Client:
Environment Agency, UK

National Groundwater Modelling System

Phase 2 - Detailed
(Change Control Note 2005/03)

Hardware and Infrastructure Design Document
Version 1.0 (final product Phase 2)

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Preface

Groundwater Models have been in use by the Agency and its predecessors for many years and these have been initiated and implemented at Regional level. These models were not linked in a national context. Groundwater models are also costly and have not been easily linked to the needs of operational customers. The fragmented approach to modelling was highlighted by the development of source protection zones in the early 1990s. It was recognised that a centrally co-ordinated, strategic approach was required to avoid duplication and reduce the risk of challenge.

To address this situation, a Strategic Review of Groundwater Modelling (R&D Project W6-034, R&D Technical Report W214; Brown and Hulme, 2001) was undertaken. The main output of the Strategic Review was the *Environment Agency Framework for Groundwater Resources Conceptual and Numerical Modelling* (R&D Technical Report W214) which contained a nationally consistent technical approach and programme for regional groundwater resources assessment and modelling.

The Head Office Hydrogeology Team presented a summary *Implementation Plan* for this work jointly with the Science Group which was accepted by the national Water Resource Management Team (WRMT) in October 2004. Regional modelling strategies were also recognised by WRMT as strategic Water Resources capital programmes. This work therefore supports the Streamlining Abstraction Processes (SAP) and Restoring Sustainable Abstraction (RSA) programmes managed by the national Water Resources Regulation team.

The Head Office Hydrogeology team is now developing a more detailed *Implementation Strategy* comprising a series of measures to support groundwater modelling, ensuring appropriate national consistency, improving efficiency and accessibility by customers. The Implementation Strategy will address concerns like national planning of model development, benefit realisation, succession planning, business efficiency, IS performance, and customer accessibility to models.
An *IT Strategy for Groundwater Resource Assessment and Modelling* is being prepared to address the infrastructure and IS performance issues.

The National Flood Forecasting Projects (NFFS) is currently implementing an IT architecture for a centrally hosted flood forecasting system for the Environment Agency (EA). It is recognised that there are strong links between the proposed IT Strategy for Groundwater Modelling and the NFFS. A feasibility study has been conducted which concluded that the IT-backbone, named National Groundwater Modelling System (NGMS), can be based on the NFFS architecture (and software components) if some minor modifications and extensions are implemented. This outcome was the starting point of phase 2, the detailed architectural design. In this phase the required modifications and extensions need to be made explicit.

Phase 2 of the NGMS will produce the following documents…

1. Update of phase 1 User Requirements Document (URD)
2. Update of phase 1 Software Requirements Document (SRD)
3. Architecture Design Document (ADD)
4. User Interface Specification Document (UISD)

5. Interface Definition Document (IDD)
6. Hardware and Infrastructure Design document (HID)
7. Update of Project Implementation Plan (PIP)

The *Hardware and Infrastructure Design* is presented in this document.

Guide to the reader

The document lying before you provides the high-level Hardware and Infrastructure design for the pilot phase of the *National Groundwater Modelling system*.

Please note that it is not intended to be a detailed parts specification list. The server types and key sizing factors are identified but prior to any acquisition, discussions with IS are requirement to determine the detailed

Chapter 1 sets the context in which the Groundwater modelling system will reside; it describes the key external components that have an influence (both data and control) on the proposed system.

Chapter 2 details the current NFFS architecture together with the differences associated with the NGMS requirements. The required hardware and infrastructure software are listed as well as a discussion on the migration path as the project moves to the next phase of full implementation.

Discussions with CIS are required to determine and agree on the detailed specification.

New in this document

This is the initial version of the document.

Contents

1 Introduction

1.1 Introduction

Current Groundwater Modelling systems used with the Environment agency are operated and maintained on a number of standalone servers. This means that models - and the associated input and output data - are hard to access by others than an individual modeller and that the effort required for performing a module run is large.

A centralised system has a number of key benefits:

- Ability to execute model runs efficiently and with minimal system knowledge.
- Change management controls on modules, module data sets, output etc.
- Wider access to module data (input and output)
- Increased knowledge sharing

1.2 System Context

The diagram below shows the National Groundwater Modelling System (NGMS) in the centre and all the information and control flows across the system boundary. It illustrates external systems or components that are likely to have an interaction with a Groundwater Modelling system and need to be considered when proposing a solution.

