WATER REFORM
long term technical assistance

EU-AFD TECHNICAL ASSISTANCE PROGRAMME TO SUPPORT REFORMS IN THE WATER AND WASTEWATER SECTORS IN LEBANON

Funded by the European Union

Implemented by AFD

CONCEPTUAL DESIGN OF GIS SYSTEMS FOR WATER ESTABLISHMENTS

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Hydroconseil L'ingénierie au service du développement
HYDROPHIL
VA

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AFD	Agence Française de Développement
BMLWE	Beirut and Mount Lebanon Water Establishment
BoQ	Bill of Quantities
BWE	Beqaa Water Establishment
CDR	Council for Development and Reconstruction
DMA	District Metering Area
DEM	Digital Elevation Model
EU	European Union
EUD	European Union Delegation
GIS	Geographic Information System
GPS	Geographic Positioning System
HR	Human Resources
KE	Key Expert
LRA	Litani River Authority
LTTA	Long Term Technical Assistance
MoEW	Ministry of Energy and Water
NLWE	North Lebanon Water Establishment
NRW	Non-Revenue Water
NWSS	National Water Sector Strategy
PMA	Pressure Management Area
SLWE	South Lebanon Water Establishment
TA	Technical Assistance
TL	Team Leader
ToR	Terms of Reference
WE	Water Establishments
WMP	Water Master Plan
WSMP	Water Supply Master Plan
WTP	Water Treatment Plant

1 INTRODUCTION

Within the framework of the "*Technical Assistance Program to support Reforms in the Water and Wastewater sectors in Lebanon*", funded by the European Union and implemented by AFD, is foreseen Activity A15: *Strengthen regional planning tools*, out of which are the GIS systems.

As a planning tool, a GIS system must be linked to the WEs corporate systems and tools for addressing key aspects of day-to-day management as well as setting up strategic plans. This requires reviewing the status of the existing GIS systems in the view of setting up a system suitable for serving its purposes and compliant with international standards.

During a previous phase, the LTTA reviewed and assessed the status of the GIS systems currently in use in the four WEs, in terms of IT infrastructure, tools, database, and human resources. The following main points were covered :

- Identifying in each WE the available GIS IT infrastructures such as servers, workstations, GIS tools, licenses, and highlight gaps and needs if any.
- Assessing the current situation in each WE regarding the GIS Database structure and architecture, the available data, the type of data (physical, operational, etc.), compliance, cleanness, completeness, accuracy, historical and geographical coverage, verify the compliance of the GIS data to be used in hydraulic modeling and investment planning, and identify gaps and upgrades to build a relevant GIS database.
- Verifying the integration of the GIS with other systems in use such as ERP, Water Quality management system, O&M CMMS system, SCADA, etc.
- Listing and evaluate the Human resources assigned to GIS activities (permanent, on-demand, etc.), their education level, experience, and acquired skills, training, and certificates, and identify the needs for additional staff.

Four assessment reports were then produced, highlighting the gaps and proposing upgrades to bring up the GIS systems to the level of management and planning tools for capital investment projects.

During this previous phase appeared the need to unify the GIS architecture in the all four WEs in order to have a standard structure suitable for management and planning and for addressing day-to-day issues and challenges.

The present report proposes the conceptual design for the standardization of the WEs' GIS systems and the required upgrades to the level of a planning tool adapted for water exploitation establishments.

The ultimate objective of the present report is to provide the WEs with an updated GIS system, as a database for storage and diagnosis in the first stage, and in the second stage as a tool for management, operations and planning of water systems. These GIS specificities all gathered into one system, will form a decision support system for daily tasks, and for future planning by establishing Strategic Scenarios for short to long term new investments at WEs.

The concept design phase shall be complemented by the preparation of the detailed designs for the various GIS updates required, including database schema changes and updates to custom codes and batch processes. A key requirement is to limit the impact of the GIS updates on legacy systems to avoid unnecessary risk and development cost. The detailed design will be prepared by an expert recruited for a short-term mission, in full coordination with the TA team, to support the WEs in:

- Implementing the GIS updates according to the conceptual design report and the TOR list of tasks related to the recruitment of the short-term expert.
- Detailing the requirements related to database architecture, layers structures, attributes accuracy, and possible links with the other platforms.
- Design and write an SOPs for the data flow process diagram to standardize data collection and data entry from different sources.
- Writing code and macros necessary to set up new tailored modules.
- Technical input into the overall implementation planning and change management.
- Extending recommendations during system integration and user acceptance testing.

2 OBJECTIVES OF IMPLEMENTING A GIS FOR WATER ESTABLISHMENTS

2.1 GIS Basics

A geographic information system (GIS) is a computer-based tool that uses all types of information based on geographic location. The purpose of a GIS is to gather data from different sources in a way to handle queries, perform statistical analysis and visualization, and ultimately provide a spatial framework for decision support.

GIS is usually built on three main components: hardware, software, and data (graphical and tabular data).

2.2 Main Triggers

The technical assessment of the current GIS database at the WEs allowed to point out the following:

- Some projects and assets are not yet included in the WE database.
- A number of valuable data are still paper based information (failures, complaints, etc.).
- Fragmentation of information (drawings and textual are not together).
- Design approach of the GIS database is not clear nor well defined.
- No uniform standards for capturing and entering data.
- No standardized software and versions.
- No proper definition of attributes and labels.
- No proper procedure for attributes input.
- No systematic procedure for updating information.
- Links with other WE business platforms are not standardized.
- Data flow process is not defined.
- Topology and geometry concept in drafting networks is not addressed yet.
- Focus on Water supply systems, wastewater and irrigation systems are not priorities in terms of GIS databases.
- No proper understanding of the GIS capabilities for water utilities facilities administration.

2.3 Objectives

GIS represents a Management Information System that can be best described as a system to store and deliver reliable data, analyse and ease daily tasks, and support the required management and planning processes. Ultimately, GIS will be used as a tool in the WE for a smoothly functioning workflow process that integrates information for water demand forecasting, engineering, assets, client management, operation, and maintenance inventory of systems assets.

Consequently, the GIS system will:

- Provide a storage pool to gather all relevant data related to water systems;
- Act as a storage pool for digital spatial data;
- Produce cartographic maps;
- Provide easy access to spatial data and as-built drawings;
- Perform simple spatial analysis, spatial modelling, and simulations;
- Provide means to organize the data;
- Aid in conducting statistical analysis to forecast future outcomes;
- Generate options and alternatives for investment planning;
- Ultimately, act as a management and planning tool for short-term work plans and long-term strategies.

3 GIS DESIGN APPROACH

3.1 GIS: a prerequisite for efficient water management

Water Establishments collect and process large amounts of different data daily from different departments and with different purposes, such as a digital land base, network data, hydraulic network models, operation and maintenance logs, failure databases, customer and subscription information systems, water demand, production volume, recording, and readings on flows and pressures, leaks and repairs.

Water Establishments should pool the available information, combine it and foster good working relationships through interdepartmental team-work. This approach will improve early management and operation efforts and allow the most efficient counteractive measures to be selected.

The figure below illustrates the various interactions between the different sources of information and how they can be grouped, into the GIS.

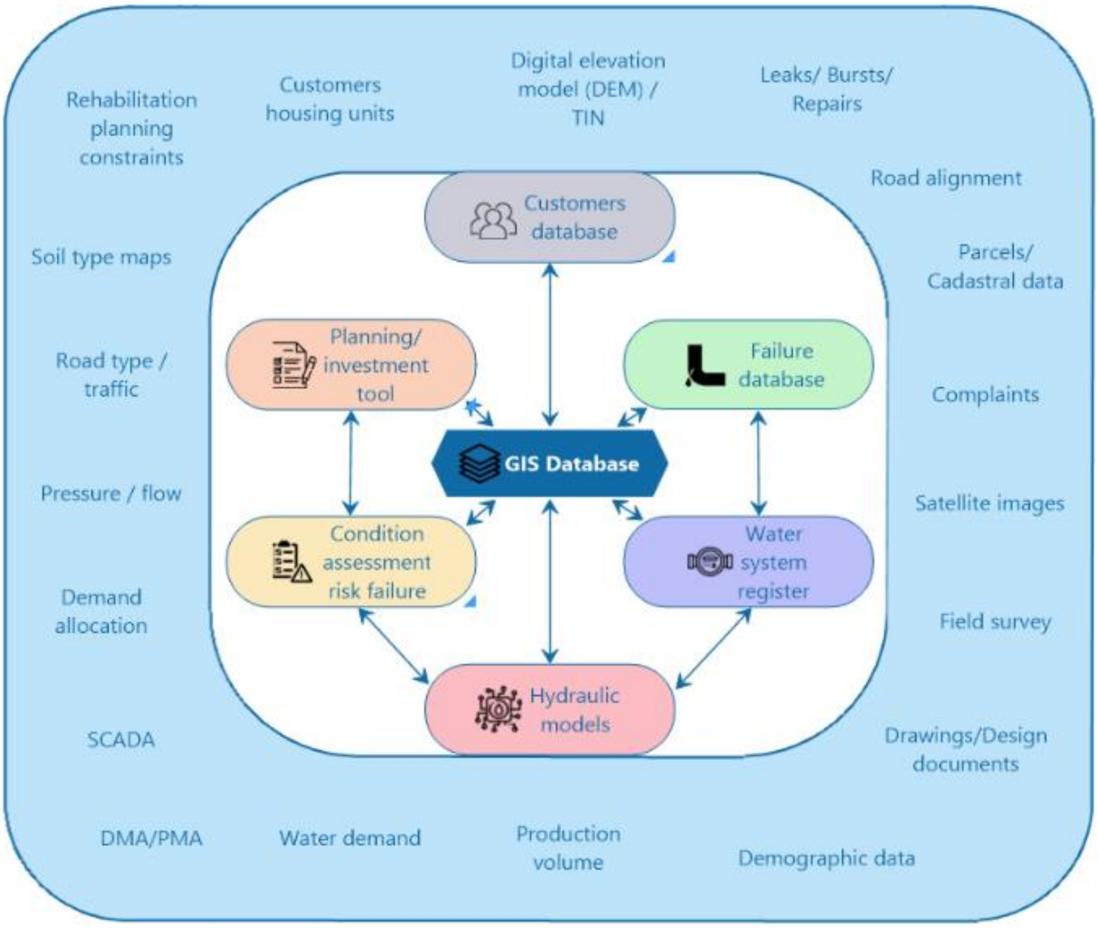


Figure 1 Design approach scheme and interaction with the different information systems

3.2 Benefits of standardizing the GIS system

All resources within a water establishment are actually based on location, such as production and treatment facilities, distribution and collection networks, service areas, pressure zones, inventories, customers, and employee and crew locations. As such the use of a geographic platform is necessary for sustainable water establishments operations. The benefits of GIS as the geo-localization platform for water systems are many. Here are the benefits of what a proper GIS system offers:

3.2.1 Powerful Asset register

The pipe network usually represents 60 to 80% of a water system's capital assets. A digital GIS-based network register is a powerful system that enables water utilities to:

- Have instant access to necessary information
- Reduce time-consuming paper-based processes
- Improve maintenance and operation efforts
- Support in defining leakage management scenarios
- Identify and predict system failures
- Accelerate and facilitate the localization of emergency repairs
- Facilitate long-term rehabilitation and extension planning.

It is to be noted that setting up an entire network register is a multi-stage process which frequently takes three to five years for large water distribution networks.

3.2.2 Generate automatic failure reports and maps

A GIS enables water establishments to generate reports automatically by making a spatial selection based on service area, pipe material, leaks location, leak size, leak type, and leak repair status, etc. Using the capability of spatial analysis allows for more efficient planning of field interventions such as repairs and pipe replacement projects. Graphic visualization of the results helps to reveal hotspots, prioritize interventions (leak repair and pipe replacement), identify problematic areas, and effectively deploy intervention teams to the field.

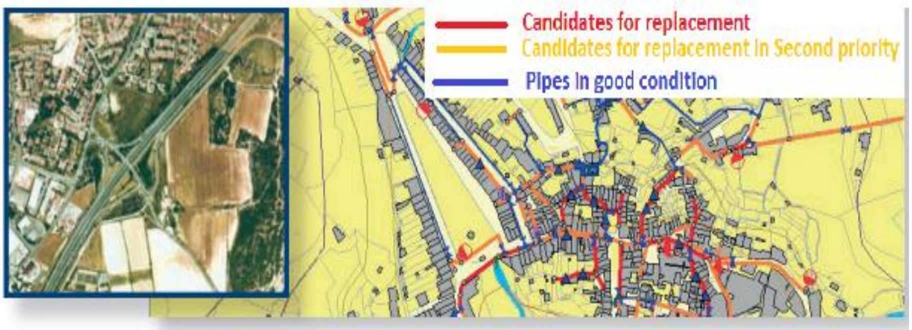


Figure 2 Spatial analysis and identification of problematic pipes

3.2.3 Facilitate and accelerate the hydraulic modeling

Hydraulic network models are indispensable for analyzing system capacity under different conditions and scenarios and they are very useful tools to design DMAs and PMAs. The setting up of an appropriate GIS database will facilitate and accelerate the model-building process tremendously by Linking the hydraulic model to the GIS-based network register.

