NOVEL UNIFIED VIEWER FOR NETWORK PERFORMANCE TWIN

National Gas - Novel Unified Viewer for Network Performance Twin - Close-out Report

National Gas Transmission plc

Report no.: 10591500-01, Rev. 1
Document no.: 2896380
Date: 2026-04-15

Project name:	Novel Unified Viewer for Network Performance Twin	DNV Services UK Limited Energy Systems
Report title:	National Gas - Novel Unified Viewer for Network Performance Twin - Close-out Report	Digital Energy
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Date of issue:	2026-04-15	GB 440 60 13 95
Project no.:	10591500	
Organization unit:	Digital Energy	
Report no.:	10591500-01, Rev. 1	
Document no.:	2896380	

Applicable contract(s) governing the provision of this Report:

Objective: Summarise the project work completed by DNV during the Novel Unified Viewer for a Network Performance Twin project.

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Keywords

Rev. no.	Date	Reason for issue	Prepared by	Verified by	Approved by
0	2026-03-31	First issue	DR	DG	GF
1	2026-04-15	Address comments on first issue	DR	DG	GF

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1 INTRODUCTION

At the request of National Gas Transmission ("National Gas", "NGT"), DNV has been supporting the development of a unified digital twin ecosystem that will underpin NGT's long-term Network Performance Twin ("NPT") vision. This work forms part of the Network Innovation Allowance (NIA) project "Novel Unified Viewer for NGT Performance Twin" and builds on the foundations established through the Collaborative Visual Data Twin ("CVDT") project delivered between 2022 and 2024.

National Gas is undertaking a strategic digital transformation to enhance the resilience, efficiency and sustainability of the UK's National Transmission System (NTS). This transformation is driven by two converging imperatives: the need to repurpose the network for hydrogen as a low-carbon energy source, and the growing climate-related risks, particularly flooding, that the NTS must be able to anticipate and manage. In response, this project, the Network Performance Twin ("NPT") combines three flagship initiatives, developed in consortium with the Centre for Modelling and Simulation ("CFMS"):

- The existing CVDT demonstrator; a flagship digitalisation initiative that combines real-time and historical asset data from the FutureGrid test site located at DNV Spadeadam with immersive 3D models. Integrating Building Information Modelling ("BIM"), GIS and SCADA data enables the CVDT platform to support use cases spanning live data monitoring, virtual training and predictive maintenance.
- The HyNTS Dataset Automation Project; a structured geodatabase developed to assess the hydrogen readiness of existing methane infrastructure. The HyNTS Dataset automates the ingestion, classification and visualisation of (predominantly) pipeline data.
- A new flood twin; developed using DNV Climatics Flood Modelling Engine, this initiative aims to combat the 2024 Climate Change Adaptation Report's findings that flooding poses a critical risk to infrastructure. Integrating flood twin capabilities into the existing CVDT platform supports NGT's ongoing ambitions on climate resilience planning and adaptation.

During this project, DNV have (in partnership with CFMS) integrated the above components into a single digital twin environment capable of visualising, simulating and managing the performance and risks of critical gas infrastructure in a hydrogen-enabled, climate-resilient future. This digital twin environment is henceforth referred to as NPT; the Network Performance Twin.

The digital twin environment selected for this integration was the existing CVDT infrastructure which was developed, and continues to be hosted, by DNV and CFMS. The infrastructure was designed to be scalable both vertically and horizontally, and as such could accommodate both new use cases and the incorporation of new sites associated with these use cases – selected to be [redacted] Multijunction, [redacted] and [redacted] Valve Station.

Finally, a feasibility study was conducted to assess how the NPT solution could be scaled, integrated and governed within National Gas's IT estate in RIIO-3, outlining the NPT's core components, required IT procedures, priority use cases, key gaps and the recommended next steps toward production-grade readiness. At the request of NGT team, the gap analysis and risk assessment elements of this study were postponed and will be undertaken in a future project.

This report summarises the work undertaken by DNV under this scope.

2 BASIS FOR WORK

National Gas issued a request for proposal titled Novel Unified Viewer for NGT Performance Twin Proposal issued 11th August 2025. Table 2-1 shows how the NPT project proposal builds on the previous CVDT Phase 1 and CVDT Phase 2 projects.

Table 2-1: Comparison of the NPT project with the previous CVDT Phase 1 and 2 projects.

	CVDT Phase 1	CVDT Phase 2	NPT
Aim	Explore the feasibility of a digital twin solution.	Build a demonstration digital twin of the FutureGrid test site.	Expand on the existing digital twin to integrate HyNTS and virtual twin and flood model data sets.
Relationship	Standalone feasibility phase.	Build out of CVDT Phase 1.	Expansion of CVDT Phase 2.
Example Use Cases	Understand NGT requirements, explore potential technologies and define project partner roles.	Real-time monitoring of FutureGrid Hydrogen test program, hazardous area visualisation and training VR app.	Demonstrate integration with NGT data sets (addition of NGT AGIs), expansion to include pipeline inspection data and visualisation of flood modelling.
Data	Define data architecture.	FutureGrid sensor (IoT) data, structured asset data (metadata) and unstructured asset data (files).	Additional AGI metadata, pipeline inspection data and flood modelling results (both data and visualisations).
Maturity	Conceptual.	Proof-of-concept digital twin.	Demonstrable compatibility with NGT system data.

3 METHODOLOGY & ARCHITECTURE

3.1 Key tasks and activities

The key tasks delivered by DNV under this project are described in Table 3-1:

Table 3-1: Task names and descriptions for tasks delivered by DNV.

Task	Name	Description
1a	Feasibility study	• Evaluate the current functionality of the CVDT application against NGT IT requirements and strategic digitalisation ambitions. • Assess the scalability of CVDT to meet future use cases. • *Assess technologies within NGT's IT estate that could enhance the functionality of CVDT – deferred to a future project.*
1b	Virtual twin integration	• Collect the necessary metadata associated with the 3 sites being integrated into the digital twin – [redacted] – and populate the asset database with this data.
2	HyNTS integration	• Conduct a thorough review of the HyNTS dataset to identify the key requirements for integration, develop an integration strategy and make this data available via API for front-end visualisation.
3a	Flood scenario modelling	• Build a flood exposure map using regional UK watershed data • Apply damage functions to screen NGT's assets for their flood vulnerability • Present that data in a form that is accessible and useful for decision making.
3b	Flood twin integration	• Modify the asset database to host the results and outputs from Task 3a. • Make this data available via API for front-end visualization.

The starting point for this project was the existing CVDT application, utilising all components that had previously been developed under the NIA-funded Phase 2 of that project.

The objective of the project was to expand the functionality of the existing web application; both the front-end developed and hosted by CFMS and the data management system developed and hosted by DNV. The completion of the key tasks described above demonstrates the scalability of the CVDT application to act as a Novel Unified Viewer for a Network Performance Twin. As such, the decision was taken by NGT to rename the application from CVDT to NPT.

3.2 Responsibilities of each partner

The main technical tasks performed by DNV and CFMS during this project are outlined in Table 3-2:

Table 3-2: Project tasks and responsible project partner.

No.	Task	Responsible
1	**Feasibility study & virtual twin integration**	
1.1	Feasibility study – alignment of NPT with NGT IT requirements and strategic roadmap.	DNV
1.2	Integration of 3 new virtual twins into existing NPT viewer	CFMS
1.3	Metadata collection & population of asset database with 3 new sites	DNV
2	**NPT & HyNTS Dataset Integration**	
2.1	Integrate NPT asset database with HyNTS dataset	DNV
2.2	Display data on NPT front end	CFMS
3	**Integration of Flood Twin data with NPT**	
3.1	Flood scenario modelling	DNV
3.2	Integration of Flood Twin data with asset database	DNV
3.3	Visualise flood scenarios on NPT front end	CFMS

3.3 NPT Solution Architecture

Following a detailed review of requirements at project kick-off, it was determined that significant architectural changes were not required to the data management system to meet the needs of the additional use cases. Rather, changes were implemented in the form of new data pipelines to ingest new datasets and transform them to align with the existing asset hierarchy. The architecture diagram developed under the CVDT Phase 2 project was updated with the changes associated with NPT and is displayed in Figure 3-1.

DNV

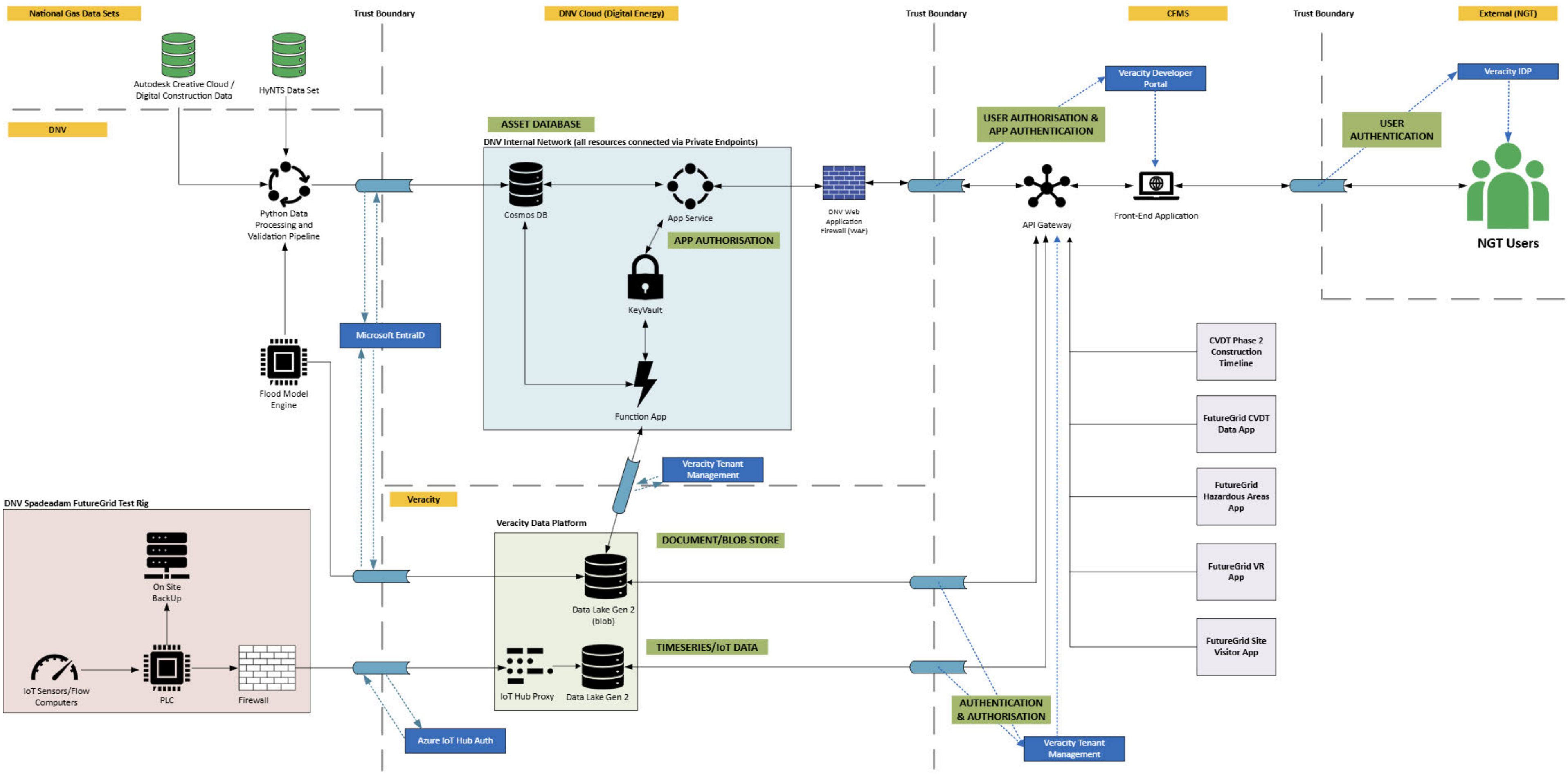

Figure 3-1: NPT Digital Twin Architecture Diagram

4 WORK PACKAGE 1A – FEASIBILITY STUDY

NGT requires confidence that the existing CVDT solution can be scaled, integrated, and governed within its IT estate in a way that aligns with its strategic digitalisation roadmap. To this end, NGT requested that DNV conduct an initial feasibility study, encompassing:

- The key components and functions of NPT
- The NGT IT procedures that would govern its integration
- The priority use cases (identified in previous project phases) and the scalability of the solution to meet these use cases.

4.1 Key components and functions of NPT

NPT is composed of several core components, each responsible for a specific function within the digital twin and with hosting spread across multiple organisations. This section outlines the as-is state of these elements, which will form the basis of an eventual migration into NGT's IT estate as part of a full solution transition. Table 4-1 provides an overview of the key systems, their components and sub-components, and the technologies or platforms on which each is hosted:

Table 4-1: Key components of NPT.

System	Component	Sub-component	Tech/hosted on
CVDT Angular Webapp	Website	N/A	CFMS Datacentre
DNV Data Management System	Asset Database	Asset Register (noSQL)	Azure Cosmos DB
	Veracity Data Workbench	IoT (timeseries) data	Azure Gen 2 Datalake
		Unstructured asset data (i.e PDF, XLSX and Geotiff files)	Azure Gen 2 Datalake
Connections	PY Fast API	N/A	Azure Webapp
	Veracity API	N/A	Veracity
	Direct transfer via SAS	N/A	Veracity
	API Gateway	Gravitee.io APIM	CFMS Datacentre
Visualisation Layers	CFMS webapp	Login Page	CFMS Webapp
		Site Map Tile	CFMS Webapp

System	Component	Sub-component	Tech/hosted on
		Visualisations of CAD Models	CFMS Webapp
		Detailed View Page	CFMS Webapp
		Sensor Data Plots	CFMS Webapp
		Metadata Overlay	CFMS Webapp
		Flood Visualisation	CFMS Webapp
Integrated Datasets	HyNTS Data sets	HyNTS ESRI GeoDatabase	ESRI
		HyNTS Sharepoint	Sharepoint
Integrated Flood twin	Flood modelling	Flood Modelling Engine	DNV Climatics
DNV Identity Management System	Authentication Layer	Veracity IDP	CVDT Dashboard Identity Service App
			CVDT Dashboard Identity App
			Veracity Data Workbench Credentials
CFMS Authentication	Authentication Layer	Custom Python Backend Service	CFMS Datacentre
3D Model Repository	3D Model Repository	Plastic SCM	CFMS Datacentre

4.1.1 NPT Angular Web Application

The Web Application for the NPT project which acts as the primary interface between the user and the digital twin, giving users a central website through which they can access and interact with the solution and the data provided for the project. The website is administered by CFMS and is hosted within the CFMS datacenter.