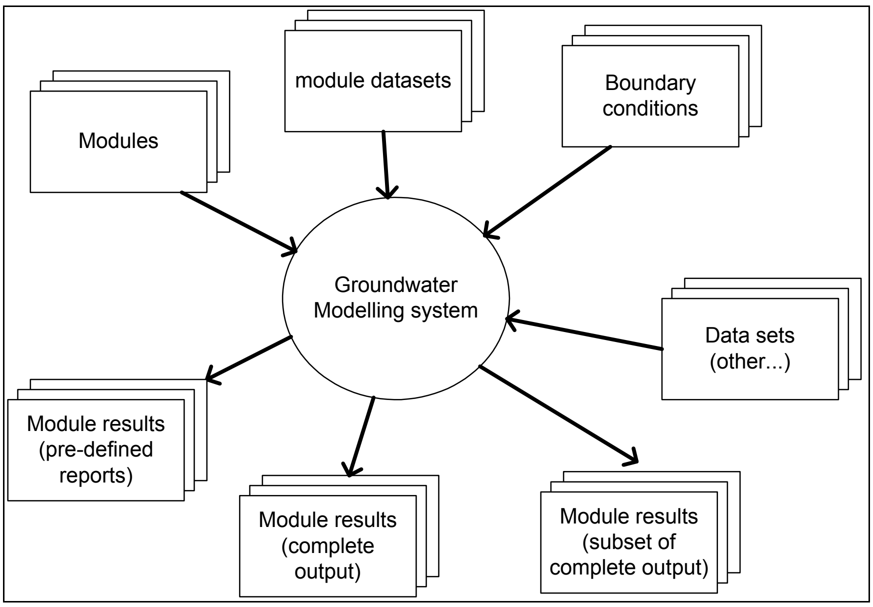

Figure 1: The NGMS context

The external entities are described below:

- **Module**
  These are executable(s) that encapsulate the underlying physics of Groundwater modelling (for example Modflow96).

- **Module datasets**
  Module datasets are the parameterisation of the physical aspects of the groundwater system (aquifers etc.) and the system parameters. These parameters are derived from, among other data, geological maps etc.

- **Boundary conditions**
  The criteria that describe the situation being modelled. These include, for example, precipitation and evaporation for the recharge modules, and recharge and abstractions for the groundwater models.

- **Module results (complete output)**
  The output file created when executing the Module (e.g. Modflow). These files consist of a number of data values per model cell and per time step. The size of these output files can be quite considerable, in some cases reaching several GBs.

- **Module results (subset of complete output)**
  A subset of the data contained within the Module output file. These subsets are typically created via bespoke applications, which extract the appropriate data from the complete results data file.

- **Module results (pre-defined reports)**
  A report (graphs and tables) in a pre-defined format. These will be generated using the output from a Module run.

1.3 General constraints and assumptions

In assessing the user requirements for a Groundwater Modelling system, a number of constraints and assumptions have been noted. These have an impact on the type of functionality that can be provided by a system and the suitability for potential system architectures.

The assumptions and constraints identified at this stage are listed below:

- The Module input and output files can be large.
  They can range from ~Mb's up to a number of Gb's. Initial analysis has shown that they do compress (using Winzip) quite considerably but the resulting files are still of the order 10-100MBs.

- Only subsets of the module output files are ever used in analysis and reporting.
  The full output from a module run is rarely analysed in its entirety, usually slices are taken on a spatial or temporal basis for further investigation.

- Module run times can exceed 12 hours.
  This is not expected to be an issue as this is the expected duration for most large scale models.

- The scope of the system is to provide an environment to execute pre-configure Groundwater modules, not to provide a complete module development environment.

- As well as a centralised system, there is considerable benefit in having a version of the system that can operate in "stand-alone" mode. This could prove useful in enabling model development, demonstrations of models and output to third parties etc.

- Pilot user numbers are expected to be ~10-15

- Module dataset sizes range from 10MB to 20GB

1.4 Recommendation by the feasibility study

The feasibility study concluded with the recommendation to take the NFFS architecture as a starting point and develop a (minimal set of) additional functionality to provide the flexibility as requested by the groundwater modellers of EA.

1.5 Additional functionality needs

The formal requirements of the feasibility study have been updated at the start of the second phase (see v.2.0 of the User Requirements Document and the Software Requirements document). Compared to the existing NFFS capabilities, the request for additional functionality can be summarized (in 'free wording') as:

- ability to identify a suitable module and module data set
  - visualize module input data sets
  - provide model logbook
- ability to configure abstraction locations that can be served by the module data set, but are not yet incorporated in the system configuration
- ability to manage output and sub-sets
  - control the raw module output production
  - slice sub-sets of data from the bulky data output
  - provide statistical and mathematical post-processing functionality to condense results
- ability to provide output that meets the demand from the groundwater community
  - specific graphic views such as accretion curves, splodge plots, winterbourne signatures
  - availability for publication on webserver
  - data available for download in Excel and shape format
- ability to inspect and interrupt job execution
  - inspect module output and diagnostics while computation job is running
  - manual and automated interruption procedures

- management of network traffic and disk space
- ability to handle various versions of a basically similar core module code
- ability to trace module runs

2 System Infrastructure

The previous feasibility project determined that the NFFS architecture is a suitable framework for NGMS. The next section details the NFFS architecture and introduces the key points that have been considered for the NGMS case. Although this document is the design for the pilot phase of NGMS, comments are made on the potential migration path from the pilot to the full implementation in terms of the systems infrastructure.

