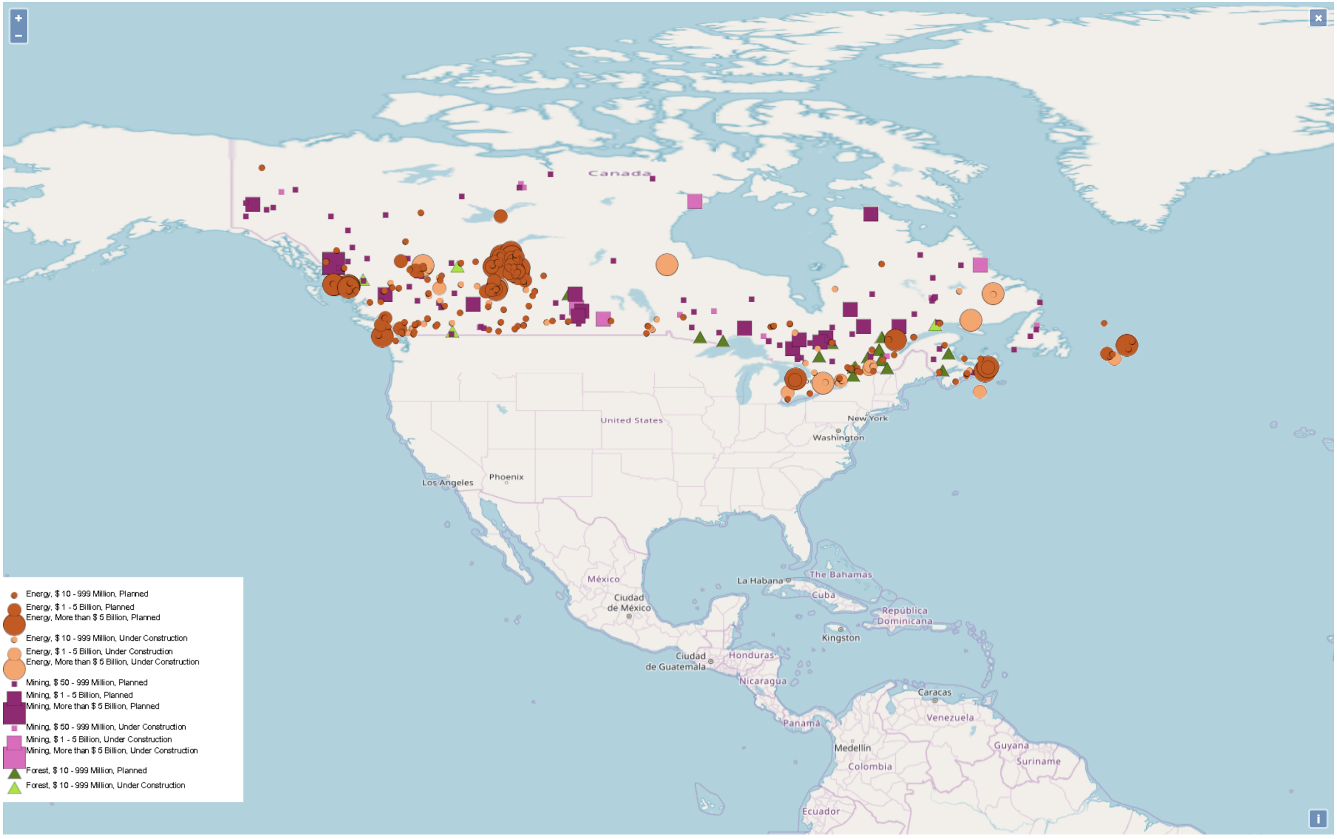
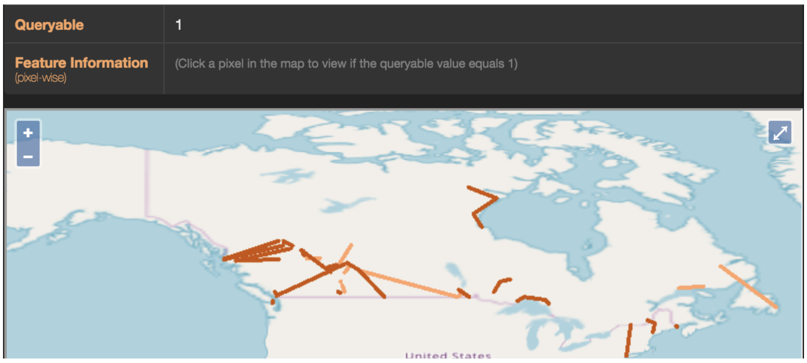

Canada
United States
New York
Washington
Los Angeles
Phoenix
México
Ciudad de México
La Habana
The Bahamas
Cuba
República Dominicana
Kingston
Ciudad de Guatemala
Honduras
Nicaragua
Panamá
Caracas
Venezuela
Medellín
Colombia
Guyana
Suriname
Ecuador
Energy, $ 10 - 999 Million, Planned
Energy, $ 1 - 5 Billion, Planned
Energy, More than $ 5 Billion, Planned
Energy, $ 10 - 999 Million, Under Construction
Energy, $ 1 - 5 Billion, Under Construction
Energy, More than $ 5 Billion, Under Construction
Mining, $ 50 - 999 Million, Planned
Mining, $ 1 - 5 Billion, Planned
Mining, More than $ 5 Billion, Planned
Mining, $ 50 - 999 Million, Under Construction
Mining, $ 1 - 5 Billion, Under Construction
Mining, More than $ 5 Billion, Under Construction
Forest, $ 10 - 999 Million, Planned
Forest, $ 10 - 999 Million, Under Construction

Figure 11. Full Screen Map with Legend

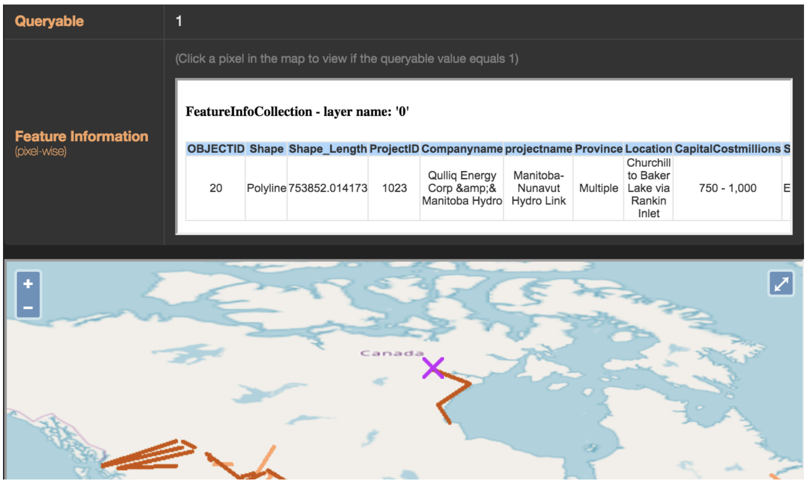
5.3.2.3. Feature Attributes

As described in the above sections, the feature information is loaded in real time instead of being cached together with other layer metadata elements. Therefore, the feature information value is left empty when users select a WMS layer (Figure 12). The feature information value is filled, once users click a feature pixel in the map window, provided the layer is queryable. In this process, a GetFeatureInfo request is constructed in real time, then the response of the request is shown as the feature information value. If no feature information is returned or the user clicks on an empty pixel, the feature information value is shown like that in Figure 13. At the same time, a purple cross symbol will appear on the map, whose center means the location of the selected pixel (Figure 13, Figure 14).



Queryable	1
Feature Information (pixel-wise)	(Click a pixel in the map to view if the queryable value equals 1)

Figure 12. No Pixel Selected

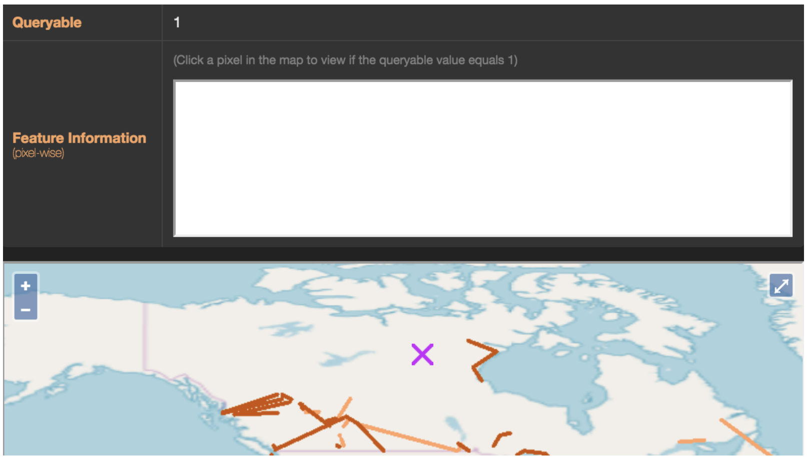


Queryable
1
Feature Information
(pixel-wise)
(Click a pixel in the map to view if the queryable value equals 1)
+
−
Canada

FeatureInfoCollection - layer name: '0'

OBJECTID	Shape	Shape_Length	ProjectID	Companyname	projectname	Province	Location	CapitalCostmillions	S
20	Polyline	753852.014173	1023	Qulliq Energy Corp &amp;& Manitoba Hydro	Manitoba-Nunavut Hydro Link	Multiple	Churchill to Baker Lake via Rankin Inlet	750 - 1,000	E

Figure 13. A Feature Pixel Selected

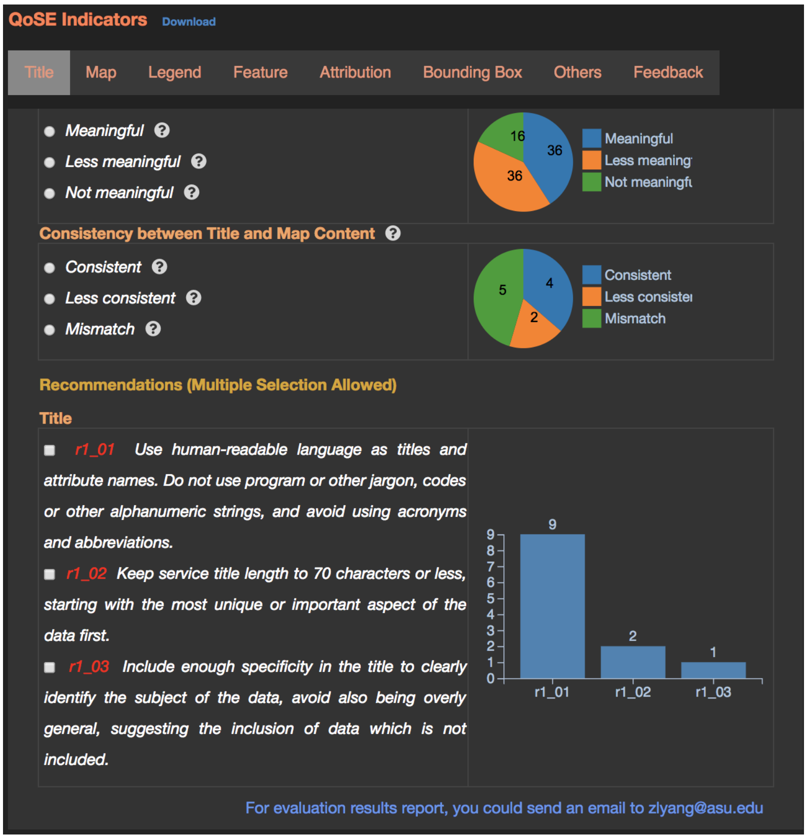


Queryable
1
Feature Information
(pixel-wise)
(Click a pixel in the map to view if the queryable value equals 1)
+
−

Figure 14. An Empty Pixel Selected

5.3.2.4. Criteria Assessment

There are two types of QoSE indicators, criteria and recommendations. For the criteria, the items are mutually exclusive. Therefore, a radio button group is adopted in our client (Figure 15). For QoSE recommendations, users can suggest multiple items belonging to the same recommendation (Figure 15). Once users give their assessments, the corresponding statistical graphs of past results will change immediately.



● *Meaningful* ?
● *Less meaningful* ?
● *Not meaningful* ?

Consistency between Title and Map Content ?

● *Consistent* ?
● *Less consistent* ?
● *Mismatch* ?

Recommendations (Multiple Selection Allowed)

Title

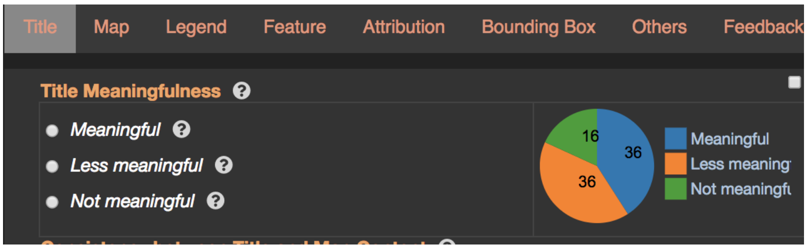
■ *r1_01 Use human-readable language as titles and attribute names. Do not use program or other jargon, codes or other alphanumeric strings, and avoid using acronyms and abbreviations.*

■ *r1_02 Keep service title length to 70 characters or less, starting with the most unique or important aspect of the data first.*

■ *r1_03 Include enough specificity in the title to clearly identify the subject of the data, avoid also being overly general, suggesting the inclusion of data which is not included.*

For evaluation results report, you could send an email to zlyang@asu.edu

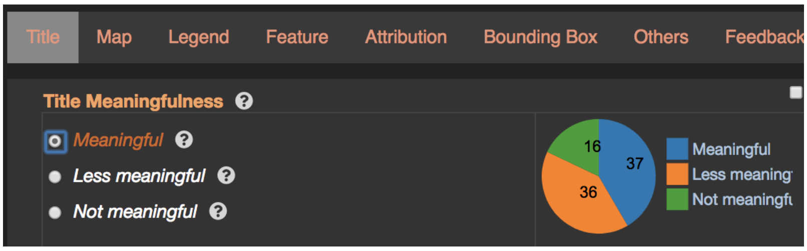
Figure 15. QoSE Indicators Assessment and Presentation



Title Meaningfulness ?

● *Meaningful* ?
● *Less meaningful* ?
● *Not meaningful* ?