4.1.2 DNV Data Management System

Comprised of the Asset Database and the IoT Pipeline, this system houses the authoritative asset information for the digital twin, providing a central repository that serves as the source of truth for NG assets that have been moved to Spadeadam for the FutureGrid demonstration project. It combines live operational data from FutureGrid with supporting asset records, including PDFs and other unstructured documentation.

- The Asset Database, which contains the Asset Register (noSQL), is hosted on Azure Cosmos DB, while the IoT Pipeline, comprising both operational data and unstructured asset data, is hosted on Azure Gen 2 Datalake.

It is important to note that both phases of the CVDT project were pilot studies, developed on testing environments outside of the National Gas IT estate.

4.1.3 Connections

The 'connections' within the solution provide the mechanisms through which data held within the digital twin's various back-end components is served between systems and ultimately to the front-end application. They enable communication between the asset database, the IoT data stores, and the visualisation layers by exposing secure, controlled interfaces for each data flow.

- The Python FastAPI service, hosted on Azure WebApp Service, provides the pathway through which the Asset Register is accessed by the front end.
- The Veracity API, operating within the DNV Veracity platform, serves as the route through which IoT data is delivered to the user interface.
- Unstructured asset data stored in the Azure Data Lake is made available through a direct SAS-token transfer mechanism, also facilitated by Veracity.
- Finally, the API Gateway, implemented using Gravitee.io APIM within the CFMS datacentre, governs all external API access, ensuring that calls to these services remain secure, authenticated, and consistently managed.

4.1.4 Visualisation Layers (CFMS Webapp)

Comprised entirely of modules within the CFMS Webapp, the Visualisation Layers system provides the full suite of user-facing views through which the digital twin is explored and interpreted. Operating from the CFMS Webapp platform, these components enable users to navigate the site, inspect assets, and observe live and historical sensor data.

The system includes several elements:

- The Login Page, which controls initial access to the platform
- Site Map Tile, which presents an interactive spatial overview of the site
- CAD Model Visualisations, which renders detailed 3D engineering models for asset inspection.
- Additional components include the Detailed View Page, used for asset-specific information; Sensor Data Plots, which display IoT time-series data; Metadata Overlays, providing contextual information on top of visual layers; 3D

Hazardous are maps, developed by Premtech and the Flood Visualisation component, which integrates flood-modelling outputs directly into the interface.

All visualisation components of the digital twin are run on the CFMS Webapp.

4.1.5 Integrated Datasets

The newly integrated HyNTS datasets originate from the HyNTS Dataset Automation project, a data platform developed to support the repurposing of the UK's National Transmission System (NTS) by providing structured, high-fidelity asset data essential for hydrogen transition planning. It enables automated ingestion, classification, and spatial visualisation of pipeline and site data, supporting risk mapping, integrity assessments, and integration with GIS platforms.

Within the digital twin, these datasets provide geospatial and reference information that can used for spatial analysis, network modelling, and broader asset understanding. This system brings together two external data sources: the HyNTS ESRI GeoDatabase, hosted on the ESRI platform and containing geospatial data relevant to the hydrogen transmission network, and HyNTS SharePoint, which stores supplementary documents and structured records used to provide asset context across the solution.

4.1.6 Integrated Flood Twin

The Integrated Flood Twin provides flood-modelling capability within the digital twin, enabling National Gas to assess how its assets may be exposed to future flood scenarios. Built on the DNV Climatics Flood Modelling Engine, this system supports both present-day and future vulnerability assessments through providing interactive geospatial visualisations of flood depth and exposure.

4.1.7 DNV Identity Management System

The DNV Identity Management System is comprised of set of identity and access-control components and provides the authentication layer that governs how users and applications securely interact with the digital twin.

Built around the Veracity IDP, this system ensures that only authorised Veracity accounts can access the CVDT Webapp through the CVDT Dashboard Identity Service App, which manages user-level permissions. Alongside this, the CVDT Dashboard Identity App supplies the application credentials required to interrogate the Asset Register API, enabling controlled access to underlying asset data. Complementing these, Veracity Data Workbench Credentials allow the front-end components to retrieve information from the Data Management System as needed.

4.1.8 CFMS Authentication

Comprised of a single backend authentication component, the CFMS Authentication system provides an additional layer of authority and access control within the digital twin architecture. Operating as a custom python backend service hosted in the CFMS Datacentre, this component integrates directly with the Veracity Identity Provider

The 3D Model Repository acts as the dedicated storage system for all engineering and geometric assets used within the digital twin's visualisation environment. Hosted in the CFMS Datacentre and built on Plastic SCM, the repository contains the full library of 3D models alongside their associated JSON metadata file.

4.2 National Gas IT Procedures & Integration Requirements

The Gas IT Delivery Framework (GIDF) defines the procedures for introducing new or changed IT solutions into the National Gas IT estate. It sets out governance, stage-gate controls, and service acceptance requirements that apply to all IT projects, including the potential integration of NPT into National Gas' IT estate. The framework covers initiation, design, build, test, deployment, and transition into operational service, and requires an architecture review, design authority approval, security assessment, service transition checks, testing documentation, and financial and commercial processes.

Integration of NPT into the IT estate would therefore need to follow the GIDF stage-gated process, completing the required design approvals, meeting Secure-by-Design requirements, passing service transition controls, and aligning with the standard operational, architectural, and governance procedures defined within the framework.

The following summarises the necessary stages and procedures that NPT would have to follow within the GIDF process to be successfully integrated into national gases IT estate.

Stage Gate 1

- Approved Investment Paper (GTIC)
- Stakeholder Engagement Plan
- My Finance – WBS (Opex/Capex)
- ADO – New Project Request
- Gas Design Authority – GDA Stage Gate 1, (CSA – Design Approval)
    - (Inclusive of a solution vision document, ITAR)
- Security Triage Assessment
- Service Transition Initiation & Checklist

Stage Gate 2

- Test Closure Report Approval
- Gas Design Authority (GDA Stage Gate 2)
- (Deployment Approval)
- Secure By Design (SBD) Approval
- Service Transition Approval
- (Service Acceptance Criteria)
- Service Transition Go/No Go Checklist

Stage Gate 3

- Early Life Support exit sign-off
- Investment Closure – GTIC
- Finance Closure

At the request of NGT, it was agreed that the gap analysis and risk assessment elements of the feasibility study would be placed on-hold and revisited during RIIO-3. The information gathered in this work package will feed into this process when it takes place, allowing NGT to make an informed decision for the eventual integration of NPT into the IT estate.

4.3 Priority Digital Twin Use Cases

NGT is undertaking a strategic digital transformation to enhance the resilience, efficiency, and sustainability of the UK's National Transmission System (NTS). This transformation is driven by two converging imperatives: the transition to hydrogen as a low-carbon energy source and the increasing risks posed by climate change, particularly flooding.

NGT's 2026 Digitalisation Strategy /1/ has explicitly called out digitalisation as an enabler of change, driving the transition of the organisational culture from one of local knowledge (with decisions made based on experience and judgement, which can be subjective and variable) to a culture that is data driven. The vision is that disaggregated, repeatable actions can be completed using data and advanced tools, allowing experts to focus their attention on complex issues.

Two initiatives called out in the Digitalisation Strategy, CVDT (NPT) and HyNTS, have been selected for integration in this project due to the continued importance to NGT's ambitions in this space. In RIIO-3, there is an ambition to firmly embed both tools into normal business-as-usual processes. In parallel, the flood twin use case was selected due to the extensive investment NGT is making to address flood vulnerabilities of its assets, but also due to the alignment this use case has with elements of the strategy. Table 4-2 demonstrates some of the key elements of the Digitalisation Strategy, and expands on how the use case selected in this project aligns with these elements:

Table 4-2: Alignment of NPT project with NGT Digitalisation Strategy.

Strategy Element	Alignment with NPT Project
Facilitate access to complete, accurate, trusted and wide range of datasets to support analytical capability development.	Expanding NPT to include the HyNTS data and the data from the [redacted] AGIs supports this vision of centralised and trusted access to data.
Enhance visibility of our assets through their lifecycle to improve asset management capabilities.	Increased number of assets – both pipes and AGI equipment – have been displayed in NPT viewer, including new flood management advice to strengthen asset management.
Leverage digital technologies to simplify and improve effectiveness of processes and/or improve efficiency of our workforce.	NPT acts as a central, saleable digital twin to improve workforce/process efficiency by minimising time lost due to incomplete data.
Selectively utilise frontier technologies including analytics and AI to enable enhanced and automated data-driven decision making	AI enabled flood modelling capabilities have been integrated with NPT
Implement simple and consistent data architecture and system design to improve data quality and enforce data security.	NPT data architecture remains aligned with NGT's data hierarchy.

By expanding the scope of NPT beyond FutureGrid, and incorporating data from the broader NTS and additional AGIs, this project has demonstrated the potential of NPT acting as a single, unified visualisation layer for NGT's digitalisation ambitions. Incorporating flood twin capabilities has allowed the solution to act as a test bed for the environmental modelling use cases which was previously identified, further allowing NPT to be tested for future roll-out across NGT.

5 WORK PACKAGE 1B – VIRTUAL TWIN INTEGRATION

A key aim of the NPT project was to demonstrate the scalability of the application by ingesting new data sources and visualising three new virtual twin sites on the front-end web application, Figure 5-1. The additional sites to be integrated had been modelled by another flagship NGT digitalisation project; Digital Construction:

- [redacted];
- [redacted]; and
- [redacted], a Combined Cycle Gas Turbine (CCGT) power plant in [redacted]

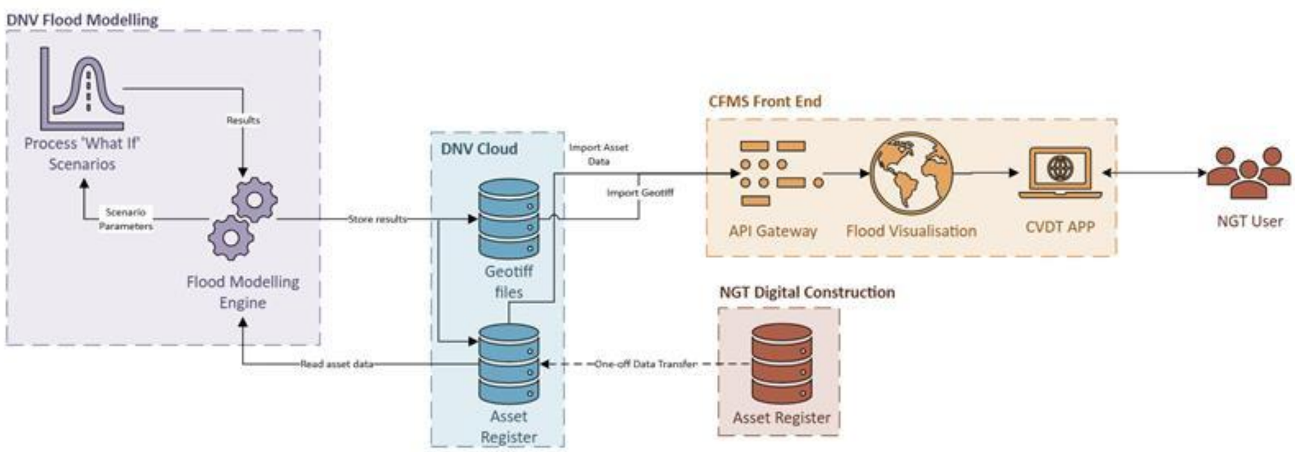

Figure 5-1: Updated NPT architecture.

5.1 Digital Construction data

Under the direction of NGT, DNV have used the Digital Construction dataset as the source of truth for populating the asset database with the new metadata required for the virtual twin sites. The data is hosted directly on another flagship digitalisation project completed by NGT, using Autodesk Construction Cloud ("ACC"). DNV was provided with access to data files in the ACC platform where the asset data was found in an XLSX format. DNV created a data processing pipeline to ingest these XLSX files, perform the necessary transformations (to JSON structure) and validation checks to ensure data integrity before uploading the data to the asset database in NPT. Having created a scalable data processing pipeline, it allows future enhancements such as integrating new data sets or connecting directly to a data repository so that the data accessed via the NPT application is continuously updated.

The dataset includes static descriptions of assets; GIS coordinates and metadata such as manufacturer and material. The data was aligned to a hierarchy based on a location code for each asset; however, as stated below there were numerous issues surrounding the quality of the location codes which presented a challenge in determining the hierarchy. Assumptions were made and agreed with NGT to replicate this hierarchy as much as practicable.

Asset names were not found within the database, with often duplicated descriptions, so the location code has been used as the display name for the assets. Also, though the location code provides an idea of asset grouping into systems and subsites, details of the systems and subsites were unavailable so a sequential naming scheme has been adopted for these layers in the hierarchy (I.e. Subsite 1, Subsite 2…).

5.2 Expansion of asset registry

The asset registry, which was previously used to host FutureGrid asset data, has been expanded with the inclusion of three additional sites; and the additional data included in the Digital Construction data set. This enables the data to be made available via API to NGT and to the NPT application.

The approach to the previous CVDT project has been demonstrated to be scalable with the inclusion of the three new AGIs in the NPT project which made use of the existing data validation models (which define the data structure) to ensure compatibility with the CFMS front end application.

As the dataset for the new AGIs was more comprehensive than the FutureGrid dataset, a property has been added to the Asset model ("digital_construction_data") which stores the Digital Construction data as a key-value pair dictionary which allows for the addition of the Digital Construction data without having to remodel the existing FutureGrid data within the database. This minor change enables future expansion of the data stored to capture more information within the application.