2.1 Current NFFS Infrastructure

The current NFFS system is installed on the following key infrastructure:

Server	**NFFS Component**	**Server type**	**OS**	**Infrastructure Software**
Central Server (Application Server)	System Controller/Dispatcher (Master Controller)	HP Unix server	HP-UX 11i	WebLogic 8.1 SP3+
Central Server (Database Server)	Central Storage	HP Unix server	HP-UX 11i	Oracle 9.2.0.6
Central Disk Array	Central Storage	HP EVA array	N/a	N/a
Central Shell server (8)	Forecasting Shell Server: • Module controller • Delft FEWs • Module adapters • Modules	HP DL360 (Intel)	W2K	Standard CIS build.
Workstation	Thick client (Operator Client)		W2K/XP	Java runtime
Workstation	Thin Client (browser)		W2K/XP	Internet Explorer

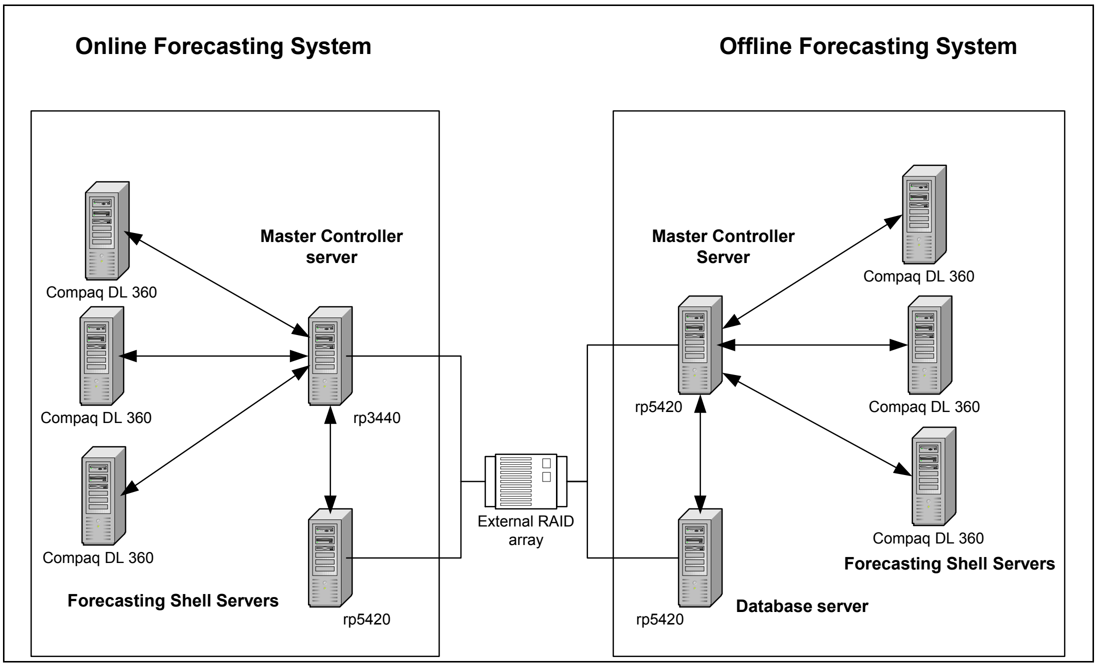

Figure 2-1 The current NFFS infrastructure (single site only)

2.2 Potential NGMS Infrastructure - considerations

The proposed NGMS should follow a similar de-coupled approach as with the NFFS, consisting a central server(s) and associated shell servers. The size of the associated data files (both input and output) would necessitate a form of large disk storage (such as the EVA).

In addition, the following factors will impact the selection of the hardware for the NGMS:

1. *System resilience*
   Compared to the NFFS, the NGMS does not have the same high level of availability and reliability requirements. As a result, it should be sufficient for the system to reside on a single site without automatic failover capability.

2. *Task Controller/dispatcher*
   The NFFS requires a reasonable amount of throughput regarding task dispatch and management. Forecasts are scheduled in timescales of minutes and hours. This is not the case for the NGMS where the timescales are likely to be in the order of days/weeks, hence the performance requirements for the controller (and the infrastructure it resides upon) is likely to be considerably less.

3. *Separation of regions.*
   Unlike the NFFS, the NGMS does not need to separate all regions individually. Due to the nature of the modelling (and underlying Physics) it is likely that there are only two distinct partitions of the system. The distinction will be made based on the work load (i.e. size) of the individual models. This will result in a reduced number of Oracle databases (and the associated overhead) compared to NFFS.

4. *Output*
   The output of the module indicates that there is still a requirement for a reasonable amount of disk storage, both for the online data and any potentially archived modules and associated datasets.

5. *Separation of database archive and database working space.*
   The database archive of module runs is designed to hold important runs that have jurisdictional value. For the pilot phase there is not the requirement to provide a separate archive system, however the phase will determine the scope of the archived module runs and the various operational processes required to support them.

6. *Shell Servers*
   The type of Shell servers required would needs investigation; the decision will be based upon the following factors:

   - Likely number of concurrent module runs (within the system as a whole).
   - This would determine the total number of servers required.
   - Performance of a typical module run (on the potential hardware platforms).
   - Whether dedicated servers for particular modules are required. This is driven by two factors:
     - Capacity
     - Run-time platform dependencies (e.g. do the modules require W2K or Unix)

7. *Phase 3 – Pilot Implementation*
   The next phase of the project is a pilot implementation, not a full production rollout. Its purpose is to provide an incremental development of the NGMS system, allowing for the flexibility to assess the required functionality and to develop the associated organisation roles and business processes. In addition, it allows an assessment to be made of the required future infrastructure requirements for the full implementation rollout. Consequently the infrastructure design for NGMS will evolve over the lifetime of phase 3. However, it is important that the phase 3 infrastructure should provide sufficient performance and capacity that the users can assess the NGMS system throughout (and beyond) the initial pilot phase. One important factor is that the pilot client-server system will only be implemented at a single host data centre.