The benefits of linking the GIS to the Hydraulic modeling are multiple. Here below are some examples:

- Topology of the hydraulic model will be updated automatically upon any changes to the network register and sources of possible data processing errors will be reduced.
- Simulation results are directly stored, visualized and analyzed at their location in the network register.

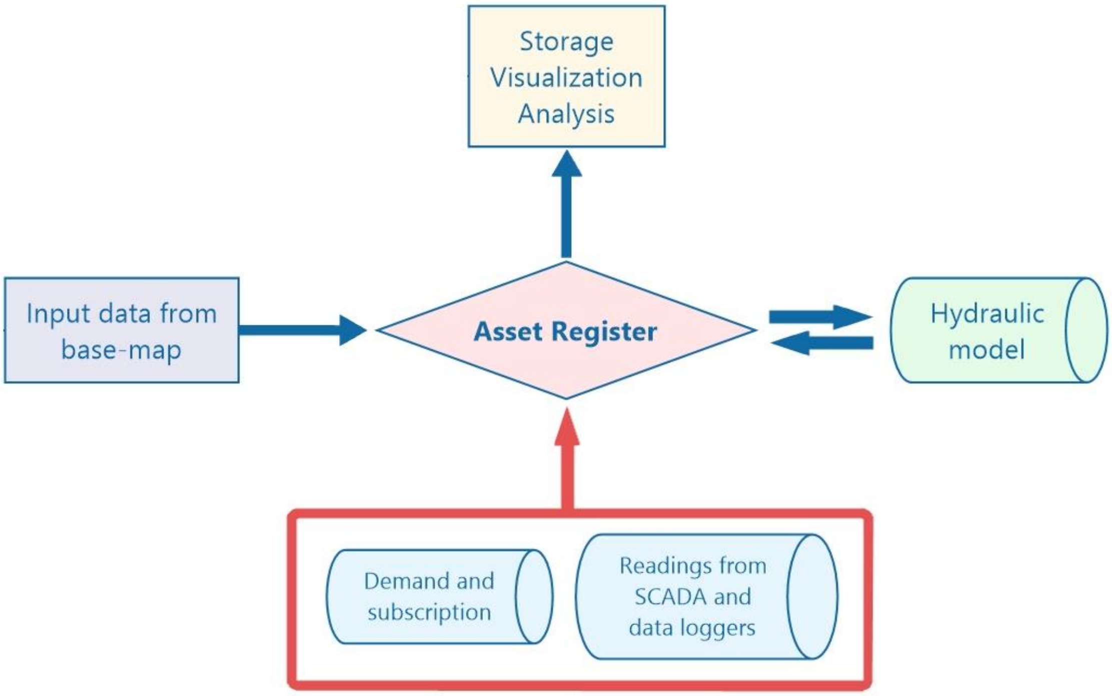


Figure 3 Linking the hydraulic network model to the network register

The integrated solution will initially require significant efforts as both systems have to be harmonized with each other. In the long term, the integrated system of the GIS and the hydraulic model is more efficient because it allows more frequent calculations to provide planners with a solid basis for decision-making.

3.2.4 Main driver to improve the reliability of performance indicators

KPI are important tools for continuous analysis and benchmarking. Data reliability and accuracy are major factors in the calculation of KPI. Acquiring standardized GIS will improve the usefulness of the KPI and can positively help and facilitate the putting in place the KPIs.

The following presents the importance and how GIS can support the implementation of the different groups of KPIs:

Table 1 GIS and KPIs implementation

Element	Area	Count of Indicators	Impact	How GIS support the KPIs implementation
Technical Operations	Service Coverage	2	High	Facilitate archiving, update, calculation of all related KPIs. Enables the testing of impact and visualize the relationship with other geographic parameters. Help the WE to identify areas not covered by the WE services
	Water production	2	High	Locate hotspots subscribers and areas. Help the WE to understand the relationship with the produced, consumed/ or sold volumes.
	Water consumption	5	High	Locate and visualize hotspots subscribers and zones. Help the WE to understand the relationship with the produced, consumed/ or sold volumes.
	Distribution and NRW	3	High	Visualize, track leakage at subscribers and zones levels. Support the definition of DMAs and PMAs
	Water treatment & quality	2	High	Map and track the quality of water in terms of compliance and frequency
	Asset management	2	High	Archiving, Visualizing and support to plan and intervene
Commercial Management	Billings	8	High	Map
	Collections	2	High	Map and track subscribers and areas
	Metering	2	High	Map and track
	Quality of service	2	High	Map hotspots areas
Financial Management	Operating costs	10	Medium	Visualize areas with high operating costs
	Financial performance	6	Medium	
Human Resource Management	Staff performance	5	High	Facilitate to visualize these KPI at the level of distribution zone and water system
Organization and Strategy	Valuation	2	High	Essential register for asset valuation
	Growth	2	High	Essential tool for strategic planning

3.2.5 An essential instrument to reduce leakage and define DMA and PMAs

The integrated Hydraulic GIS-based solution allows for optimizing scenarios in the hydraulic model using the capability of defining DMA and PMA.

Linking the output of the DMA and PMA modules of the hydraulic models enables the different departments, in particular the distribution department, to perform spatial analysis by combining the different generated scenarios with the available geo-database which makes it possible to optimize the implementation of NRW plans and the deployment of staff during the setting in place of these plans.

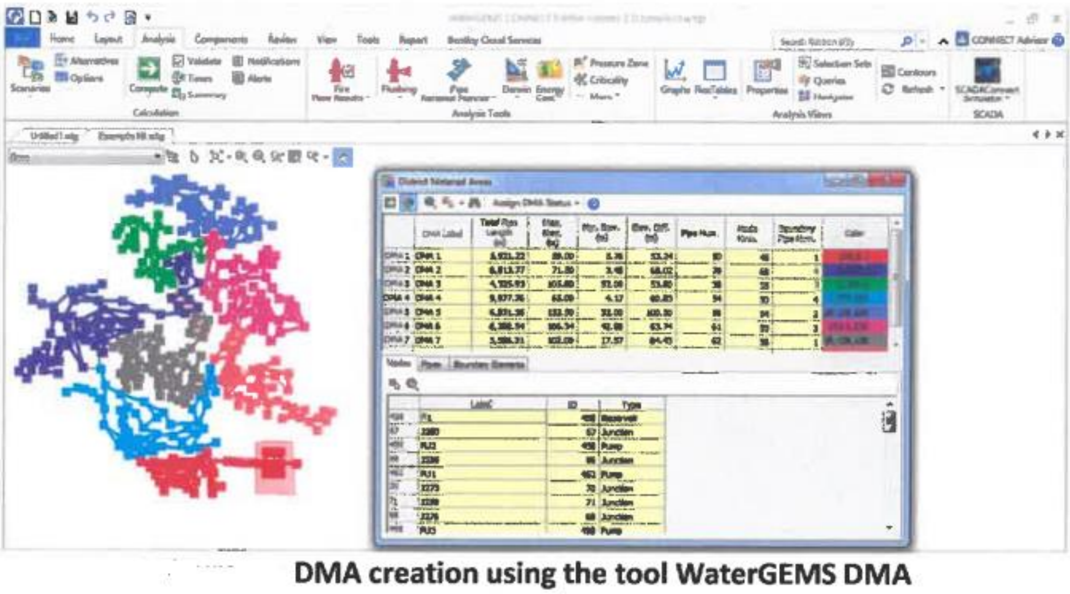


Figure 4 Integrate the DMA and PMAs capabilities of the Water GEMS

3.2.6 GIS a step towards smart water management

Smart water system management starts with GIS to allow energy and leakage reduction and goes far beyond short- and long-term planning. Depending on the level of smartness in terms of device for control and monitoring, benefits are:

- Reduce time consuming daily operations in terms of identifying failures, interventions, control and decisions.
- Reduce energy consumption and leakage through the equipping of control/regulation device for pressures and flows.

3.2.7 The basis for a decision support tool for optimized renewal programs and strategic planning

3.2.7.1 GIS as main pillar for the planning tool

An asset water management and planning tool will be very useful for short term and strategic planning management tool. The decision aid tool will rely on the combination of three main pillars:

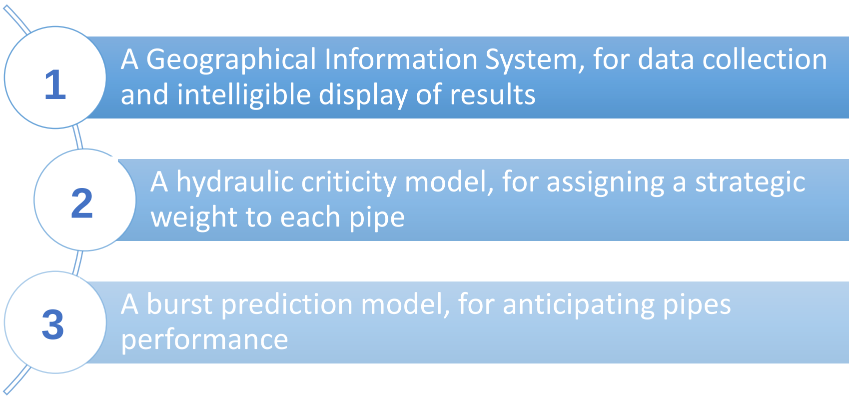


Figure 5 The three main pillars

The planning tool/Module will be based on a multi-criteria decision support approach, which will be designed to create a hierarchy of potential rehabilitation candidates, defined by an individual pipe global score, and consider both the impact of failures and the opportunities for rehabilitation as selection criteria. All data processed to compute the global score originates from the GIS by means of:

- Failure data collection procedures through the network interventions management module.
- Tools designed to control and adapt network topology to hydraulic reliability modelling requirements.

3.2.7.2 Description of the planning tool: the 5 steps approach

5 steps are required to identify assets in need of replacement, they are:

Data collection

Data sheet (Physical, failure, etc.) from GIS data base for each water system

Processed data from Specific tools (Risk analysis, failure, hydraulic criticality, etc.).

Multi-criteria analysis settings

Definition of a set of hypotheses

Weighting of renewal criteria

The multi-criteria analysis relies on the weighting of each criterion so as to translate the preferences and objectives of the decision maker and represent the specifics and issues of the local context.

Calculation of the renewal criteria

Burst prediction is based on a mathematical process model (Linear Extended Yull, Poisson, etc.)

Other criteria (water loss index, disruption on traffic, repair and rehab costs, etc.)

Data sharing with a multi-networks database

Centralized and multi-networks shared databases will enable pipe bursts prediction validity to improve as data quantity and representativeness get higher.

Customized visualization

Identification and cartographic visualization of critical pipe sections candidate to rehabilitation.

Global cost estimate for the renewal of critical pipe sections.

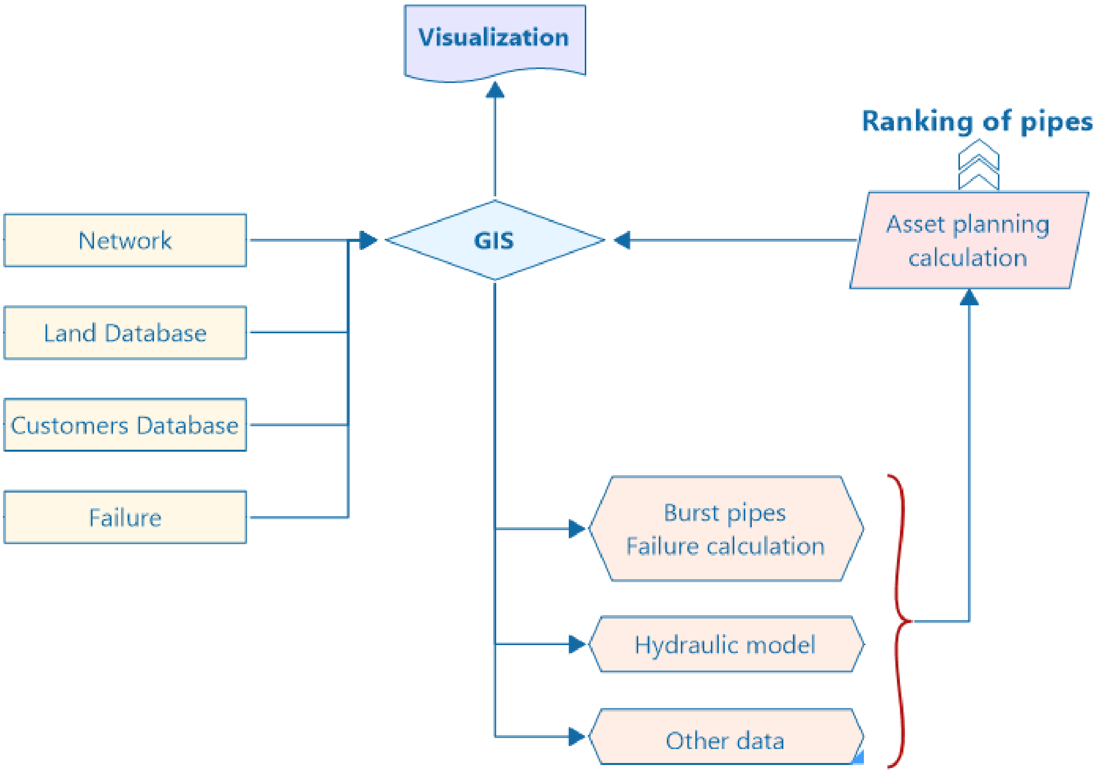


Figure 6 Calculation flow process of the asset planning tool for optimized short term and strategic planning

In addition to the GIS platform, it is necessary to use the following:

- Mathematical model to calculate the failure rate for each pipe.
- Ranking model for pipes prioritization and selection of pipes candidates to replacement.

