



Report:

Climate Technology Centre & Network (CTCN): National Water and Sewerage Authority, Grenada (NAWASA) – Improvement of water supply management through a GIS based monitoring and control system for water loss reduction in Grenada

Project Output 2: Review of GIS systems and recommendations for future development

Deliverable 2D: Data interface and data exchange protocol

1. Introduction

The following report issued on the 26th July 2019 was developed by the Wood/GISCAD team as a core deliverable of CTCN project entitled “Improvement of water supply management through a GIS based monitoring and control system for water loss reduction in Grenada”. This project was delivered in collaboration with technical staff within the National Water and Sewerage Authority of Grenada (NAWASA).

The scope of the technical note relates to the following objectives of Output 2 of the project:

- Data interface and data exchange protocol

The remainder of the technical note focuses on the following priority areas of data interface and exchange, namely

- Overview of the new centralised GIS database and data model created for NAWASA;
- Accessing data in the central GIS database, including overview of processes for:
 - Admin management of the database;
 - Editing of data layers held in the database;
 - Viewing of data layers held in the database;
- Examples of core data update process, including:
 - Future update and improvement of NAWASA’s clean water network GIS layer;
 - Future update of NAWASA fixed customer meter location held in GIS; and

- Connecting meter data held in NAWASA's customer management system and mapping it within GIS.
- Server folders used for interface and data exchange
- Guidance for future figure production

These workflows will be fully defined, developed and tested using the GIS systems which are currently under development for NAWASA.

2. Overview of the new centralised database and data model

A key deliverable of this project was the creation of a series of centralised enterprise-level GIS databases for NAWASA using PostgreSQL and the accompanying PostGIS extension. These databases will be used to store NAWASA's corporate GIS data. At the time of writing this document, four databases have been established. These are:

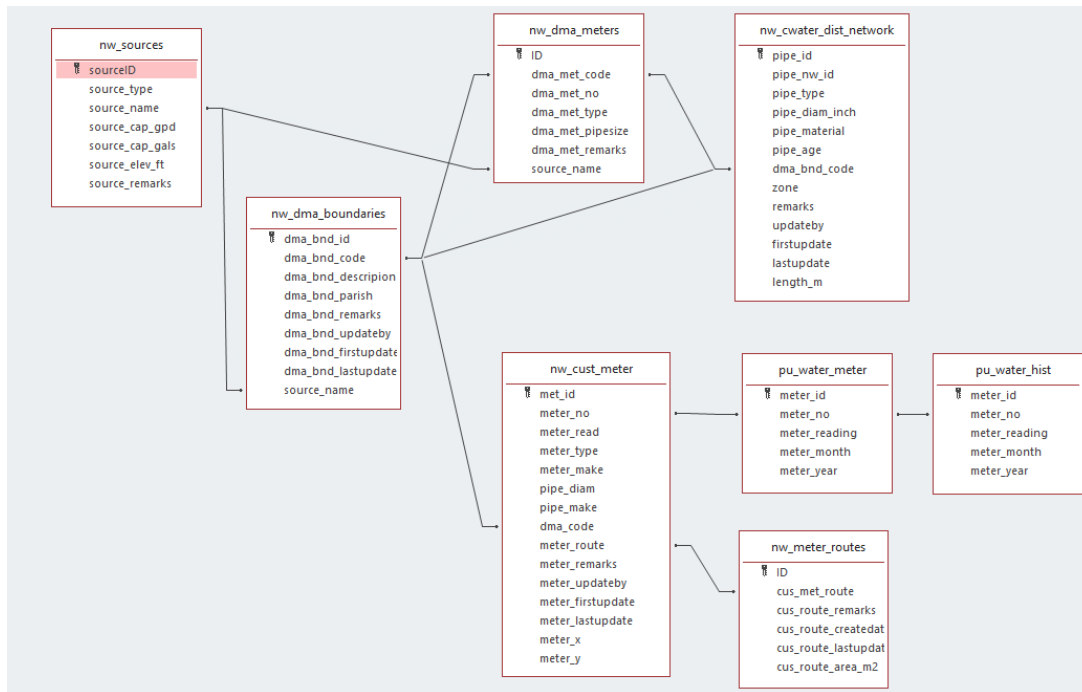
- **nawasa_master**
Master GIS database containing the latest versions of data. Access to this database will be read-only for most GIS users in NAWASA.
- **nawasa_wip**
Work in progress (WIP) database containing temporary / development versions of data. No data held in this database must be used for official analysis of mapping products.
- **nawasa_archive**
Archive database to hold "point in time" versions of specific data. No data held in this database must be used for official analysis of mapping products.
- **nawasa_training**
Database designed specifically for training and testing purposes. No data held in this database must be used for official analysis of mapping products.

The database design also includes a structured approach to the assignment of GIS users, roles and data schemas. The different tiers of this model work together to ensure effective management and control of the data held in the databases. Full details are presented project data model report 2C.