8. *Data rates and volumes*

   Appendix B provides details of the potential data flows and volumes. Note that the information is based on all the modules for all the regions, the pilot will only consider a very reduced subset of these modules.

   In summary:

   Required Shell Server disk space = 100GB
   Required Master Controller/Database server disk space:
   - Internal = 50GB
   - External (via shared disk array) = 400GB

2.3 Potential NGMS Infrastructure – Phase 3 Pilot Implementation

2.3.1 Infrastructure approach

Taking into account the considerations in section 2.2, the following approach is proposed:

1. Utilise a single (centrally located) Unix server to house both the Master Controller components and the Oracle database.
2. Provide a single Oracle database instance to cover the central data-store requirements. The Oracle instance should access disk space on a shared (or dedicated?) external disk array.
3. A minimum of 2 Shell servers is required to perform the module runs. This provides sufficient capacity for parallel execution and testing.
4. Machine specifications (processors, memory etc.) are detailed in later sections and are based on our experience with NFFS and the data collated as part of the requirements phase of the NGMS project.

2.3.2 Architecture

The diagram below illustrates the proposed architecture. The key points are as follows:

1. A single Unix server to host both the Master Controller components and the Oracle Software.
2. Access to a shared network storage for the Oracle database.
3. At least 2 Shell servers
4. Switch to allow a dedicated link between the Master Controller/Database server and the shell servers. Significant network traffic is required between these components and requires isolation from the main network traffic.

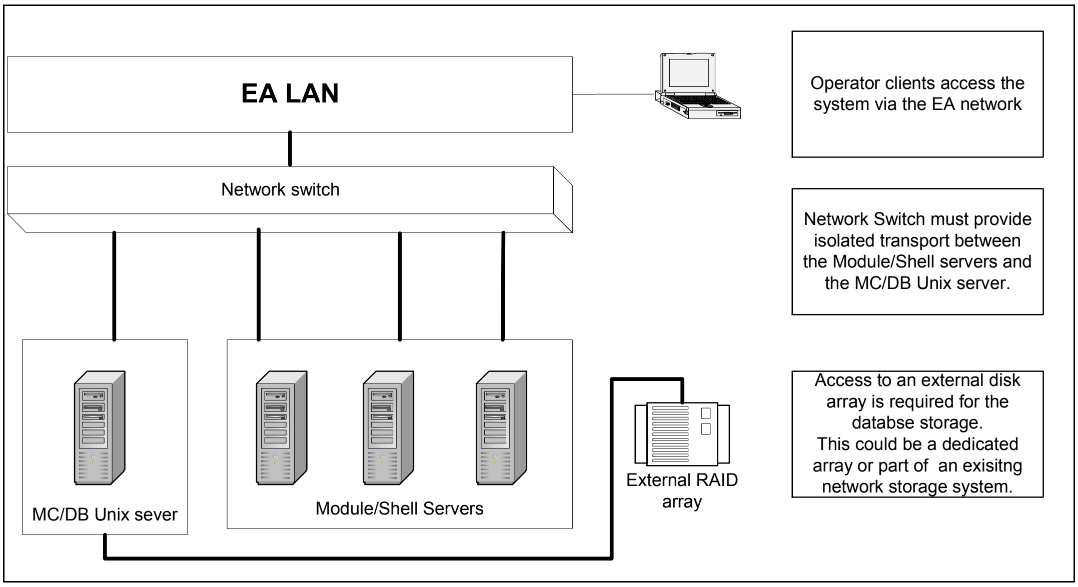

Figure 2-2 The proposed NGMS infrastructure (pilot phase 3)

2.3.3 Infrastructure – Central system hardware

The key hardware components comprising the NGMS are detailed below. They are suggested as guidelines, prior to any acquisition of equipment, detailed component listings will need to be provide and will require discussion with CIS.

Component	**Hardware**	**Specification**	**Number**
MC/DB Unix server	2-processor HP rp3410	**Processor:** 2 x 800+ Mhz **Memory:** ~6 GB **Internal Disk:** 2 x 72GB **Network card(s)**	1
Shell Server	HP dl360	**Processor:** 2 x 3 Ghz **Memory**: ~ 2GB **Internal Disks:** minimum 2 x 146GB **Network card(s)**	Minimum of 2
Network switch	CIS to determine	CIS to determine	
Access to disk array.		~400GB space required.	

2.3.4 Infrastructure – Client hardware

Recommended client machine specification (i.e. desktop PC's):

- Processor: >1GHz
- Memory: 1Gb

2.3.5 Infrastructure – Central system software

This section details the key infrastructure software required to support NGMS.

The diagram below illustrates the infrastructure software components that reside on the servers. Each Shell server in the system will require the appropriate software installed.

The HP Web service package provides the framework for the browser based Administration Interface application. This exposes system management functionality.