Figure 16. Unselect

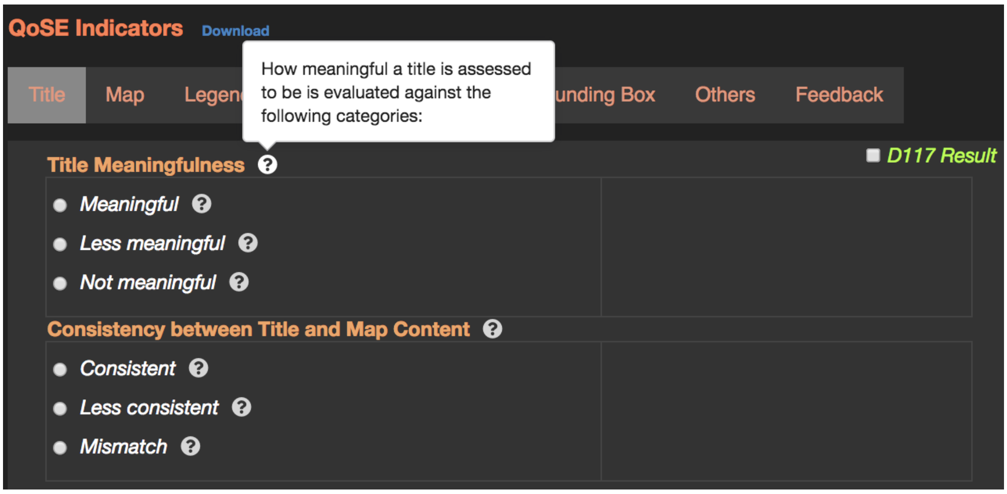


Title Meaningfulness ?

◉ *Meaningful* ?
● *Less meaningful* ?
● *Not meaningful* ?

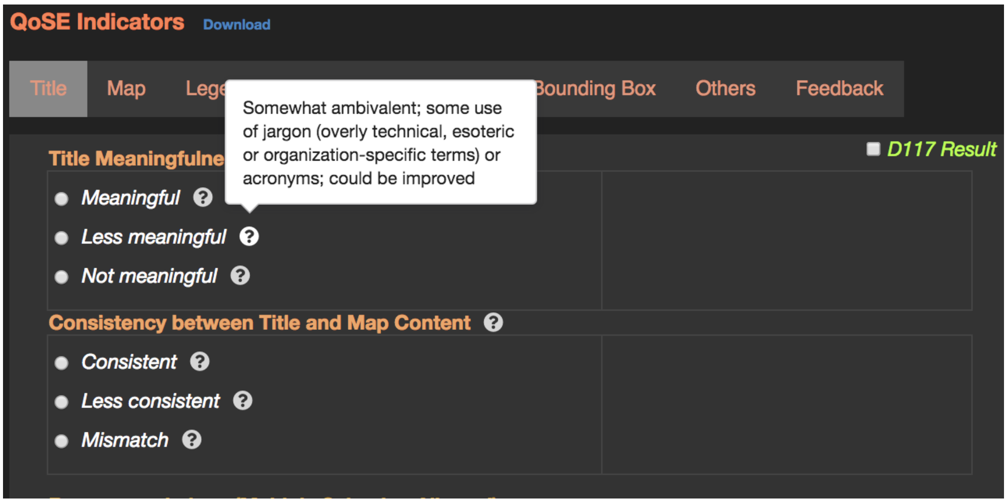
Figure 17. Select

There are some friendly prompt functions implemented to assist users' operations. For example, users can view the detailed description of each QoSE indicator and their items by moving the mouse on the (?) symbols (Figure 18, Figure 19). If the operation is layer dependent, users should first select a layer of interest, otherwise a prompt like Figure 20 will popup.



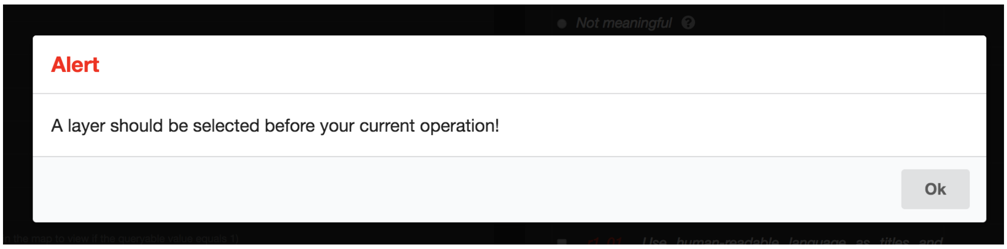
How meaningful a title is assessed to be is evaluated against the following categories:

Figure 18. Indicator Prompt



Somewhat ambivalent; some use of jargon (overly technical, esoteric or organization-specific terms) or acronyms; could be improved

Figure 19. Indicator Item Prompt

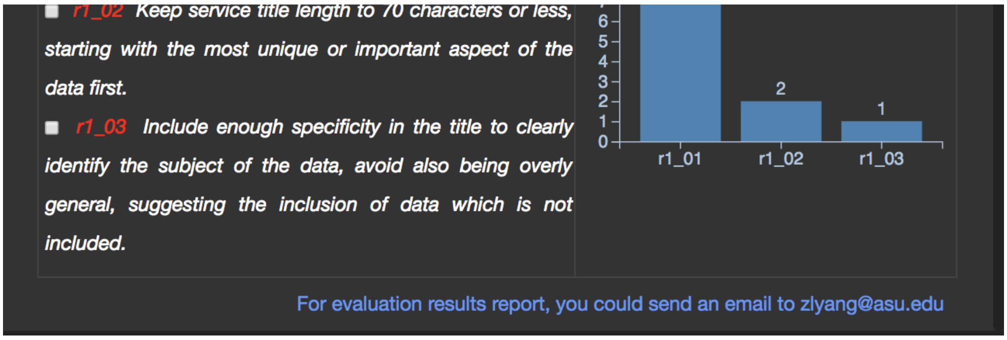


A layer should be selected before your current operation!

Figure 20. No Layer Selected Prompt

5.3.2.5. Assessment Report

If users or service providers want to get a complete QoSE report for a layer or a service, they can send an email to us using the address listed in the bottom in the Figure 21.



□ r1_02 Keep service title length to 70 characters or less, starting with the most unique or important aspect of the data first.

□ r1_03 Include enough specificity in the title to clearly identify the subject of the data, avoid also being overly general, suggesting the inclusion of data which is not included.

For evaluation results report, you could send an email to zlyang@asu.edu

Figure 21. Get the Assessment Report by Email

5.3.2.6. User Management

A user profile is sometimes important for analyzing the QoSE results. For example, an expert in Geographic Information Systems (GIS) is usually more professional than a common user for a QoSE assessment. Therefore, a user management module is developed, and the profile information list in Figure 22 will be collected. In addition, the client also allows users to share their assessment as a guest. Users can check their logged status in the location shown in Figure 24.

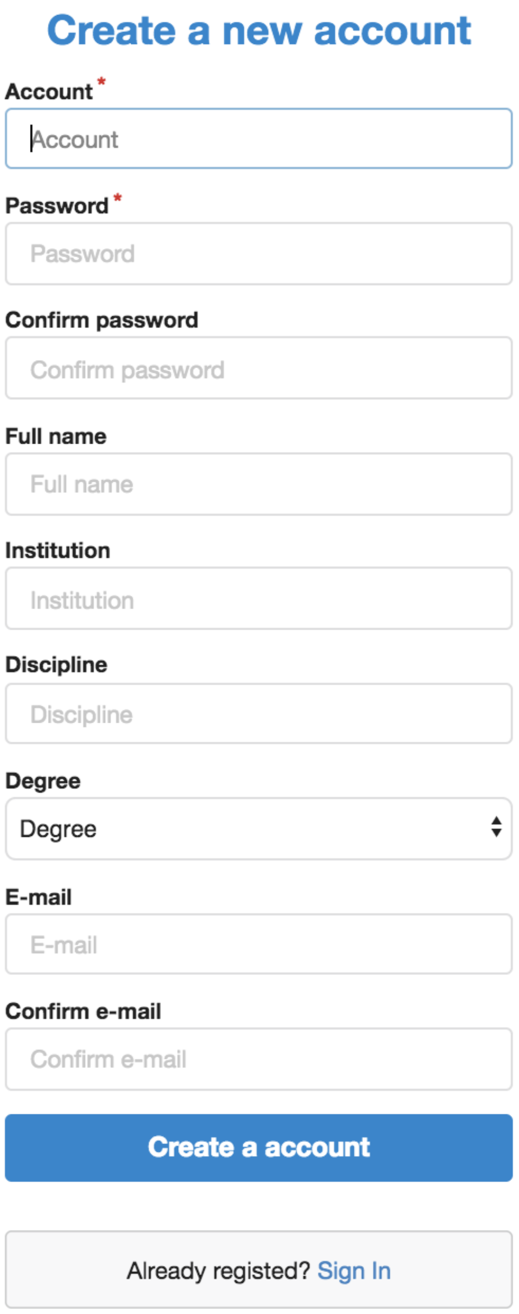


Figure 22. Sign Up

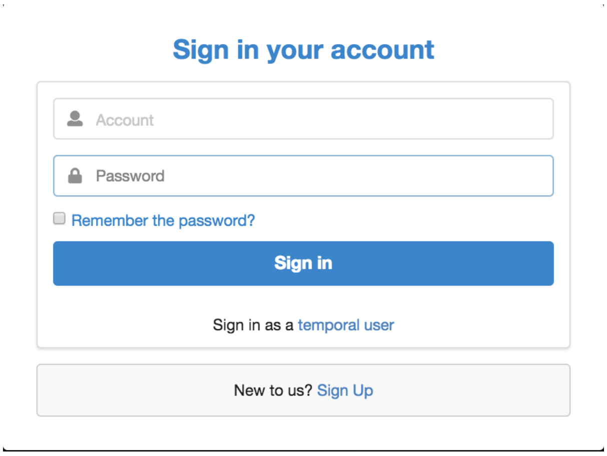
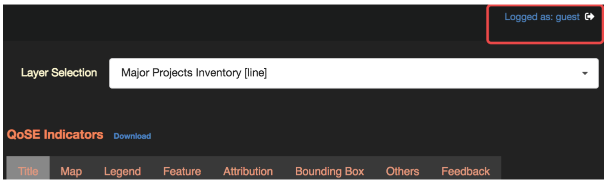


Figure 23. Sign In

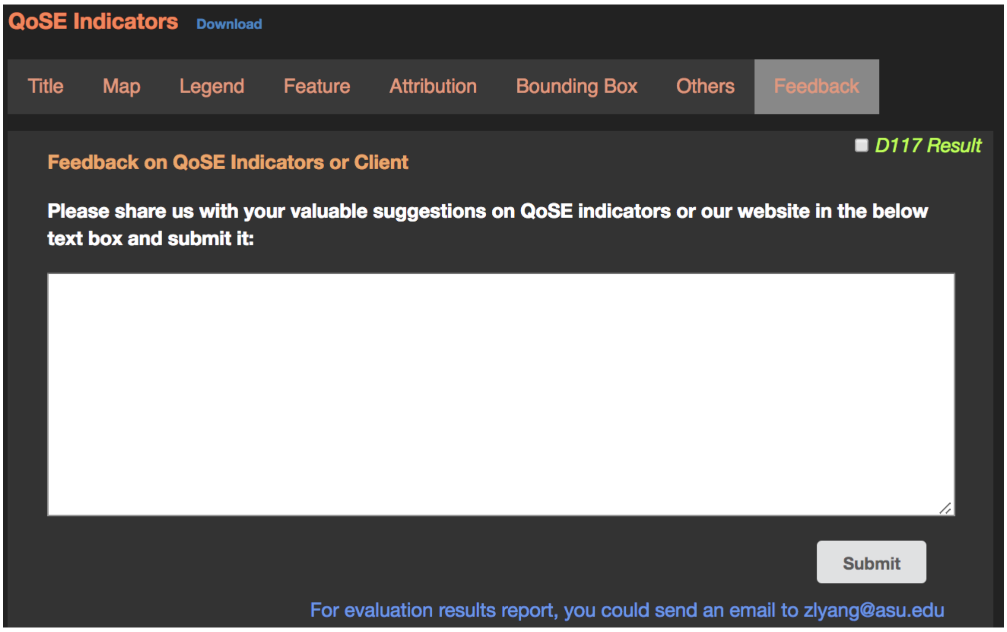


Layer Selection: Major Projects Inventory [line]

Figure 24. Sign Status

5.3.2.7. Feedback Collector

If users want to share their opinions on the QoSE indicators or our client, the feedback menu tab allows them to describe and submit them (Figure 25). Some friendly prompt functions are also developed like those in Figure 27.

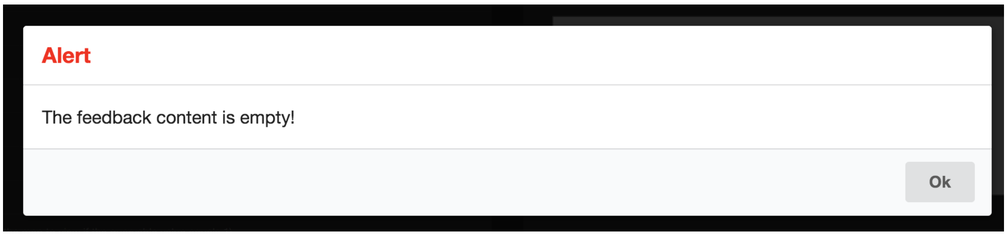


Feedback on QoSE Indicators or Client

Please share us with your valuable suggestions on QoSE indicators or our website in the below text box and submit it:

For evaluation results report, you could send an email to zlyang@asu.edu

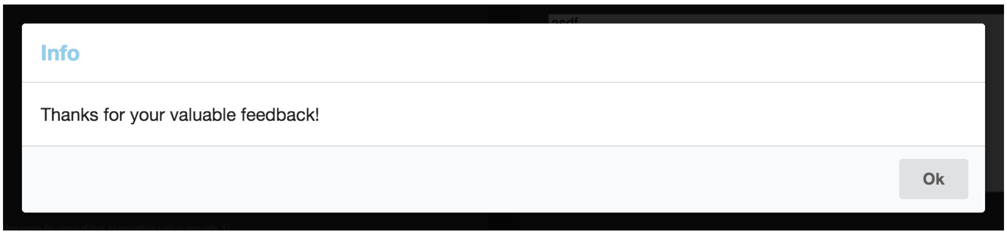
Figure 25. Feedback



Alert

The feedback content is empty!

Figure 26. No Feedback Content Prompt



Info

Thanks for your valuable feedback!

Figure 27. Successful Feedback Prompt

5.4. Test Suite for WMS Service Quality Assessment

The test suite is implemented to programmatically test and validate whether best practices have been successfully implemented, and it can automatically assess part of the quality of service according to the assessment criteria and validate or flag services that do not comply to best practices/recommendations.