Another key feature of the design was the development of a database relationship model to define the key relationships between NAWASA core clean water datasets. This structure will be refined during the subsequent stages of the project and ultimately provide a detailed structure for future management of infrastructure data within the organisation. This includes potential future extension to the management of sewer infrastructure data which sits outside the scope of the immediate project.

The working data model is presented in overleaf in Plate 1 and Table 1.

Plate 1 NAWSA central GIS database – core dataset relationships model



The core layers defined in the relationships table are detailed below in Table 1.

Table 1 Core data tables

Dataset name	Description	Existing NAWASA dataset
nw_sources	Sources (Boreholes, Tanks and Treatment Plants)	Tanks_boreholes.shp (ESRI shapefile)
nw_dma_boundaries	DMA boundary areas (polygon)	DMA_boundaries.shp (ESRI shapefile)
nw_dma_meters	DMA meter locations (points)	DMA meters (ESRI shapefile)
nw_cwater_dist_network	Clean water distribution network (polyline)	Various ESRI shapefile layers currently being reviewed
nw_cust_meters	Customer meter locations	Currently held in 189 individual ESRI shapefiles – data to be merged into single new layer
nw_meter_routes	189 route area which define the monthly recording of customer meters	Borders.shp (ESRI shapefile)
pu_water_meter	SQL table defining the key account details for the customer meters	Northstar SQL table – pu_water_meter
pu_water_hist	SQL table defining the historical record of monthly meter readings for the customer meters	Northstar SQL table – pu_water_hist

The structure of this design will be discussed and agreed in collaboration with NAWASA staff.

3. Accessing data in the central GIS database

Access to data within the new centralised database is provided through several different software tools. These tools include: the in-built editing and management tools within the QGIS desktop software product; the database DB manager within QGIS and the PostgreSQL database pgAdmin 4 toolkit.

Access and functionality within these tools will be directly controlled by database user permissions assigned by approved administration level users of the database. The remainder of this section outlines the tools which will be accessible to the three levels of users - admin, editor and viewer.

3.1 Database administrators

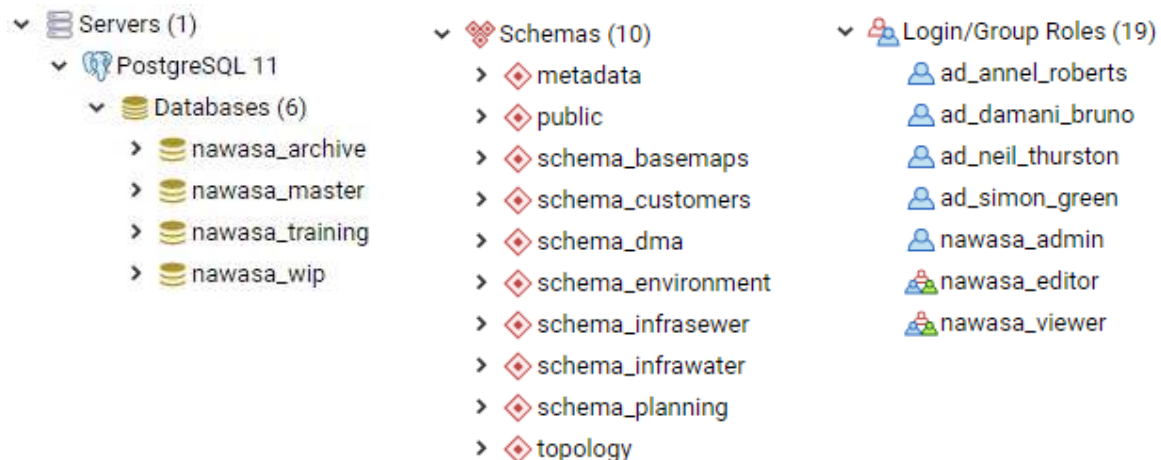
The highest level of user access will be by the administrator (admin) users who will be able to perform a full range of the core administration tasks on the database. These tasks will include: adding new database users, role and schemas; running SQL queries on the database; restarting the database/server if required; and creating, adding, query and editing data layers held in the master database.

Administrator levels will be able to use three core tools to achieve these tasks. These are:

pgAdmin 4

This desktop software tool installed on the NAWASA's central GIS server will enable approved admin users to add and/or update new database users, role and schemas; running SQL queries on the database and monitor levels of database use. Screen shots showing example tasks are provided below in Plate 2. Further details regarding the administration of the GIS databases are provided in accompanying project deliverable report 2C.