The asset database is a continuation of the database used in the previous CVDT project, with the asset hierarchy of site, subsite, system and assets with assets having data channels and documents assigned. Each relation is one-to-many (i.e. one site can have many subsites, one system can have many assets, and one asset can have many datachannels); this hierarchy is shown in Figure 5-2.

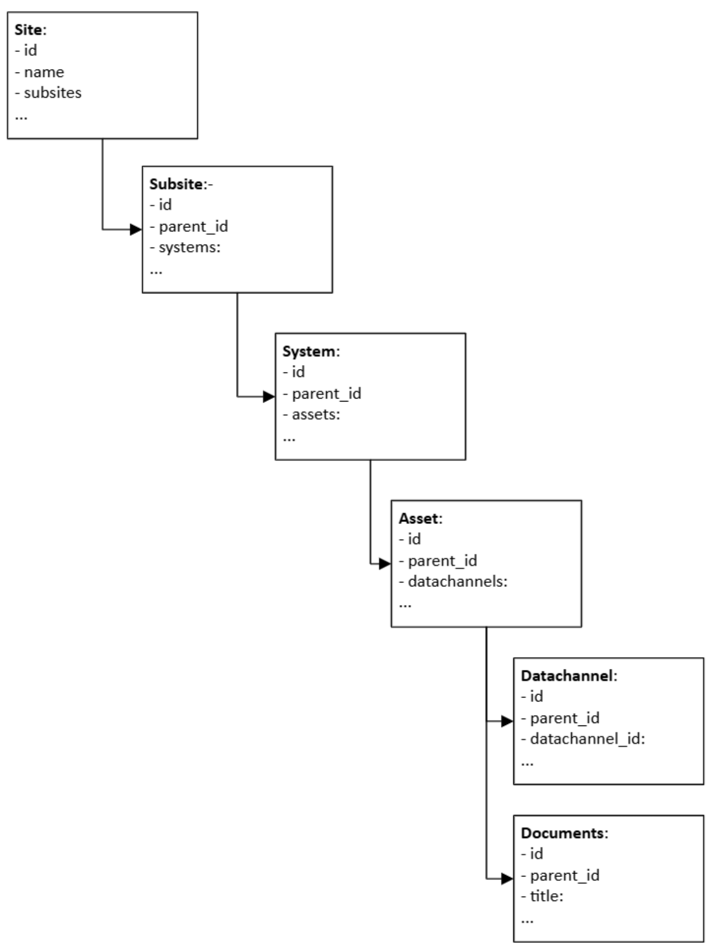

Figure 5-2: Asset hierarchy in the NPT asset database.

The data ingest was performed through a bespoke Python data processing pipeline to allow quick ingestion of a large quantity of data while performing data quality and validation checks to ensure the database contents are accurate and complete. This made use of the APIs data validation mechanisms to ensure data was correctly assigned on ingest to the database, and that unexpected/superfluous data was stripped to keep the database contents clean.

The ingestion process utilised the location code attribute to deduce the hierarchy of assets at the site to match the hierarchy used for the FutureGrid site. This includes a allocating asset data into the site, subsite, system and assets structure.

DNV determined the location code to be the only viable way to structure the data in the pre-existing hierarchy, but its format was often inconsistent, and the data completeness was poor. Where possible, accurate names and descriptions have been attributed to the associated Site, Subsite, System, and Asset though this has not always been possible as DNV noticed a large variation in the quality of the Digital Construction data set. A summary of the data coverage of problematic values is below:

[redacted]

- Coordinates: Less than 50% of assets have X or Y coordinates.
- Location Code: ~2% coverage.
- Manufacturer: Only 26.42% of assets have a manufacturer value (G0040_MANUFACTURER or Manufacturer).

[redacted]

- Location Code: Low coverage at 15.15%.
- Manufacturer: ~30% coverage.

[redacted]

- Coordinates: ~50% of assets have X or Y coordinates.
- Location Code: 28% coverage.
- Manufacturer: 25% coverage.

To address this, an additional System was created for each site to host assets where it was not possible to ascertain which system an asset belonged to (i.e. the location code was absent). This enables all the data to be made available through the NPT application, while also allowing the option of updating the location code and correcting its associated system in the future. The result is a successful transformation of Digital Construction data and subsequent ingest into the NPT asset registry which allows the data to be retrieved by an API gateway for visualisation in the NPT application.

Despite successfully completing a data upload as part of this project, DNV recommends a data quality assurance activity on the Digital Construction dataset, as more sites such as [redacted] continue to be modelled, to derisk the future integration of further AGIs and datasets.

6 WORK PACKAGE 2 – NPT & HYNTS INTEGRATION

DNV was tasked with integrating the HyNTS dataset into the NPT application to show how a unified viewer could be used to access data from multiple data sources. DNV subdivided this task into:

1) Requirements gathering
2) Data integration design
3) Delivery of a POC

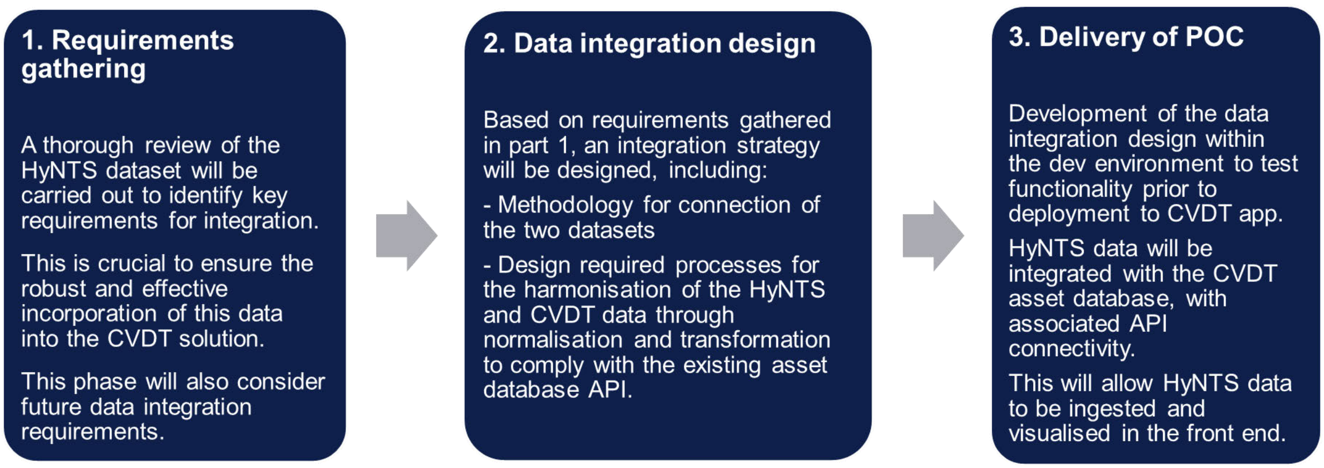

Figure 6-1: NPT & HyNTS integration approach.

6.1 HyNTS data

The HyNTS Pipeline Dataset is the output of another digitalisation project completed by NGT, delivered by Rosen. It is a georeferenced SQL geodatabase containing records of all in-line inspection ("ILI") work completed on various feeders across the NTS. It was exported and converted to CSV format for upload to the asset database.

6.2 Requirements gathering

DNV liaised with ROSEN to identify the structure and format of the HyNTS data set and to design the best solution for integrating the HyNTS dataset into the NPT estate. The chosen solution was to perform a direct export from the ROSEN SQL database into a series of files which could then be ingested into DNV's IT estate. As the data was structured and of a large quantity, the NPT asset database was chosen to be the optimal location to store the data for access through the NPT application; this is due to the intrinsically scalable nature of the cloud-hosted database, it being purposely designed to host structured data, and it's design enables the HyNTS data to be use the existing hierarchy design to associate data with specific pipelines. Any non-structured data could then be hosted in the blob store for retrieval via the NPT application. Figure Figure 6-2 shows how the HyNTS files were aligned with the existing NPT data sources, with the structured data mapping to the asset database and unstructured data (files) being best integrated with the blob store.

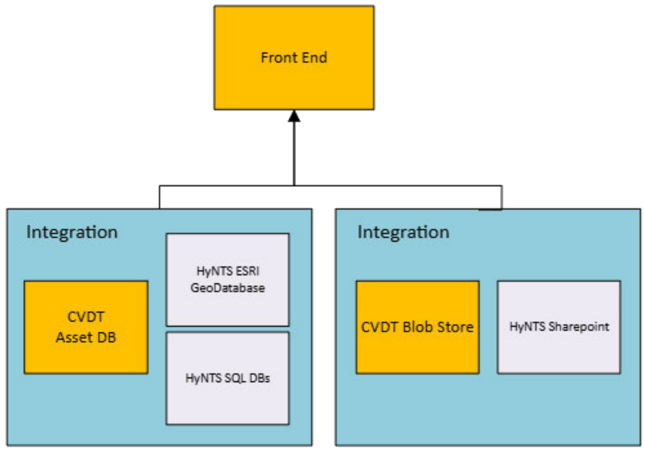

Figure 6-2: Integration approach for HyNTS Pipeline Dataset.

6.3 Data integration design

DNV developed a data ingestion pipeline based on a direct export from the HyNTS dataset.

As the data, mostly pipeline inspection data, is associated with the pipelines that connect sites together, rather than the sites themselves, and new model class was defined for Pipes. This sits at the same level in the asset hierarchy as sites, and it enables CFMS to use fewer API calls to allow the web app to function yet provides full flexibility in the data they request.

For each Pipe, there is an associated Inspection which itself contains a list of Inspection Points. This allows future Inspections (with multiple inspection points) to be added to the dataset without combining inspection points from different inspections. An example of the hierarchy structure employed is shown in Figure 6-3, and it follows the same one-to-many relationship as the AGI asset data; i.e. one pipe can have many inspections, and each inspection can have many inspection points. This ensures that the pipeline would be able to handle future expansion to the dataset for quick and efficient upload of data into the NPT application – this was demonstrably scalable during the upload of the 4 inspections included in this project which, when combined, consisted of 17,044 individual inspection point items.

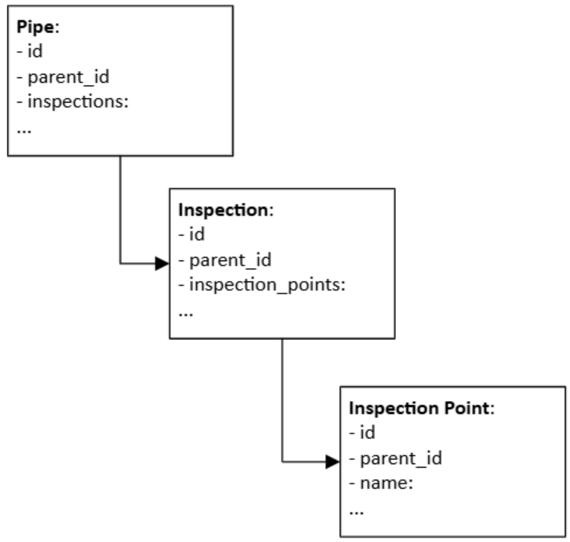

Figure 6-3: Example pipe asset hierarchy schematic.

Each of the item levels (Pipe, Inspection and Inspection Point) is validated using Pydantic model validation both on the upload to the database (to ensure completeness and compliance with the data structure) and on the response returned in an API call (to ensure the data in the response is as expected). This provides the additional benefit of the complete response details being reflected in the API documentation.

6.4 Delivery of a POC

To deliver the POC, DNV followed its software development process to provide seamless, robust deployments. This consisted of 3 stages:

1) Project developer making the required changes to the codebase and writing sufficient unit tests to check for functionality and robustness against edge cases.
2) Deployment of the app to DNV's test environment which is contained within DNV's internal network (not accessible via public internet). Synthetic data, which followed the same structure as the NGT dataset, was produced and uploaded to the test database (note, this was *not* NGT's data, but mock data) and the API endpoints were then tested for functionality and to check the response matched the project requirements.
3) The changes were then deployed into DNV's production environment which exposes the data via API to CFMS for visualisation in the NPT application.

The development process utilised a standard branching policy with automated Azure CI/CD pipelines to provide rapid deployments. These CI/CD pipelines also automatically check for and continue only on a 100% pass rate of unit tests, ensuring robust functionality. Alongside cyber security measures such as input parameterisation, token-based authorisation and disabled public access to resources, DNV also implemented an IP whitelist to ensure the API could only be accessed from the DNV internal network and the CFMS server. This drastically reduces the likelihood the NPT API developed by DNV could be the target of an external cyber-attack.

7 WORK PACKAGE 3A – FLOOD SCENARIO MODELLING

National Gas Transmission asked DNV to review how flooding could affect the assets at three NPT above ground installation sites 1. [redacted] multi-junction 2 [redacted] and 3. [redacted] This review looked at the Flood exposure and vulnerability of individual equipment items, such as valves, pig traps, meters, the control room, and power intake. As well as the potential impact on the wider site.

The assessment used mapped flood depths from NaFRA2 (using both historical and climate change) but also added flash flood projections from UKCP18 climate projections and combined these with equipment locations, heights, and functions. The goal was to understand which items could fail during a flood, how likely failure might be, and how this would affect the operation of the entire site.

[redacted]

Figure 7-1: NGT NPT sites for flood risk assessment

The initial scope considered multiple sites as shown in Figure 7-1 above however our review identified inconsistencies in the available flood information across locations. Specifically, only [redacted] Junction is covered by NaFRA2 flood mapping and has flood exposure, while [redacted] shows no flood exposure and [redacted] lies outside the NAFRA2 data extent since the site itself lies in [redacted] As a result, the detailed assessment has been carried out for [redacted] multi-junction only and this site is used for Flood exposure mapping (section 7.1), vulnerability assessment (section 7.2) and economic damage modelling (section 7.3).

7.1 AGI Exposure to Flooding

The flood exposure assessment for the NPT sites was undertaken using the Environment Agency's NaFRA2 flood mapping dataset, supplemented with future rainfall uplift projections derived from UKCP18. This allowed DNV to evaluate the likelihood and severity of inundation at each AGI under both present-day and 2050s climate conditions. Exposure was assessed through a combination of flood depth, extent, velocity and hazard ratings, with flood information mapped against the precise location and elevations of equipment across each site.