Results of applying the proposed approach will be displayed as follow:

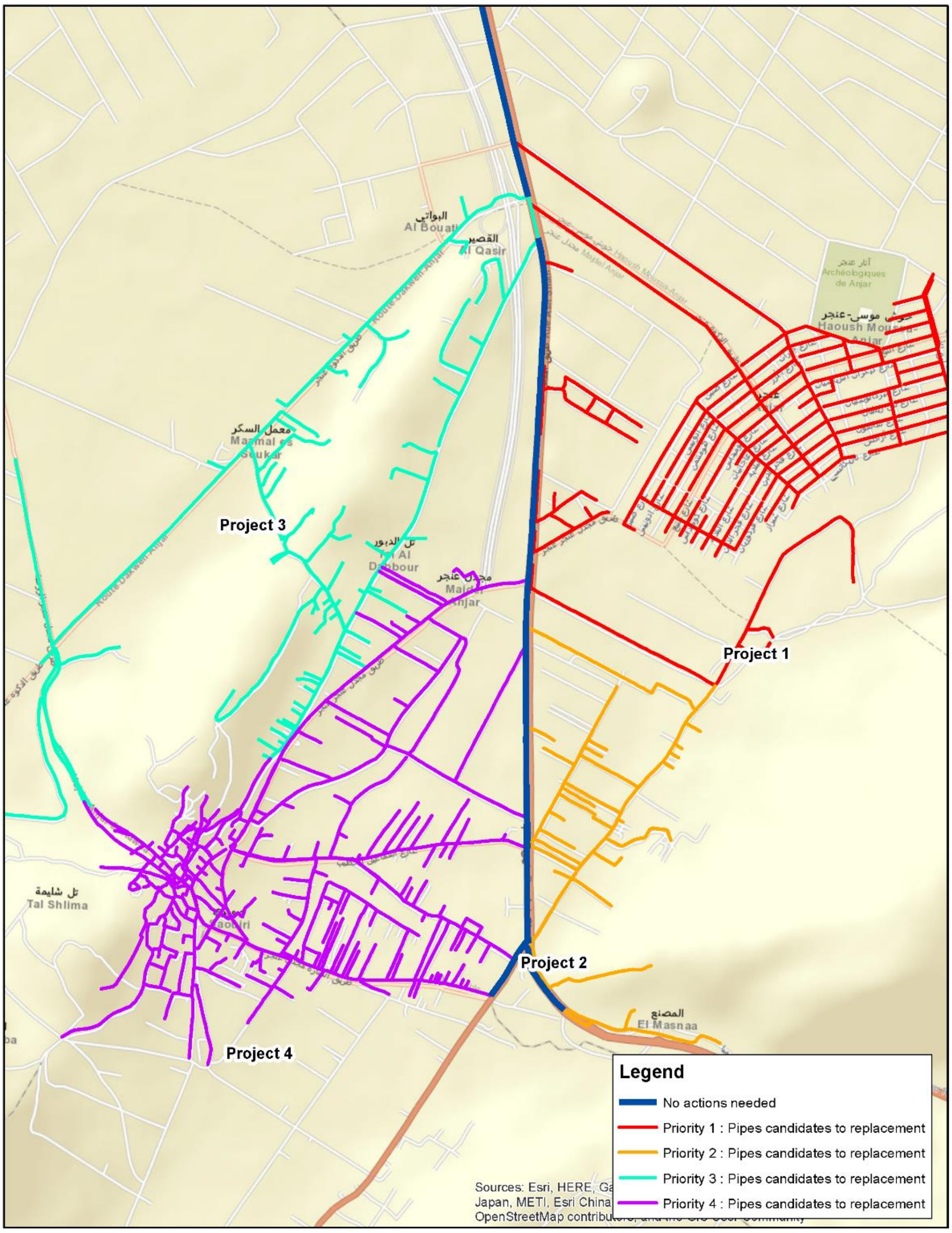


Figure 7 Visualization of applying the asset planning tool combined with the GIS

3.3 Design approach

To establish a data model suitable to real needs and organize the data collection consequently, particular attention shall be given to:

- Understanding of the need for the GIS system (what is it intended for? Storage? Diagnosis? Analysis? Asset Valuation? Planning? etc.?),

- Deduce requirements in terms of accuracy, coverage, completeness, compliance, data collection procedures, data integration, topology, geometry, etc.
- Accurate understanding of the “Asset Water Management” concept.

The first 2 points will be discussed in the next section, while the concept of Asset Water management is discussed in the previous paragraph.

3.4 Defining objectives and requirements

An essential step that the WE should consider before drawing the architecture of the GIS system is to set up the objectives of using that system and the requirement regarding the collected data in terms of accuracy and level of details.

3.4.1 Objectives of use of the GIS

The design of a GIS-based decision support system has to be objective-oriented. WE management, has to identify these objectives in clear and precise terms, in close discussion with the GIS department/unit, to avoid either excessive or insufficient data collection.

The table presents the objective that the GIS should achieve in order to optimize and improve water establishment management and planning.

Table 2 Objectives of a GIS-based decision support system for management

Objective	Description
Storage and archive	GIS system reduces time consuming and easy access to information
Spatial Analysis	GIS system allows combining, querying, analyzing and visualizing large amounts of data from different sources
Operation	GIS system accelerates repairs and identification of failures
Planning	Powerful decision tool for rehabilitation program and strategic planning

3.4.2 Data requirements

The WE shall define objectives before the setting in place a GIS system. As such it will be useful in order to answer some difficult questions: What type of data will be required? What are the departments that will be involved? What is the data that the WE has to collect through field survey? What are the data that the WE should purchase or collect from other public authorities? What is the architecture and the structure of the GIS database? What type and size of software and hardware should we use?

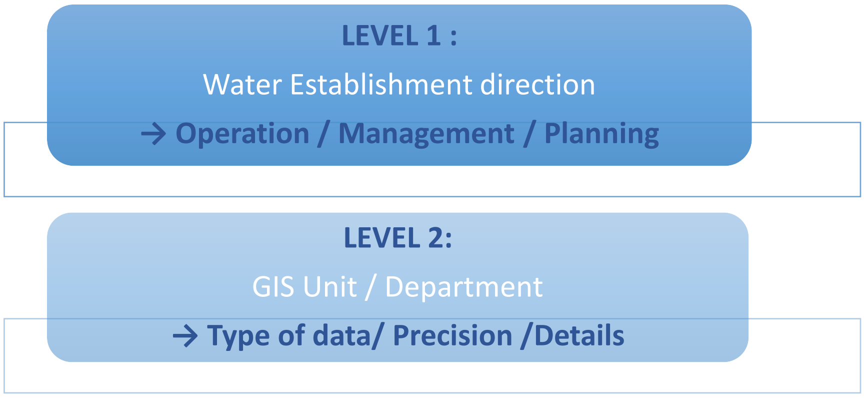


Figure 8 Levels & Objectives

3.5 GIS Integrated based solution is the foundation towards digital transformation for the Water establishments

Digital transformation is one of the options that increases opportunities and reduces problems related to water. Internet of Things (IoT) and sensor systems capabilities are already being introduced in several areas. Switching from traditional systems to smart systems shall be a consistent target for WEs and will be driving the WEs towards the digitalization.

Nowadays digitalization has become an imperative solution and not a choice. The digital solutions will enable water establishments to face the upcoming challenges of rapidly increasing water demand, scarcity of water resources and economic crisis and will also address the traditional sector challenges related to NRW, energy shortage, and financial stability.

The GIS system will be the basis toward the digital transformation of the water establishment through the Integration of the GIS system with the different platforms.

Digital platforms such as Management Information Systems (MIS) and Enterprise Resource Planning (ERP), Laboratory Management System (LMS), Supply Chain, Procurement and Inventory System, Asset Management System, SCADA System as a tool for operating and monitoring, GIS Application as a tool for network system maintenance and customer service, Cost centers, HR & payroll System to support more effective utility management and providing a foundation for digitalization across all water establishments' operations.

Combined with service model data collection and Smart Solutions in Managing Utilities as mobile data acquisition, mobile payments, GPS collector for assets survey and system register, repairs identification, and smart metering will become essential for effective management of the water establishment.

The table below presents the key platforms and technologies that shall be covered to set up the digital transformation for a water establishment. The GIS platform will play the central backbone to support the digitalization in terms of archiving, link with the different platforms, analysis, integration analytics and generation of scenarios for rehabilitation and strategic planning that are the ultimate goals of a water establishment.

Table 3 Key platforms description

	Key platforms	Description
	Customer Information Systems (CIS) and Call Center	Tools that ease customer-Water establishment relationships as billing, payments, complaints, etc.
	Smart Data Acquisition	Digital data collection of assets, operational data as failure, leakage and readings (sensor, GPS and mobile collector, Smart metering, etc.)
	Communication Infrastructure	Infrastructure for communication and connection as wireless, radio telemetry and fiber optic
	Processing and storage	Tools for processing and storage of data from different sources as ERP, GIS, etc.
	Management and Control	Tools used for monitoring and controls (e.g. SCADA system, etc.)
	Modelling, Analysis, Integration, Operation and` Planning	The integration of data sets for specific analysis as identification of leaking areas, identification DMAs and PMAs, and the tools for decision making (planning of annual replacement and long-term strategy)

A quick assessment of the current situation in terms of digital transformation was carried out regarding the use of the above-mentioned platforms. The following table summarizes the findings in the 4 Water establishments:

Table 4 Global normalized score for the 4 WEs

Technology domains	BMLWE	BWE	SLWE	NLWE
Customer-WE	3	3	3	3
Smart Data Acquisition	0	0	5	0
Communication Infrastructure	4	4	2	2
Processing and storage	5 (GIS) 5 (ERP)	5 (GIS) 5 (ERP)	8 (GIS) 6 (ERP)	5 (GIS) 5 (ERP)
Management and Control	5	5	3	3
Modelling, analysis, optimization and planning	2	2	5	2
Global Normalized Score (GNS)	**3**	**3**	**4**	**2.8**

The scoring system was constructed based on the findings and results of the diagnostic activity (A9). Below is the explanation of the assigned score for each technology:

Table 5 Technology score

Technology Score	Status	Explanation of Score
0	Not addressed	*The water establishment is not using this technology*
1-5	In process (1-3) Partially used (4-5)	*Technology in process, or used partially*
6-10	To be revised (6-8) No actions (8-10)	*Technology is implemented,* *Score 3 for WE in need to review and update.* *Score 4 for WE in need of minor updates and corrections* *Score 5 where there is no need for further actions.*

It is of great interest to notice the following:

- The 4 WEs are generally using the necessary platform to switch to digital transformation.
- The 4 WEs have critical issues in existing databases and data shall be revised, and cleaned.
- Smart and mobile solutions are partially used.

- Integration was addressed locally in some pilot areas but was not generalized to the entire WE.
- Design Objectives were not identified to implement the different databases and without taking in consideration eventual integration

3.6 GIS based decision support can drive the water reform

GIS-based decision support is an essential tool to push the reform in the water sector forward. The GIS Integrated platforms will be the base for the short and long run decisions and will facilitate optimized management solutions that will serve the defined goals and align with the vision of modern water establishments.

The GIS integrated solution will provide a reliable data register, a tool to ease daily activities, interventions, operations and analytics, and a powerful tool for strategic and short-term decisions.

A Standardized GIS system will support the implementation of the Water reform owing to the imperative link with the various actions defined in the water reform program. The impact and benefits of implementing the recommended GIS system are determined by measuring the improvement that can be achieved once the GIS system is in place.