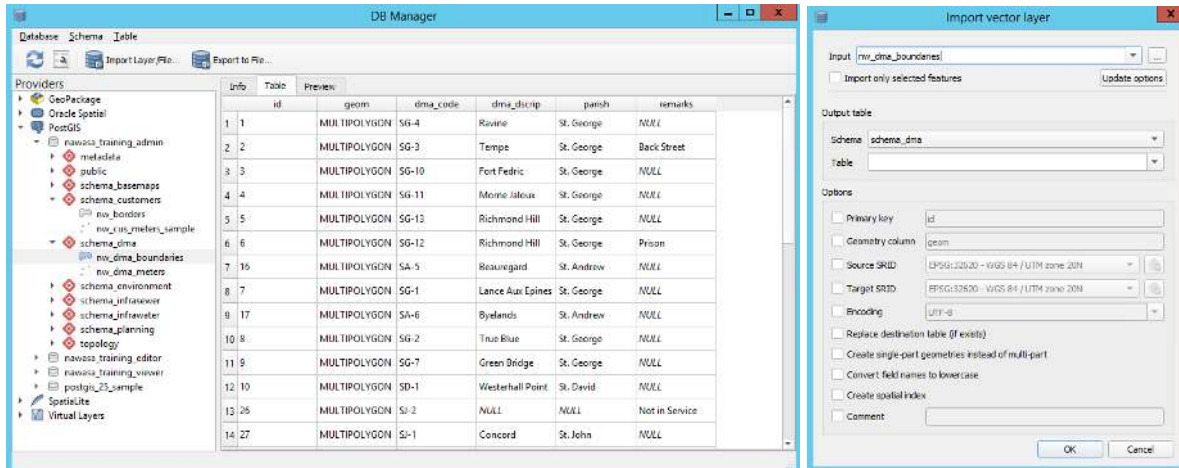
Plate 2 pgAdmin 4 interface



QGIS DB Manager

This tool included within the standard QGIS product will enable admin users to import new spatial datasets into the master database from within QGIS. The basic interface for this tool is provided below in Plate 3.

Plate 3 QGIS DB manager interface used to manage the GIS databases



QGIS

Admin level users will also be able to undertake the full range of data tasks using the full range of editing tools available within QGIS

It is expected that a maximum of 3 NAWASA staff will have full administrator rights to the database.

3.2 Editor users

The second level of user access will enable approved users to add, query and update data layers held in the master database. These tasks will be possible using an editor level connection to the PostgreSQL database from within QGIS.

Users with this permission level will not be able to create new layers in the master database but will be able to add, query, edit and create layers held in the Work in Progress (WIP) database. It is expected that around 10 NAWASA staff will have full editor rights to the database.

3.3 Viewer users

The third level of user access will enable approved users to add and query data layers held in the master database. These tasks will be possible using a viewer level connection to the PostgreSQL database from within QGIS.

Users with this permission level will not be able to edit existing or create new layers in the master database but will be able to add, query, edit and create layers held in the Work in Progress (WIP) database.

The number of viewer users is unlikely to be restricted.

4. Future update and improvement of NAWASA's clean water network GIS layer

4.1 Background

The effectiveness of NAWASA GIS system is reliant on access to high quality and consistent spatial data. A key layer within this system is the long-term development of effective and "fit for purpose" network representation of pipeline assets. This is one of the key inputs needed to assess non-revenue water (NRW) losses.

The importance of this requirement was reflected in the time spent by the Wood team reviewing the scope and quality of existing NAWASA's GIS layers undertaken in May 2019. This review highlighted the existence of a series of different network datasets. These datasets were mapped using different projection systems; included transformation offsets; feature duplication; different routes alignments; and a range of different attribute definitions. Meetings with NAWASA staff also highlighted that several infrastructure features are not currently recorded in the system.

As part of the review, the Wood team worked to create two individual datasets representing the key pipeline features in the NAWASA network. This work included adding flags in the datasets to indicate if the feature should be kept or removed. These two datasets were provided back to NAWASA at the end of June 2019 to enable further refinement of the spatial structure of the pipeline features. Additional schematic drawings were created by NAWASA staff to assist in this update process.

It should also be noted that the two datasets contained two different sets of fields and attribute values. To address this issue, a common data schema for a final data layers was defined in collaboration with NAWASA. This structure is detailed below in Section 2.2 and provides the template for the data interface process which is defined below. Further details of the process for future capture of network infrastructure data is outlined later in this document.

4.2 Schema definition

Based upon the review, a series of field / domain values listed in Table 2 were established with NAWASA for future update and maintenance of the master pipeline dataset held in NAWASA's central PostgreSQL GIS database. This dataset is called "nw_water_pipeline_master" and is stored under the "schema_infrawater" schema of the database.

Table 2 NAWASA clean water pipeline dataset - Schema design

Field	Field Type	Lookup values	Unique value	Needs to be completed	Additional Information
pipe_id	AutoNumber	Unique integer number	Yes	Yes	Unique database ID
pipe_nw_id	Integer	Unique integer number	No	No	Additional NAWASA coding – use existing NUMBER field where available
pipe_type	Text (50)	Distribution Transmission	No	Yes	Distribution Transmission