7.1.1 Flood Exposure Mapping Data and Methodology

For [redacted] the AGI was assessed across a suite of flood scenarios that included:

1 Baseline (present day)

a) Surface water and fluvial flood depths

b) Flood extents for 1-in-2yr, 1-in-30yr and 1-in-100yr events

c) Standardised depth bands(e.g. 0-20cm, 20-40cm, 40-60cm, >60cm)

d) Associated hazard and velocity hazards

2 2050s Climate change scenarios

a) NAFRA2 climate adjusted flood layers

b) UKCP18 derived rainfall uplift factors (central and upper end allowances) applied to relevant storm durations.

c) Return period adjustments reflecting higher rainfall intensity

3 Short duration/flash flood scenario

a) Application of convective permitting rainfall uplift for 1-in-2yr, 1-in-30yr and 1-in-100yr for 2050s with UKCP18 scenario.

b) Focus on rapid inundation affecting near-surface equipment.

A 5 km × 5 km buffer was applied around the AGI to match the spatial resolution of UKCP18 rainfall uplift data while ensuring that the higher-resolution NaFRA2 layers were fully preserved for the immediate site.

This analysis provided a detailed spatial understanding of which parts of the [redacted] site become inundated under each scenario and to what depth.

Figure 7-2: Site location, equipment layout and baseline flood risk for [redacted] multijunction.

A three-panel overview of the [redacted] Multijunction AGI, illustrating (i) the location of the site, (ii) the distribution of equipment items included in the assessment, and (iii) the baseline (present-day) flood risk affecting the installation is shown in Figure 7-2.

Left panel – Site Location

The left panel shows the [redacted] AGI within its surrounding landscape. The aerial imagery highlights the site boundary, access routes, and general land cover. This provides geographic context for the assessment and illustrates the relationship between the AGI and the adjacent transport and agricultural areas.

Middle panel – Equipment of Interest

The central panel maps all equipment items included in the vulnerability assessment. Each point represents a specific asset, such as valves, pipework components, metering and instrumentation units, and ancillary structures distributed across the site. The dense clustering of points within the main compound reflects areas with high equipment concentration and operational interdependencies.

Right panel – Baseline Flood Risk

The right panel overlays the equipment dataset onto NAFRA2's baseline surface-water flood risk categories. The colour-coding indicates the annual probability of flooding:

- **Yellow** – Low risk (less than 1% annual chance)
- **Orange** – Medium risk (1–3.3% annual chance)
- **Red** – High risk (greater than 3.3% annual chance)

The map shows that several areas around the northern and central parts of the AGI fall within medium-to-high baseline flood risk classes. Some equipment clusters intersect with shallow flood cells, highlighting zones where assets are more exposed to surface-water accumulation during present-day conditions. Conversely, other equipment groupings lie entirely outside the identified hazard zones, indicating minimal baseline exposure.

7.1.2 Climate adjusted flood exposure scenarios for [redacted] multi-junction.

To understand how flood exposure at the [redacted] Multijunction AGI may change under future climate conditions, DNV developed a set of climate-adjusted flood exposure scenarios that build on the Environment Agency's NAFRA2 flood mapping. Baseline and 2050s climate-change flood layers from NAFRA2 were used as the foundation, providing nationally consistent flood depth, extent and probability information for surface-water flooding at the site.

In addition, UKCP18 rainfall uplift projections were incorporated to account for increases in short- and long-duration rainfall intensity that are not fully captured in standard flood mapping. These uplifts reflect evidence that future extreme rainfall is expected to become more intense and frequent, particularly for convective and prolonged storm events, which can significantly influence surface-water accumulation at site scale. Including rainfall uplift therefore provides a more realistic representation of future flood exposure and supports a robust screening-level assessment of how flood risk at the AGI may evolve over time.

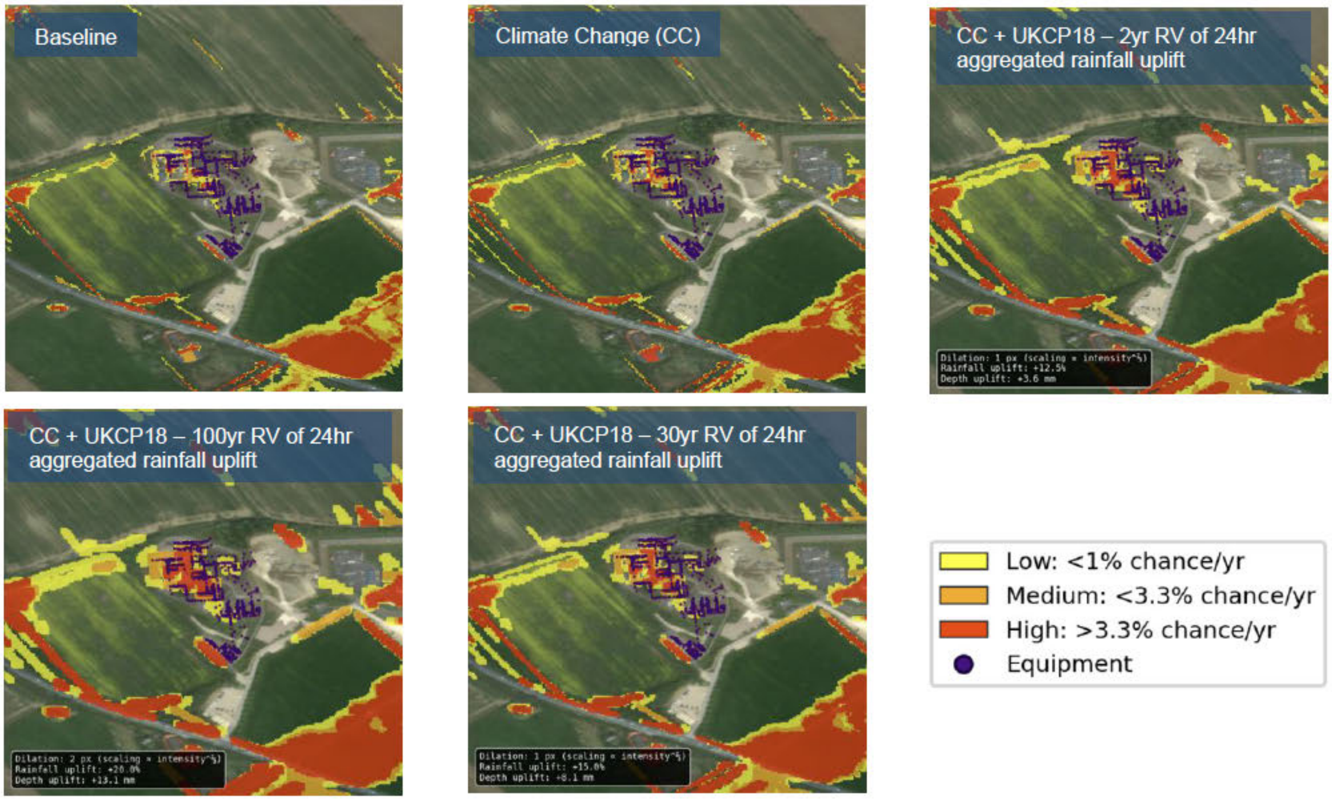

Figure 7-3: Comparison of Baseline, Climate Change, and UKCP18-Enhanced Flood Scenarios .Yellow is low risk (<1% annual chance), orange is medium risk (1% - 3.3% annual chance) and red is high risk (>3.3% annual chance)

Figure 7-3 illustrates how flood exposure at the [redacted] Multijunction AGI evolves under a sequence of increasingly severe or climate-adjusted scenarios. Each panel overlays NAFRA2/UKCP18 flood risk categories onto the AGI equipment layout, enabling a like-for-like comparison across scenarios. Together, the panels demonstrate how both depth and spatial spread of inundation increase as climate change and rainfall uplift factors are incorporated.

Under historical and present-day conditions (Figure 7-3, Panel 1), flooding is concentrated in depressions around the central and northern portions of the AGI. Several equipment clusters lie adjacent to medium-risk flood cells, while the majority of assets remain outside areas of high baseline hazard. The overall flood footprint is relatively contained, with shallow inundation patterns typical of surface-water accumulation. In future CC when NAFRA2's 2050s (Figure7-3, Panel 2) climate-change adjustments are applied, the extent and connectivity of flood cells increase. Medium-risk areas expand across the northern sections of the AGI, and isolated high-risk patches begin to appear. This reflects the effect of higher-intensity rainfall and future hydrological conditions embedded within the NAFRA2 climate scenario. Although equipment inundation remains limited, more assets sit closer to flood-affected zones.

To translate UKCP18 rainfall uplifts into corresponding spatial changes, DNV applied a sub-linear hydraulic scaling relationship between rainfall intensity and flood extent. Based on shallow-water flow theory, flood footprint expansion scales approximately with rainfall intensity raised to the power of two-thirds, reflecting the well-established principle that flood extent increases less than proportionally with rainfall. This relationship is widely documented in the flood-modelling literature and underpins many national-scale inundation models. The resulting flood exposure maps demonstrate a clear progression in both the extent and probability classification of flooding across the AGI as rainfall intensity increases:

- Under the 2-year return-value uplift, shallow but spatially widespread flooding emerges across internal site areas that remain unaffected in baseline conditions, highlighting sensitivity to intense but frequent rainfall events. (Figure 7-3, Panel 3)
- The 30-year uplift scenario shows a substantial increase in medium- and high-probability flood zones, particularly across the central AGI where equipment density is highest. (Figure 7-3, Panel 4)
- The 100-year uplift scenario represents the most severe case, with extensive connectivity between high-probability flood cells and a marked increase in the number of equipment clusters intersecting flood-prone areas. (Figure 7-3, Panel 5)

Across all future scenarios, flood depths and spatial coverage increase progressively, and previously isolated flood cells begin to merge, indicating a higher likelihood of compound-wide surface water accumulation during extreme events. These climate-adjusted exposure layers form the basis for the AGI vulnerability assessment presented in Section 7.2. By explicitly incorporating both long-term climate change and short-to-moderate return-value rainfall extremes, the analysis provides a robust framework for understanding how future flood conditions may affect equipment performance and overall site operability at [redacted] Multijunction.

7.2 AGI Vulnerability to Flooding

Assessing exposure to flooding only provides part of the picture – a key question remains "so what?" Assessing the vulnerability of assets to flood exposure (i.e. how the performance of the equipment will be affected by flooding) is key to determining what impact this might have on AGI performance and what adaptation may be needed.

7.2.1 Asset Selection and Data Preparation

The assessment covered [redacted] equipment items, including:

- [redacted] main gas valves
- [redacted] pig traps and associated bypass valves
- [redacted] main meter stations
- The control building
- The main power intake

These equipment items were selected because:

- They were potentially impacted by flood waters.
- Location data was available for them.
- They were identifiable (in terms of tag number and PnPID)

- There was sufficient information about the equipment to determine archetypes (valves, pig traps, meters, etc.) and damage functions.

For each item, DNV mapped:

- Latitude and longitude
- Height above or below ground
- Estimated flood depths across several scenarios (NaFRA2 baseline and three UKCP18 return periods: 2-year, 30-year, and 100-year events)

This allowed the grouping of the equipment by archetype and the development damage functions linking the flood exposure to potential for equipment failure. DNV then researched outage potential for each archetype. This is presented as an indicative Mean Time To Repair (MTTR) made up of a procurement period and a site works period. It was assumed that like-for-like equipment was not available in stock to ensure the assumptions were conservative.

Some other equipment was considered but not included:

- Pipework/ Pipelines – Not impacted by acute flood events. Chronic increases in soil moisture may impact corrosion rates but this is driven by a wide range of other variables (coatings, CP performance etc.) Movement due to buoyancy may occur away from AGIs if the soil conditions are right but it was assumed that there is sufficient anchoring within the AGI to prevent buoyancy effects.
- Pipe Supports – Pipe supports are typically above the flood water level. It was also assumed that no flood induced subsidence is prevalent, however, this may be a topic for further investigation with input from geotechnical expertise.
- Cathodic Protection - No asset or locational data available. Flood may affect the performance of impressed current and passive systems but without clear indication of equipment items this cannot be identified. The impact will also be more chronic than acute resulting in higher corrosion rates.

Equipment Configuration

It should be noted that only equipment shown on the general arrangement drawing (5335-5010-01 R1 Site GA) was covered so that equipment configuration could be determined. It was important to understand configuration partly to ensure equipment was placed correctly (based on one source of truth) (see Figure 7-5) and partly to understand the implications of failure. Figure 7-4 shows the general arrangement drawing the with offsite connections marked. This allowed the link between outage of the equipment and its implications for the flow of gas across the site.

[redacted]

[redacted]

There is a pig launcher and other equipment to the south of the [redacted] Junction site that is not covered by the drawing and so has not been included in the flood assessment.

Data Set

The asset data received from NGT was found the be largely consistent and complete for the equipment items covered but not all equipment was covered (see comments regarding Equipment Configuration and Cathodic Protection). Additionally, the general arrangement drawing mentioned above had incomplete marking of key valves and seems to have certain equipment blanked out. This meant identifying the correct configuration in some cases was based on engineering judgement.

7.2.2 Development of Assumption Sets

For each equipment type, DNV built assumptions covering:

- How floodwater interacts with the asset
- Likelihood of failure at certain water depths
- Consequences of failure for site operations
- Time needed to repair or replace the equipment

These assumptions were needed because the AGI contains a wide range of equipment with different designs and elevations.

Some examples of assumptions include:

- Valves: Flood depth must exceed the asset height by 0.5 m before the actuator or gearbox has a 10% chance of failure.
- Pig Traps: Doors are assumed to be at least 700 mm above grade; flood depths above this height could jam the door mechanism.
- Control Room: Any water ingress above 0.20 m has a high chance of entering the building and damaging power supplies and electronic racks.
- Power Intake: Flood depths above 0.10 m can enter the underground manhole and lead to deliberate isolation or tripping of electrical equipment for safety.
- Meters: Flood reaching device height is assumed to disable metering electronics.

7.2.3 Equipment Performance Index (EPI)

DNV created a relative scoring system, the Equipment Performance Index (EPI), which measured the importance of each item during a flood event.

The EPI includes:

- Flood exposure
- Probability of equipment failure
- Impact on site performance if the item fails
- Duration needed to bring the asset back to full operation

A high EPI means the asset has both a high chance of being affected and a high operational importance.