5.4.1. Methods

There are tens of assessment criteria and recommendations for assessing the quality of service. Some of them are easy to programmatically test, but some others are too difficult to automatically test, even for people. This section describes which QoSE indicators have been implemented in the current test suite and briefly describes how to test them programmatically. The other QoSE indicators remain unsolved and reasons are summarized in the future research section.

5.4.1.1. Title

The WMS specifications allow WMS providers to edit layer titles as free text. This section removes the special symbols first, and then conducts word segmentation to split the title into individual words.

5.4.1.1.1. Title Length and Uniqueness

The title length could be easily calculated by counting words. Title uniqueness requires the title to start with the most unique or important aspect of the data first. Because different WMS providers organized their layers based on different indicators, the layer title uniqueness calculation on service level is more reasonable than that across all WMS. In addition, it would be a 'big task' to consider all WMS layer titles as more WMS come. To calculate the title uniqueness, the number of each word occurrence is counted among all layer titles in the same WMS. Then a new title could be generated by changing word sequences based on their occurrence time for each title. Finally, the uniqueness is calculated by comparing the new title and the old one.

5.4.1.1.2. Title Readability & Meaningfulness

Title readability plays a key role in measuring the title meaningfulness, and a less readable title is hard to be meaningful. In our test suite, the title readability is measured by the ratio of words in the title, which could be found in the English and French dictionary. Then two thresholds on the ratio are given to split the title as not meaningful, less meaningful and readable. To check whether the title is meaningful, human involved assessment is required.

5.4.1.2. Feature

In WMS specifications, only queryable layers support the GetFeatureInfo operation. Therefore, the queryable attribute value could be used to determine whether corresponding QoSE indicators are applicable. It is hard to download all feature information, because the GetFeatureInfo operation only allows users to request the feature information on one pixel at one time. Here, 100 feature pixels are randomly selected to get their feature attributes in each queryable layer map. Then the duplicated records will be removed. Finally, the feature information table will be used to evaluate the corresponding QoSE indicators.

5.4.1.3. Metadata, Supporting Docs and Abstract

In our current test suite, it can test whether the metadata and supporting docs are available. As for their understandability, it still needs human involvement.

5.4.1.4. Legend

Legend Necessity: An InceptionResnetV2 model is trained to check the legend necessity using manually labeled maps.

5.4.1.5. Map

Map Scaling Consistency: It could be tested by checking whether the minimum and maximum scale denominator exist.

5.4.1.6. Other

5.4.1.6.1. Fees, Access Constraints and Attribution

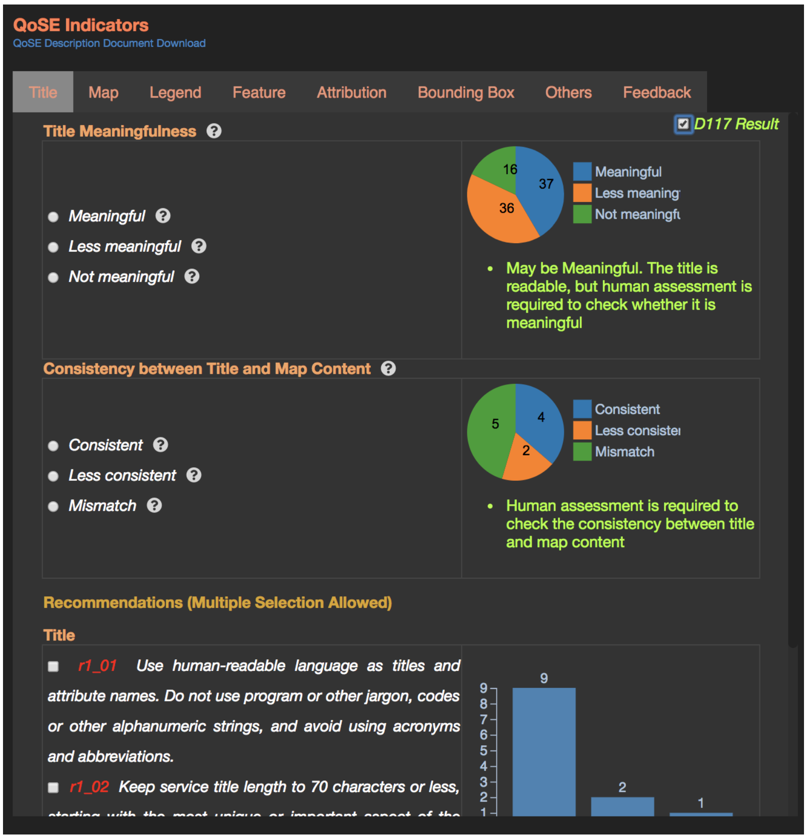
The recommendations related to the above metadata elements could be tested by comparing the elements' values with corresponding descriptions in recommendations.

5.4.1.6.2. Bounding Boxes

To test whether the spatial coverage of a layer map is global, a VGG19 model was trained using some manually labeled maps. As for maps with non-global spatial coverage, it still needs humans to determine.

5.4.2. Results

Because the test suite adopts the same QoSE indicators set as that in the client, the human evaluation results from the client could be used to assess that from the test suite. Therefore, a test suite results presentation module has been implemented, which is located below the statistical graph (Figure). Users can open or close it by checking or unchecking the checkbox named D117 Result in the top-right.



- Meaningful
- Less meaningful
- Not meaningful

- May be Meaningful. The title is readable, but human assessment is required to check whether it is meaningful

- Consistent
- Less consistent
- Mismatch

- Human assessment is required to check the consistency between title and map content

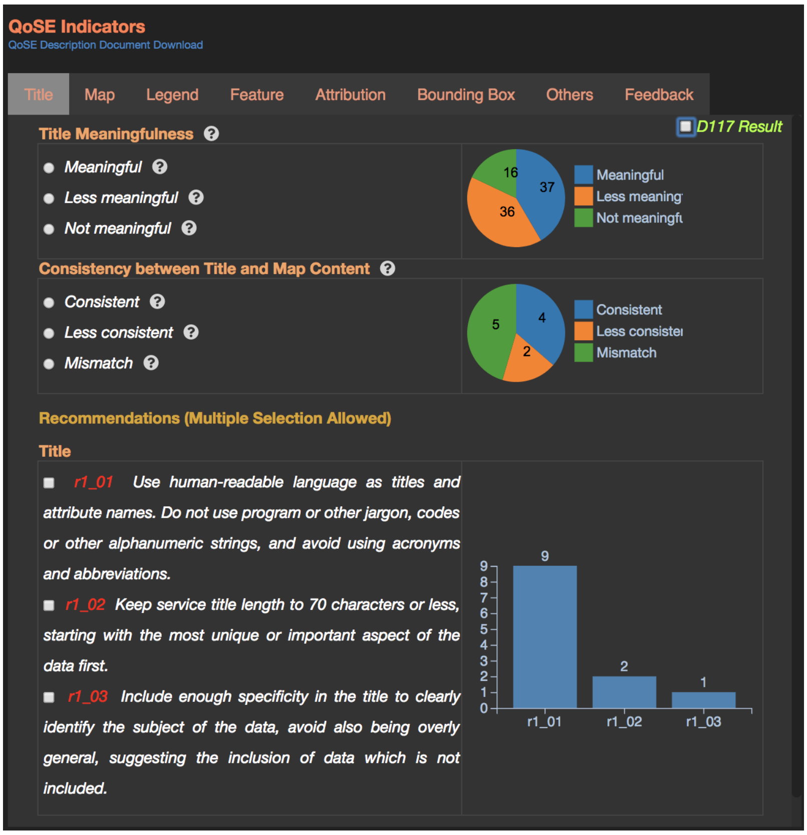
Recommendations (Multiple Selection Allowed)

Title

■ r1_01 Use human-readable language as titles and attribute names. Do not use program or other jargon, codes or other alphanumeric strings, and avoid using acronyms and abbreviations.

■ r1_02 Keep service title length to 70 characters or less, starting with the most unique or important aspect of the

Figure 28. Show Test Suite Results



- Meaningful
- Less meaningful
- Not meaningful

- Consistent
- Less consistent
- Mismatch

Recommendations (Multiple Selection Allowed)

Title

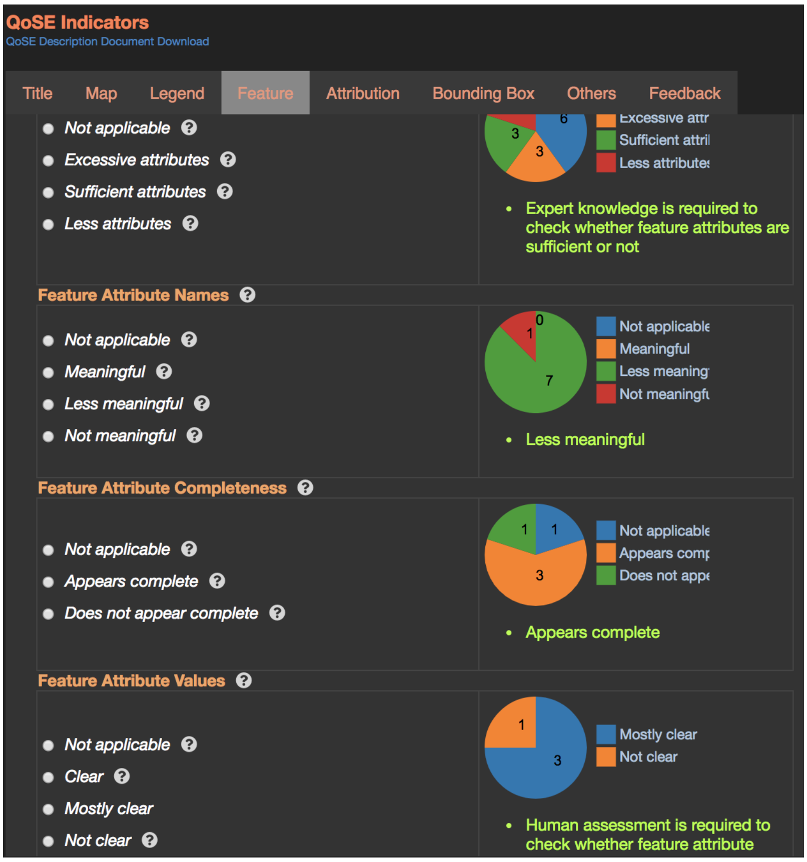
■ r1_01 Use human-readable language as titles and attribute names. Do not use program or other jargon, codes or other alphanumeric strings, and avoid using acronyms and abbreviations.

■ r1_02 Keep service title length to 70 characters or less, starting with the most unique or important aspect of the data first.

■ r1_03 Include enough specificity in the title to clearly identify the subject of the data, avoid also being overly general, suggesting the inclusion of data which is not included.

Figure 29. Hide Test Suite Results

In group discussion, some QoSE indicators are too subjective or too hard for computers to programmatically evaluate them. For example, the feature attribute criteria measure the number and relevance of attributes provided for each feature. To assess it, an expert knowledge database is in demand which should contain attributes' requirements for each feature type in different applications. In the test suite result presentation module, descriptions of difficulty for programmatically assessing them are presented instead of test suite results.



- Not applicable
- Excessive attributes
- Sufficient attributes
- Less attributes

- Expert knowledge is required to check whether feature attributes are sufficient or not

Feature Attribute Names

- Not applicable
- Meaningful
- Less meaningful
- Not meaningful

- Less meaningful

Feature Attribute Completeness

- Not applicable
- Appears complete
- Does not appear complete

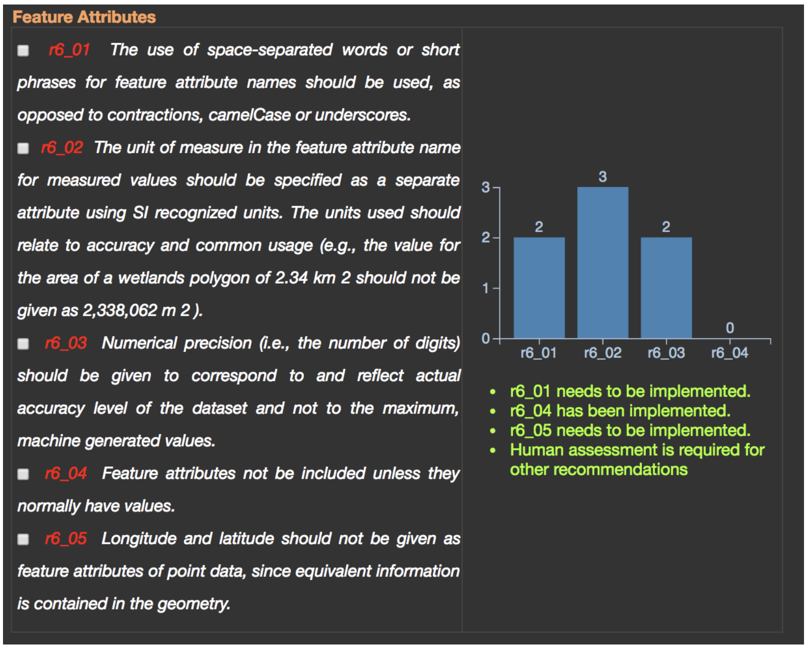
- Appears complete

Feature Attribute Values

- Not applicable
- Clear
- Mostly clear
- Not clear

- Human assessment is required to check whether feature attribute

Figure 30. An example of Test Suite Results on Feature Related Criteria



Feature Attributes

- ■ r6_01 The use of space-separated words or short phrases for feature attribute names should be used, as opposed to contractions, camelCase or underscores.
- ■ r6_02 The unit of measure in the feature attribute name for measured values should be specified as a separate attribute using SI recognized units. The units used should relate to accuracy and common usage (e.g., the value for the area of a wetlands polygon of 2.34 km 2 should not be given as 2,338,062 m 2).
- ■ r6_03 Numerical precision (i.e., the number of digits) should be given to correspond to and reflect actual accuracy level of the dataset and not to the maximum, machine generated values.
- ■ r6_04 Feature attributes not be included unless they normally have values.
- ■ r6_05 Longitude and latitude should not be given as feature attributes of point data, since equivalent information is contained in the geometry.

- r6_01 needs to be implemented.
- r6_04 has been implemented.
- r6_05 needs to be implemented.
- Human assessment is required for other recommendations

Figure 31. An Example of Test Suite Results on Feature Related Recommendations

Note that test results of the JMeter (see next section) component have been integrated into the portal, under the tab “Performance Load Reports”. GeoSolutions' QoS monitor, outlined later, is also integrated into the portal, under the tab “QoS Monitor”.