Field	Field Type	Lookup values	Unique value	Needs to be completed	Additional Information
		Distribution / Transmission Unknown			Distribution / Transmission Unknown
pipe_diam_inch	Float	1.5 2 3 4 5 6 8 10 12 Unknown	No	Yes	Size in inches
pipe_material	Text (10)	DI GI PVC U	No	Yes	Ductile Iron Galvanised Iron PVC pipeline Unknown Attributes of current data need to be checked.
pipe_age	Text (50)	Free text data entry		No	Details of age – if known
zone	Text (50)	Annandale Chemin Concord ConcordL Les_Avocates MardiGras Morne Jaloux Radix Vendome	No	yes	Additional zone values to be confirmed by NAWASA.
pipe_remarks	Text (255)	Free text data entry	No	No	Details of any prior data source or other comments.
pipe_updateby	Text (50)	Damani Bruno Annel Roberts Unknown	No	Yes	Name of the last person to add or edit the feature. List of names will be updated by NAWASA GIS administrators in the future
pipe_firstupdate	Date	Date	No	Yes	Details of the date of the first addition of the dataset to the GIS database.
pipe_lastupdate	Date	Date	No	Yes	Date of the last update to the record.
pipe_length	Decimal (3dp)	Length of the feature (m)	No	Yes	Values updated for whole dataset at end of each edit session.


4.3 Data exchange workflow

The following section outlines two methods which could be used to update the future content of the master pipeline layer. Both methods would need to be undertaken by a trained member of GIS staff (admin or editor level) with the necessary editing permissions to edit the master GIS database.

Field-based capture of the new pipeline features




The preferred method for adding new or updating existing data in the master pipeline GIS dataset is outlined below:

- Creation and deployment of a pipeline data capture package using the QFieldSync desktop add-in for QGIS. This would consist of the existing master data layer and a blank dataset with the same data structure which would be used to capture new features;
- Upload of the QField survey package to a tablet device;

An illustration of the interface of this app is provided below on Plate 1 and will include digitising the route using tools within the app. Full details of the mobile data capture process will be presented in the project's mobile workflow report;
- Entry of new infrastructure routes using the QField app;
- Entry of attribute details for the new infrastructure routes using the QField app. This will include entry of attribute values as outlined in Table 1. Most of the fields in the form will require mandatory entry of information governed by the lookup values included in the master database. This will ensure that all future data entered into the system conforms with required database data entry rules;
- Capture of digital photos of the new infrastructure using the QField app;
- Download of the new editing dataset using the QFieldSync desktop add-in for QGIS when back in the office;
- Use of QGIS tools to copy features in the editing dataset to the master version. This can be achieved using the work steps;
 - Start an edit session for both the master dataset and the new data.
 - Use the "Select feature by rectangle tool"  to select the features captured in the field
 - Click the Edit (menu)>Copy Features button.
 - Highlight the layer in the TOC that the feature will be pasted to.
 - Click the Edit (menu)>Paste Features button.
 - Save the edits on the master pipeline dataset
- Final editing of the feature to ensure that it is correctly aligned with existing infrastructure network information. This step should really be unnecessary if the asset has been correctly digitised when in the field.

Office update of the pipeline layer

The alternative method for update of the master database would be office-based digitising of the new infrastructure asset into the master GIS dataset and update of attribute values. The key steps of this editing workflow would be:

- Add the master pipeline layer to QGIS using an editor connection
- Make the layer editable using the Toggle Edit 
- Add new feature using the Edit – Add Line Feature tool 
- Digitise feature and then right mouse click
- Complete the requested attribute values and hit Ok
- Save edits by selecting Toggle Editing 

A key disadvantage of this approach would be ensuring that the digitised line accurately reflected the spatial location of the new asset and the inability to capture site photos directly for the feature.

5. Future update of NAWASA fixed customer meter location held in GIS

5.1 Background

The evaluation of Non-Revenue Water (NRW) across Grenada is reliant on developing an effective understanding of water use by NAWASA customers and relating this to the total volume of water generated from Grenada's key water resource (boreholes and tank) locations.

At present, the key sources of information relating to customer level water use are: existing GIS mapping of customer meters and the associated monthly meter readings, which are entered and held in the current Northstar CIS system. The focus of this section is on the first of these two datasets, with Section 6 outlining a workflow for linking the GIS dataset of meter location and the time-series of meter flow readings held in Northstar database.

It is estimated that there around 33,400 meter locations which have previously been mapped by NAWASA. This information is currently held in a series of 199 individual GIS files. Additional work will be undertaken during the project to create a work single meter data layer from the individual files.

To enable the creation of this dataset, a common data schema for the new master meter dataset was defined in collaboration with NAWASA. This structure is detailed below in Section 5.2 and provides the template for the data interface process which is defined below. This schema is based upon the data structure used before commencement of the CTCN study.

5.2 Schema definition

Based upon the review, the following field / domain values listed in Table 3 have been established with NAWASA for future update and maintenance of the master customer meter dataset held in NAWASA's central PostgreSQL GIS database. This dataset is called "nw_water_meters_master" and is stored under the "schema_customers" schema of the database.