7.2.4 General Findings

The assessment found that:

- Nine equipment items would be impacted by flooding.
- Seven of these are below-ground valves, which are more exposed due to actuator height and trench design.
- There is little difference between the smallest and largest flood events – most sensitive equipment is already low-lying enough that even shallow flooding reaches it.

Two valves ([redacted]) and the Control Room have the highest operational impact.

No flooding scenario would fully shut down gas flow through the site, but several scenarios would reduce the ability to reconfigure flows or monitor the site remotely.

This means the site remains functional in all modelled flood conditions but with reduced flexibility and reduced control capability.

However, it should also be noted that one of the access points to the site (western side of the site) is also subject to flooding which may limit the ability to get personnel to the site from the public road.

7.2.5 Asset-Specific Vulnerability and Impacts

Valves

Out of the many valves assessed, seven were identified as vulnerable because their actuators or gearboxes are located low enough to be flooded.

Key findings include:

- Valves [redacted] and [redacted] have the highest EPI score (7.26). These valves sit between major feeder routes and compressor discharge/suction lines.
- Failure would **not** stop gas flow, but it would:
  - Prevent double isolation of the discharge to feeders 9 and 22
  - Prevent isolation of compressor suction lines

Valve repair or replacement typically requires long procurement times, especially for large-diameter units.

Pig Traps

Pig traps themselves are designed with some elevation placing them above most flood depths; however:

- Floodwaters above door height could jam door mechanisms.
- Bypass valve gearboxes may fail when wetted.
- Failure of pig traps does **not** stop gas flow but prevents pigging operations.
- A failed pig trap is assumed to affect only the feeder it serves.

Control Room

The control room is a critical asset on site. Flooding above 0.20 m could cause:

- Loss of SCADA coverage
- Damage to power supplies in equipment racks
- Loss of remote monitoring and flow control

Failure does **not** result in a loss in gas flow but in a 20% reduction in overall site performance/ efficiency as the AGI configuration no longer reflects the changing network needs.

Power Intake

The power intake is in a below-ground manhole. Floodwater can:

- Enter the manhole at shallow depths
- Cause earth-leakage trips
- Lead to deliberate manual shutdown for safety

Failure does **not** result in a loss in gas flow but in a 20% performance reduction, similar to the control room.

Meters

Metering equipment is vulnerable when flood depth reaches device height.

Loss of metering does **not** stop gas flow but reduces operational efficiency and situational awareness.

7.2.6 Site-Wide Impacts and Findings

The assessment concluded that:

- Site-wide outages are unlikely.
- Loss of valves, metering, control room functionality, or power intake each reduces site performance by about 20%.
- Chronic issues (not modelled here) could appear over time, such as:
  - Higher corrosion risk

- Increased need for interventions
- Reduced long-term reliability

Pipework and pipe supports were not expected to fail under flood conditions, but cathodic protection systems may be affected due to a lack of data on their installation.

7.2.7 Conclusions

The flood vulnerability assessment shows that [redacted] Junction AGI is resilient in terms of maintaining gas flow, but operational flexibility and remote control are at risk during flood events. Key conclusions include:

1. Nine equipment items are vulnerable, most of which are below-ground valves.
2. Two valves ([redacted]) present the highest operational risk due to their central role in managing compressor connections. These impact Feeders [redacted], and compressor suction and discharge line isolation.
3. The control room and power intake are single-point vulnerabilities, with failures leading to loss of visibility and reduced operational performance.
4. Flood severity does not greatly change the outcome – even relatively shallow floods affect low-lying actuators and underground facilities.
5. The site will continue to flow gas, but with reduced efficiency, reduced control capability, and higher operational burden.
6. Recovery times for key equipment (especially valves and control room systems) can be long, extending from weeks to many months depending on procurement and installation needs.
7. Access to the site is potentially impacted by flood waters making it difficult to get personnel onsite to facilitate remediation.

Overall, the assessment highlights the need for targeted flood-resilience measures for valves, the control room, and electrical infrastructure to maintain operational flexibility and system performance during extreme weather events.

7.3 Economic Damages

The following sets out the approach and indicative estimates for the economic damages associated with flooding impacts on [redacted] Junction, focusing on valves, pig traps, the control building and the main power intake. The methodology has been developed to align with principles of the *Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal* (Penning-Rowsell et al. 2013 - hereafter referred to as the Multi-Coloured Manual (MCM)) /4/, the UK's standard reference for flood risk benefit-cost analysis. The MCM provides depth-damage data for various asset types and emphasises distinguishing direct tangible costs (physical damage repair/replacement) from indirect intangible costs (like service downtime, societal impacts).

As per the MCM, this report separates economic damages into direct damages and indirect damages. Direct damages represent the physical costs of repair, replacement, clean-up, reinstatement, testing, and recommissioning of flooded assets, essentially the reinstatement cost required to restore pre-event operational condition and function. Indirect damages represent subsequent economic consequences arising from impaired operation during recovery, such as reduced performance, increased manual intervention, temporary operating constraints, and extended periods without remote monitoring or optimal flow configuration. This separation is consistent with the assumptions applied at [redacted] Junction, where it is explicitly assumed that flood impacts do not lead to total stoppage of gas flow through the site, but do affect the site's ability to reconfigure and monitor flows, with knock-on performance degradation.

Economic damages are calculated on an event basis using flood depths derived from the combined NaFRA2 and UKCP18 datasets. However, for [redacted] Junction, the flood depths at impacted assets were estimated to be broadly similar across the modelled events (e.g., riverine inundation around the 200 mm level, with relatively small additional rainfall depth increments across more extreme events). This has a key implication for damages where the flood depth crosses a functional failure threshold (for example, the control building threshold), event damages may be relatively "flat" across return periods because the same failure mode is triggered across multiple events.

Labour is a substantial component of flood recovery costs. After flooding, crews must first wait for waters to recede or pump out the site, then perform inspections, testing, and gradual recommissioning of equipment. Labour costs include: removing damaged components, installing and calibrating new parts, conducting safety tests (pressure tests for pipes, functional tests for controls), and providing temporary services in the interim. These manpower costs often match or exceed the equipment costs for critical infrastructure.

Direct damage estimation: valves (replacement and reinstatement)

National Gas' public "Valves Engineering Justification Paper" (2019) /2/ indicates planned investment of £[redacted] for [redacted] valve interventions, implying an average unit cost of approximately £[redacted] per valve when costs are averaged across a broad valve population and interventions. This value is used as a defensible baseline unit cost for direct replacement or major intervention where a flooded valve or actuator/gearbox is assumed to require replacement, particularly in the absence of detailed valve-by-valve procurement and installation cost data. This unit cost is then applied consistent with the [redacted] assumptions that flooded actuators and gearboxes can fail depending on relative elevation and flood depth, and that procurement lead times can be significant (30–150 days depending on size), reinforcing that event damages should include not only hardware but also reinstatement works and commissioning.

Direct damage estimation: control room/control building (component-based rebuild)

Control-room direct damages are modelled as a component-based replacement cost, rather than a single "building replacement" line item, because the damage mechanism is dictated by the failure of low-level electrical and electronic systems once water ingress occurs. It has been assumed that the control building is not specifically flood resistant and that if flood depth is greater than 0.20 m, failure is likely, with rack-mounted electronics assumed to have power supplies at the base of each rack, making them vulnerable to shallow inundation. These assumptions imply that even relatively modest flood depths may lead to complete loss of the control room's functional systems and necessitate extensive reinstatement.

Table 7-1 below provides indicative cost ranges for control room equipment replacement. All monetary values for the control room were developed using a component-based engineering-cost methodology, which is the accepted practice in UK infrastructure risk modelling when market pricing is commercially confidential. The actual damage to the control room is highly dependent on the exact equipment arrangement and as such there is a significant variability in potential damages.

Table 7-1: Indicative Direct Damages Control Room Costs

Cost Category	Low (£ 000's)	High (£ 000's)	Cost assumptions	Notes
Building fabric (shell, strip-out, interior refit)	160	300	Full internal strip-out and reinstatement due to floodwater ingress above the assumed building threshold; includes demolition/disposal, slab/interface works, building shell and internal fit-out.	Control building assumed not specifically flood resistant; failure threshold assumed at >0.20 m flooding.
Electrical distribution & switchgear	120	275	Replace LV switchboard/switchgear, distribution boards, cabling/containment, earthing/bonding, and UPS due to immersion/contamination; assumes replacement rather than drying/repair.	Power supplies and low-level equipment vulnerable to shallow inundation.
SCADA, PLC & telemetry systems	130	350	Full replacement of PLC racks, I/O, SCADA servers/workstations, telemetry/RTU interfaces and associated configuration due to water damage; assumes new equipment procurement and reconfiguration.	Long lead times and extensive re-commissioning consistent with 180–300 day lead time assumptions.
Communications & IT systems	35	95	Replace network racks, fibre termination/patching, switches/routers/firewalls, telecoms interfaces and associated cabling due to contamination and loss of integrity.	Assumes loss of remote monitoring connectivity following control-room flooding.
Fire & Gas systems (F&G)	43	92	Replace F&G panels, detectors/sensors, alarm interfaces, loops and associated configuration/testing; assumes safety-critical systems require certified post-flood performance.	Full replacement assumed for compliance and reliability.
HVAC & environmental control	35	80	Replace HVAC unit(s), ventilation/ducting, and dehumidification/environmental control components affected by floodwater and prolonged high humidity.	Environmental control required to protect replacement electronics.
Testing, integration & commissioning	60	130	Allow for electrical testing/certification, PLC/SCADA FAT/SAT, telemetry integration, F&G functional testing and site commissioning to restore full operational capability.	Assumes extensive recommissioning and field-instrumentation reconnection.
TOTAL (Control-room full replacement)	583	1,322	Sum of component ranges for full-loss scenario.	Excludes indirect/outage costs

Direct damage estimation: pig traps (pressure-containing equipment and associated valves)

Pig trap (launcher/receiver) costs are also treated as direct replacement costs when failure is assumed, that pig trap failure affects pigging capability and does not necessarily stop gas flow through the feeder. Pig traps are bespoke engineered systems with no published standard costs but direct replacement costs can be high as they are bespoke pressure-containing systems. Inundation of the pig trap may result in damages to several sub-components including closure mechanisms, nozzles, instrumentation (e.g., signalers). Additional costs associated with repair reinstatement may also include design/fabrication to pipeline codes and client specifications, features that typically drive significant bespoke fabrication and QA/QC requirements.

Table 7-2 below provides indicative cost ranges for equipment and installation.

Table 7-2: Indicative Direct Damages Pig Trap Costs.

Pig Trap Type	Typical UK Indicative Cost Range* (£ 000's)	Notes
Standard manual pig launcher/receiver (8"–16")	150 – 300	Fully fabricated vessel with closure, fittings, valves.
Medium diameter (20"–36") pig trap	300 – 750	Higher steel mass, higher pressure class.
Large diameter or high-pressure trap (≥ 40", ANSI 600–900)	750 – 1,500	Heavy fabrication, bespoke skids, advanced closures.
Installation / integration	150 – 500+	Depends on tie-ins, civils, isolation, shutdown, hydrotesting.
*These figures reflect typical UK/EU gas transmission procurement experience—not published vendor prices (which do not exist publicly). They are consistent with market norms for pressure-rated fabricated vessels, high-spec closures, and skid packages.		

Direct damage estimation: main power intake (switchgear-focused reinstatement)

The main power intake is assumed to be below ground (estimated at approximately 1.5 mbGL), and flooding can cause the power supply to be isolated for safety or trip due to earth leakage, with the consequence being loss of control room function and power to field devices (likely performance reduction rather than stoppage of gas flow). As a result, the direct damage model for the power intake is built around switchgear and electrical distribution reinstatement, including replacement of LV cabinets/boards, terminations, cable sections, manhole remediation, and testing/recommissioning. The inclusion of LV switchgear as a major component is consistent with UK suppliers' descriptions of LV switchboards as custom-built engineered assemblies, often provided as modular systems designed to appropriate standards.

Based on publicly available costs for similar equipment we estimate a range of £80k - £250k for direct damage costs associated with the restatement of the main power intake. This assumes below-ground intake; flooding causes isolation/trip and switchgear damage (no transformer); includes cabinet/switchgear replacement, terminations/cabling, manhole remediation, testing and recommissioning. Additional considerations include typical lead time is 30–40 days with 7–14 days site works and an acute outage duration of 45 days, providing a programme basis for reinstatement cost allowances and reinforcing the need to include testing and recommissioning costs in the direct damage estimate.

Indirect damages: performance reduction

Although it is acknowledged that an interruption or reduction in supply is highly unlikely as a result of flooding at [redacted] it is still prudent to consider costs associated with any loss of supply. A Department of Trade & Industry report (Oxera, 2007) /3/ found domestic customers would pay ~£10–£20 to avoid losing one unit of energy. This generally agrees with Ofgem's "Value of Lost Load" (VoLL) for electricity which is ~£17 per kWh for domestic customers with gas being treated analogously. The MCM manual adopts 10/kWh for flood risk analysis of utilities.

It's also worth noting that compensation schemes are lower, under Ofgem's Guaranteed Standards, a household gets £75 after a 24-hour gas outage (plus £75 per any additional day). That equates to roughly £2.40 per kWh for a day-long cut, far below the survey-based WTP, suggesting that actual welfare losses exceed the mandated payouts. As such, households would willingly pay several times the compensation amount to avoid an outage, reflecting the true inconvenience and welfare impact.

Although flooding at [redacted] is not expected to stop gas flow entirely, there would likely be a significant increase in operational complexity and associated manpower requirement to ensure continuity of service throughout the repair / reinstatement period. Potential operational tasks requiring manual intervention on site post flood event include:

- Manual monitoring of site conditions
    - Regular inspection rounds of valves and feeders
    - Manual recording of pressures, flows, temperatures
    - Replacing automated alerts with human monitoring (because SCADA visibility is lost)
- Manual configuration of feeder routing
    - Adjusting feeder valves by hand
    - Confirming isolation positions physically
    - Implementing network-controller instructions locally (since remote reconfiguration is unavailable)
- Manual verification of metering readings
    - Collecting meter data on the ground
    - Confirming linepack trends via physical gauges and portable diagnostic tools (because SCADA metering visibility is lost)
- Safety monitoring & emergency readiness
    - Additional staff to meet dual-person confined space / safe working requirements

It is estimated that additional manpower could range as per below

- Additional 2 to 6 Field Operators / Site Technicians per shift
- Additional 1 to 2 Operations Supervisors coordinating manual operations
- Occasional support from offsite controllers and Area Operations Managers

It should also be noted that any redeployment of manpower will result in reduced capacity elsewhere with associated reduction in productivity across the NG network.