Table 6 Impacts and benefits of the listed actions

#	Action listed in the Water Reform Program	Score C: Current F: Future	Link, use, impact and benefits
A9.	Carry out an initial diagnosis	C: Medium F: High	C: GIS has been used to analyze the actual situation of the WEs in terms of assets and infrastructures. The exiting GIS system was used to reduce time consuming data accumulation; however, it was identified that the existing GIS systems at present cannot be used to draw an accurate picture and perform diagnosis for the WEs. F: GIS will be the core and the preferable tool to carry out technical diagnosis.
A14.	Set up KPIs for the WEs	C: Low F: High	*C: Exiting GIS database is not able to calculate KPIs* *F: Will reduce time in computing the KPIs* *Will Increase the accuracy of KPIs* *In advanced stages, it will help generation, analysis, and comparison of scenarios* *Will allow to display Hotspot areas*
A10.	Draft and implement a capacity building plan of WEs	C: Low F: High	C: GIS Recruitment and trainings is not expected. F: New recruited staff and capacity building program will support the WEs to implement, update and operate the proposed GIS system
A6.	Opex / CAPEX studies	C: Low F: High	C: GIS is not used to carry out this type of study F: GIS will help plan and optimize OPEX/CAPEX studies and facilitate the generation of scenarios, technical reports along with mapping of each WWTP and all related information as population, coverage areas, technical and operational data. The GIS will be the preferable tool to carry out diagnosis, assessment and produce short term programs and long-term strategies

Table 6 Impacts and benefits of the listed actions

#	Action listed in the Water Reform Program	Score C: Current F: Future	Link, use, impact and benefits
A13.	Conduct tariff studies for the WEs	C: Low F: Medium	C: The GIS is not able to generate data for tariff studies. The integration with the ERP is not yet addressed. F: The integrated GIS solution will generate and visualize Scenarios and their impact
A31.	Conduct customers census studies in the view of addressing NRW and water tariff	C: Low F: High	C: The GIS is not able to generate maps or reports relative to customer location. The integration with the customer information system (ERP) is not yet addressed. F: Strengthening the GIS system will improve the records of the customer data base In the long run, GIS will reduce time consumed for tasks in relation to customers
A32.	Evaluating District Metering Areas (DMA) in view of addressing NRW and water tariff	C: Low F: High	C: The link between the hydraulic models and the GIS is not yet addressed. F: The integrated GIS based solution will facilitate the modeling at the first stage and later on the GIS will enable the efficient generation of DMAs and PMAs in a way to optimize leakage detection and energy consumption
A16.	Draft a project analysis grid	C: Low F: High	C: GIS is not able to generate a project analysis grid. F: GIS will facilitate and optimize the generation of a project analysis grid built on a multi-criteria analysis
A17.	Reassess the pertinence of the projects and set up a priority list based on the agreed upon analysis grid	C: Low F: High	C: GIS is not able to check the feasibility of projects and define project priority F: The GIS platform will be complemented by a multi-criteria decision system to be able to prioritize and test the pertinence of selected projects.
A18.	Organize and set-up a multi-actor reflection process centered on reviewed projects	See A17.	See A17.
A15.	Strengthen regional planning tools	C: Low F: High	C: Presently, the GIS is used to store data and to perform simple spatial analysis F: GIS will be the foundation for the planning tools
A19.	Select priority projects and conduct feasibility studies	See A17.	See A17.
A33.	Digitalization	C: Low F: High	C: GIS is used as separate technology for simple tasks F: GIS will be the core for the development of the digital transformation of the WEs
A7.	Support MoEW in updating a planning tool	C: Low F: High	C: GIS is not used as central and standardized planning tool F: Setting up a standardized GIS database at the level of WEs will be the starting point to set up a centralized and shared database at the level of the MoEW.
A8.	Support MoEW in complementary studies identified in the update of the national strategy	C: Low F: Medium	C: GIS is only used for mapping F: The GIS will be the efficient tool to set up Strategies at the national level
A25.	Set up the Water and Wastewater observatory	C: Low F: High	C: is not currently addressed. A centralized and shared GIS database will be the platform for the water sector observatory
A20.		C: Low	

Table 6 Impacts and benefits of the listed actions

#	Action listed in the Water Reform Program	Score C: Current F: Future	Link, use, impact and benefits
	Develop sectoral coordination tools	F: Medium	GIS will improve the development of sectoral coordination tools
A21.	Support the consultation framework between MoEW and the establishments	C: Low F: Medium	C: The GIS cannot be used for such objective F: The GIS will be used as platform to support the consultation by visualization of the current situation and the generation of future plans for WEs
A22.	Support water establishments in creating and leading a dialogue group	No link	No link
A23.	Strengthen the MoEW/Donors/WEs concertation framework	C: Low F: Low	Low impact regarding this action
A27.	Launch communication campaigns (national, regional)	C: Low F: Low	GIS can be used to produce maps and brochures
A28.	Strengthen establishments' communication in supporting implementation of communication plans and definition of supplementary tools	C: Low F: Low	GIS can be used to produce maps and brochures

3.7 Requirements and design criteria

The success of a GIS system highly depends on the requirements and design criteria considered during the implementation. The following presents the design criteria that the WE should take in consideration:

3.7.1 Database content

For optimal performance, a GIS system shall integrate the information from five subsystems (Base map, Water network register, Failure, Hydraulic model, Customers' information system). They are as follows:

3.7.1.1 Base map

Input data for the base map:

Base map consists of acquiring, digitizing and geo-referencing topographic maps and aerial or satellite photography which form the backbone for all other data. Other data may be used to complement the base map such as cadastral data (land plots), digital elevation models (DEM) and/or TIN, soil type, hydrological and meteorological data, land use information, traffic data, administrative limits, demographics and population distribution, commercial and industrial entities. Acquiring the base map requires setting up cooperation with the concerned public authorities, for example, the Direction of Geographic affairs of the Lebanese Army, the transportation authority of the Ministry of Public Works, the Tele detection Lebanese National Center, the central administration of Statistics, the cadastral authorities, ministry of Telecommunication, etc.

Contents of the base map:

The minimum content of the base map consists of:

- Housing units and buildings adjoining roadways and pipe alignments
- All other significant structures (dams, bridges, etc.)
- Roads, walkways, rails, Fiber lines, etc.
- Land plots.

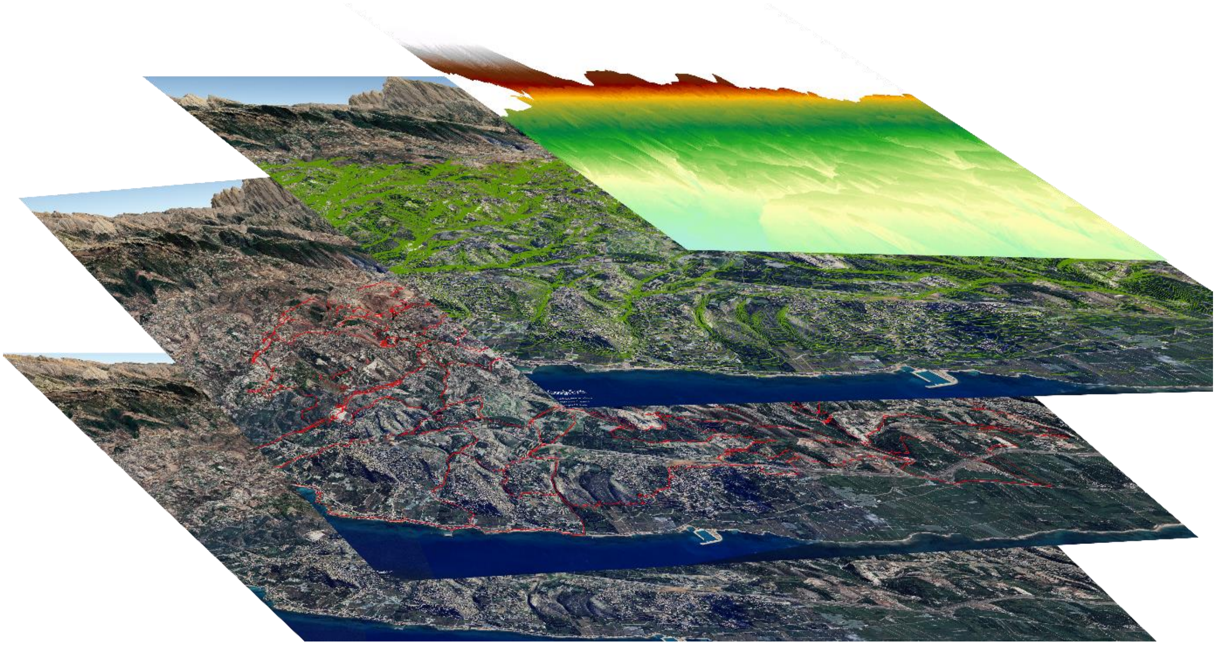


Figure 9 Contents of the base map

Data quality considerations

A high degree of accuracy and precision are required at the initial set up of the GIS because inaccuracy may cause very costly problems and impact many processed data and ultimately the results.

To produce a highly reliable representation of the available land base in the WEs, the following issues should be considered:

- Map projection: type and coordinate system,
- Accuracy (sub-meter precision or ± ... meters),
- Resolution of the satellite images and aerial photographs,

- Timeliness of the used data,
- Elevation information from a DEM with an average elevation error of ± 5 m can be used neither for hydraulic model calibration, nor to design a correct pressure management scheme,

High accuracy entails high costs, so the Water establishment should always keep in mind the planned objectives of the GIS when setting up the land base.

3.7.1.2 Network register

Setting up an entire network register is a multi-stage process which normally requires up to five years for large water distribution networks.

An important requirement after the initial cleaning and setting up is achieved, consists of continuously updating the system. In this line, staff should be appointed to add new pipe extensions, new customers, rehabilitation, and leak repairs.

Input data for the pipe register

The following are the main sources of data to pipe register:

- Electronic or hardcopy system maps constitute the basis for the network register and the hydraulic model.
- As-built location, size and selected parameters of pipes, valves, pumps, service connections, meters, etc. can be scanned and linked to their respective asset in the map database.
- Task orders for interventions, failures, reports.
- SCADA measurements, consumption patterns, water quality data.
- Field survey.

Accuracy requirements

The quality of the input data in relation with the pipe register is a very important issue. For this reason, it is important to gather accurate data at the construction stage of the networks.

The pipe location can be precisely measured in the field in the open ditch during construction and accuracy will be very high, otherwise, when the works are completed, surface measurements from the pipe to the street valve chamber will only be approximate.

The accuracy will be reduced after the construction is over; for example, from CAD design drawings; hand-drawn sketches or even based on verbal statements.

The origin of the data and the level of accuracy should be documented in metadata. In the interest of readability, the accuracy of all network elements should be adjusted to the scale of the desired output maps.

3.7.1.3 Processed and hydraulic modelling data

Hydraulic models are used to graphically describe assets of a water system. Nodes are usually used to represent facilities (P.S., valve, etc.) and/or to assign demand and links are used homogeneous section of a pipe.

Hydraulic model requirements

Data in most hydraulic models is organized in a set of tables or databases with a hierarchical structure. The tables of nodes and links with their respective attributes form the first level of this structure.

More complex attributes are usually stored in secondary and tertiary tables and can be assigned to nodes and links via their unique IDs.

3.7.1.4 Customer database

The customer database contains information about all of a water utility's customers, either private persons, enterprises or public institutions. Each customer is identified by a unique ID that links the client to the property and meter databases and the billing system.

Content

The customer database shall cover, but not limited to, the following:

- ID number.
- Subscribed volume.
- Meter/ gauge serial number.
- Subscriber Name and personal information.
- Village name.
- Building reference.
- Number of apartments/units and comments.
- Type of the subscription as domestic, touristic, commercial, etc.
- Box size.
- Location and coordinates (X, Y, Z) in the Lebanese coordinate system.
- Name of DMA where the subscriber is assigned.
- Lot and cadastral numbers.

Linking failure data and network register data

The various methods used to link subscribers to a specific location are as follows:

1. Land parcel Number
   All WEs use land parcel numbers to locate a subscriber. However, this geographic reference is highly unreliable due to:
   - On a national level, cadastral maps undergo many changes on a daily basis, including subdivision operations and land pooling, which generate new land parcel numbers. Consequently, it is extremely hard for public institutions and government departments like the WE to keep their cadastral maps up-to-date in order to be able to locate new subscribers.
   - Around 10% of Lebanese cities and villages do not have cadastral maps and are still classified as “Alam Wa Khabar”, whereas 30% have approximate cadastral maps which are far from accurate, do not preserve the true shape of the land and the scale is largely distorted. These maps can be found at the Land Registry as outdated hand-drawn sketches and in paper format only, consequently it is impossible to geo-reference them with aerial imagery to join them spatially to the buildings footprints/ subscribers’ locations.
   - Many land parcels include more than one building. Consequently, the WE’s collectors fail to deliver the water bills to the corresponding subscriber, leaving behind thousands of unpaid subscriptions.
2. Descriptive addresses
   In many cases, the land parcel number on the water bill and receipt is replaced by a descriptive address only (i.e. address: near the food shop of Mr. X). Descriptive addresses are highly unsustainable and unreliable because, even if the current collector is familiar with the points of interest that are taken as a reference, in this case “the shop of Mr. X”, a new collector having to replace the previous one at some point will be unfamiliar with these inaccurate references.
3. Collector’s memory and personal experience
   In general, 35% of water bills don’t include an address. The distribution relies on the collector’s memory and personal experience in the area who distinguishes the subscribers through their names. Consequently, when collectors are replaced by others over time, WEs are left with thousands of undistributed water bills, simply because the new collector is incapable of locating the subscribers.
4. Street addressing systems
   Since 2013, implementing street addressing systems by municipalities (on an individual level) became a trend, where most of them hired non-professionals who did not follow international regulations and standards, which greatly affected the system’s adaptability with urban expansion, causing the interruption of the system’s update. Also, only around 180 municipalities across Lebanon (10%) have implemented a street addressing system.