5.5. WMS Stress Testing with JMeter

Note that the decision to use JMeter as the tool for running the stress tests was not a requirement by the sponsors, rather it was based on a QoSE Testbed-14 team discussion. Other software alternatives, such as GeoHealthCheck (mentioned later in this report) and Spatineo Monitor, could of course be used to accomplish the same or similar results. Apart from stress testing, these tools can be used for monitoring the OGC Web Service availability and its changes over longer periods; however, here integration with (these) other tools was not considered.

5.5.1. On stress testing and benchmarking

Stress testing is crucial to investigating the behavior of infrastructure or an application under heavy load. It usually involves measuring the following:

- Scalability, as in the ability to keep performing under increasing loads
- Speed, as in the ability to respond with acceptable and stable response time to requests

Note: There needs to be a discussion or agreement on stress testing against operational services with the server and service provider in order to avoid formal blocking of requests by the provider.

From an implementation/deployment standpoint the goal of stress testing is to gather concrete numbers about the characteristics that can be used over time to check the effect of evolutions. It can also be used to dimension hardware infrastructure and redundant deployments as well as to impose QoS restrictions to protect production deployment (e.g. limit number of parallel requests to a value that is closer but lower than the maximum throughput).

From a developer standpoint stress testing is also important in order to investigate software and architectural bottlenecks. As a developer trying to assess scalability, performance and availability of an infrastructure the goal is to hit the latter with a load that can force it to its limits (i.e. maximum resource utilization) and then analyze the effect on the underlying resources, find the bottleneck, fix it and then move to the next one. As an instance, bottlenecks can be identified in a WMS implementation (e.g. unnecessary synchronizations or inefficient code of sort) by not being able to fully exploit Central Processing Unit (CPU) and Memory under huge load. By experience, if at increasing load the throughput falls and the response time significantly increases but CPUs and/or memory are not fully utilized this is a clear indication that unless the implementation is being affected by slow Input/Output (slow disk, slow DBMS), then the implementation has some bottlenecks that need fixing.

Given what is written above, stress testing and benchmarking is an activity that should encompass the entire lifecycle of an infrastructure; it should be done during development. To do a sanity check on written code and chosen components, stress testing should also be done at deployment time to ensure proper dimensioning, it should also be done periodically when in production to double check and reconcile assumptions and expectation with reality. All this falls under the umbrella of Application Performance Management (https://en.wikipedia.org/wiki/Application_performance_management).

A useful case for stress testing is whenever server software, data sources or their configurations are changed: stress testing before and after modifying the service would verify if everything is still working as expected, or if the made changes had a real effect on service performance.

5.5.2. JMeter introduction

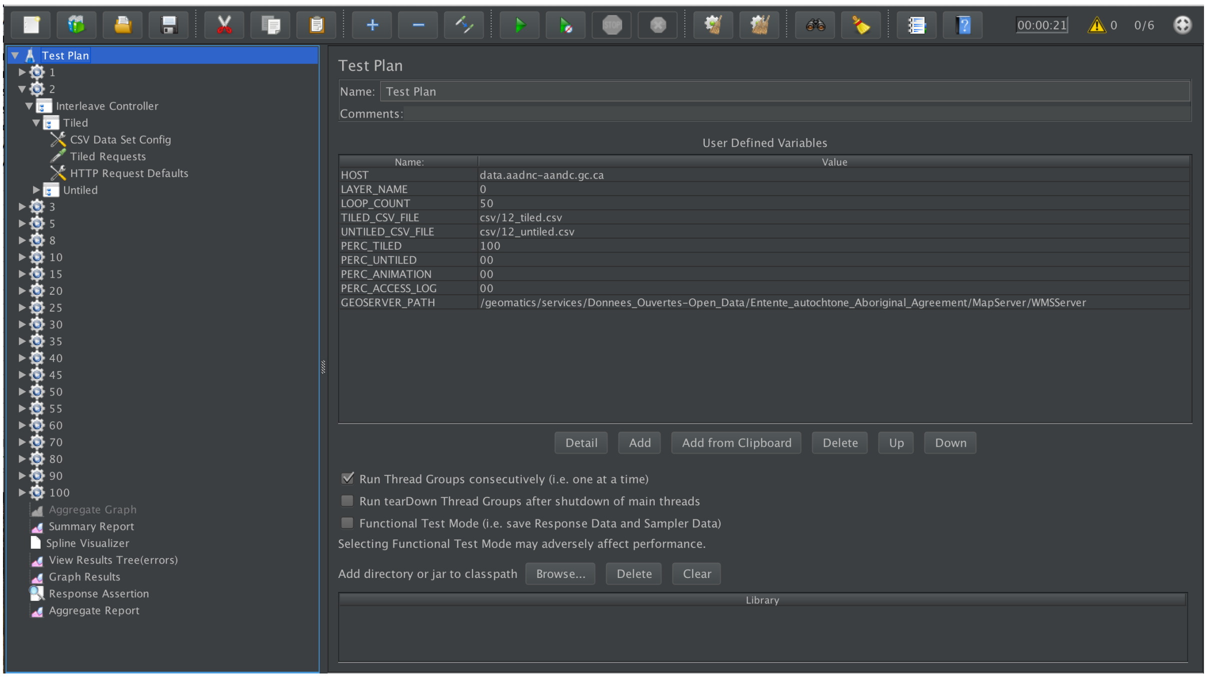
Apache JMeter (http://jmeter.apache.org/) is a popular open source tool used to load test (or stress test) web applications. JMeter lets us send an arbitrary amount of custom tailored OGC WMS requests to server applications to derive information about response time, throughput and availability of the services against heavy load conditions. Some of JMeter points of strength are mentioned below:

- Open source and free to use software
- It ships with an easy-to-use GUI;
- It allows to set up multiple thread groups, different parallelism and request count, to ramp up the load;
- It can use Comma-Separated Value (CSV) files to generate semi-randomized requests (needed to bypass server cache);
- It can execute parameterized tests;
- It reports results in simple tables and text files;
- It uses assertions for checking test results;
- It can be executed in headless mode (i.e. without the GUI) as part of a larger script.
- It is supported by a large active community. Multiple open source plugins have been developed by its community that make the tool applicable for tests to many different websites.

Within JMeter, a web performance test can be built, executed and analyzed.

1. **Building web performance test plan**: Building a test plan in JMeter for a WMS is fairly straightforward. First, define a set of variables that describe the specifics of the WMS and the global parameters for the entire run (in the case of Testbed-14 the path to the tiled or untiled variable domains, the throughput and the number of loops each ‘user’ should query the WMS. Depending on the type of test, specify a set of ‘threads’ or concurrent users to simulate parallel querying of the WMS. And finally define a number of reports and graphs to capture the results of the test.
2. **Executing your test**: Once a test plan has been built, there are various ways to run the test. This can be done either through the GUI or through the command line. The most preferable way is using the command line but due to limited time Testbed-14 chose the GUI to run the performance tests. The test environment can influence the performance test results (see below). Setup the JMeter tests outside the WMS infrastructure to avoid the test influencing the behavior of the WMS and if possible, a cloud service should be used simply as the load cannot be generated by a single server to simulate a large number of real users due to limited hardware resources of a single computer. Testbed-14 chose to use an Amazon Cloud service made available by GeoSolutions to run the JMeter load tests.
3. **Analyzing test results**: Load test results can be saved as CSV files. Testbed-14 chose to analyze how the ‘transaction throughput’ would behave with increasing the number of threads, and the same for response time. For this test, the result reports created include the raw data as well as graphs of: a) transaction throughput versus threads and, b) Response time versus threads. These are created both for WMS tiled and untiled services of the same WMS.

Figure 32 shows an example of a JMeter load test plan, showing the global variables, a set of threads (1-100) and some result output options (summary reports and graphs).



Test Plan

Name: Test Plan

Comments:

User Defined Variables

Name:	Value
HOST	data.aadnc-aandc.gc.ca
LAYER_NAME	0
LOOP_COUNT	50
TILED_CSV_FILE	csv/12_tiled.csv
UNTILED_CSV_FILE	csv/12_untiled.csv
PERC_TILED	100
PERC_UNTILED	00
PERC_ANIMATION	00
PERC_ACCESS_LOG	00
GEOSERVER_PATH	/geomatics/services/Donnees_Ouvertes-Open_Data/Entente_autochtone_Aboriginal_Agreement/MapServer/WMSServer

☑ Run Thread Groups consecutively (i.e. one at a time)

☐ Run tearDown Thread Groups after shutdown of main threads

☐ Functional Test Mode (i.e. save Response Data and Sampler Data)

Selecting Functional Test Mode may adversely affect performance.

Add directory or jar to classpath

Figure 32. Load test plan in JMeter

For a more thorough discussion on JMeter and its capabilities, the reader is referred back to the official JMeter documentation as well as to the GeoSolutions training which contains a section on how to stress test GeoServer using JMeter (https://geoserver.geo-solutions.it/edu/en/enterprise/jmeter.html).

As mentioned above, performance tests have the objective of probing the swiftness and behavior of a service under various load levels. Performance tests also reconstruct the throughput and average response time curves under increasing concurrent load to simulate different real-world conditions. In order to do so, JMeter test plans send an increasingly higher number of concurrent WMS requests to test services performance under various load conditions.

Below the most important points to consider when setting up a stress test plan; this ER will then discuss how one of these test plans is set up.

5.5.3. Simulating concurrent users

Generally speaking, software developers tend to associate a single user to a single thread in JMeter to send requests. When it comes to WMS this is partially true since, if an end-user is interacting with a WMS service via a web-based applications that uses map-tiling, a single user can send up to 6 requests in parallel (depending on the web browser of choice) and even more if tricks like setting up multiple names for the same cluster under tests have been set up.

So the equivalent between threads in a JMeter ThreadGroup and end-users needs to be evaluated on a case by case basis. However, when if doubt it is safe to assume that JMeter can simulate a single user interaction with a single thread.

5.5.4. Separation from the tested infrastructure

JMeter uses multithreading to simulate concurrent users, by having multiple threads sending requests in parallel and therefore when trying to simulate a huge load it can become quite heavy on the underlying infrastructure. Rule of thumb is therefore to avoid adding extra load to the infrastructure that is being stress tested by having JMeter run on a different one.

It is important to remark on the fact that a number of online services that can be used to generate a huge load based on a JMeter plan. In the past GeoSolutions have used https://flood.io/ for testing a large infrastructure, but there are other options like https://www.blazemeter.com/. In addition, JMeter can be used to run distribute tests by exploiting multiple slave machines from a single master as explained in the JMeter documentation (https://jmeter.apache.org/usermanual/jmeter_distributed_testing_step_by_step.pdf).

5.5.5. Impact of Network and other tools

When planning and executing a stress test with JMeter, carefully evaluate the impact of all the tools that sit between JMeter and the infrastructure that is being tested. This includes:

- Network capacity and eventual QoS configurations (firewall and so on). It is necessary to make sure that the network bandwidth and network devices in between JMeter and the infrastructure to test do not become bottlenecks and then generate results that are worse than could be achieved. The typical examples are poor outbound bandwidth on the server-side or anti Distributed Denial-of-Service (DDoS) protections at the firewall level which could impede huge parallel loads on the infrastructure when testing.
- It is necessary to make sure that, while running the tests, no other component apart from those that are being tested is generating load on the underlying hardware infrastructure. Failure to do so could lead to false results. The opposite is also true, it is necessary to make sure that the tests will not impact other critical parts of the overall infrastructure.

5.5.6. Synthetic requests versus real-world requests

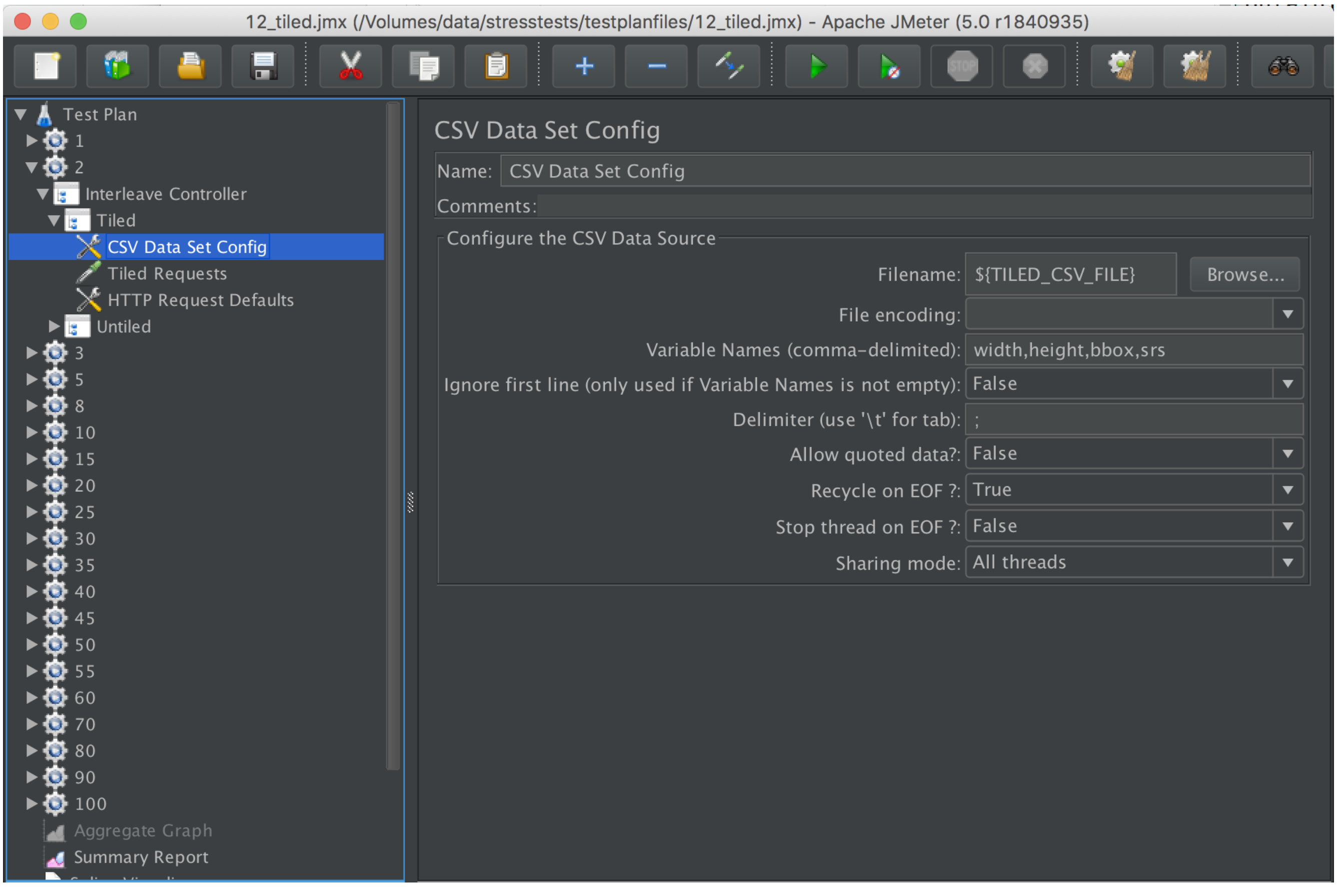
It is obviously crucial that the requests used to generate the stress test load are as representative as possible of real-world usage patterns. This is possible for systems that have already been launched and made accessible to end-users (e.g. by collecting and curating access logs) but it is not always possible for pre-flight stress tests; moreover it is always important to somehow randomize requests (see also below) in order to discover bad behaviors that are not always obvious during normal usage.