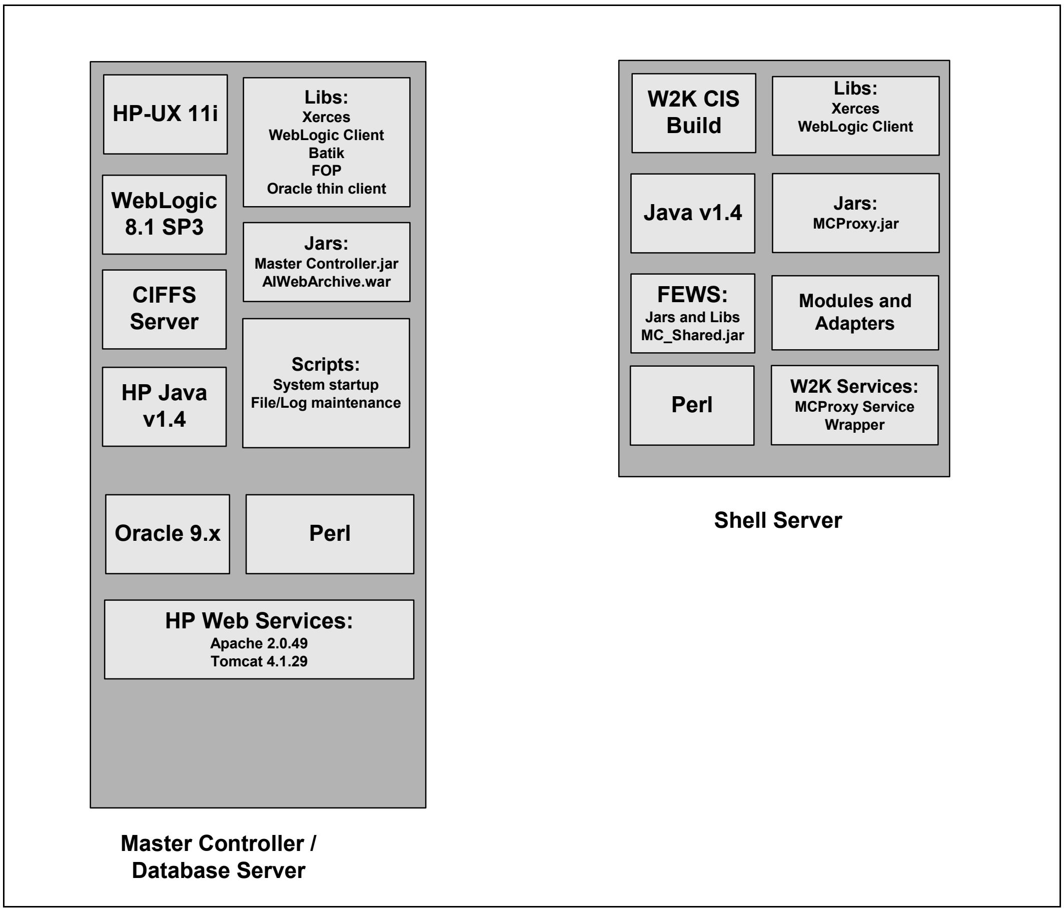

Figure 2-3 Infrastructure software required for NGMS

The table below provides licence information for the required software.

Infrastructure Software	**Location**	**Licence Required?**	**Number of users for Phase 3**
HP-UX 11i	MC/DB Unix server	Part of H/W	N/a
Oracle	MC/DB Unix server	Standard Edition.	<15
WebLogic 8.1 SP3	MC/DB Unix server	Express version.	<15
Windows 2000 server	Each Shell server	Standard build	<5 (note that users do not have direct access to these servers)

Note: Does not include baseline CIS infrastructure (i.e. virus scan, backup management software etc.)

2.3.6 Infrastructure – Client system software

The following infrastructure requirements are recommended:

- CIS standard W2K build
- Java 1.4

2.4 Migration to full implementation

Assuming the pilot phase of the project is successful, the next stage is a full rollout of the system, including additional functionality requirements together with the inclusion of all the operational ground water modules. This will require an update of the infrastructure design, and will utilise the findings from the pilot phase to assist in server selection and sizing. At this stage, the following modifications to the infrastructure seem likely:

1. De-couple the central system onto multiple servers (i.e. a Master Controller server and a database server).
2. Increase the installed memory on the central servers
3. Increase the accessible disk space for the database server (i.e. increased allocation on a shared array or a dedicated array)
4. Provide additional Shell servers.

Note the hardware provided for the pilot phase will be usable as part of the full implementation. The Unix server would provide an adequate basis for a dedicated Master Controller server.

As the various regions have different ranges of hardware requirements, with Anglian being an exceptional case, it seems wise to set up to service level agreement(s) with CIS Service Delivery to ensure proper sizing of hardware. Two alternatives should be considered: (a) region specific SLAs, or (b) one national SLA with region-specific detail.

A Alternative Infrastructure Configurations

The NGMS does have a number of key differences from the NFFS, and therefore there is the potential to undertake a number of alternative options. These have been discussed with CIS in the feasibility phase of the project and are documented here for completeness.

Option	Item	Option	Issue
1	Central Servers (application and database)	Combine servers onto one physical server	Performance. [Feedback from CIS] For shared architecture the CIS requirement is to maintain the separation. For dedicated systems this requirement is relaxed.
2	Central Servers (application and database)	Use of Linux as the OS (and potentially Intel hardware)	CIS technical directions. [Feedback from CIS] Current direction is HP-UX.
3	Central Servers (application and database)	Alternatives to WebLogic.	CIS technical directions. [Feedback from CIS] Current direction is Web Logic.