Limitations and recommended next steps

The cost model presented here is designed to be transparent and consistent with the scheme flood modeling assumptions, nonetheless, it remains sensitive to site-specific configuration details. The largest sources of uncertainty are: the exact control room equipment inventory (number of racks, SCADA architecture redundancy, UPS rating and runtime), valve arrangement (gearbox and telemetry), and pig traps, and the exact design of the power intake (e.g., presence/absence of transformer equipment within scope). It is acknowledged that for the control room and power intake, assumptions were made about configuration due to limited asset data and this uncertainty should be carried through as cost ranges and/or contingencies. As a next step, targeted data gathering (panel schedules, SCADA/PLC inventories, valve arrangements and actuation types) would allow for refining of cost ranges and improved confidence in damage estimates.

8 WORK PACKAGE 3B – FLOOD TWIN INTEGRATION

This work package involved DNV integrating the flood modelling results (Work Package 3A) with the existing CVDT architecture, allowing the effects of flooding to be visualised on the NPT application. At the request of NGT, the developed solution is hosted on DNV's Azure ecosystem and Veracity platform.

8.1 Obtain data from Digital Construction Cloud

DNV extracted relevant asset data from NGT Digital Construction to maintain an airgap between the DNV and NGT services. By utilising an "offline" copy of the data (and not connecting directly to NGT's IT estate) DNV was able to rapidly develop the solution, avoiding potential delays due to key IT resource availability.

8.2 Expansion of DNV Asset Database

DNV expanded its Azure No SQL database to allow for a new model class to be used to store flood modelling results. This enabled validation of the data to be performed during the upload and subsequent retrieval of data via the API. It also allows the data to be explored efficiently by utilising the level_id parameter, as well as enabling easy updating of the data in the future.

The geotiff files used to visualise the flood impact were hosted within DNV's Veracity DataWorkbench product which is already used within the NPT application and utilises Veracity's authentication and tenant management solution.

DNV was mindful to use common services such as blob stores and NoSQL databases to maintain compatibility for any potential future migration to NGT's IT estate.

This solution allowed the reuse/extension of existing APIs from the CVDT project which allowed for seamless integration into the existing Digital Twin.

8.3 DNV Flood Modelling Results

The flood modelling results are available to CFMS and the web application via the existing asset registry API. The results are appended to the associated asset on receipt of a relevant API request. The results are validated against a defined data model to ensure correctness and completeness of the data. This flexible approach allows for future updates to the flood modelling results, as well as expansion to cover additional sites and assets.

8.4 Provision to CFMS Front End

Once the data is returned from an API request, it is available for use. CFMS have expanded the visualisation capabilities in the front end to allow the flood modelling data to be made available to end users.

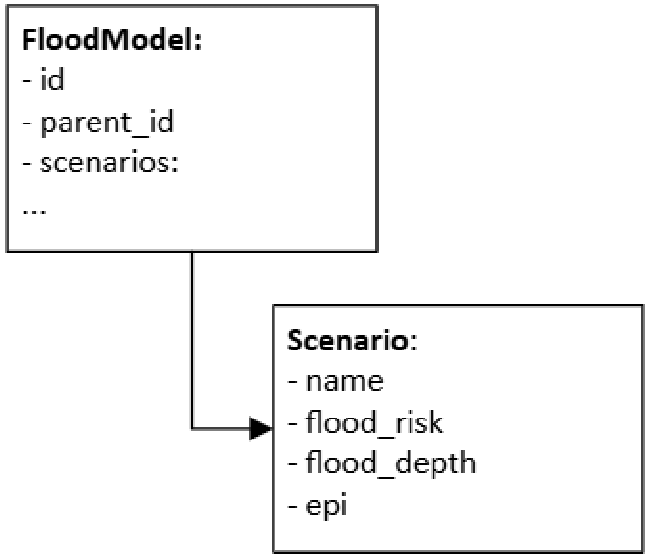

Figure 8-1: Flood model data hierarchy in NPT.

9 CONCLUSION & NEXT STEPS

The NPT project marks the third phase of NGT's strategic digital twin journey, and has seen the consortium (DNV and CFMS) grow and expand the capabilities of the solution developed in Phase 2. DNV has delivered an expansion of its data management system to incorporate new datasets, allowing more information to be presented to analysts and engineers and integrating with the outputs of other flagship digitalisation projects at NGT. New flood modelling capabilities, grounded in a proven, science-based methodology have been included and applied to NTS sites, helping to aid investment planning and further demonstrating the ability of the solution to scale. Finally, a feasibility study has been completed to begin the process of identifying the steps that would have to be completed for the eventual migration of the application into NGT's IT estate. DNV believes that our project outputs will help further shape NGT's digital transformation.

Key findings and recommendations from the project are as follows:

- DNV has successfully expanded our existing data management system from Phase 2 of the CVDT project, enabling its integration with:
    - The metadata associated with 3 new AGIs – [redacted] – using NGT's ACC Database as the source of truth.
    - The pipeline inspection data contained within the HyNTS Pipeline Dataset project, numbering over 17,000 inspection points.
    - Equipment specific flood modelling capabilities, for a range of scenarios based on the most recent UK climate change data.
- There is a lack of a coherent and reliable asset hierarchy within the ACC Database, which in turn highlighted a series of wider data-quality challenges as listed below:
    - Incomplete or incorrect spatial data:
        - Significant gaps in coordinate coverage across many asset types.
        - Some coordinates appear erroneous (e.g. plotting offshore or out-of-bounds) without explanation.
        - Coordinates lack metadata (OSGB36 format but in millimetres).
    - Poor asset hierarchy data:
        - Very low coverage (<30% of assets at best) of Location Code, which is the only field which defines the asset hierarchy.
    - Incomplete metadata:
        - Low population of key metadata such as Manufacturer.
        - Descriptions and PnPID generally complete, but other attributes are inconsistent or missing.
    - Structural and consistency issues:
        - Duplicate sheets with different names (e.g. tee vs single branch fittings).
        - Duplicate assets across sheets.

- These challenges have particular relevance given the upcoming Capgemini-led location-codes conversion, and the broader need to strengthen the data foundations required for future digital initiatives. DNV are preparing a brief for NGT that would support improvement in this space.
- The feasibility study has defined the components of the NPT system, both back and front ends, and the initial set of processes and requirements the solution will have to comply with as the migration process takes place. At the request of NGT, a full gap analysis will be completed in a future project.
- Data delivery from the FutureGrid site at Spadeadam continued throughout the duration of the project.
- The data management system, developed by DNV under Phase 2 of the CVDT project, showed a significant ability to be scaled and expanded to accommodate new use cases. Our recommendation is that keeping the application functional, up-to-date and secure will provide a strong test case for any future digital twin development work completed by NGT.
- As new use cases are implemented, our expectation is that computational resource allocation will be sufficient to meet the requirements of new dataset integrations. This is exemplified by the app's performance remaining strong despite the tens of thousands of new datapoints and front-end visualisations that have been implemented. However, should increased usage result in a reduction in performance, the scalable nature of the Azure webapp service used means that increased demand can be easily met.
- The sites selected for flood modelling were chosen due to an availability of the data, and not due to the likelihood of flooding. DNV recommends scaling and expanding the flood twin methodology to approach more high risk sites across the NTS.

10 REFERENCES

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/2/	National Gas (2019). Valves Engineering Justification Paper ([redacted] December 2019. Internal engineering justification document supporting strategic gas transmission infrastructure assessments.
/3/	Oxera, 2007. An assessment of the potential measures to improve gas security of supply.
/4/	Penning-Rowsell, E., Priest, S., Parker, D., Morris, J., Tunstall, S., Viavattene, C., Chatterton, J. and Owen, D. (2013). *Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal*. Abingdon: Routledge.

11 GLOSSARY

Azure CosmosDB

Azure Cosmos DB is a fully managed, cloud-native NoSQL database designed to deliver ultra-low latency and elastic scalability at a global scale. It uses a schema-agnostic JSON document model which makes it easy for developers to store and query flexible data structures. It supports vector search and hybrid search, enabling AI-driven experiences like RAG and agentic apps.

Azure Data Lake Storage Gen 2

Azure Data Lake Storage is a set of capabilities dedicated to big data analytics, built on Azure Blob Storage. Data Lake Storage makes Azure Storage the foundation for building enterprise data lakes on Azure.

Collaborative Visual Data Twin (CVDT)

Collaborative Visual Data Twin was a 2-stage project which developed a solution to connect into both historic and live network databases and links to virtual network models utilising an open AGI interface that can provide insights required by the digital twin use cases.

Network Performance Twin (NPT)

The Network Performance Twin creates a virtual model of the physical world of network infrastructure together with all its inter-relationships. NPT will act as a bridge between the physical and digital worlds, augmented by real-time data about the physical assets from Operational Technology (OT) sensors.

Novel Unified Viewer (NUV)

The Novel Unified Viewer expands on the Network Performance Twin to encompass real-time asset monitoring, predictive flood modelling, and advanced data visualisation.

User Interface (UI)

A user interface is the point of interaction, communication, and control between a human and a digital device or software.

Veracity Data Platform

The Veracity Data Platform brings together secure data storage, robust governance, advanced analytics, and a growing ecosystem of partners. It supports both developers building services using comprehensive APIs and business users working through the Data Workbench UI.

Veracity Data Workbench

Data workbench is a web portal for the Veracity Data Platform, and it enables users to interact with, share and control access to data.

Veracity Identity Platform (IDP)

Veracity Identity is the identity provider (IDP) for the Veracity platform. It provides a secure authentication mechanism for first-party and third-party services, and authorisation capabilities for first-party services. The service is built on Microsoft Azure Active Directory B2C (Azure AD B2C) and uses industry standards such as OpenID Connect and the authorisation code flow to authenticate users.

About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimizing the performance of a wind farm, analyzing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.

CFMS Services Ltd.

0444 Novel Unified Viewer for NGT Performance Twin

D5.2 CFMS Final Technical Report

Document Management

Reference	0444 Novel Unified Viewer for NGT Performance Twin D5.2
Issue No.	1.0
Issue Date	02/04/2026
Submitted to	National Gas
Classification	Commercial in Confidence

Authorisation

	Name	Title/Role	Signature
Prepared	[redacted]	Junior Software Engineer	[redacted]
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Authorised	[redacted]	CTO	

Amendment History

Issue	Section	Description of Change	Date	Initials
0.1	All	Initial draft for review	26-03-2026	CG
1.0	All	Reviewed and updated	02-04-2026	CG

Distribution

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Sabia Sadiya	National Gas
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Executive Summary

Phase 2.1 of the Novel Unified Viewer for NGT Performance Twin (NPT) project features work by CFMS to integrate new data into the NPT application. Specifically, the work required:

- The integration of the 3 additional sites, namely [redacted].
- The integration of the HyNTS dataset
- The integration of Flood Twin outputs for the [redacted] site

New features were implemented to facilitate the incorporation of the new data. This report describes the details of the work, comprising:

- Architecture Changes
- Multi-Site Functionality
- HyNTS Data Integration
- Flood Twin Integration

Additionally, CFMS went beyond the original project scope by adding other data sources, to demonstrate the ease of integrating new information, contextually visualising it, and proving the benefits of the flexible software architecture to internal National Gas stakeholders. This work includes:

- Implementing the capability to load and render explorable 3D site models on the GIS map (see Section 2.3).
- Converting the 3D site models from the Navisworks (.nwc) file format to the GLTF Binary (.glb) file format required.
- Integrating the Unaccounted For Gas simulation data produced at CFMS (see Section 6.1.2) as an extra contextualised presentation of operationally important data.

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Glossary of Terms

API	Application Programming Interface
AssetDB	Asset Database
CORS	Cross-Origin Resource Sharing
GIS	Geographic Information System
HyNTS	Hydrogen in the National Transmission System
NG	National Gas
NPT	Network Performance Twin
NTS	National Transmission System
PoC	Proof of Concept
RBAC	Role-Based Access Control
UI	User Interface
UX	User Experience

1. Introduction

This document is the CFMS Final Technical Report for the Phase 2.1 of the Novel Unified Viewer for NGT Performance Twin project commissioned by National Gas.

1.1. Purpose and Scope

The purpose of this document is to provide a detailed description of the updates made to the NPT web application following the previous phase. These changes were necessary to facilitate the new features implemented in this phase which are also documented in this report. It also aims to provide insights into what can be achieved in future phases of this project.

1.2. Document Structure

This document is structured as follows:

Chapter 1. Introduction
Chapter 2. Architecture Changes
Chapter 3. Multi-site Functionality
Chapter 4. HyNTS Data Integration
Chapter 5. Flood Twin Integration
Chapter 6. Future Work and Improvements

2. Architecture Upgrades

To accommodate the requirements of this phase of NPT, various modifications and improvements were necessary for the application to function efficiently and effectively.

2.1. Data Workbench Integration

Coming into this phase, the DataFabric service used for storing and serving documents was decommissioned, and replaced by DNV with the new Data Workbench service. This change required adjustments to be made to the API gateway to ensure that the NPT dashboard could request the necessary resources from the new service. A new endpoint for the Data Workbench was set up using the Gravitee API management platform. Updated credentials, provided by DNV, are used to obtain an access token that is then used to authorize requests made to the Data Workbench service.

2.1.1. Downloads

To circumvent download requests getting blocked by CORS, a path for the new Data Workbench endpoint was created. This path allows resource downloads to be serviced through the API gateway that acts as a proxy. The API gateway is configured to allow CORS between itself and the NPT app. Whenever a document, or map tile image is downloaded in the NPT app, the requests are sent to the API gateway.