In general, so-called synthetic requests tend to be created starting from valid WMS requests and then randomizing in a controlled manner some of the parameters like BBOX, width, height and so on. Often, mixed stress tests tend to be used where some of the requests are real-world requests and others are synthetic requests.

5.5.7. Randomization of requests parameters

Some of the parameters of each request (width, height, bounding box) are varied continuously to avoid aggressive caching on the server-side, this is done using JMeter "CSV Data Set Config" element that allows us to fetch the above-mentioned parameters from pre-generated Comma-Separated Value (CSV) files containing pseudo-random values for each of the parameters as described below.

A way to perform this randomization is given by using a feature within JMeter that allows use of an external CSV file to override certain default parameters of a WMS request using the values taken from the CSV file itself. An example is shown below(Figure 33). Web Map Services can be set up as tiled and untiled services. For each an external CSV with chaning boundary boxes has to be specified.



CSV Data Set Config

Name: CSV Data Set Config

Comments:

Configure the CSV Data Source

Filename: ${TILED_CSV_FILE}

File encoding:

Variable Names (comma-delimited): width,height,bbox,srs

Ignore first line (only used if Variable Names is not empty): False

Delimiter (use '\t' for tab): ;

Allow quoted data?: False

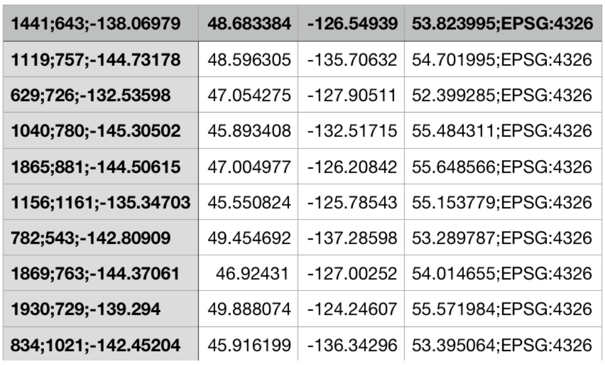
Recycle on EOF ?: True

Stop thread on EOF ?: False

Sharing mode: All threads

Figure 33. CSV Data Set Config element within JMeter

The config in the previous figure is responsible for fetching parameters from CSV files (file system path set in the TILED_CSV_FILE variable). An example of an external CSV file is given in Figure 34.



1441;643;-138.06979	**48.683384**	**-126.54939**	**53.823995;EPSG:4326**
1119;757;-144.73178	48.596305	-135.70632	54.701995;EPSG:4326
629;726;-132.53598	47.054275	-127.90511	52.399285;EPSG:4326
1040;780;-145.30502	45.893408	-132.51715	55.484311;EPSG:4326
1865;881;-144.50615	47.004977	-126.20842	55.648566;EPSG:4326
1156;1161;-135.34703	45.550824	-125.78543	55.153779;EPSG:4326
782;543;-142.80909	49.454692	-137.28598	53.289787;EPSG:4326
1869;763;-144.37061	46.92431	-127.00252	54.014655;EPSG:4326
1930;729;-139.294	49.888074	-124.24607	55.571984;EPSG:4326
834;1021;-142.45204	45.916199	-136.34296	53.395064;EPSG:4326

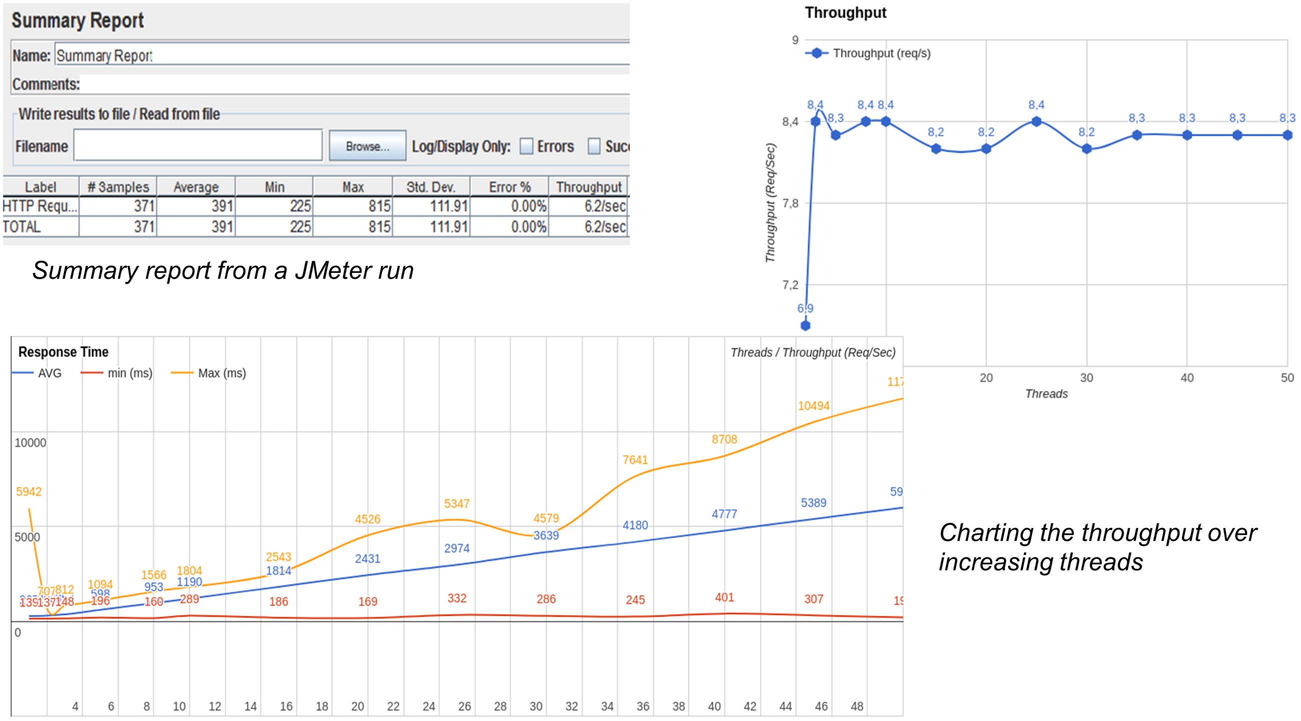
Figure 34. Example of an external CSV file

Fields are separated by a semicolon, the first two represent the values for width and height, next is the coordinates for the bounding box followed by the reference system for these coordinates.

A number of scripts exist already for the generation of the randomized parameters. GeoSolutions has put together Python scripts that can be used to generate parameters for WMS requests (and also for other services). These are available in a public GitHub repository (https://github.com/geosolutions-it/scripts/tree/master/performance_tests/WMS.

5.5.8. Putting together the results

JMeter can produce the results in Hypertext Markup Language (HTML) outputs but this output is somewhat cumbersome and requires some plugins and an installation hosted on a web server. GeoSolutions typically uses spreadsheets to record the output of the JMeter plans (shown below in Figure 35) using the number of threads as the independent variable and the throughput and response time as the dependent variable. Below are some examples charts for throughput and response time.



Summary Report

Name: Summary Report

Comments:

Write results to file / Read from file

Filename | Browse... | Log/Display Only: □ Errors □ Suc

Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput
HTTP Requ...	371	391	225	815	111.91	0.00%	6.2/sec
TOTAL	371	391	225	815	111.91	0.00%	6.2/sec

Summary report from a JMeter run

Charting the throughput over increasing threads

Figure 35. Output of the JMeter

5.5.9. JMeter case study example

To demonstrate the use of JMeter for this study we choose to do a load performance test on the WMS that is made available through: https://open.canada.ca/data/en/dataset/be0a3350-f755-418e-b04b-7ff9fd2ebeac. And choose a layer named “0”. This layer was selected using QGIS and represents geospatial data of “Pelagic Seabird Atlas, West Coast of Canada - Average Grid Cell Density, 2009” and has the following boundary box: -147.0,45.16666699999999968 : -123.08333299999999961,56.0 (see Figure 36).

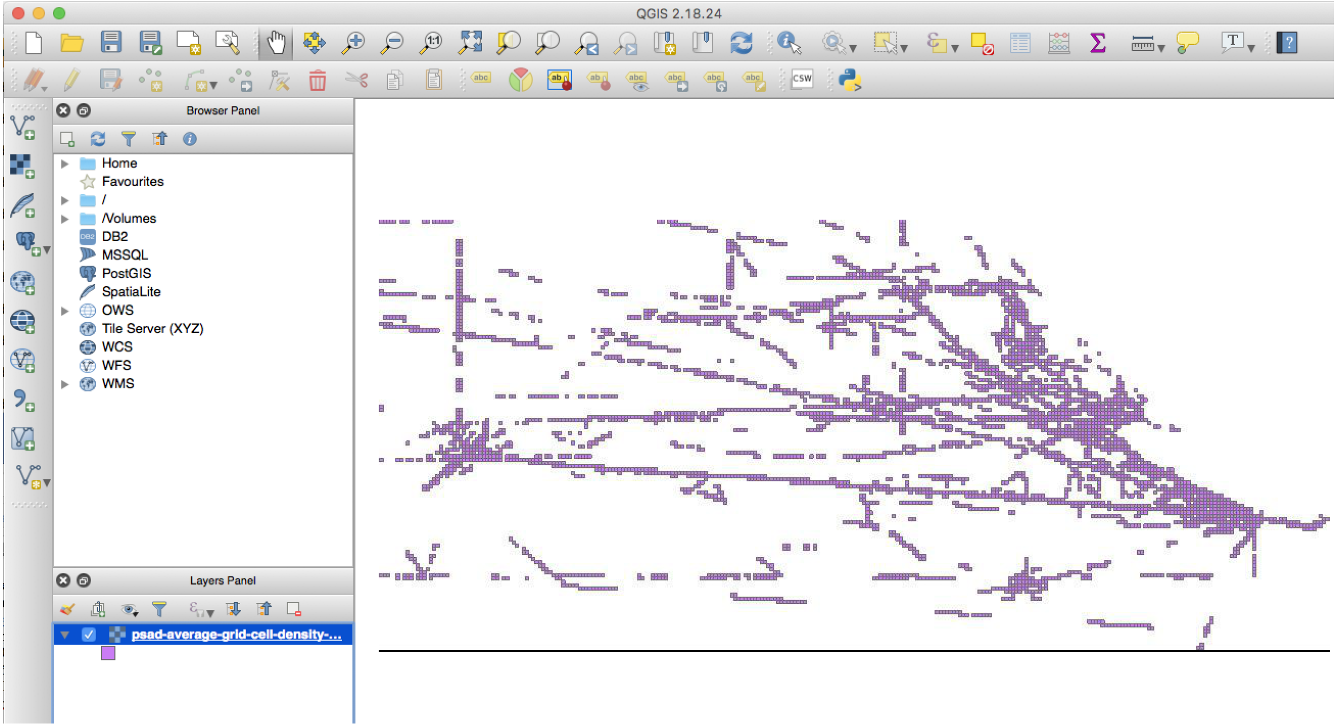
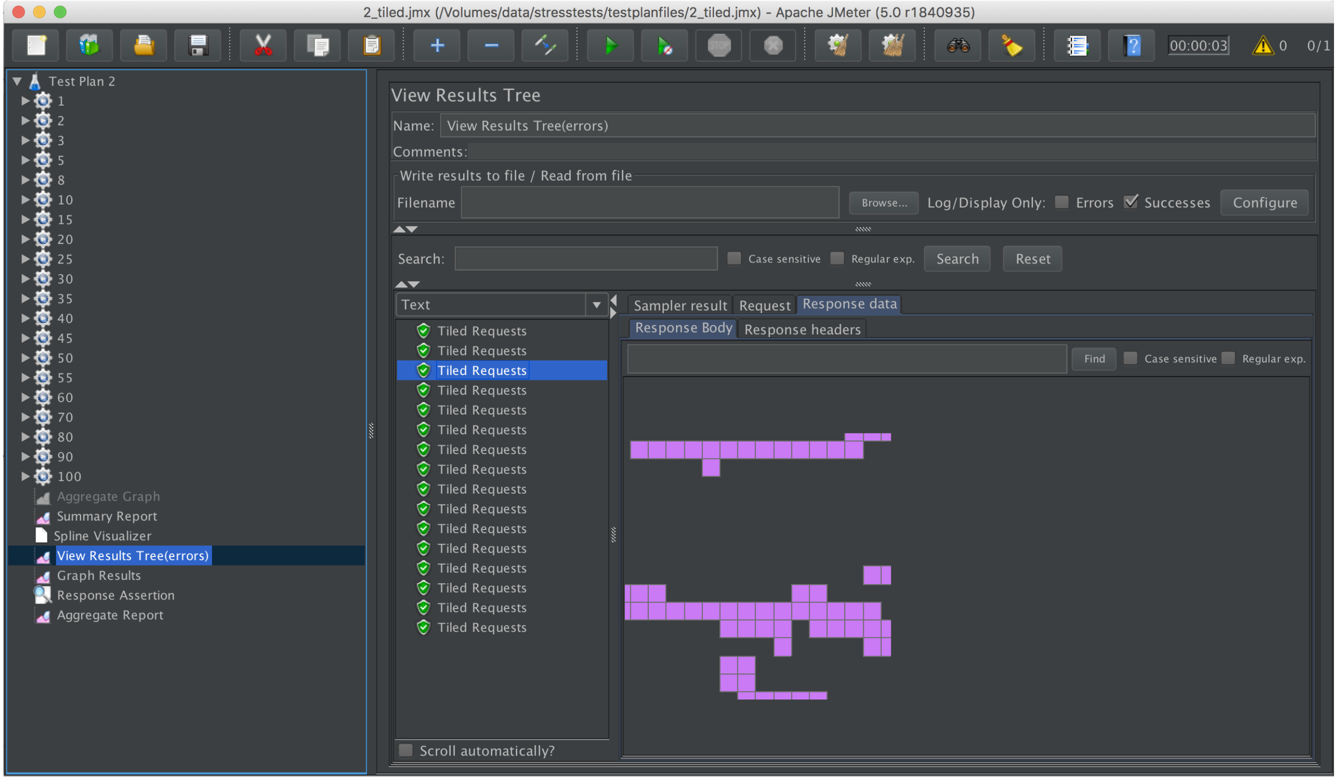


Figure 36. QGIS representatation of the WMS data that is used for the performance test

This maximum boundary box was used to generate tiled and untiled variable boundary boxes with changing height and with running the script provided by GeoSolutions to a CSV file, similar as is shown in Figure 34. Once the tiled and untiled CSV files are in place the load performance test plan is built in JMeter (similar as shown in Figure 32). All in-place test runs should be conducted to make sure that JMeter receives data about the WMS when querying for tiled and untiled services. Make sure to log successful connections. These test runs can be done on a desktop in the JMeter GUI environment, and if all works well should show a snapshot of the geospatial data each time JMeter sends out a data request, see Figure 37.