3.7.1.5 Failure database

A critical issue facing the water establishment is the assessment of the condition of water system components because most of them are underground. Archiving the data pertaining to failures into the GIS data base will be used to perform statistical analysis and graphic display of failures which allow to identify spatial, temporal or material specific build-ups of failures and combinations thereof.

This conclusion is essential for establishing an efficient planning program, selecting pipes for replacement in a timely manner, and determining periodic maintenance and leakage works.

Failure data content

Attention should be made to the data sheet that should be used to collect data failure in a way to invest the data in the statistical analysis and projection.

A standardized data sheet in hard or digital format should be used for systemically recording the failures.

The standardized data sheet should have, but not limited to, the following:

- Operator information.
- Address or geographic position: the failure should be linked to a location.
- Date, time and name of the informant.
- Type of damaged asset; valve, pipe, connection, joint, etc.
- Data specific to assets: nominal diameter, material, and the type of connection used in the part in question.
- Digital photos of the recorded damage and linking them to the failure database.
- Nature of the failure: burst, break, hole, problem in connections and defective valves.
- Cause of failure: corrosion, material failure, construction failure, soil movement, excessive running of vehicles or other external causes.
- Selected repair methods and the cost of repairs.
- A description of failures that cause leaks should always be recorded. Failures that do not involve leakage may also be registered in order to gain a broad overview of the weak points in the network.

Linking failure data and network register data

To link information from the failure database and the network register, a data exchange interface between both systems should be set up, otherwise directly integrating failure data into the network register.

Failure analysis and processing

Linking the two information, the asset and the failure, will offer possibilities for analysis and visual display. This will allow to study failures in detail, the relation with a certain material, age, date of installation, diameter or period of construction, the combination of all available data, the spatial allocation by calculating the number of breaks per pipe section, street or pressure zone.

The definition of categories of failures will help the WE detect relationships between the failure rate and age, traffic load, system pressure or soil characteristics. The correct interpretation of these results will help to find an optimal strategy for operating, maintaining and rehabilitating the network.

In advanced stages, if the WE has records and readings on pressure at the time of failures, the link will allow the WE to set up a pressure management plan to reduce leaks and decrease drastically the number of bursts.

3.7.2 Type of data

Geographic data can be classified under four main categories depending on their specific characteristics: vector data (Spatial objects with well-defined shapes), raster data (Aerial photos, data is divided into pixels of uniform sizes), triangulated irregular networks (set of nodes with elevation information which are interconnected with a network of edges) and object information (descriptive information which has no spatial reference by itself).

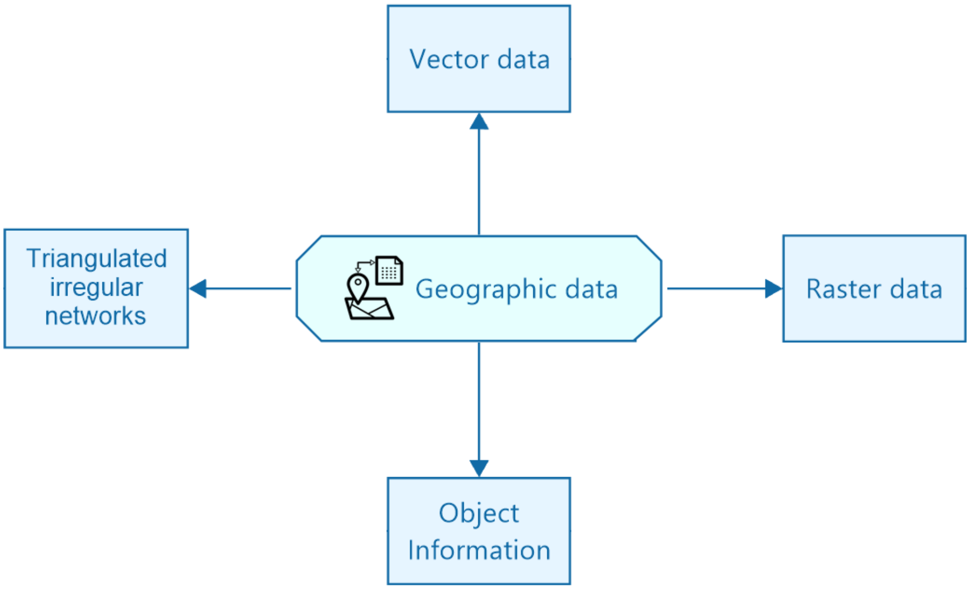


Figure 10 Type of geographic data

3.7.3 Database architecture

The database architecture shall take in consideration the design criteria defined in the section related to the design approach, the allocated staff and their skills and the time of implementation of the GIS system. Consequently, three types of architecture can be identified:

3.7.3.1 Centralized Architecture (Top-Bottom architecture)

This type of architecture depends on gathering the data from all departments and distribution zones in one main centralized database.

3.7.3.2 Hybrid Architecture

The data is organized in separate layers at the level of the distribution zones and gathered in different sub databases at the level of the WE.

3.7.3.3 Decentralized Architecture (Down Top Architecture)

Datasets and layers will be organized per water system and will be consolidated at the level of distribution zones and so far at the level of the water establishment.