B Data flows and volumes

To assess the volumes for data storage and network traffic, the following assumptions are made:

1. Data volumes associated with submitting tasks and XML configuration files is minimal
2. Modifications to input files are sent as the differences (i.e. not new versions of the input file). This is feasible as the data is in the NGMS format (xml etc.) which will allow such decomposition. The module adapter will combine this modification with a basic input file to create a new input file which is fed to the computational core.
3. Downloads to the Operator clients will consist primarily of the sliced output files, not the full output file.
4. All data is stored and sent compressed (as is the case with NFFS at the present moment)
5. For the pilot, only a small number of modules will be investigated, hence minimising the overall network and capacity load (the tables below consider **all** of the module datasets).
6. The key network concern is the MC→ OC and OC→MC traffic. MC→ OC traffic is mainly output related, while OC→MC is mainly input and run settings related. The other links are dedicated between the servers.
7. Regarding the MC→OC and OC→MC links, transferring large amounts of data is not an issue in itself, the synchronisation mechanism provides a "trickle-down" approach, the issue to be addressed in the pilot is whether the overall download times are acceptable.

Based on those assumptions a list of tables is made to:

1. assess which storage and network utilities are involved in various main workflows
2. module data set sizes
3. data storage per module run
4. data storage per post-processing / slicing run
5. data storage per post-processing / slicing download
6. network traffic per task

Data storage and network traffic associated to the main workflows

Task	Central Data-store	MC→ SS	SS →MC	SS local data-store	MC→OC	OC→MC	OC local data-store	
	Data storage	Network traffic	Network traffic	Data storage	Network traffic	Network traffic	Data storage	Comment
Run Module (complete run)								
Submit modified input file	x	x		x		x (reduced)	x (reduced)	1
Create output file								
Create output file (compressed)	Optional		Optional	x	rarely			
Create sliced output file (compressed)	x		x	x	x		x	
Run Module (What-if run) pre-configured								3
Submit modified input file	x	x		x		x (reduced)	x (reduced)	1
Create output file								
Create output file (compressed)	Optional		Optional	Optional	rarely			
Create sliced output file (compressed)	x		x	x	x		x	
Perform Post-processing / further slicing								4
Create sliced output file (compressed)	x		x	x	x		x	
Viewing Post-processing / sliced output								5
View sliced output file					x		x	

1 Requires mechanism for minimising the amount of modified input data that has to be sent up to the central system. Although the data is being transferred in NGMS XML format, it could just be the deltas rather than the full file. The module adapter should combine the deltas and the original input file to a new input file for the computational core.
2 In 80% cases the data would only be stored in the central database for a short period (days/weeks).
3 Assumes that you do not need to store the complete (compressed) output file
4 Includes viewing on the client
5 Viewing results that have already been created

Module dataset sizes

The table below gives an indication of the module dataset sizes. It is based on the information provided in the feasibility phase of the project.

	Input file compression %	75%				
	Output file compression %	75%				
	Typical output file reduction due to slicing %	80%				
Region	**Module dataset**	**Input size (MB)**	**Input size (compressed) (MB)**	**Output size (MB)**	**Output size (compressed) (MB)**	**Output size (sliced) (MB)**
Midlands	West Midlands Worfe (Modflow)	150.0	37.5	1900.0	475.0	47.5
	East Shropshire (Modflow)	201.0	50.3	2000.0	500.0	50.0
	New Notts-Doncaster-Selby (Modflow)	200.0	50.0	4000.0	1000.0	100.0
Southern	Dour (ICMM)	8.0	2.0	223.0	55.8	5.6
	Itchen (4R)	631.0	157.8	0.1	0.0	0.0
	Itchen (Modflow VKD)		0.0	972.0	243.0	24.3
Anglian	Yare & North Norfolk (Modflow VKD) - daily stress periods	80000.0	20000.0	18000.0	4500.0	450.0
	Yare & North Norfolk (Modflow VKD) - monthly stress periods	20000.0	5000.0	18000.0	4500.0	450.0
Thames	Kennet (Modflow)	300.0	75.0	2000.0	500.0	50.0
	London Basin Model (ICMM)	100.0	25.0	1000.0	250.0	25.0
	Mimram (Upper Lee) (Modflow)	150.0	37.5	1000.0	250.0	25.0
	Colne (Modflow)	300.0	75.0	2000.0	500.0	50.0
North East	Chalk model	3.0	0.8	4.5	1.1	0.1
	Sandstone model	355.0	88.8	430.0	107.5	10.8
	Corallian model	31.0	7.8	42.0	10.5	1.1
North West	Wirral (Modflow)	200.0	50.0	300.0	75.0	7.5
	East Cheshire (Modflow)	70.0	17.5	200.0	50.0	5.0
	Sefton (Modflow)	240.0	60.0	880.0	220.0	22.0
	Fylde (ICMM)	2.0	0.5	70.0	17.5	1.8
South West	Bourne & Nine Mile (Modflow)	529.0	132.3	1600.0	400.0	40.0
	Avon (Modflow)	3000.0	750.0	4200.0	1050.0	105.0
	New Wylye (Modflow)	1900.0	475.0	637.0	159.3	15.9
	Future Stour Frome and Piddle (Modflow)	3000.0	750.0	4200.0	1050.0	105.0
Science	Operational models (testing purposes)	500.0	125.0	1000.0	250.0	25.0
	EA recharge code	1000.0	250.0	1000.0	250.0	25.0
	ZOOMQ3D	500.0	125.0	500.0	125.0	12.5