2_tiled.jmx (/Volumes/data/stresstests/testplanfiles/2_tiled.jmx) - Apache JMeter (5.0 r1840935)

View Results Tree

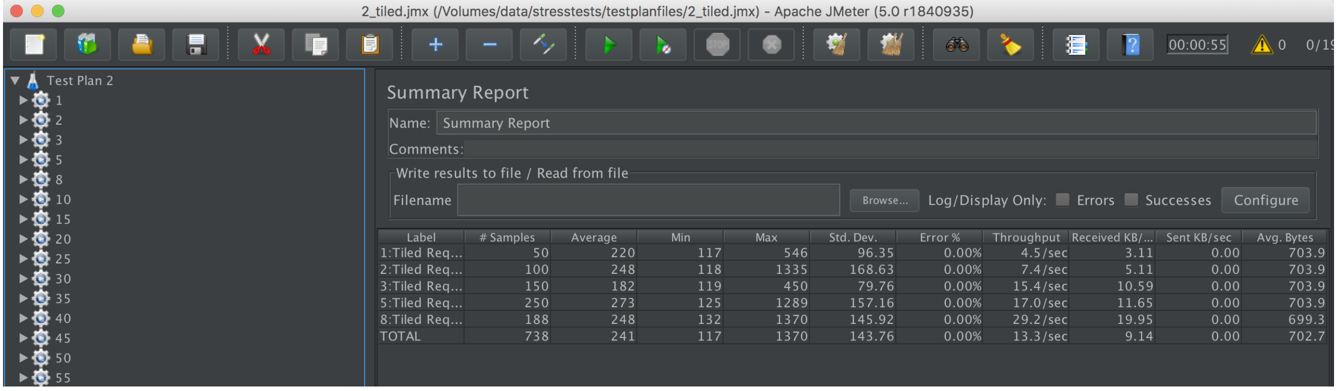
Name: View Results Tree(errors)

Log/Display Only: □ Errors ☑ Successes

Figure 37. JMeter representation of successfully retrieved WMS data

Potentially, parameters need to be tweaked to be able to receive spatial data. Testbed-14 participants found that they could not create the variable boundary boxes captured by the CSV files for all WMS instances provided by Natural Resources Canada. Especially for datasets that cover only a very small spatial area these variable boundary boxes could not be generated and therefore the WMS site could not be tested. Also, for some WMS the tiled option was not activated and therefore this WMS capability could not be tested either.

Successful load performance tests are then moved and executed in the cloud. Running in the cloud, a summary report informs (see Figure 38) the user of the state of the execution and a graphical report (see Figure 39) provides a first indication of the performance of the WMS instance over time.


2_tiled.jmx (/Volumes/data/stresstests/testplanfiles/2_tiled.jmx) - Apache JMeter (5.0 r1840935)
00:00:55
0
Test Plan 2
1
2
3
5
8
10
15
20
25
30
35
40
45
50
55

Summary Report

Name: Summary Report

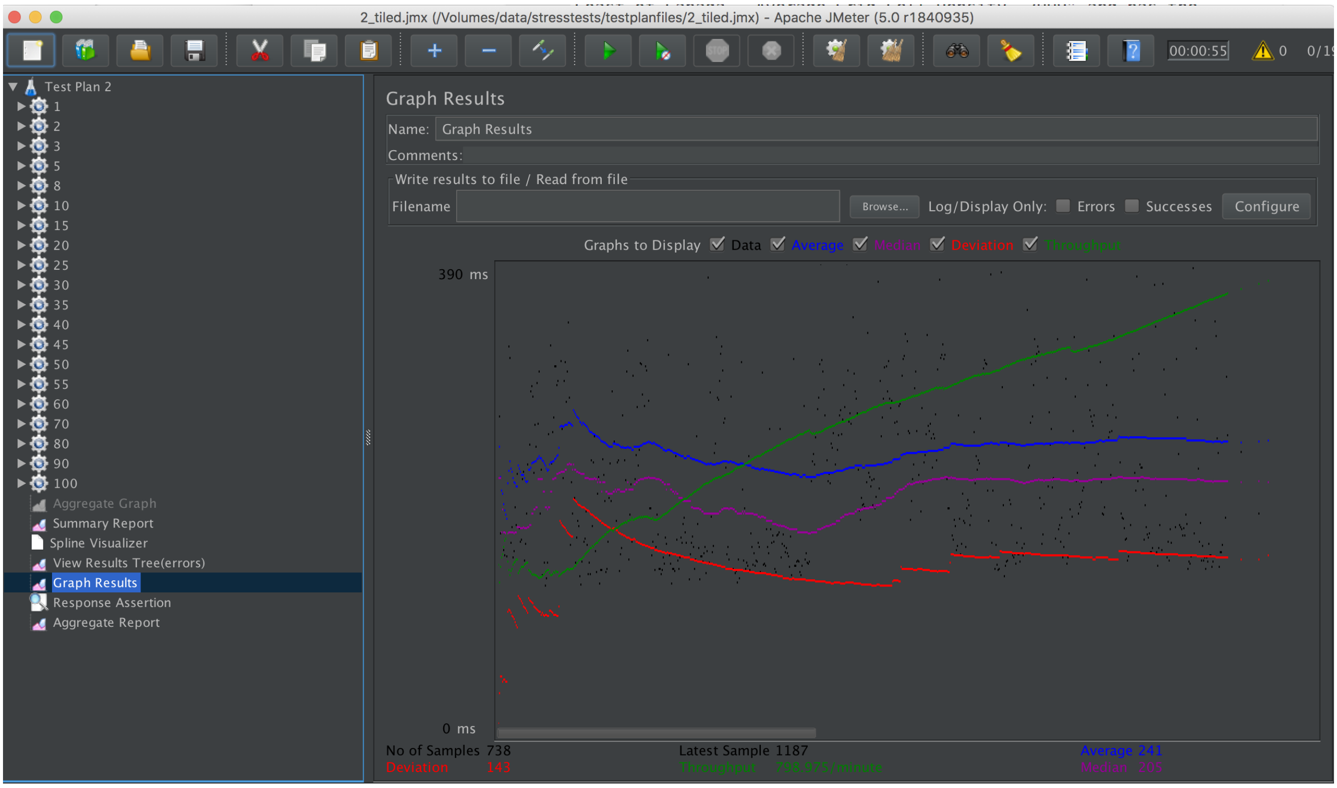
Comments:

Write results to file / Read from file

Filename [Browse...] Log/Display Only: □ Errors □ Successes [Configure]

Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received KB/...	Sent KB/sec	Avg. Bytes
1:Tiled Req...	50	220	117	546	96.35	0.00%	4.5/sec	3.11	0.00	703.9
2:Tiled Req...	100	248	118	1335	168.63	0.00%	7.4/sec	5.11	0.00	703.9
3:Tiled Req...	150	182	119	450	79.76	0.00%	15.4/sec	10.59	0.00	703.9
5:Tiled Req...	250	273	125	1289	157.16	0.00%	17.0/sec	11.65	0.00	703.9
8:Tiled Req...	188	248	132	1370	145.92	0.00%	29.2/sec	19.95	0.00	699.3
TOTAL	738	241	117	1370	143.76	0.00%	13.3/sec	9.14	0.00	702.7

Figure 38. JMeter Summary report of a WMS instance, showing the number of loops for each thread it has processed already



Graph Results

Name: Graph Results

Comments:

Write results to file / Read from file

Filename [Browse...] Log/Display Only: □ Errors □ Successes [Configure]

Graphs to Display ☑ Data ☑ Average ☑ Median ☑ Deviation ☑ Throughput

No of Samples 738 Latest Sample 1187 Average 241
Deviation 143 Throughput 798.975/minute Median 205

Figure 39. JMeter graphical representation of the performance of a WMS instance.

Two informative diagrams (Transaction Throughput and Response Time) are generated for each WMS instance that a load performance test is created for in the cloud (Figure 40). The graph on the left shows how transaction throughput time increases with increasing number of threads (concurrent users) until it levels out. So basically, it shows the statistical maximum possible number of transactions based on number of users accessing the WMS. Any more users that query the WMS at the same time will not affect the transaction throughput time anymore. In this case that happens after 35 to 40 users for the tiled service (orange line) and already at between 5 to 8 users for the untiled service (blue line). The graph on the right shows 2 interesting things. First, the untiled service (blue line) has significant slower responses with increasing threads (from 2 to 14 seconds). Secondly, for the tiled WMS service, the response time does start to increase with increasing users at around 30-35 threads but stays below 2 seconds, even with a 100 threads (users, each querying the WMS with 50 requests).

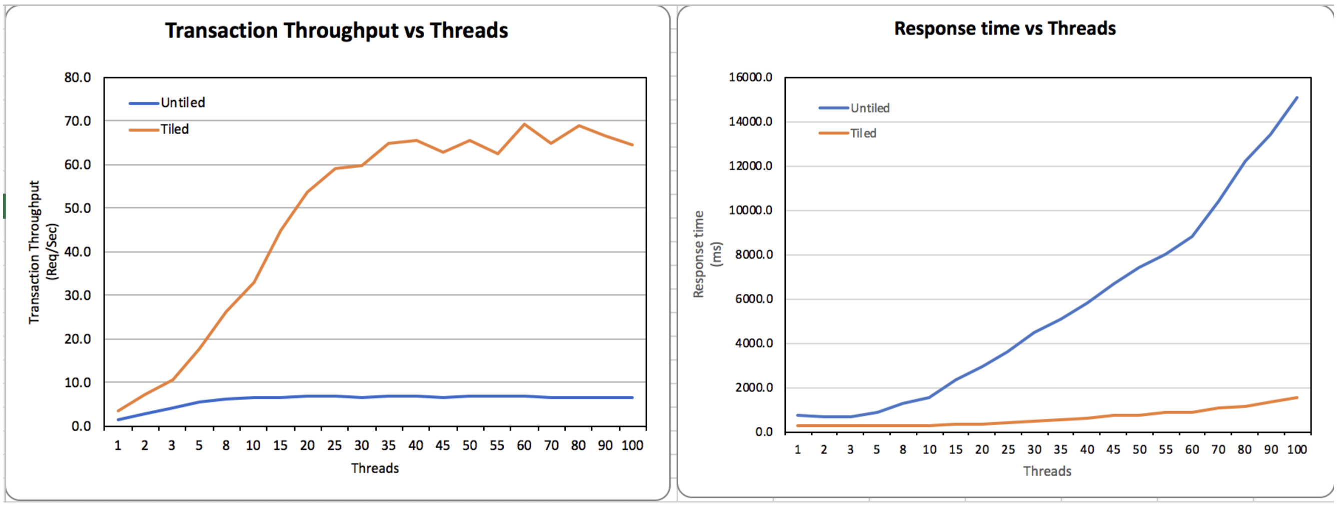


Figure 40. Transaction Throughput and Response Time, both per increasing number of threads.

5.5.10. Integration with other QoS tools

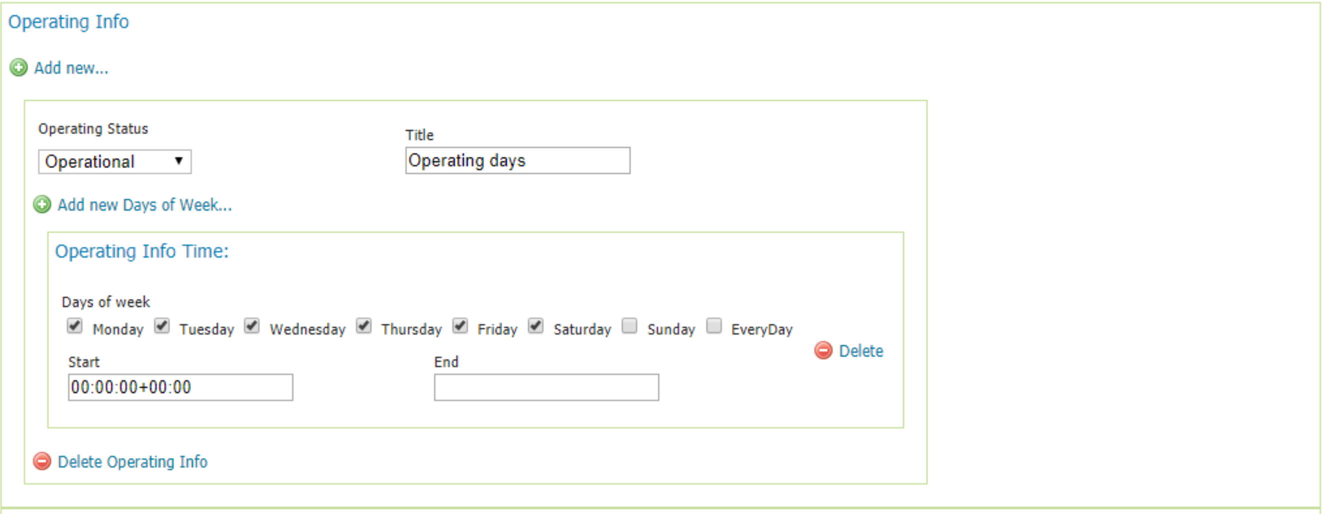
JMeter stress tests are ran, over time, for a variety of WMS provided by Natural Resources Canada (NRCan). NRCan is in the process of migrating some of their provided WMS to another platform, and this provides a perfect opportunity to see if the hosted WMS will perform better when migrated over. The stress tests reports will be made available online, such that they can be easily integrated into the "GUI for WMS Service Quality Assessment" effort mentioned above.