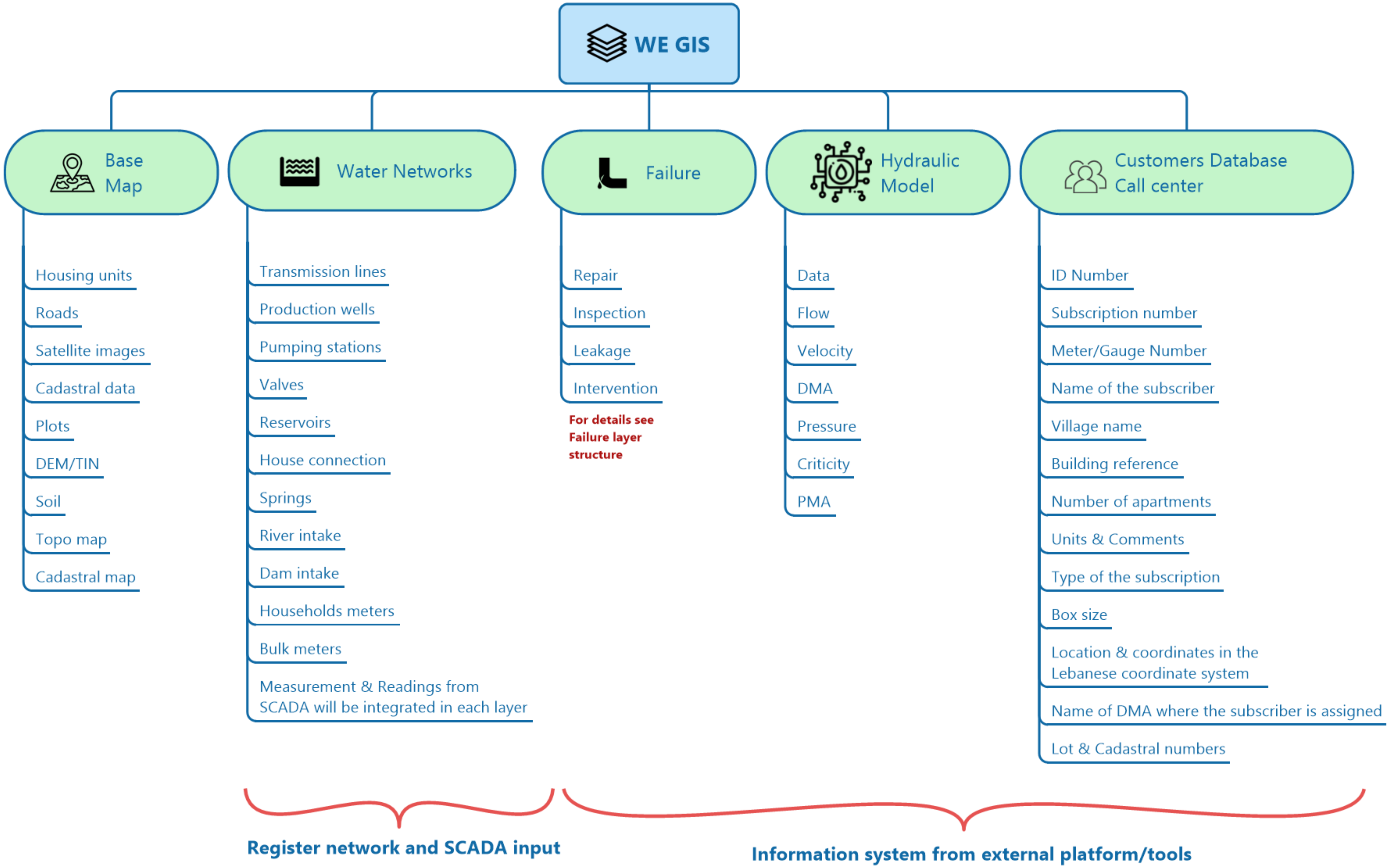


Figure 11 Centralized Architecture

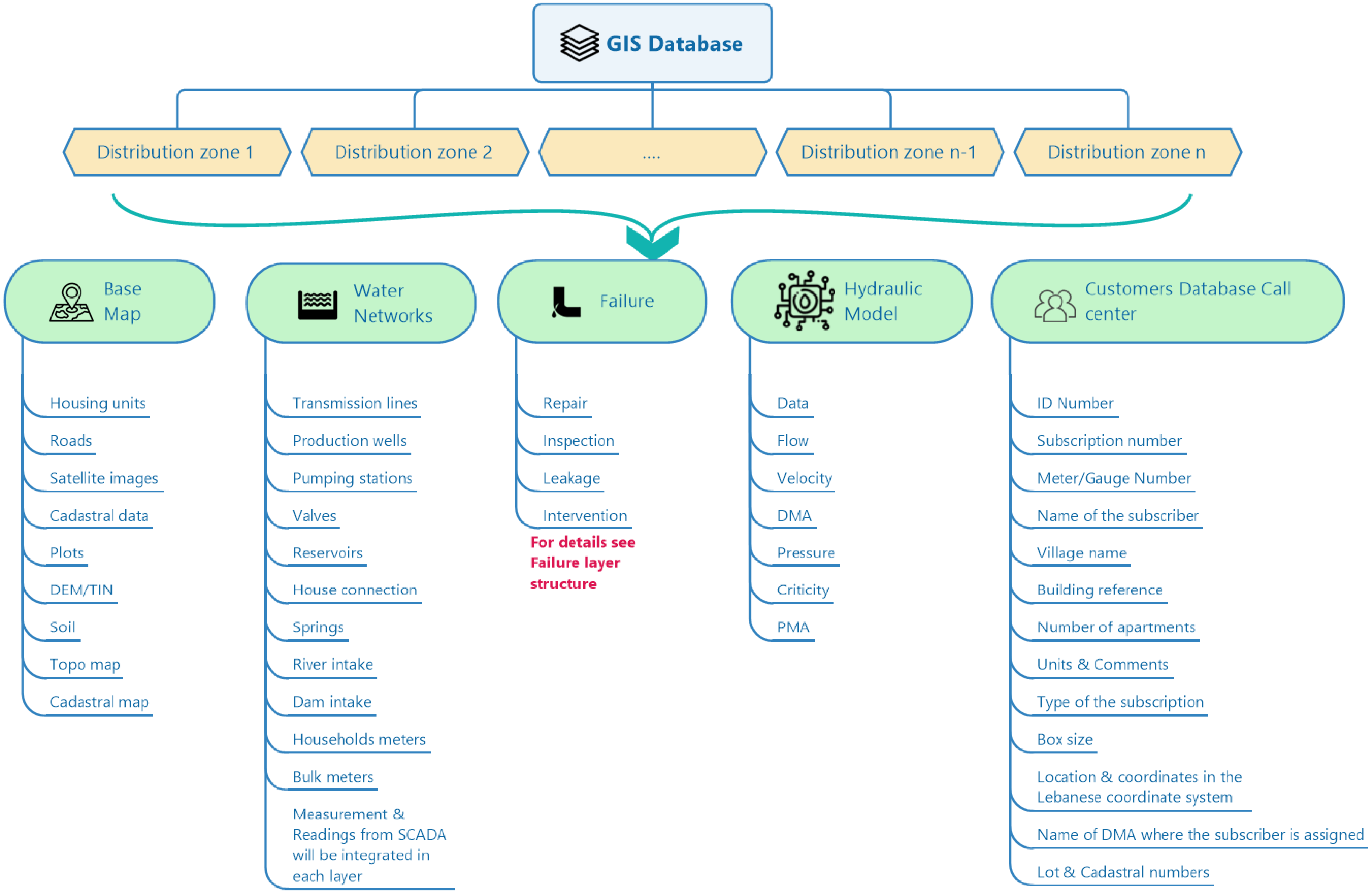


Figure 12 Hybrid Architecture

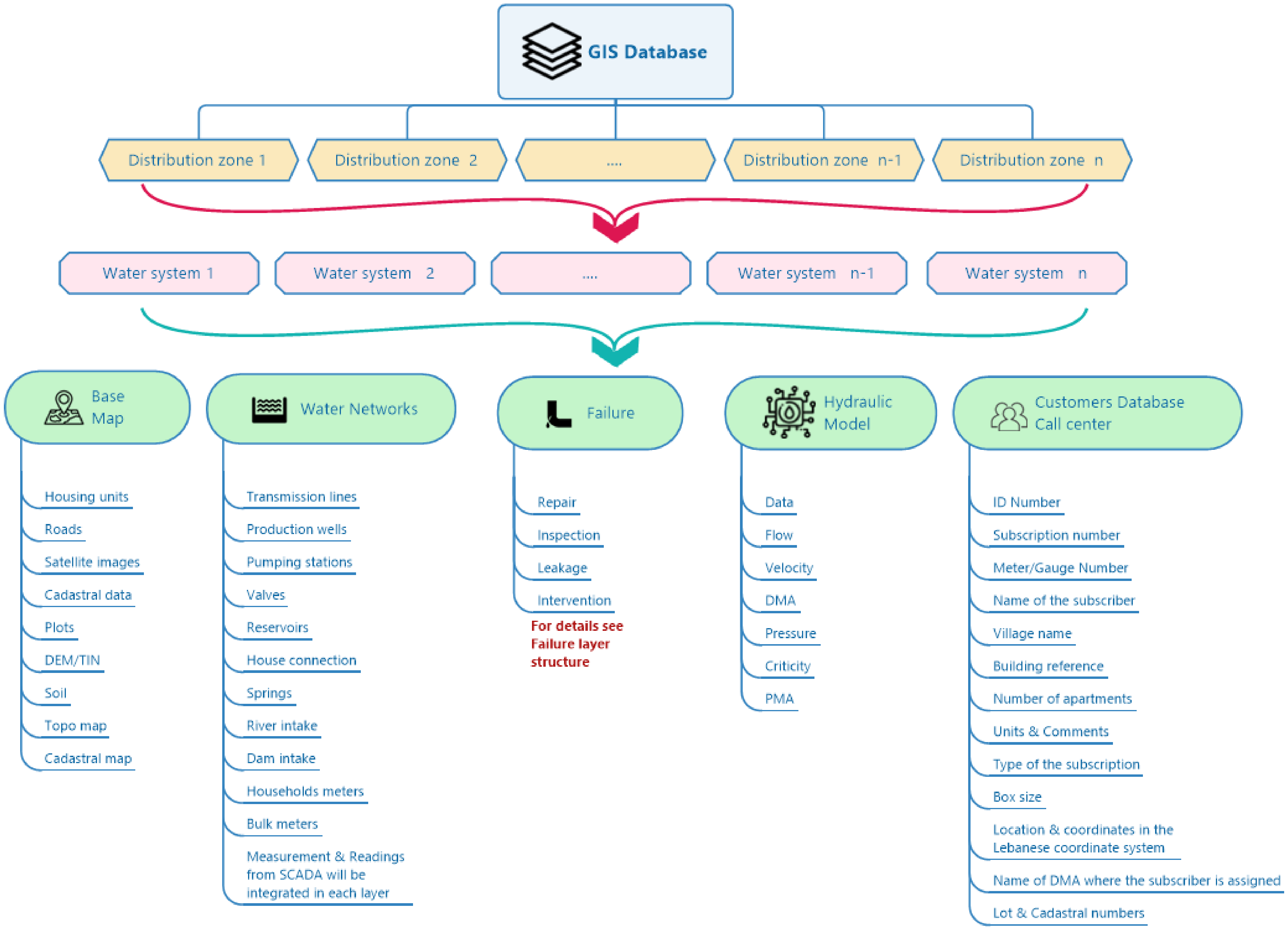


Figure 13 Decentralized Architecture

3.7.4 GIS Database Structure

Numerous commercial solutions use different data formats to structure and store data. Relational databases are the most convenient data structure for storing all kinds of spatial, topological, and attribute data. Relational databases can be used to organize data into broad categories of related data. Geographic data can be stored inside a relational database as single object classes or can be combined to create sets of related data. Figure below illustrates one example of a possible GIS network structure.

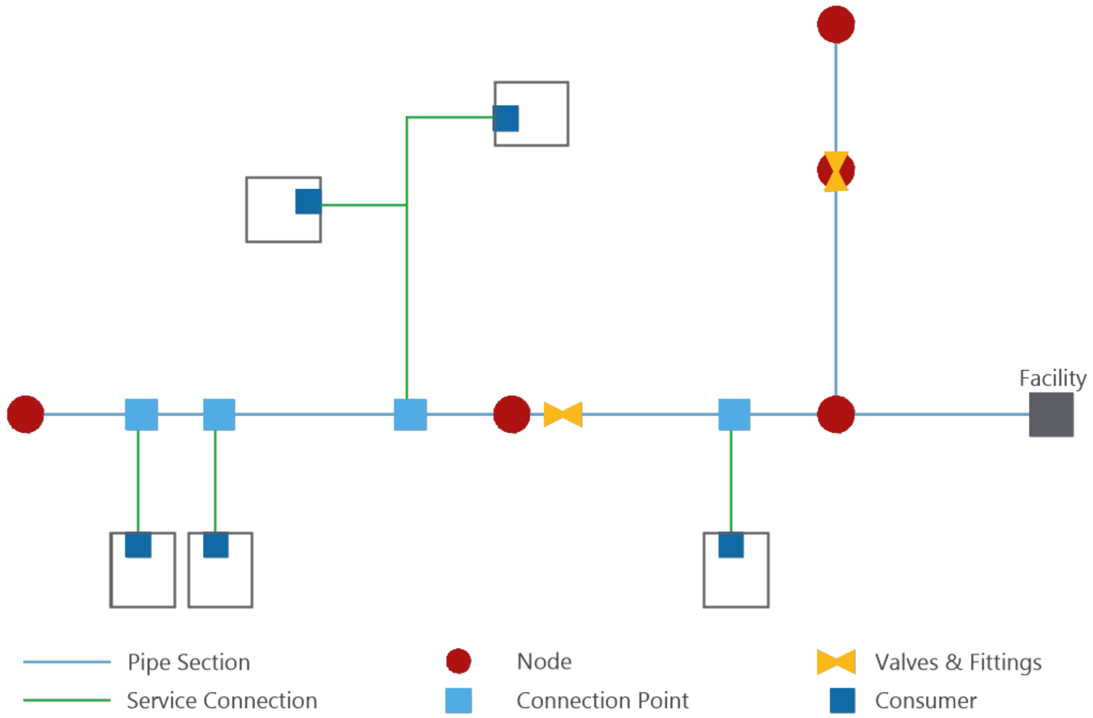


Figure 14 Schematic view for GIS water network structure

To support the WEs to set requirements for developing the GIS register catering to their specific needs, we recommend a standardized data structure which can be summarized as follows:

3.7.4.1 Physical Data

Transmission main and distribution network are divided into discrete pipe sections with identical attributes (material, diameter, etc.). A new pipe section has to be established if one attribute changes along a pipe alignment. In the same way, a new pipe section has to be created at every branch. A node has to be located at the start and end point of every pipe section. Pipe sections can be divided automatically at zone boundaries or administrative limits.

Service connections form a separate object class. One or more service connection can be connected to a pipe section. Where the service connection is connected to the pipe section, a connection point has to be set. A service connection is not seen as a branch and therefore does not divide a pipe section into two. Service connections can be branched and can supply multiple consumers. A new service connection has to be defined at branches.

Locating valves and fittings does not require that a pipe be divided into two pipe sections. Yet, a pipe can be divided into two pipe sections at a valve if necessary (e.g. at boundary valves).

Facilities comprise all plants that produce, convey, store and treat water within the system, for example wells, pumps, tanks and treatment plants. Each network has to begin or end at a facility.

Structure of a GIS based on databases, data sets and single object classes.

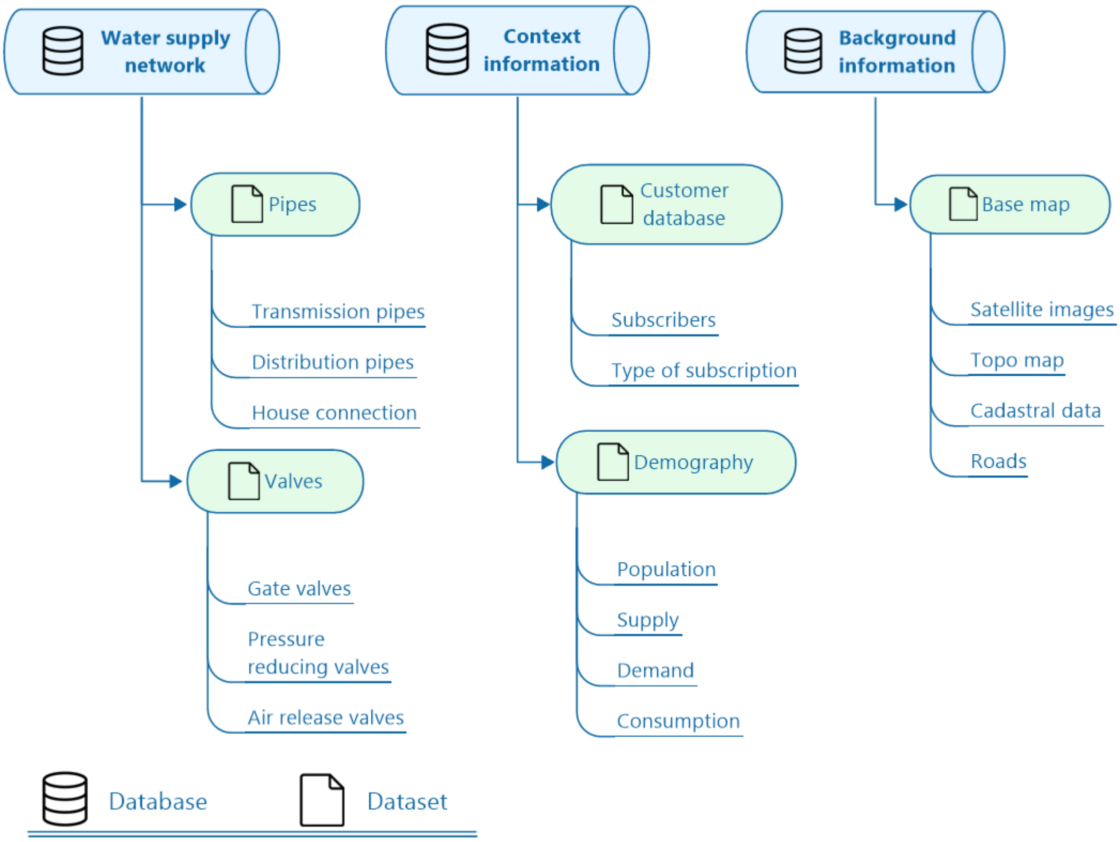


Figure 15 Structure of a GIS database

Collecting various data set types is usually the first step in setting up a GIS. The original set of databases can be continuously enhanced by adding data sets and advanced capabilities in order to cope with the WE' requirements.

3.7.5 Level of implementation

At an enterprise level, different departments may have responsibility for different data sets. In this case, the databases may also echo the utility's organizational structure. The GIS system can be implemented at one of four scales:

- Water system or Project level: supporting a single project objective.
- Department or distribution scale: supporting the needs of one distribution district or department.
- Enterprise scale/Water establishment: inter-departmental sharing of data that meets the needs of two or more departments.
- Inter water establishment level: sharing applications and data with external users.

GIS solutions at project or distribution zone scale (Decentralized) are generally less expensive than large-scale GIS solutions requiring heavy investments in terms of hardware and software. Nevertheless, decentralized GIS solutions often leads to work redundancy and data islands: the same piece of information is produced and stored by different departments within the water establishment without being linked.