Table 3 NAWASA clean water pipeline dataset - Schema

Field	Field Type	Domain Values	Unique value	Needs to be completed	Additional Information
meter_id	AutoNumber	Unique Integer Number	Yes	Yes	Unique database ID
meter_no	Text (20)	Unique text ID for the meter name	Yes	No	Unique text ID for the meter name
meter_read	Text (5)	cubi gals	No	Yes	Type of meter – cubic meters(m3) or gallons. Almost all cubic
meter_type	Text (10)	counter dial gals	No	Yes	Current data includes a variety of incorrect values – additional work needed to clean up data
meter_make	Text (10)	Abb Abb* Actaris Amco Counter Elster Flonidan Genebre Kent Neptune Other Socam Woltex	No	Yes	Current data includes a variety of incorrect values – additional work needed to clean up data
pipe_diam_inch	Text (50)	0.5 0.75 1 1.5 2 3 4 6	No	No	Size in inches
pipe_make	Text (10)	DI GI PVC U	No	Yes	Ductile Iron Galvanised Iron PVC pipeline Unknown
met_dma	Text (10)	Drop down list of current DMA numbers	No	Yes	Value automatically updated for all new/edited features in the database
met_route	Integer	Drop down list of current round numbers	No	Yes	4 digit reference number indicating the meter route in which the meter is allocated. Only updated by manual editing.
met_remarks	Text (255)	Free text data entry	No	No	Details of any prior data source or other remarks
met_updateby	Text (50)	Damani Bruno Annel Roberts Unknown	No	Yes	Name of the last person to add or edit the feature

Field	Field Type	Domain Values	Unique value	Needs to be completed	Additional Information
met_firstupdate	Date	Date	No	Yes	Date of initial upload of the layer to the master database
met_lastupdate	Date	Date	No	Yes	Date of the last update
met_x	Integer	-	Yes	Yes	X (easting) coordinate for the meter location. Calculated automatically in QGIS on each upload.
met_y	Integer	-	Yes	Yes	Y (northing) coordinate for the meter location. Calculated automatically in QGIS on each upload.

5.3 Data exchange workflow

The preferred method for adding new or updating existing data in the master meter GIS dataset is outlined below:

- Creation and deployment of a meter data capture package using the QFieldSync desktop add-in for QGIS. This would consist of a copy of the master data layer which will be used to capture the location of new features and/or revised meter locations;
- Upload of the QField survey package to a tablet device;
- Entry of new or update of existing meter locations using the QField app;
- Entry and/or update of attribute details for the new or updated meter locations using the QField app. This will include entry of the attribute values outlined in Table 2. Most of the fields in the form will require mandatory entry of information governed by the lookup values included in the master database. This will ensure that all future data entered into the system conforms with established database entry rules;
- Capture of a digital photo of the meter location using the QField app;
- Download of the new editing dataset when back at the NAWASA head office;
- Use of QGIS or FME workflow to transfer all new /edited features from editing dataset to the master version. This coded workflow will consist of the following steps:
 - Backup of the existing master dataset will be made to WIP database;
 - Selection of all new/edited features in the mobile version;
 - Field calculation will add 1 to the value held in "version" field. This new value will current version;
 - Transfer of all new/edited features to the master meter database;
 - Update of the "Latestversion" field to flag the newest feature for each unique meter number; and
 - Update of the "met_dma" field to identify the DMA in which the meter is located/connected. This will be necessary for future data analysis purposes.

This workflow will be developed during the next stage of the project.

- Final manual QA checks to ensure the correct alignment of the revised meter location with available infrastructure network information. This step should really be unnecessary if the asset has been correctly digitised when in the field.

It is expected that this process will over time improve the quality and consistency of data held in the GIS database.

6. Data exchange between GIS and the NorthStar customer management system

6.1 Background

A key development within this project will be the ability to link the available mapping of existing meter location with the historical time series of customer water use which is currently recorded in the Northstar CIS system.

The primary objective of this work will be to enable time-series analysis of water usage by DMA areas and ultimately presenting summaries of this information in GIS.

This information will also be key to developing future non-revenue water (NRW) assessments for individual and groups of DMAs.

6.2 Data exchange workflow

Our approach for this workflow will be focus on using the MS SQL server connection and SQL database query capabilities of QGIS, The MSSQL connection allows direct connection to SQL Server database instances while the functionality of the QGIS DB Manager allows the running of both tabular and spatially orientated SQL queries.