5.6. GeoServer Extension for QoS

Over the past year, the OGC QoSE DWG has established a set of basic QoS indicators as acknowledged key performance indicators of spatial data service instances or endpoints. The aim is to improve the quality of the web services and Application Programming Interfaces (APIs), including factors like availability, capacity and performance by using well-defined metrics in order to provide comparable QoS measurements. The declared QoSE metadata will contribute to a complete picture of the QoS of the entire Spatial Data Infrastructure (SDI), and more effectively maintain high QoE for its end-users.

GeoSolutions has implemented an extension for WMS and Web Feature Service (WFS) functionality in GeoServer that allows the administrator to declare several statements of the service such as:

- Operating Info - Video Tutorial [https://youtu.be/EQaeDAkLySc]
    - Operational status (test/demo/beta/production etc.)
    - Operating days & hours (default: 24/7)



Operating Info

Add new...

Operating Status: Operational ▼

Title: Operating days

Add new Days of Week...

Operating Info Time:

Days of week

☑ Monday ☑ Tuesday ☑ Wednesday ☑ Thursday ☑ Friday ☑ Saturday □ Sunday □ EveryDay

Start: 00:00:00+00:00

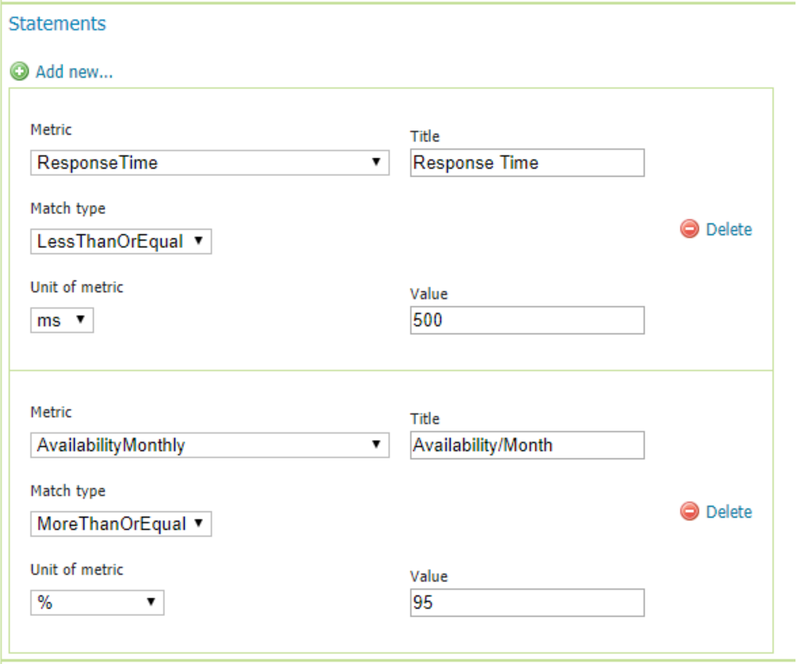
End:

Delete

Delete Operating Info

Figure 41. Operating Info

- QoS statements of the entire service - Video Tutorial [https://youtu.be/JpimmBmmxAU]
  - Metrics & minimum values to be expected, performance, availability, capacity etc.



Statements

Add new...

Metric: ResponseTime ▼

Title: Response Time

Match type: LessThanOrEqual ▼

Delete

Unit of metric: ms ▼

Value: 500

Metric: AvailabilityMonthly ▼

Title: Availability/Month

Match type: MoreThanOrEqual ▼

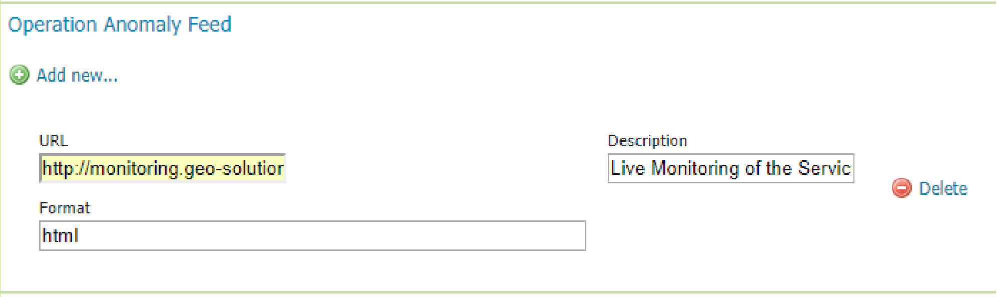
Delete

Unit of metric: % ▼

Value: 95

Figure 42. Metrics Statements Declaration

- Operation Anomaly Feed - Video Tutorial [https://youtu.be/6zFrfhz6cEM]
  - Maintenance periods, downtimes



Operation Anomaly Feed

Add new...

URL: http://monitoring.geo-solutior

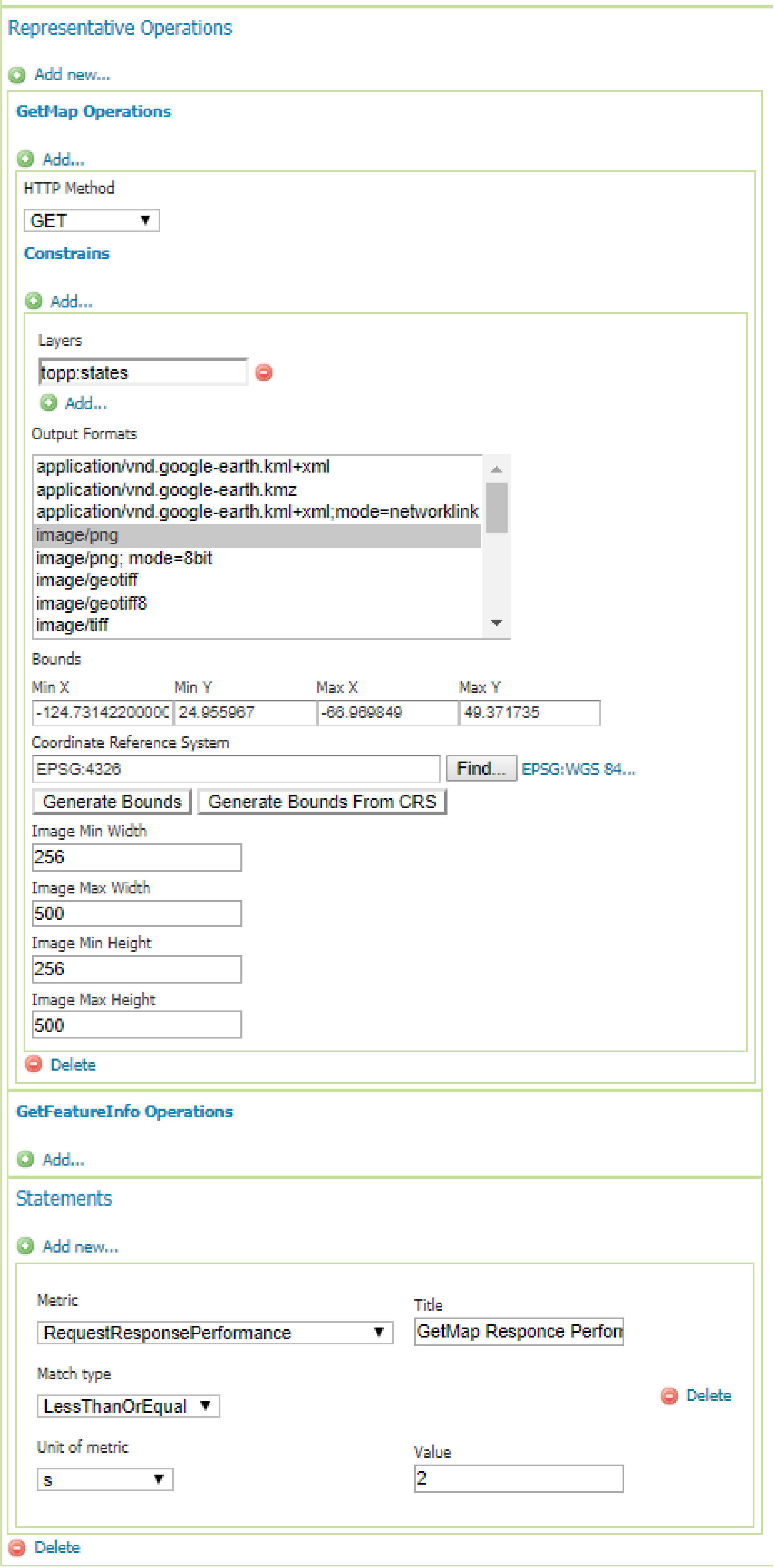
Description: Live Monitoring of the Servic

Delete

Format: html

Figure 43. Operation Anomaly Feed

- Representative operations - Video Tutorial [https://youtu.be/FS-h7wjf0TI]
  - QoS statements for given operations & limited request parameters
  - Auto-configuration for QoS monitoring tools



Representative Operations

Add new...

GetMap Operations

Add...

HTTP Method

GET ▼

Constrains

Add...

Layers

topp:states

Add...

Output Formats

- application/vnd.google-earth.kml+xml
- application/vnd.google-earth.kmz
- application/vnd.google-earth.kml+xml;mode=networklink
- image/png
- image/png; mode=8bit
- image/geotiff
- image/geotiff8
- image/tiff

Bounds

Min X	Min Y	Max X	Max Y
-124.73142200000	24.955967	-66.969849	49.371735

Coordinate Reference System

EPSG:4326 Find... EPSG:WGS 84...

Generate Bounds | Generate Bounds From CRS

Image Min Width

256

Image Max Width

500

Image Min Height

256

Image Max Height

500

Delete

GetFeatureInfo Operations

Add...

Statements

Add new...

Metric

RequestResponsePerformance ▼

Title

GetMap Responce Perfon

Match type

LessThanOrEqual ▼

Delete

Unit of metric

s ▼

Value

2

Delete

Figure 44. Representative operations

Documentation on how to install and configure the module can be found here [http://docs.geoserver.org/latest/en/user/community/qose-module/index.html].

The latter statements declared by the user will be embedded in the Extensible Markup Language (XML) GetCapabilities file of the WMS or the WFS service.

A few examples for extended GetCapabilities responses are provided below and more can be found in the GitHub repository for the QoSE DWG [1: https://github.com/opengeospatial/QoSE-DWG/tree/master/QoSMetadata].

Declaring operating hours for a WMS service

```
<qos-wms:QualityOfServiceMetadata>
    <qos:OperatingInfo>
        <qos:OperationalStatus xlink:href=
"http://def.opengeospatial.org/codelist/qos/status/1.0/operationalStatus.rdf#Operation
al" xlink:title="Operating Schedule - WMS"/>
        <qos:ByDaysOfWeek>
            <qos:On>Monday Tuesday Wednesday Thursday Friday</qos:On>
            <qos:StartTime>09:00:00+01:00</qos:StartTime>
            <qos:EndTime>18:00:00+01:00</qos:EndTime>
        </qos:ByDaysOfWeek>
    </qos:OperatingInfo>
```

Declaring expected Quality of Service metrics for a WMS service

```
<qos:QualityOfServiceStatement>
    <qos:Metric xlink:href=
"http://def.opengeospatial.org/codelist/qos/metrics/1.0/metrics.rdf#ContinuousAvailabi
lity" xlink:title="Continuous Availability"/>
    <qos:MoreThanOrEqual uom="%">99</qos:MoreThanOrEqual>
</qos:QualityOfServiceStatement>
```

Declaring a Live Monitoring Service

```
<qos:OperationAnomalyFeed xlink:href="http://monitoring.geo-
solutions.it/resource/71?lang=en">
    <ows:Abstract>Monitoring Summary for WMS in Cloudsdi</ows:Abstract>
    <ows:Format>html</ows:Format>
</qos:OperationAnomalyFeed>
```

NOTE

For Expert Users:

The same operations can be done via the GeoServer REST Interface. A video tutorial can be found here [https://youtu.be/zNivPjSTRik].

5.6.1. GeoSolutions Methodological Approach on Monitoring QoS

It is very important to make the QoS service very reliable, credible and transparent in terms of metadata declaration. Thus, GeoSolutions have built a Live Monitoring Service [http://monitoring.geo-solutions.it/?lang=en] based on GeoHealthCheck [http://docs.geohealthcheck.org/en/latest/] that monitors the health and the availability of the GeoServer services which will be declared in turn in the QoS module of GeoServer and therefore in the GetCapabilities file of the service.