Data storage per module run

		Run Module (complete run)		
Region	**Module dataset**	**Central data-store (per run)**	**Shell server data-store (per run)**	**OC data-store (per run)**
Midlands	West Midlands Worfe (Modflow)	132.5	607.5	132.5
	East Shropshire (Modflow)	150.3	650.3	150.3
	New Notts-Doncaster-Selby (Modflow)	250.0	1250.0	250.0
Southern	Dour (ICMM)	13.2	68.9	13.2
	Itchen (4R)	157.8	157.8	157.8
	Itchen (Modflow VKD)	48.6	291.6	48.6
Anglian	Yare & North Norfolk (Modflow VKD) - daily stress periods	20900.0	25400.0	20900.0
	Yare & North Norfolk (Modflow VKD) - monthly stress periods	5900.0	10400.0	5900.0
				0.0
Thames	Kennet (Modflow)	175.0	675.0	175.0
	London Basin Model (ICMM)	75.0	325.0	75.0
	Mimram (Upper Lee) (Modflow)	87.5	337.5	87.5
	Colne (Modflow)	175.0	675.0	175.0
North East	Chalk model	1.0	2.1	1.0
	Sandstone model	110.3	217.8	110.3
	Corallian model	9.9	20.4	9.9
North West	Wirral (Modflow)	65.0	140.0	65.0
	East Cheshire (Modflow)	27.5	77.5	27.5
	Sefton (Modflow)	104.0	324.0	104.0
	Fylde (ICMM)	4.0	21.5	4.0
South West	Bourne & Nine Mile (Modflow)	212.3	612.3	212.3
	Avon (Modflow)	960.0	2010.0	960.0
	New Wylye (Modflow)	506.9	666.1	506.9
	Future Stour Frome and Piddle (Modflow)	960.0	2010.0	960.0
Science	Operational models (testing purposes)	175.0	425.0	175.0
	EA recharge code	300.0	550.0	300.0
	ZOOMQ3D	150.0	275.0	150.0

Data storage per post-processing/slicing run

		Post processing / further slicing		
Region	**Module dataset**	**Central data-store (per run)**	**Shell server data-store (per run)**	**OC data-store (per run)**
Midlands	West Midlands Worfe (Modflow)	95.0	95.0	95.0
	East Shropshire (Modflow)	100.0	100.0	100.0
	New Notts-Doncaster-Selby (Modflow)	200.0	200.0	200.0
Southern	Dour (ICMM)	11.2	11.2	11.2
	Itchen (4R)	0.0	0.0	0.0
	Itchen (Modflow VKD)	48.6	48.6	48.6
Anglian	Yare & North Norfolk (Modflow VKD) - daily stress periods	900.0	900.0	900.0
	Yare & North Norfolk (Modflow VKD) - monthly stress periods	900.0	900.0	900.0
Thames	Kennet (Modflow)	100.0	100.0	100.0
	London Basin Model (ICMM)	50.0	50.0	50.0
	Mimram (Upper Lee) (Modflow)	50.0	50.0	50.0
	Colne (Modflow)	100.0	100.0	100.0
North East	Chalk model	0.2	0.2	0.2
	Sandstone model	21.5	21.5	21.5
	Corallian model	2.1	2.1	2.1
North West	Wirral (Modflow)	15.0	15.0	15.0
	East Cheshire (Modflow)	10.0	10.0	10.0
	Sefton (Modflow)	44.0	44.0	44.0
	Fylde (ICMM)	3.5	3.5	3.5
South West	Bourne & Nine Mile (Modflow)	80.0	80.0	80.0
	Avon (Modflow)	210.0	210.0	210.0
	New Wylye (Modflow)	31.9	31.9	31.9
	Future Stour Frome and Piddle (Modflow)	210.0	210.0	210.0
Science	Operational models (testing purposes)	50.0	50.0	50.0
	EA recharge code	50.0	50.0	50.0
	ZOOMQ3D	25.0	25.0	25.0

Data storage per post-processing/slicing download

		Viewing Post-processing/sliced output		
Region	**Module dataset**	**Central data-store (per run)**	**Shell server data-store (per run)**	**OC data-store (per run)**
Midlands	West Midlands Worfe (Modflow)			95.0
	East Shropshire (Modflow)			100.0
	New Notts-Doncaster-Selby (Modflow)			200.0
Southern	Dour (ICMM)			11.2
	Itchen (4R)			0.0
	Itchen (Modflow VKD)			48.6
Anglian	Yare & North Norfolk (Modflow VKD) - daily stress periods			900.0
	Yare & North Norfolk (Modflow VKD) - monthly stress periods			900.0
Thames	Kennet (Modflow)			100.0
	London Basin Model (ICMM)			50.0
	Mimram (Upper Lee) (Modflow)			50.0
	Colne (Modflow)			100.0
North East	Chalk model			0.2
	Sandstone model			21.5
	Corallian model			2.1
North West	Wirral (Modflow)			15.0
	East Cheshire (Modflow)			10.0
	Sefton (Modflow)			44.0
	Fylde (ICMM)			3.5
South West	Bourne & Nine Mile (Modflow)			80.0
	Avon (Modflow)			210.0
	New Wylye (Modflow)			31.9
	Future Stour Frome and Piddle (Modflow)			210.0
Science	Operational models (testing purposes)			50.0
	EA recharge code			50.0
	ZOOMQ3D			25.0