A GIS at company/Water establishment level will be more appropriate for the 4 water establishments given this factor and the many different aspects involved in the staff deployment. At present, the client-server architecture is the preferred configuration for an enterprise-level GIS, as illustrated in Figure below:

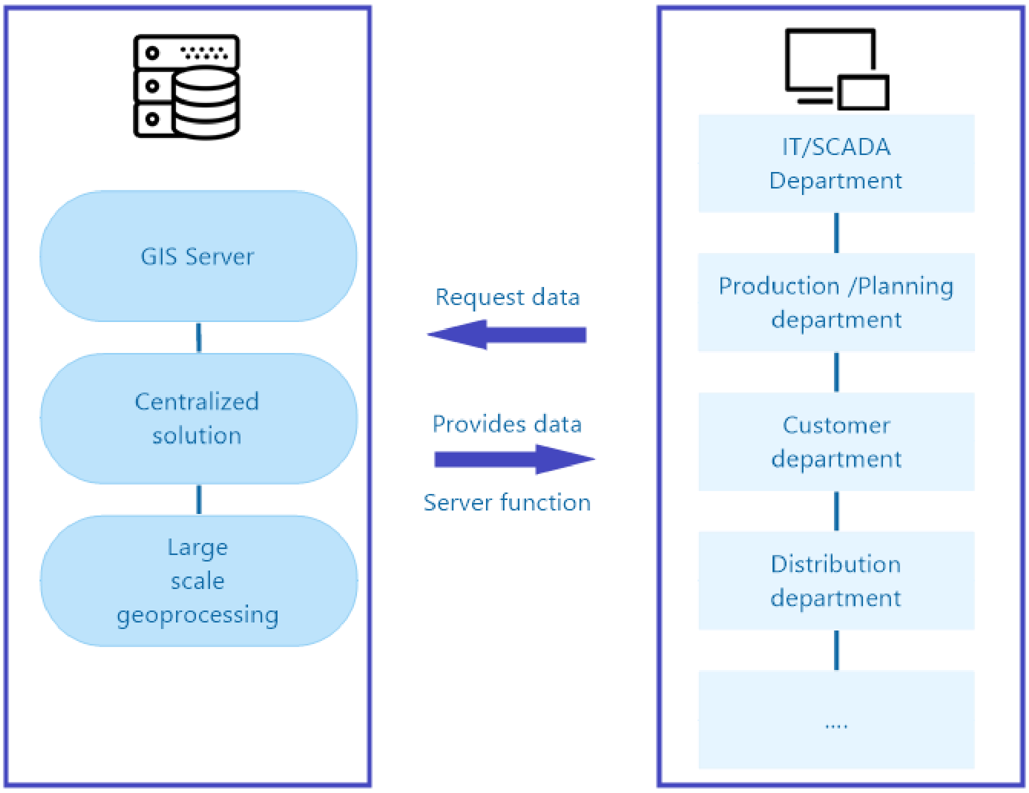


Figure 16 Client server architecture

3.7.6 Integration into one main GIS

Relevant data from the different systems/platforms should be found in an overarching GIS. This GIS should be able to exchange data with other sub-systems, which are described in detail in previous sections (See **Error! Reference source not found.**).

4 EXISTING GIS SYSTEM

This section summarizes the results obtained following the technical assessment of the GIS system at the 4 water establishments.

4.1 Main findings

The following are the main findings following the preliminary assessment

4.1.1 IT Infrastructure, Staff, and Organization chart

4.1.1.1 IT Infrastructure

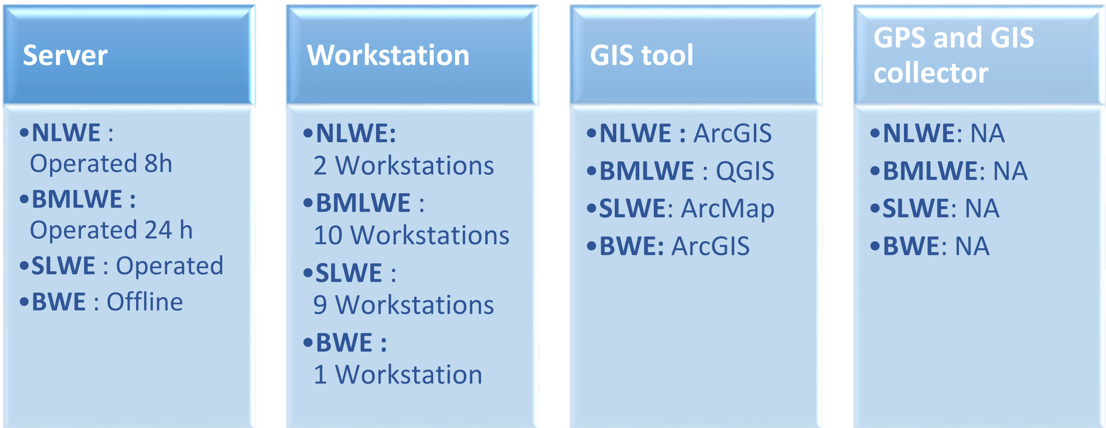


Figure 17 IT Infrastructure for the 4 water establishments

4.1.1.2 Staff

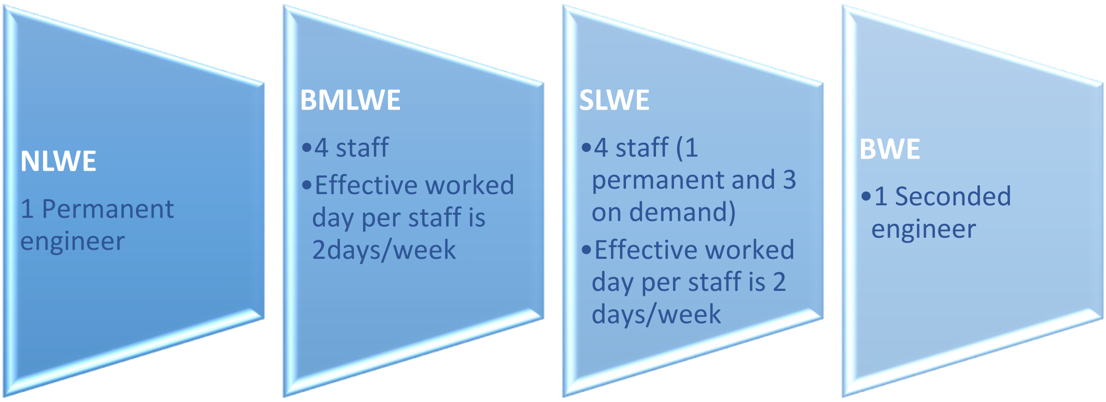


Figure 18 Staff for the 4 water establishments

4.1.1.3 GIS Unit

GIS Unit not expressed in the organization chart of the 4 water establishments.

4.1.1.4 Conclusion

The main conclusion:

- Software licenses are expired.
- Server is not operating; except Beirut the server is operating 24 hours.
- Only in SLWE the mobile and GPS collector are available.
- GIS activities are not expected in the staff organization chart.
- GIS units in NLWE and BWE are operated by one person.

4.1.2 Database (All WEs)

The main findings in relation with the GIS database in the 4 WEs are:

- No registry, SOP, guidelines, or manuals available to support the user of the database.
- Information system platforms are not designed on data exchange basis, data flow chart between the different platforms used by the WEs (ERP, Call center, SCADA, etc.), integration is addressed partially in SLWE and BWE.
- GIS database structure and architecture issues: there are no design objectives (Storage, operation, planning, accuracy, data requirements, etc.).
- Layers require to be revised in terms of attributes, labels, units, etc. in a way to be adapted to the Lebanese water sector.
- A number of attributes are useless and others need to be added.
- No indication of the 3D length.
- Codification is not addressed.
- Problem in the geometry of pipes (shape, duplication, alignment, connection, missing starting and end points)
- Operational data such as pipe failure, burst, pressure, velocity, etc. are missing and no fields were created to add the info.
- Layers and attribute tables related to subscribers, readings, valves, operational data, etc. are not well designed and data need to be updated, and layers to be reviewed and re-designed.

The table was constructed using a simple scoring system to reflect the current situation regarding different criteria (See Diagnosis results referring to the Preliminary Assessment Reports).

Table 7 GIS current situation

Topic	Criteria	BMLWE	BWE	SLWE	NLWE
SOP	Guideline and flow data chart	0	0	0	0
Database	Architecture	3	4	9	2
	Layers structure	3	4	9	3
Data status	Attributes labeling and units	3	4	8	3
	Cleanness	3	3	8	3
	Completeness	3	3	8	3
	Accuracy	3	3	8	3
	Operational data From SCADA and failure records	4	4	1	0
Topology	Geometry & readiness to Hydraulic modeling	0	0	1	5
Customer Data	Customer and subscription data	2	2	4	5
Base map Data	Topo maps, Sat. Images, TIN, Cadastre, etc.	0	0	9	0
Additional data	Road, traffic, Soil, temperature, etc.	0	0	8	0
Assessment and Planning	Use of modules	0	0	0	0
Integration with Platforms	ERP, Hydraulic models, Failures data base, etc.	0	2	5	0
TOTAL	**Multi-criteria assessment**	**2**	**2**	**6**	**2**

Below is the explanation of the assigned score regarding each criterion:

Code color	Explanation	Score
	Not addressed	0
	Review/Upgrade	1 to 5
	Minor revision/update	6 to 9
	No actions required	10

5 PROPOSED GIS SYSTEM

5.1 Architecture

As stated previously, the adoption of an architecture is strictly dependant on the allocated staff in terms of deployment and skills as well as to the attempts that the WE has set up. Below, pros and cons of the proposed GIS databases architecture (Centralized, Hybrid, and Local) are presented to enable selecting the most appropriate database architecture.

Table 8 Pros and Cons of the identified architecture

Architecture	Pros	Cons
Centralized architecture (Top Down)	Centralized database Access of all staff to the entire Data Shared data can be beneficial for water systems with missing data. The constitution of pipe categories will be used to describe the state of pipes Reduced Staff Standardized Database Adapted and beneficial at the start of setting up new GIS data base design	Focus on general and high-level problems and negligence of local and specific issues in particular in studies in relation with the DMA and NRW Less knowledge of water system Data flow from down to top and data update requires more time.
Hybrid architecture	Medium number of staff Data flow between the different department of each distribution zone will be higher	Medium time to update data Not adapted for WE in the present situation
Local architecture (Down Top)	High precision of data Suitable for leakage reduction, hydraulic models, DMAs and PMAs	High number of staff Not adapted for WE in the current situation

Based on the above, it appears that the centralized database architecture is the most appropriate to update the GIS system.

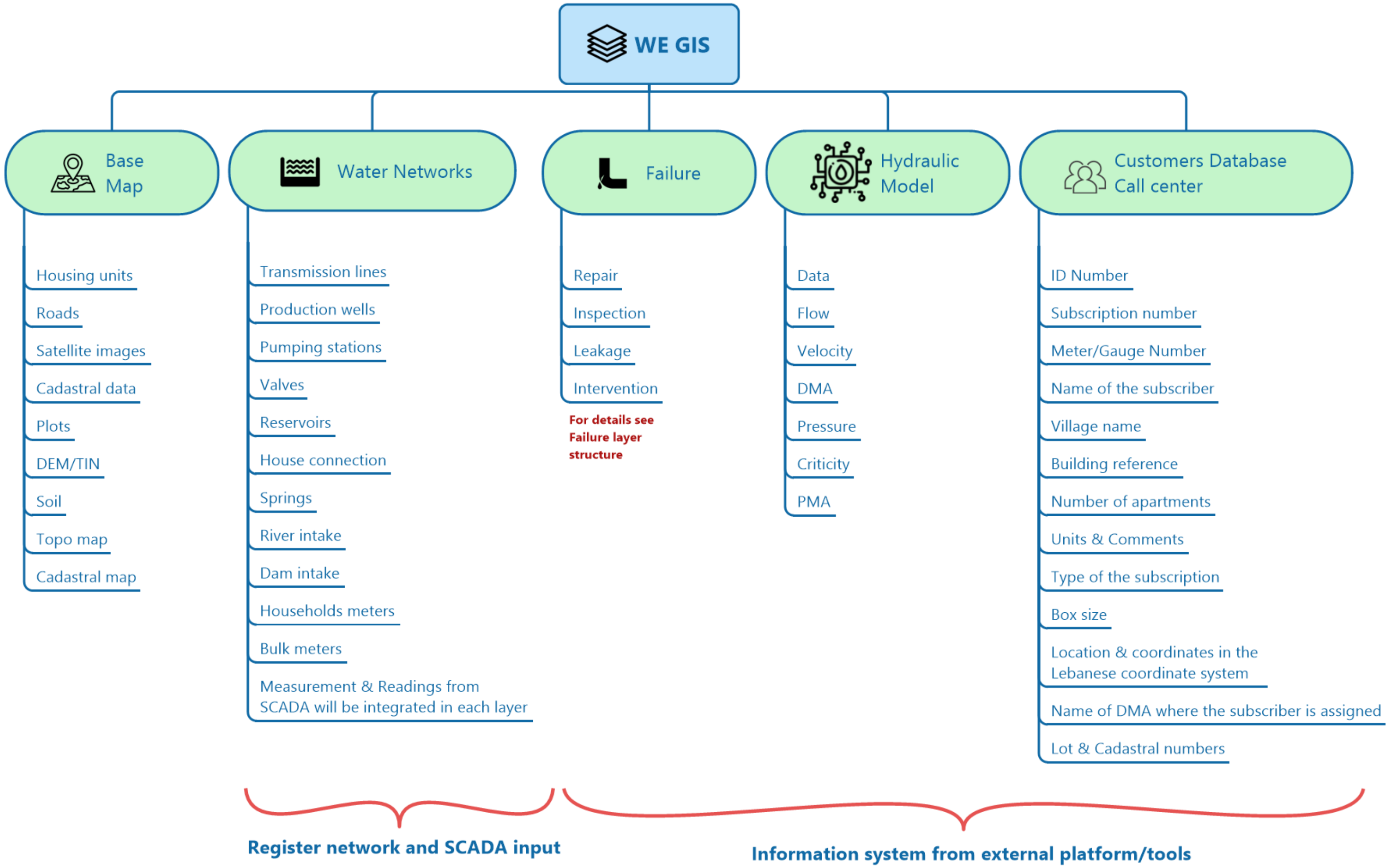


Figure 19 Recommended Architecture (Centralized)

6 IMPLEMENTATION SCHEDULE AND PRIORITIES

At present, the centralized architecture (Architecture 1 as on the chart) would be the most appropriate architecture to put in place considering the present data situation in terms of completeness, accuracy, coverage and the available human resources. However, it would be interesting to consider gradually moving towards a hybrid architecture which consists of gathering data relating to water systems within the corresponding water distribution departments/Directorates into pseudo separate GIS databases.