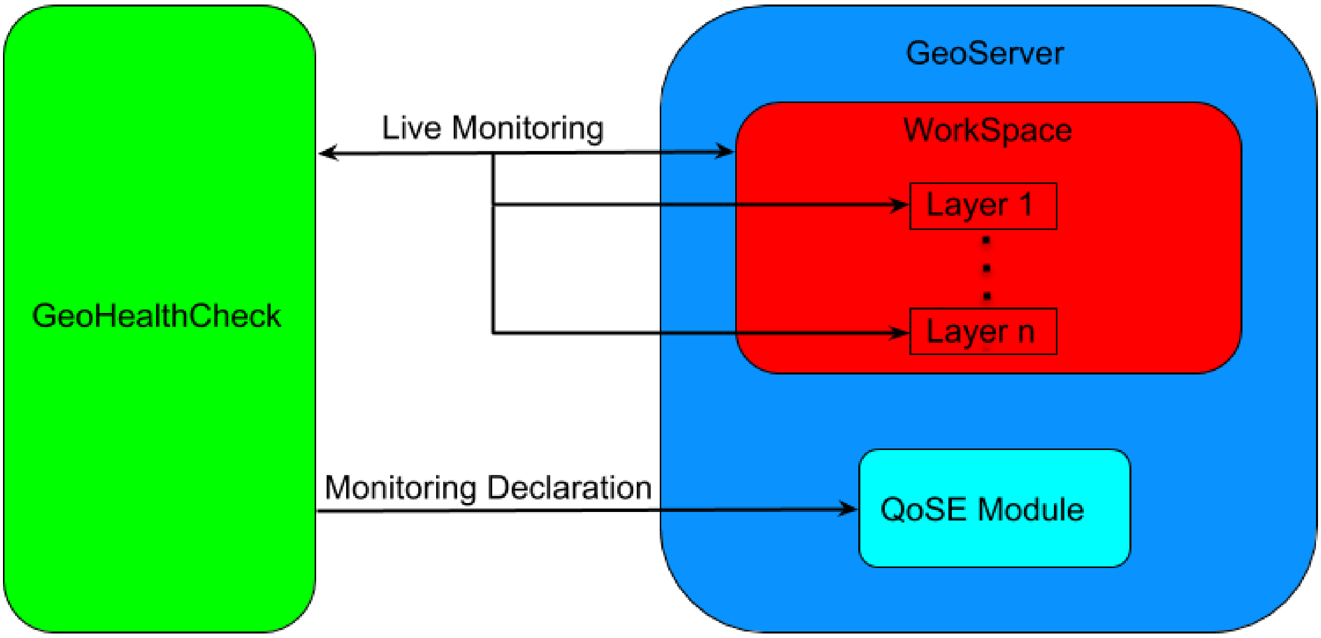
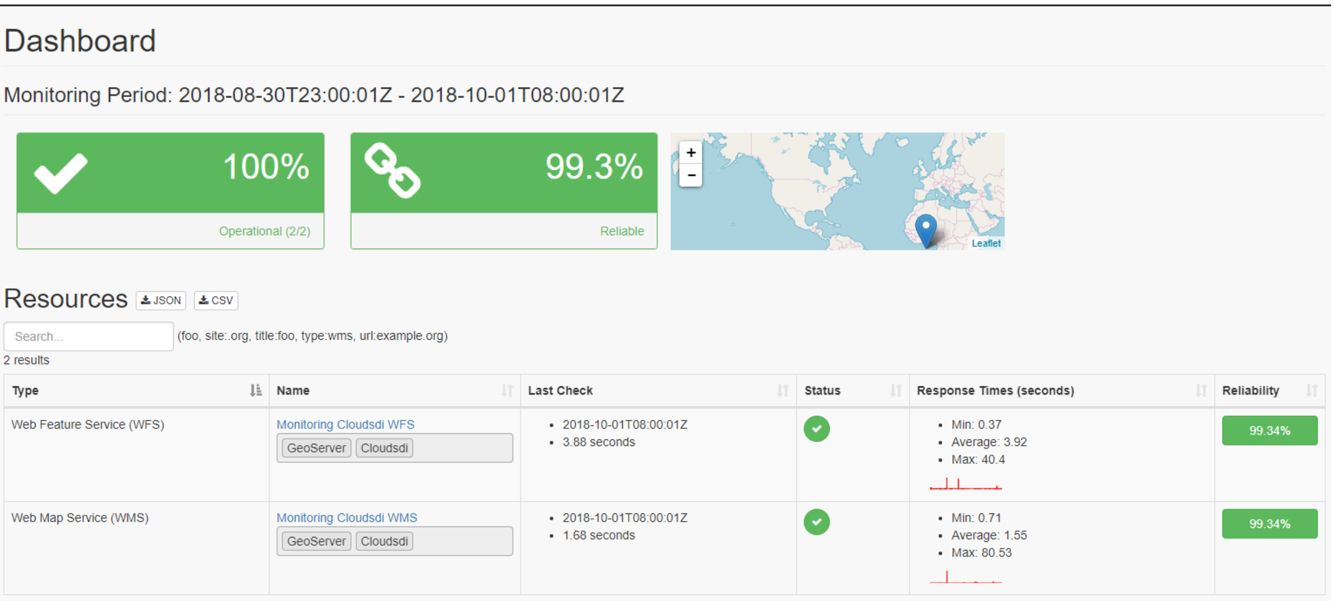


Figure 45. Monitoring Services and QoSE Module in Geoserver

The figure above shows a schema of how to explicitly monitor external services in the QoSE module in GeoServer in order to offer a reliable service to the users.

The upper side of the diagram in Figure 45 represents an external monitoring service which continuously sends GetCapabilities or GetMap requests to GeoServer on the entire workspace or on single layers to control the endpoints of the WMS and WFS services of GeoServer.



Dashboard

Monitoring Period: 2018-08-30T23:00:01Z - 2018-10-01T08:00:01Z

100% Operational (2/2)

99.3% Reliable

Resources JSON CSV

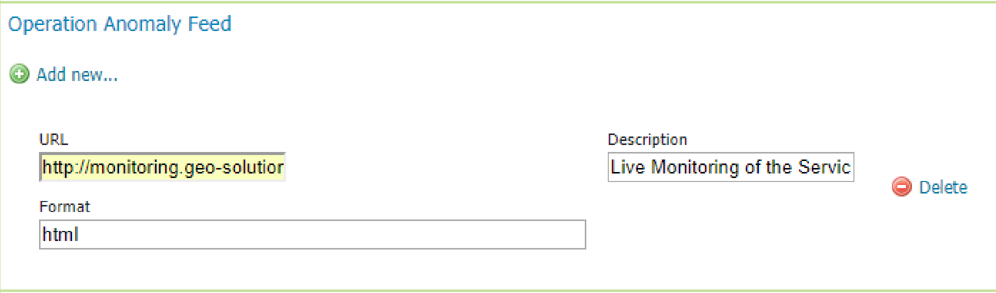
Search... (foo, site:.org, title:foo, type:wms, url:example.org)

2 results

Type	Name	Last Check	Status	Response Times (seconds)	Reliability
Web Feature Service (WFS)	Monitoring Cloudsdi WFS GeoServer Cloudsdi	2018-10-01T08:00:01Z 3.88 seconds	✓	Min: 0.37 Average: 3.92 Max: 40.4	99.34%
Web Map Service (WMS)	Monitoring Cloudsdi WMS GeoServer Cloudsdi	2018-10-01T08:00:01Z 1.68 seconds	✓	Min: 0.71 Average: 1.55 Max: 80.53	99.34%

Figure 46. WMS and WFS Live Monitoring with GeoHealthCheck

The lower side shows that the monitoring service can be declared in the QoSE module of GeoServer linking it in the Operation Anomaly Feed section of the module to demonstrate the reliability of the service to the users.


Operation Anomaly Feed

URL: http://monitoring.geo-solutior

Description: Live Monitoring of the Servic

Format: html

Figure 47. Declaring the Monitoring Service in QoSE Module

Accordingly, once a user requests the WMS or WFS GetCapabilities of the server, the user will have a way to directly check the monitoring service.

Monitoring Service Link in the GetCapabilities XML File

```
<qos:OperationAnomalyFeed xlink:href="http://monitoring.geo-
solutions.it/resource/71?lang=en">
    <ows:Abstract>Monitoring Summary for WMS in Cloudsdi</ows:Abstract>
    <ows:Format>html</ows:Format>
</qos:OperationAnomalyFeed>
```

5.7. OGC Web Service Landing Pages

It is difficult for an end-user to directly ascertain the quality of many of the existing OGC Web Services due to the fact that the specifications for these services define only machine-oriented operations. That is, they define the set of operations that a client application can use to discover and interact with the various offerings of the server, but they do not specify any standard way for an end-user to discover the offerings of the server directly using only a web browser. A sophisticated end-user who is well versed in the specification(s) for the service can manually construct a GetCapabilities request and browse the XML response. However, this is far from user friendly, and is not a viable approach for all but the most sophisticated of end-users.

The 'base' Uniform Resource Locator (URL) of an OGC Web Service is typically a URL to which one or more **mandatory** parameters must be added. Without such parameters, the service is required by its specification to return an exception report. Use of such parameters is not user-friendly. One such required parameter is the "SERVICE" parameter indicating the type of service being invoked. This is typically not part of the base URL in order to allow a single base URL to support multiple services. Another such required parameter is the "REQUEST" parameter indicating the operation being invoked. The current OGC Web Service specifications (with the exception of WFS 3.0) simply do not define any human-readable landing page for allowing an end-user to browse the offerings of an OGC Web Service via a web browser.

The solution to this is pretty obvious. The OGC Web Service specifications should be augmented to provide this functionality. To this end, this engineering report makes the following recommendations.

1. All future OGC Web Service specifications should require the base URL of the service to be sensitive to the HTTP "Accept" header. If this header indicates that text/html is preferred, then the server should be required to return an HTML landing page presenting the offerings of the

server in a human-readable format, providing hyperlinks as necessary for navigation. This landing page should provide as much metadata as it can about each offering, including (but not limited to):

   - Titles and abstracts, ideally in the language that is the closest match to the language requested by the HTTP "Accept-Language" header.
   - Spatial extents where applicable. Ideally these spatial extents should be displayed graphically in a map.
   - Source attribution, where applicable and available.
   - Any other available measure(s) of data quality.

2. If the OGC Web Service specification defines a traditional machine-readable capabilities document (like the classic OGC Web Services do), then the capabilities-document endpoint (regardless of whether it is a RESTful or service-oriented endpoint) should be sensitive to the HTTP "Accept" header and should be required to return the HTML landing page if the header indicates that text/html is preferred. In general, the HTML landing page should provide roughly the same information that is available through the capabilities document, as well as extra measures of data quality where available.
3. If the OGC Web Service specification defines a set of service-oriented operations that indicate the type of operation via SERVICE and REQUEST parameters (like the classic OGC Web Services do), it should make the REQUEST parameter optional and require that the absence of the REQUEST parameter be interpreted as a request for the HTML landing page. Perhaps it could be sensitive to the HTTP "Accept" header and return either the HTML landing page or the machine-readable capabilities document as appropriate (in which case the absence of a REQUEST parameter becomes the equivalent of REQUEST=GetCapabilities).
4. If the OGC Web Service specification defines a GetCapabilities request with an AcceptFormats parameter (like the classic OGC Web Services that are based on the OGC Web Services Common Specifications do), then it should recognize an AcceptFormats value of text/html to indicate a request for the HTML landing page.

Change requests have been submitted to augment the behaviors of the commonly-used existing OGC Web Services specifications to include this functionality. Specifically, change requests have been made against the following existing specifications:

- Request 559, for OGC Web Services Common Standard 2.0.0 (OGC 06-121r9). All OGC Web Services that are based on this specification will therefore automatically inherit this augmented behavior. These services include, but are not necessarily limited to, the WCS 2.0 Interface Standard (OGC 09-11-r4, etc.) and the Web Integration Service (OGC 16-043). This change request should make the SERVICE parameter optional in the situation where a Web Integration Service is available. It should require that the absence of the SERVICE parameter in this situation be interpreted as a request for the HTML landing page of the Web Integration Service. This, in addition to making the REQUEST parameter optional, allows the raw base URL (i.e., without any parameters) of an OGC Web Service to return an HTML landing page for the suite of services that it provides.
- Request 560, for OGC Web Services Common Specification 1.1.0 (OGC 06-121r3). All OGC Web Services that are based on this specification will therefore automatically inherit this augmented behavior. These services include, but are not necessarily limited to, the Web Map Tile Service

(WMTS) Implementation Standard (OGC 07-057r7) and the OpenGIS Web Feature Service (WFS) 2.0 Interface Standard (OGC 09-025r1).

- Request 561, for Web Map Server Implementation Specification 1.3.0 (OGC 06-042). Unfortunately, this latest WMS specification predates the OGC Web Services Common specifications, so a separate change request had to be made specifically for it.

No change request needs to be made against the WFS 3.0 specification, since it already defines this behavior.

A proof-of-concept implementation of these recommendations has been made available at https://tb14.cubewerx.com/cubewerx/cubeserv for the duration of the OGC Testbed-14 initiative (tb14guest credentials need to be provided to see the full suite of services available).

5.8. TIE and Scenario for Demonstration

5.8.1. TIE Component Implementation

The component overview graphic at the beginning of this section illustrates how the different components described above fit together. The following scenario will be used to demonstrate this in an example demo video.

Table 1. Testing and Integration Experiment (TIE)

Component	Description	Service Request	Tested
D115: HTML Landing Page	Additional quality measures to the capabilities document	WMS server	Y: TIE on 07/04/18
D116/D117: GUI of 14 Assessment Criteria	Qualitative Experience Evaluation: draft implementation and testing	WMS instances	Y: TIE on 09/18/18
D116/D117: GUI of 14 Assessment Criteria	Qualitative Experience Evaluation: implementation of NRCan recommendations	WMS instances	Y: TIE on 10/23/18
D121: WMTS Portrayal with QoSE support	GeoServer Extension for QoS, including service performance, operating capabilities (for QoSE)	WMS server	Y: TIE on 09/25/18
D122: Additional Client Support	Service performance testing (Quantitative; JMeter)	WMS server(s)	Y: TIE on 10/30/18

5.8.2. Scenario "Blueprint" for the Result Demonstration Video

After setting the story for the demonstration video including the material and short individual recordings describing each component as outlined at the start of this chapter, the Technology Integration Experiment (TIE) showcasing followed the steps below:

Step 1: Set up a couple of WMS instances that will be used to demonstrate the workflow.

Step 2: Introduce (briefly) a couple of WMS instances

Step 3: Use those instances to run through the Assessment GUI for user-based evaluation/rating

Step 4: Pull in the JMeter performance statistics of those WMS instances/services

Step 5: Showcase the GeoServer Extension for those WMS instances

Step 6: Illustrate the HTML Landing Page and its value to the community.

Appendix A: Revision History

Table 2. Revision History

Date	Editor	Release	Primary clauses modified	Descriptions
June 15, 2016	I. Simonis	.1	all	initial version
July 22, 2016	I. Simonis	.9	all	comments integrate
September 7, 2016	S. Simmons	1.0	various	preparation for publication
March 23, 2017	I. Simonis	2.0	all	template simplified
January 18, 2018	S. Serich	2.1	all	additional guidance to Editors; clean up headings in appendices
October 4, 2018	G. Hobona	2.1	all	commemts to Editors
October 16, 2018	G. Schumann	2.1	all	implemtation of commemts to Editors
October 30, 2018	G. Schumann	2.1	all	Completion of Future Work section
November 13, 2018	A. Kettner	2.1	all	Completion/Revision of JMeter section
November 20, 2018	G. Schumann	2.1	all	ER revision & implemented comments from NRCan and the QoSE DWG
November 22, 2018	Zelong	2.1	all	Completed description of QoSE GUI
November 28, 2018	G. Schumann	2.1	all	Second ER revision