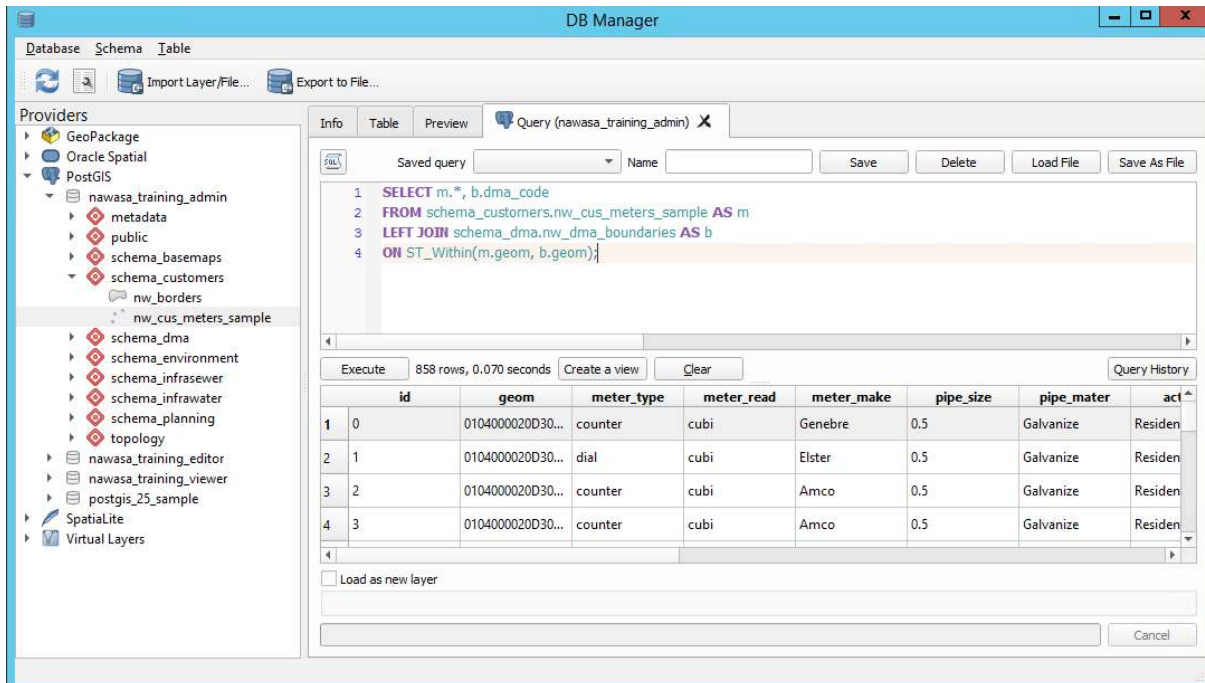
The remainder of this section outlines several different approaches to use this functionality for the future assessment of water usage and NRW by NAWASA.

Please note that the examples presented were generated using a 10% sample of a test version of NAWASA's NorthStar customer database. This was undertaken to help the development of the illustrative queries outlined in the report. Further work will be required to enable dynamic links to NAWASA's live system and the final format of the queries.

Automated tag of customer meters with the ID of the DMA in which it is located

A simple join example which enables the joining of DMA boundary information (polygon) to customer meter (points) locations is given below in Plate 4.

Plate 4 QGIS DB manager – Spatial linking customer meter locations and DMA boundary details



The output of running this code is a new temporary point layer in QGIS, which includes the spatial geometry, attributes of the original customer meter locations plus the DMA_Code field from the DMA boundary dataset -see end field of the table. This structure provides a more useful output which can be used to develop DMA based summarises.

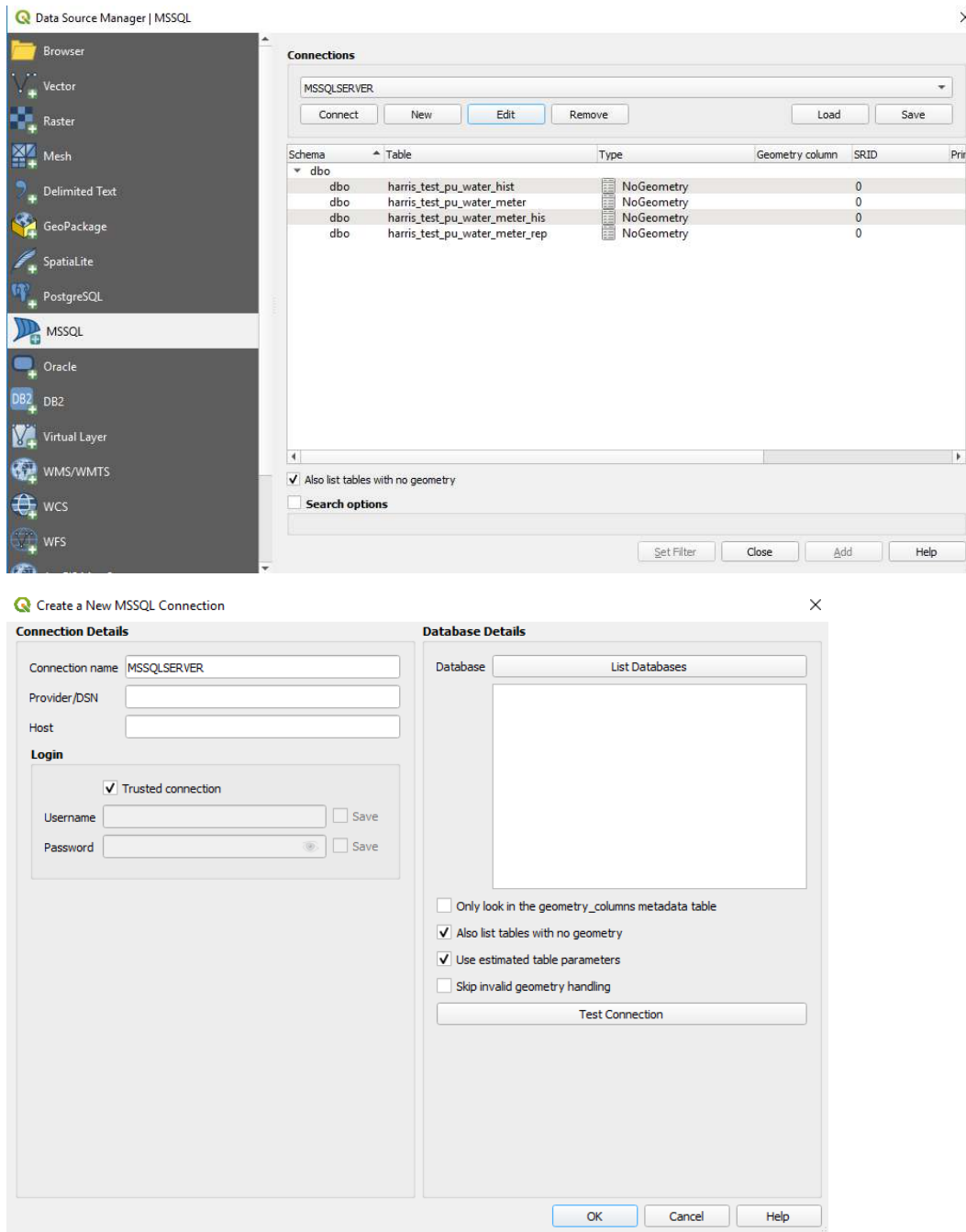
The use of this dynamic SQL approach avoids the creation of additional datasets in the master database. The final join can be stored dynamically and saved within a QGIS project.