2.1.2. TimeSeries Data

In addition to replacing the DataFabric service, the new Data Workbench backend API also provides an endpoint[1] that can be used to retrieve the live TimeSeries data previously provided by the Veracity IoT API. A path was created for the new Data Workbench endpoint in the API gateway that is used to handle routing POST requests to the appropriate underlying Data Workbench backend API. The POST request body contains the query configuration that specifies the sensor ID and time period for the sensor data being requested. For large time periods, sensor data is aggregated using multiple requests for smaller chunks of data. This only happens when the data cannot be reasonably fetched using a single query.

2.2. Optimisations

Maintaining good UX while also supporting multiple sites (see Chapter 3) would not be possible without optimising the NPT app. The data gathering approach was re-worked to accommodate the increased quantity of data that comes with the additional sites. Two optimisation techniques were used to prepare the app to handle multiple sites.

2.2.1. Lazy Loading

Prior to the addition of the new sites, the requests for all the required data were sent up-front and the app would wait for all the responses to come back from the respective backend services before navigating to the map view. This data gathering method, even for one site, took a significant amount of time and did not scale to multiple sites.

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1 https://developer.veracity.com/docs/section/api-explorer/76904bcb-1aaf-4a2f-8512-3af36fdadb2f/developerportal/dataworkbenchv2-swagger.json

The new optimised approach defers the requests to be sent only when the data needs to be displayed to the user:

- When the user navigates to the NTS map, the minimal site data for all sites is requested to place each site on the map.
- When the user navigates to a site, the comprehensive site data for just that site is requested to place each asset marker on the site map.
    - After navigation, a subsequent request is made to retrieve the 3D site model to display on the map.
- When the user clicks on an asset, the sensor data and 3D asset model are requested to display in the popup.
- When the user navigates to the asset view, the asset data is requested from the AssetDB.
    - After navigation, the sensor data and 3D model are requested and displayed when received
    - Graph data is requested and shown only when a user selects a sensor

2.2.2. Caching

A caching system was introduced to reduce the need to re-request data already retrieved from the AssetDB. When resolving asset and site data, before making a request to the AssetDB, the cache is checked for the data first. If it exists in the cache it is returned, bypassing the request. Otherwise, the data is requested and the data is cached for future use before being returned. As an extra optimisation, when resolving an asset, the asset data is extracted from the parent site data if it already exists in the cache. The cache is stored in the browser session storage and is cleared when the page is refreshed.

2.3. 3D GIS Map

Displaying 3D models on the interactive GIS map would not have been possible with the Leaflet library previously used for the NPT app. While Leaflet allows for map tiles to be rendered along with markers and popups, Leaflet only supports 2D map projections.

To achieve a 3D map effect, the Leaflet was replaced with MapLibre GL JS[2], a free and open source interactive map library provided by the MapLibre[3] organisation. This library originated as an open-source fork of Mapbox GL JS[4] prior to it switching to a non open-source software licence. MapLibre GL JS supports all the features needed to display the google map tiles, custom map tiles, markers, and popups used in the NPT app, as well as providing support for interactive 3D map projections.

The site models are loaded and rendered using Three.js[5], a library used to create and display 3D graphics and models. MapLibre GL JS supports integration with Three.js to construct a scene that can be positioned on the map at a given set of coordinates. Using these two libraries, the site models can be rendered on the map (see Figure 1).

[2] https://maplibre.org/maplibre-gl-js/docs/
[3] https://maplibre.org/
[4] https://www.mapbox.com/mapbox-gljs
[5] https://threejs.org/

Figure 1: 3D Spadeadam site model displayed on the site map.

Site models are placed on the map as a map layer, allowing their visibility to be toggled. This functionality is provided through an additional map control button. Other map controls that have been added include a button to control the rotation of the map, and a button to affect the tilt of the map.

3. Multi-site Functionality

To allow the NPT app to operate with more than one site, the navigation and routing between the different views needed to be changed:

- NTS map
    - New route: `/site-view`
    - An additional popup was implemented for the sites in this view. This new popup shows information about the site as well as providing a new button that is used to navigate to the site (see Figure 2).
- Site view
    - New route: `/site-view/<site-id>`
    - This route dynamically uses the site ID from the AssetDB to resolve the data.
- Asset view
    - New route: `/site-view/<site-id>/asset-view/<asset-id>`
    - The route for an asset is now relative to the parent site of the asset.
    - The data is retrieved from the AssetDB dynamically using the asset ID from the route.

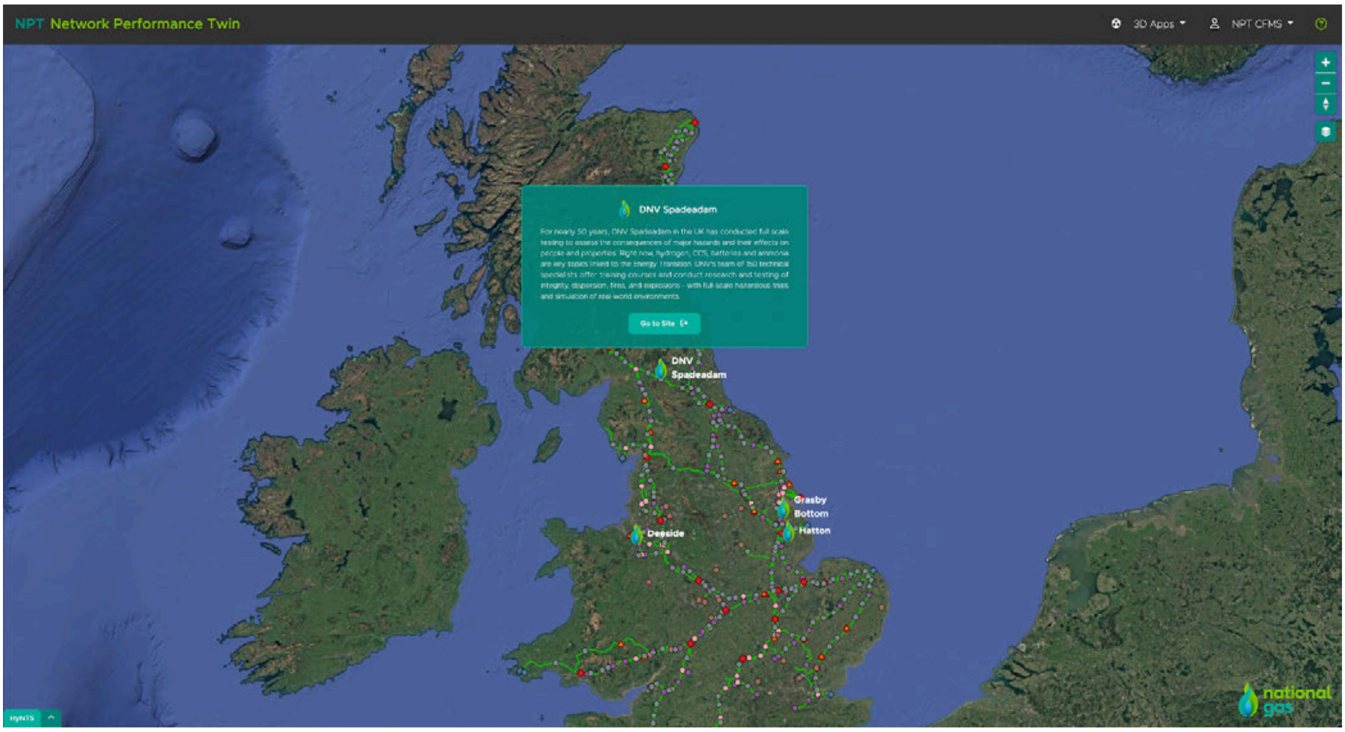

Figure 2: NTS map site popup.

Elements of the NPT app that were specific to FutureGrid have been removed in the interest of improved multi-site functionality. Previously, asset markers for the single FutureGrid site were grouped by phase, however, this grouping strategy does not generalise to the new sites. The phase of an asset was determined by looking at the name of the subsite it belonged to, which is too specific to FutureGrid. Therefore, site assets are now grouped by their construction status property which each asset possesses. The construction status property for each asset is stored in the AssetDB, allowing the NPT frontend to remain data-agnostic. With these changes it is possible to load any site from the AssetDB in the NPT frontend (see Figure 3).

[redacted]

4. HyNTS Data Integration

The HyNTS data associated with each pipe has been made available by DNV in the AssetDB where each pipeline is available as a site. On the NPT app, a new panel has been added. This panel is where a pipe can be selected and the HyNTS properties displayed (see Figure 4). The panel contains a dropdown allowing a pipe to be chosen from the list of pipes which have HyNTS data available. When selected, a request is made to the AssetDB to obtain the HyNTS data for the desired pipe. When the HyNTS data is received from the AssetDB, each inspection point is plotted on the map using a red marker.

Figure 4: HyNTS panel showing selected pipeline with inspection points plotted on the map.

Clicking an inspection point on the map populates the table in the new panel with the HyNTS properties for that point (see Figure 5). Every HyNTS property that is available in the AssetDB for an inspection point is displayed. To improve the user experience, two controls have been added:

- a search feature that can be used to find specific property values (see Figure 6).
- a filter button to hide properties for which there is no available data.

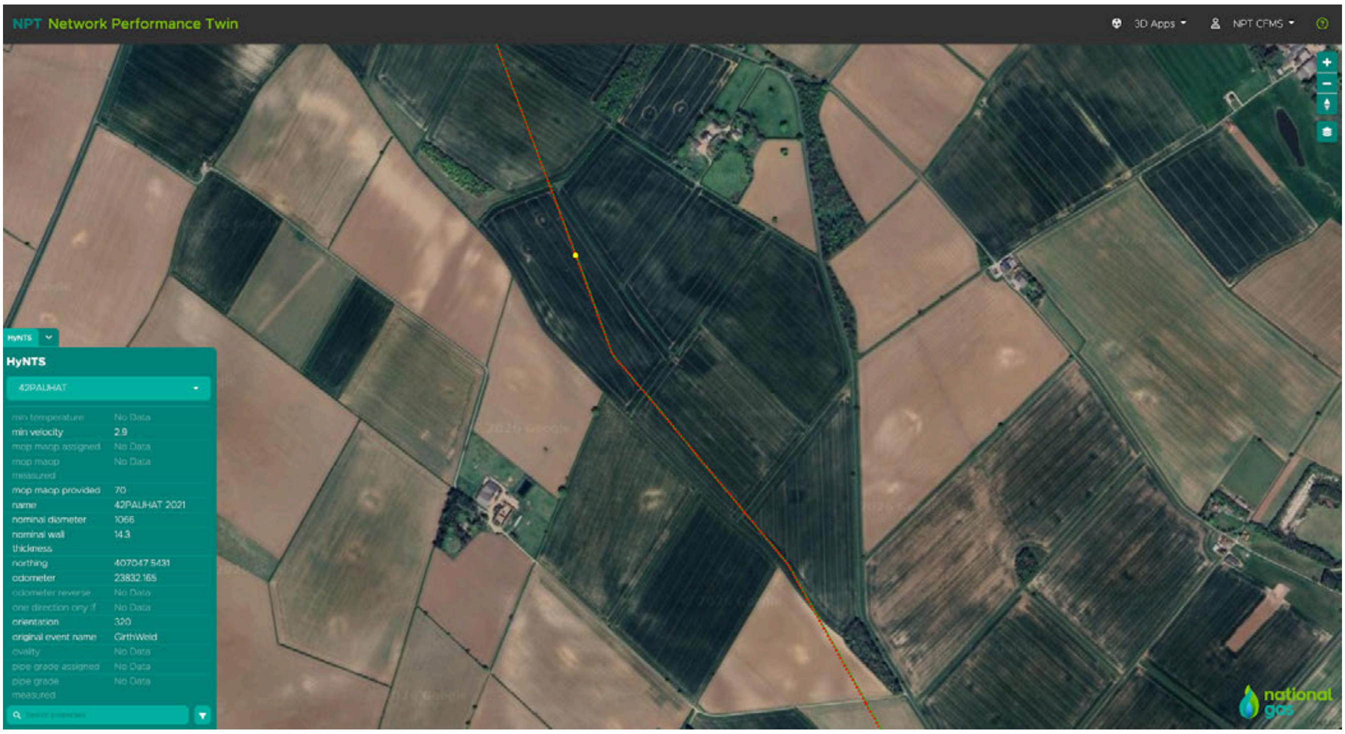

Figure 5: Default HyNTS properties table for a selected point.

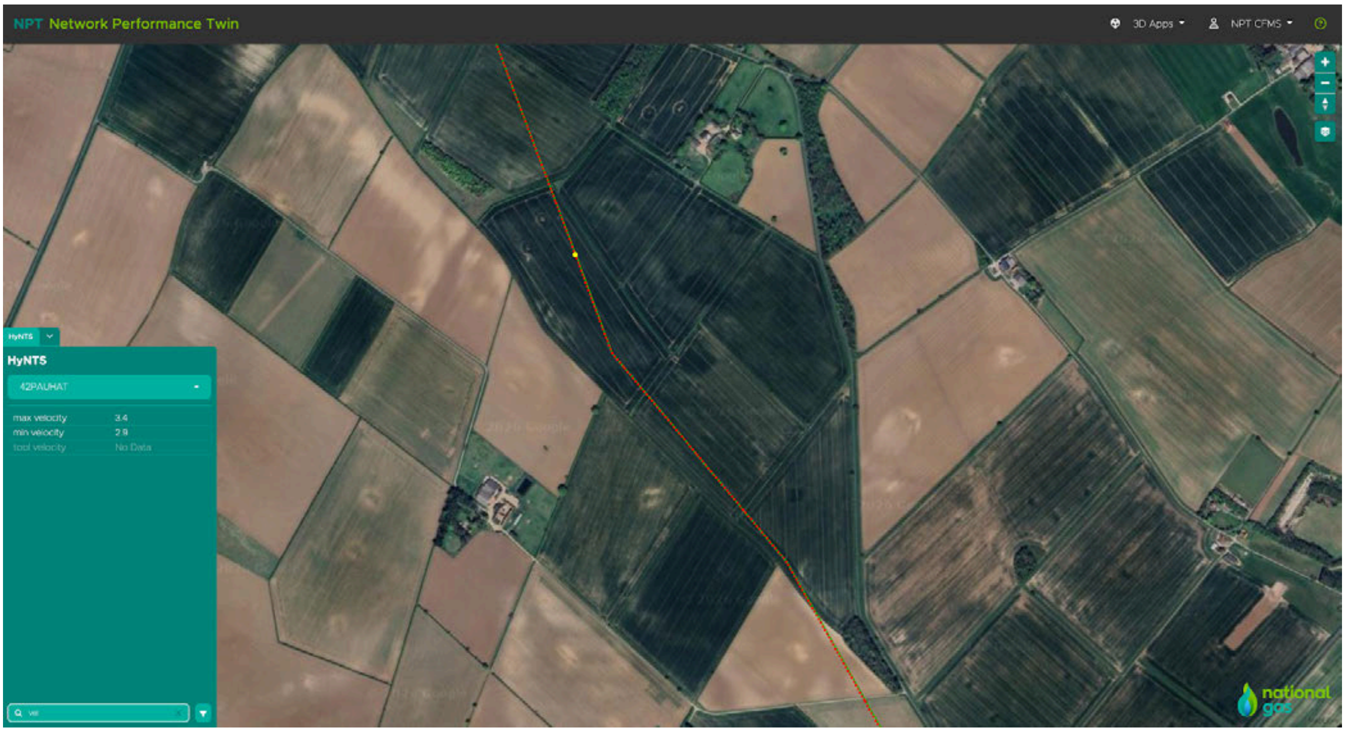

Figure 6: HyNTS properties table filtered using the search feature.