Network traffic per task

		Run Module (complete run)				Run Module (What-if run) Pre-configured			
Region	**Module dataset**	**MC→SS**	**SS→MC**	**MC→OC**	**OC→MC**	**MC→ SS**	**SS→MC**	**MC→OC**	**OC→MC**
Midlands	West Midlands Worfe (Modflow)	37.5	95.0	95.0	37.5	3.8	95.0	95.0	3.8
	East Shropshire (Modflow)	50.3	100.0	100.0	50.3	5.0	100.0	100.0	5.0
	New Notts-Doncaster-Selby (Modflow)	50.0	200.0	200.0	50.0	5.0	200.0	200.0	5.0
Southern	Dour (ICMM)	2.0	11.2	11.2	2.0	0.2	11.2	11.2	0.2
	Itchen (4R)	157.8	0.0	0.0	157.8	15.8	0.0	0.0	15.8
	Itchen (Modflow VKD)	0.0	48.6	48.6	0.0	0.0	48.6	48.6	0.0
Anglian	Yare & North Norfolk (Modflow VKD)	20000.0	900.0	900.0	20000.0	2000.0	900.0	900.0	2000.0
Thames	Kennet (Modflow)	75.0	100.0	100.0	75.0	7.5	100.0	100.0	7.5
	London Basin Model (ICMM)	25.0	50.0	50.0	25.0	2.5	50.0	50.0	2.5
	Mimram (Upper Lee) (Modflow)	37.5	50.0	50.0	37.5	3.8	50.0	50.0	3.8
	Colne (Modflow)	75.0	100.0	100.0	75.0	7.5	100.0	100.0	7.5
North East	Chalk model	0.8	0.2	0.2	0.8	0.1	0.2	0.2	0.1
	Sandstone model	88.8	21.5	21.5	88.8	8.9	21.5	21.5	8.9
	Corallian model	7.8	2.1	2.1	7.8	0.8	2.1	2.1	0.8
North West	Wirral (Modflow)	50.0	15.0	15.0	50.0	5.0	15.0	15.0	5.0
	East Cheshire (Modflow)	17.5	10.0	10.0	17.5	1.8	10.0	10.0	1.8
	Sefton (Modflow)	60.0	44.0	44.0	60.0	6.0	44.0	44.0	6.0
	Fylde (ICMM)	0.5	3.5	3.5	0.5	0.1	3.5	3.5	0.1
South West	Bourne & Nine Mile (Modflow)	132.3	80.0	80.0	132.3	13.2	80.0	80.0	13.2
	Avon (Modflow)	750.0	210.0	210.0	750.0	75.0	210.0	210.0	75.0
	New Wylye (Modflow)	475.0	31.9	31.9	475.0	47.5	31.9	31.9	47.5
	Future Stour Frome and Piddle (Modflow)	750.0	210.0	210.0	750.0	75.0	210.0	210.0	75.0
Science	Operational models (testing purposes)	125.0	50.0	50.0	125.0	12.5	50.0	50.0	12.5
	EA recharge code	250.0	50.0	50.0	250.0	25.0	50.0	50.0	25.0
	ZOOMQ3D	125.0	25.0	25.0	125.0	12.5	25.0	25.0	12.5

		Post processing / further slicing				Viewing post-processed results
Region	**Module dataset**	**MC→SS**	**SS→MC**	**MC→OC**	**OC→MC**	**MC→OC**
Midlands	West Midlands Worfe (Modflow)		95.0	95.0		95.0
	East Shropshire (Modflow)		100.0	100.0		100.0
	New Notts-Doncaster-Selby (Modflow)		200.0	200.0		200.0
Southern	Dour (ICMM)		11.2	11.2		11.2
	Itchen (4R)		0.0	0.0		0.0
	Itchen (Modflow VKD)		48.6	48.6		48.6
Anglian	Yare & North Norfolk (Modflow VKD)		900.0	900.0		900.0
Thames	Kennet (Modflow)		100.0	100.0		100.0
	London Basin Model (ICMM)		50.0	50.0		50.0
	Mimram (Upper Lee) (Modflow)		50.0	50.0		50.0
	Colne (Modflow)		100.0	100.0		100.0
North East	Chalk model		0.2	0.2		0.2
	Sandstone model		21.5	21.5		21.5
	Corallian model		2.1	2.1		2.1
North West	Wirral (Modflow)		15.0	15.0		15.0
	East Cheshire (Modflow)		10.0	10.0		10.0
	Sefton (Modflow)		44.0	44.0		44.0
	Fylde (ICMM)		3.5	3.5		3.5
South West	Bourne & Nine Mile (Modflow)		80.0	80.0		80.0
	Avon (Modflow)		210.0	210.0		210.0
	New Wylye (Modflow)		31.9	31.9		31.9
	Future Stour Frome and Piddle (Modflow)		210.0	210.0		210.0
Science	Operational models (testing purposes)		50.0	50.0		50.0
	EA recharge code		50.0	50.0		50.0
	ZOOMQ3D		25.0	25.0		25.0