Linking GIS customer location data with NorthStar customer and metering data

A similar approach can also be used to combining the master customer meters datasets and related data held in the Northstar database.

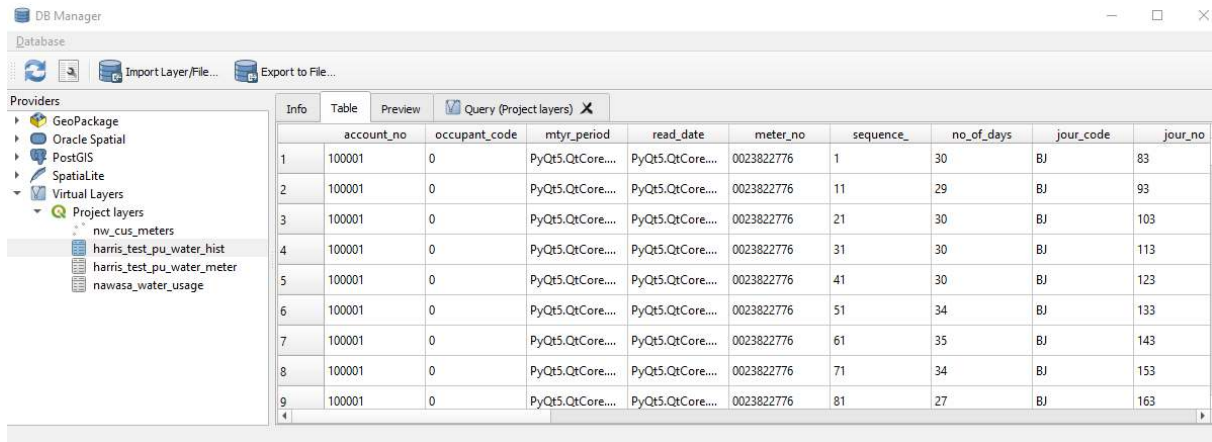
The first stage in this process is the creation of a MSSQL connection from within the QGIS Data Source Manager to the NorthStar database. This general process is illustrated in Plate 5. Please note that currently direct connections to the live NorthStar database are not possible and further work will be required to find a stable and secure route to accessing data from the live system.

Plate 5 QGIS – making a MSSQL connection to the NorthStar customer data



Tables selected for inclusion in the project are then accessible through the normal QGIS layer window. They will also be listed as virtual layers in QGIS DB Manager (see Plate 6). This means that the data can be used in further SQL queries within QGIS.