5. Flood Twin Integration

Multiple UI elements needed to be created to accommodate the integration of the flood twin data. A panel has been added to the sidebar that contains tabs that provide controls to toggle map elements. The “Construction Status” tab contains the map controls that were previously available on the map, such as the map tiles dropdown selector. The “Flood Simulation” tab has been added that contains the flood data information and simulation controls.

In the “Flood Simulation” panel, a dropdown selector can be used to choose the flood scenario from a pre-defined list. For this phase, only the Hatton site has flood twin data. When a scenario is selected, the asset markers on the map are given a coloured border that corresponds to the risk of impact to the asset for the selected scenario. Additionally, the number of assets that are affected for each impact level are also displayed as an overview of the data.

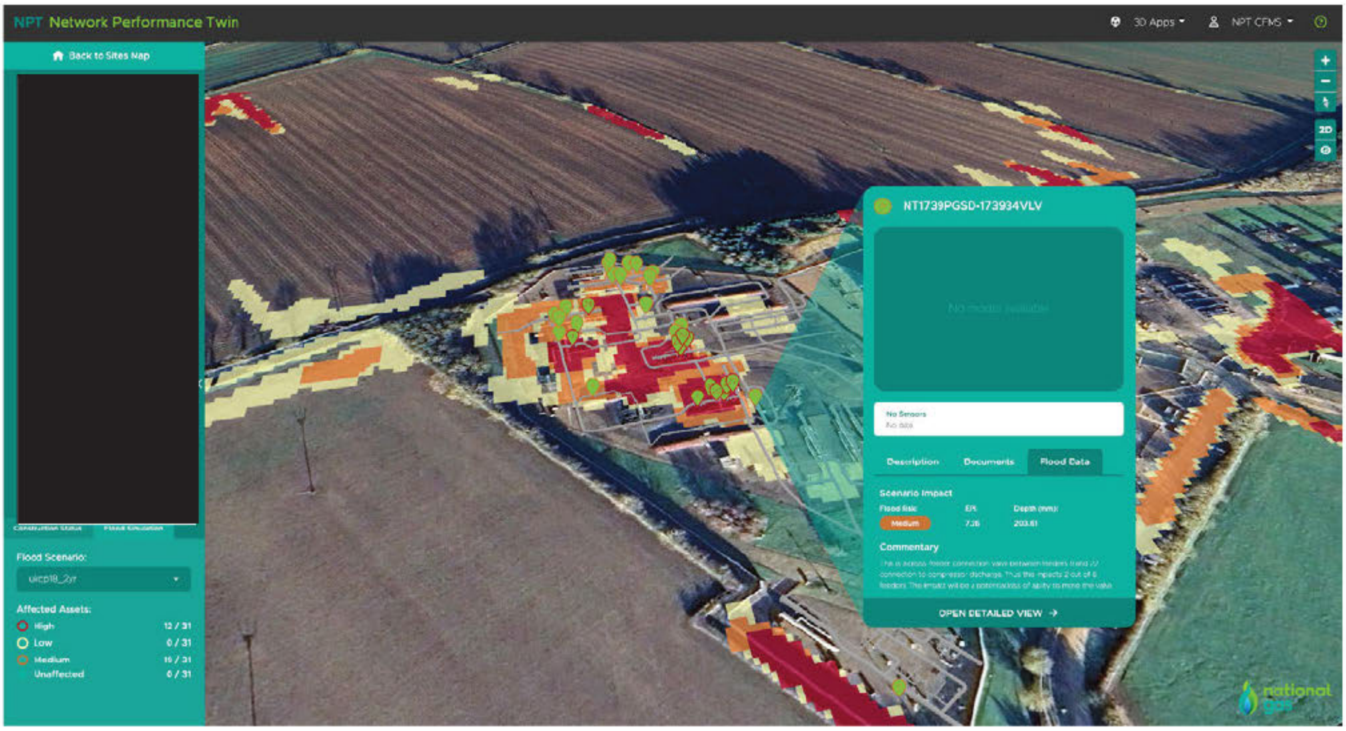

Figure 7: Flood scenario data shown on the site map. The flood impact tiles can be seen overlaid on the map. The new “Flood Data” asset popup tab is shown.

Map tiles for the flood impact areas were created from GeoTIFF images provided by DNV. The map tiles were uploaded to the DataWorkbench and loaded onto the map when a flood scenario is selected. These tiles show the areas of the site that are affected, and to what extent, under the conditions of the scenario (see Figure 7).

The popup that displays when an asset is selected has also been given an additional tab that can be used to view the information about that asset relating to the selected scenario (see Figure 7). Similarly on the asset view page, a tab has been added to show the flood impact information for each scenario (see Figure 8).

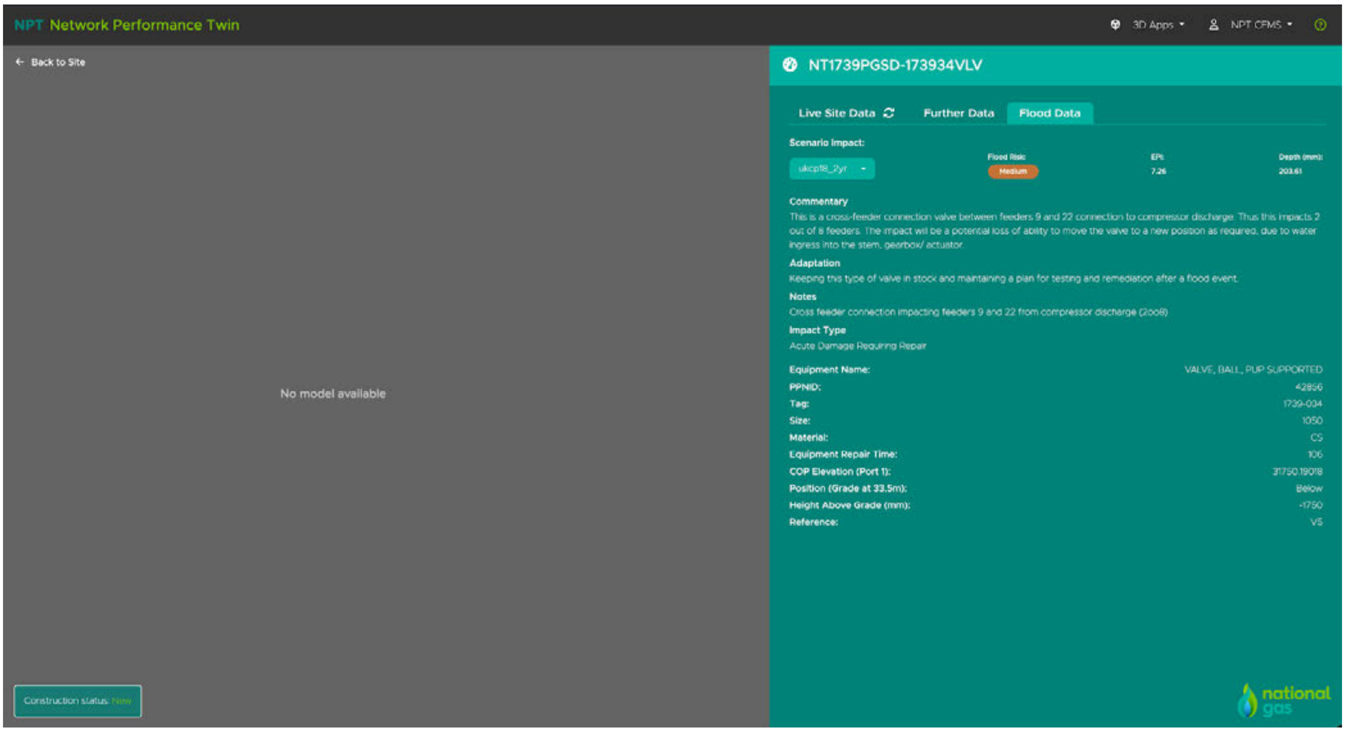

Figure 8: Flood scenario data shown on the asset view.

6. Future Work and Improvements

6.1. Additional Data Sources

The flexibility and data-agnostic nature of the NPT app makes it possible to integrate data from any source and contextualise it within the NTS network. For example, at CFMS, work has been completed by another team to simulate unaccounted for gas within the NTS network. The data generated has already been integrated into the NPT (see Section 6.1.2). Incorporating data for the next phase, as well as any other useful data, into the NPT app can further extend the applicability of the application to a wider user-base, and demonstrates the versatility the NPT solution provides.

6.1.1. ACC Data

Within the Autodesk platform, each asset has a vast amount of data that is associated with it. If this data is made available in the AssetDB for each asset, this data can be included in the NPT application. This would enrich the data provided by the NPT solution, as well as improve its relevance to more users in their work.

6.1.2. Unaccounted for Gas Simulation Data

Integration of the Unaccounted for Gas Phase 1 simulation data produced at CFMS (see Figure 9) has been completed. Currently, this data is a timeseries graph and is different from the other data that is viewed on the NTS map view. The addition of this unique data source is a demonstration of how data of different formats and sources can be integrated and contextualised. As data from the next phase becomes available, it too could be incorporated into NPT giving stakeholders valuable insight.

Figure 9: Initial integration of unaccounted for gas simulation data.

6.2. Role-Based Access Controls

As the number of disparate data sources integrated into the NPT app increases, it will become necessary to limit which data is available to which users as not every user may have permission to access all data. To achieve this, Role-Based Access Controls (RBAC) can be implemented, giving administrators control over which user roles can access different data as well as which users are assigned each role. Within the NPT app, any data that a user is not granted access to view will be hidden and the user will be able to only view and interact with the features their role permits. NPT's authorisation algorithm can be configured to interact with any Identity Provider. This could be developed by replicating National Gas' relevant groups in Veracity's Identity Provider before transitioning to use National Gas' RBAC provider (understood to be Microsoft AD/Entra).

An extension of this would be to allow a user themselves to customise the interface of the app to their needs , while also adhering to their RBAC role. To facilitate these improvements, the UI elements used in the NPT app will need to be better modularised, making it easier to programmatically include and exclude different elements.

The addition of these features would make the NPT app more versatile and allow it to cater to a larger collection of users, empowering them to complete their day-to-day tasks.

6.3. Complete Asset Data

The new assets that have been added to the AssetDB for this phase do not have sensor data or individual 3D models, as was the case with the FutureGrid in the project's previous phase (see FutureGrid site on the app). In a future phase, the missing data and models for the new sites and assets will have to be gathered and curated in order to provide a cohesive experience and have complete coverage of the integrated data.

In addition, the Spadeadam site has different map tile layers that can be overlaid on the map, as well as tiles that define the 3D map terrain underneath the site model. These tiles are stored in the Data Workbench, however, the paths to these files should also be added to the AssetDB, so that they can be pulled dynamically for other sites in the future.

6.4. Flood Twin Extension

In this phase, the flood twin data was integrated by allowing the user to modify one parameter of the flood model through the selection of a scenario from a set of pre-defined scenarios (see Chapter 5). The flood twin was implemented for just one site.

This could be extended to allow the user to control a wider selection of model parameters. In the UI, the pre-defined scenario selection would be replaced with a collection of user input fields that control various model parameters. The user could then click a button that sends the values to a backend API service that then uses them to run the flood model, returning the results to be displayed in the NPT app. This would be dependent on the backend service being created to support communication of this nature.

This concept of dynamically generating and contextualising data within the NPT app could be applied to any data source, highlighting the versatility and flexibility of the NPT solution.

6.5. Site and Asset Filtering

As more sites are added to the NTS map, it may become necessary to implement searching functionality for the list of sites. This will make it easier for a user to locate a site they are interested in viewing.

Additionally, with the increase in the number of assets, and the data that is associated with each asset such as the flood data (or any future data added), a filter system may be useful. This could allow a user to display collections of assets that meet their exact criteria, presenting the user with the assets that are of interest to their work. This feature would improve the ability of the NPT app to better meet the needs of a variety of users. Some sites could potentially have vast numbers of assets, and so a filter system could also aid in ease-of-use for such sites by reducing the amount of information a user is presented with at one time.

6.5.1. Asset Optimisations

The FutureGrid site data was divided into systems that encompassed assets which in turn listed components that comprised them. In contrast, the data delivered by the AssetDB for the 3 new sites treats each small component as if it were a system or asset, vastly multiplying the number of items to be presented on the web. This had the effect of flooding the dashboard with markers, diluting the contextualisation of the information and the usefulness to the user.

As a solution for this PoC the markers were grouped and/or filtered to improve usability, following the strategy below:

- For the [redacted] site, only assets with flood data are shown on the map.
- For the other new sites, assets that are close together are grouped into a single asset with all nearby assets listed as sub-assets.

Currently this approach is sufficient, however, going forward the curation, standardisation and sanitisation of the asset database dataset will be key to achieving a uniform, consistent and useful experience. CFMS look forward to the opportunity to contribute to that exercise.