Plate 6 QGIS – accessing MS SQL NorthStar data tables as virtual layers in the SQL Query builder

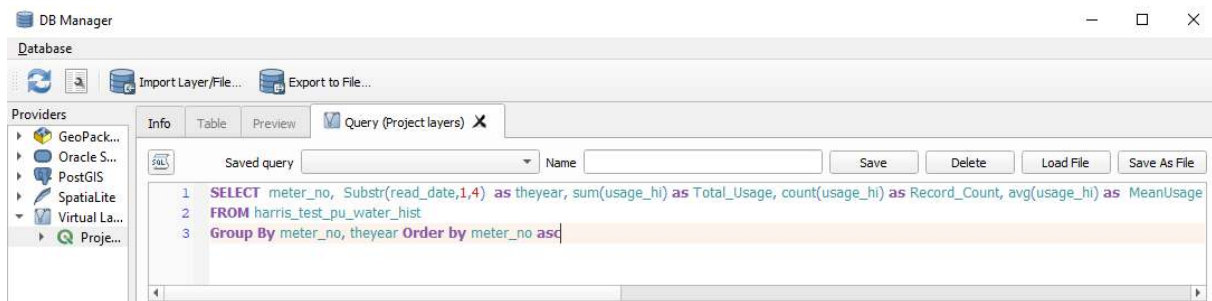


The screenshot shows the QGIS DB Manager interface. On the left, the 'Providers' tree is expanded to 'Virtual Layers' > 'Project layers' > 'nw_cus_meters'. The main window displays a table with the following columns: account_no, occupant_code, mtyr_period, read_date, meter_no, sequence_, no_of_days, jour_code, and jour_no. The table contains 9 rows of data.

	account_no	occupant_code	mtyr_period	read_date	meter_no	sequence_	no_of_days	jour_code	jour_no
1	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	1	30	BJ	83
2	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	11	29	BJ	93
3	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	21	30	BJ	103
4	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	31	30	BJ	113
5	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	41	30	BJ	123
6	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	51	34	BJ	133
7	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	61	35	BJ	143
8	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	71	34	BJ	153
9	100001	0	PyQt5.QtCore...	PyQt5.QtCore...	0023822776	81	27	BJ	163

A good example is the use of SQL in QGIS to generate summary usage statistics for either individual meter locations and/or grouped DMA zones. An example query for individual meters which was developed using sample test data is presented below in Plate 7.

Plate 7 QGIS DB manager – Query to calculate annual water consumption by individual customer meters



The screenshot shows the QGIS DB Manager interface with the 'Query (Project layers)' tab selected. The SQL query editor contains the following query:

```

1 SELECT meter_no, Substr(read_date,1,4) as theyear, sum(usage_hi) as Total_Usage, count(usage_hi) as Record_Count, avg(usage_hi) as MeanUsage
2 FROM harris_test_pu_water_hist
3 Group By meter_no, theyear Order by meter_no asc

```

The next stage of the project will refine these initial data queries and develop an approach which can use actual data from the master NorthStar database. This may focus on periodic export of selected data tables and import into PostgreSQL rather than a live link to the master SQL database. The final workflows and queries will ultimately be saved in a read-only QGIS project file, which will be accessible to approved GIS users.

7. Additional server folders

A series of project folders were also created on the new virtual NAWASA server. These folders have been established to provide a structure for future management of QGIS projects and figure outputs. The folders currently defined are:

- NAWASA_QGIS\Analysis Storage folder for GIS analysis outputs;
- NAWASA_QGIS\Figures Storage folder for QGIS project files created for figures;
- NAWASA_QGIS\Figures\PDF Storage folder for output PDFs;
- NAWASA_QGIS\Tools Storage folder for QGIS plugins and coding scripts;
- NAWASA_QGIS\Projects Storage folder for general QGIS project files;
- NAWASA_QGIS\Styles Storage folder for QGIS layer style files;
- NAWASA_QGIS\Templates Storage folder for template QGIS project files;

Sub-folders may be created under these folders to accommodate future project needs. Further information regarding the processes for GIS figure production are provided below in Section 8.

It is essential that all GIS data is stored in the centralised GIS database and not within these server folders.

8. Creation of figure outputs

The final topic covered in this report is the detailed process for the future creation of map outputs produced by NAWASA staff.

It is recommended that all GIS figures are produced using a QGIS project file using a standardised QGIS figure template. Current templates have been produced in this project and can be found under the "NAWASA_QGIS\Templates" folder on the central server. All official figure QGIS projects should be saved under the "NAWASA_QGIS\Projects" folder on the central server.

The naming of QGIS projects produced for final official figure production should also follow the following naming convention:

QGIS36_GraphicRegisterID_AuthorInitials_Description

- The first part of the filename will remain as text "QGIS36" to denote software package and version used to create the output. This should be updated should a different version of QGIS be used in the future.
- The second part of the filename will be a 5-digit unique number for the graphic output. This register will be stored on NAWASA GIS server in Microsoft Excel format.
- The third part of the filename is used for the initials of the author of the figure.
- The final part of the filename provides a short description of the contents of the figure.

An example of this format for a QGIS project would be "QGIS36_00014_DB_nawasa_clean_water_infrastructure_2019.qgs", where 00014 refers to 14th unique GIS figure output created using the new system. A PDF output created from this document would be called "QGIS36_00014_DB_nawasa_clean_water_infrastructure_2019.pdf" and stored in the PDF folder created on the new server.

All PDF figures produced using this system should be stored in the "Figures\PDF" folder created on the central server.

Issued by



Neil Thurston

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Neil Thurston

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