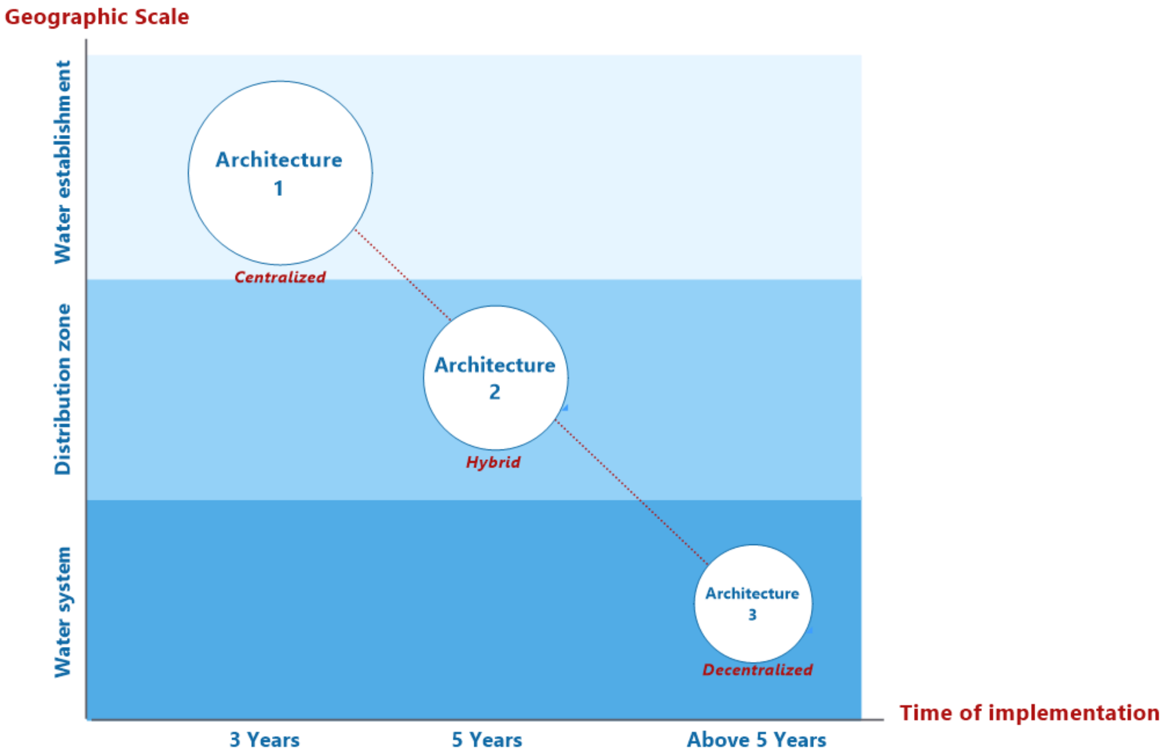


Figure 20 Proposed implementation architecture schedule

7 BENEFITS OF IMPLEMENTING THE RECOMMENDED GIS SYSTEM

GIS integrated based solutions will enable everyone in the water establishment to access any information regarding the location and status of assets, staff, and customers. The GIS will transform the WE into a more informed, efficient, and transparent organization.

The figure presents the links of the GIS with the different business platform at the WE which will revolutionize the water establishment.

The implementation of the proposed GIS will significantly improve the water establishment business practices. However, more specifically, the table below provides a list of GIS functions that can be leveraged to support the WE works identified for each core management area.

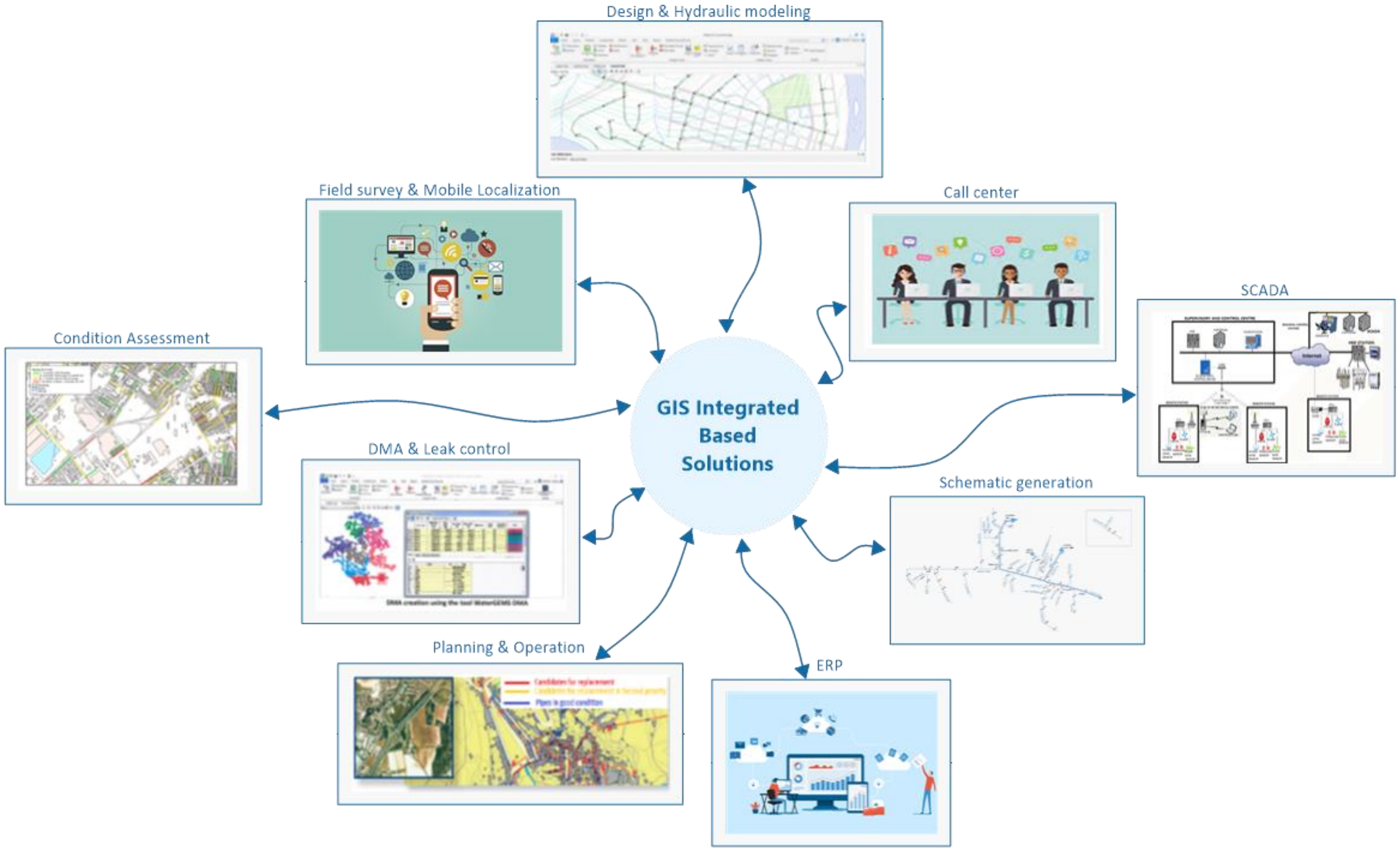
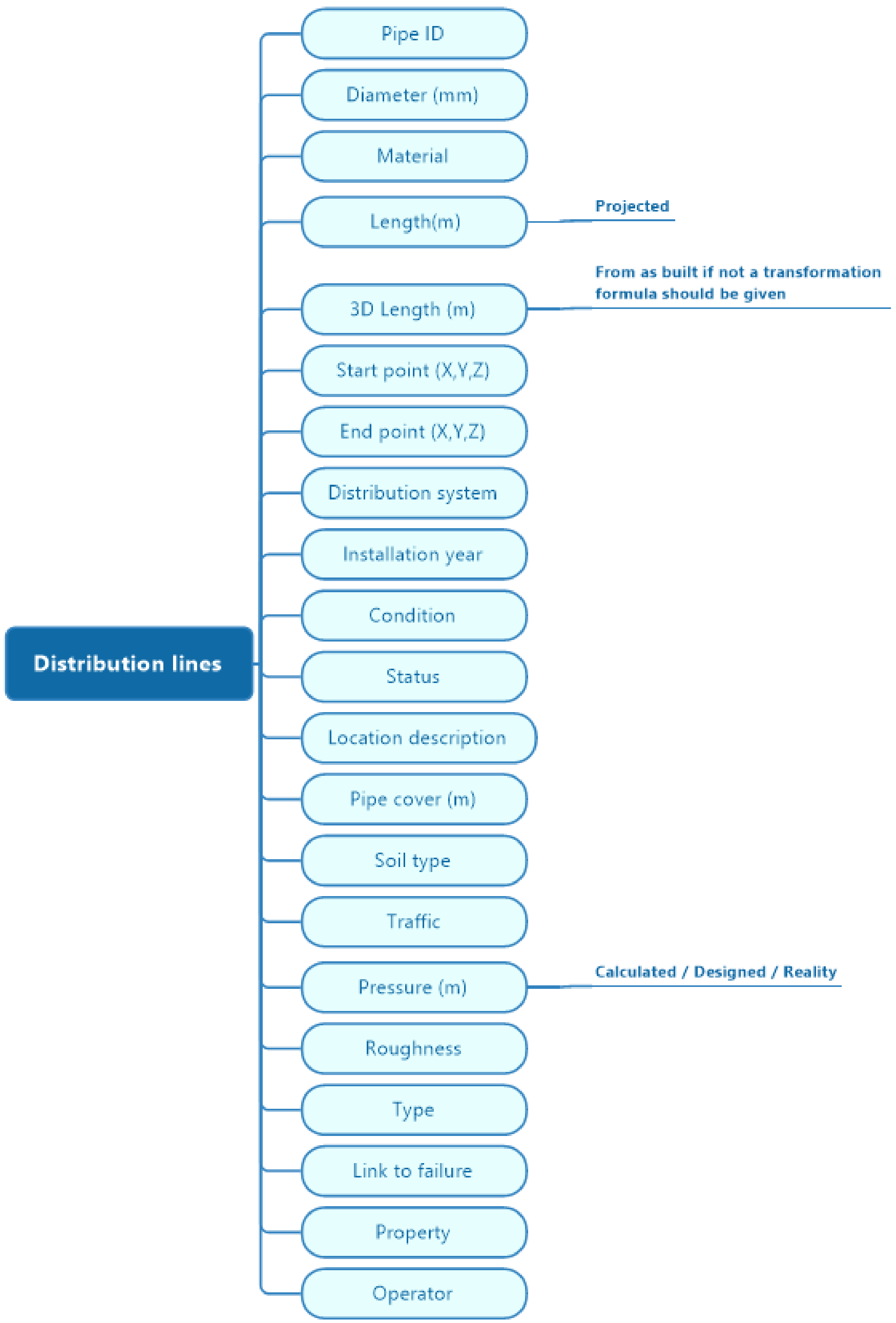
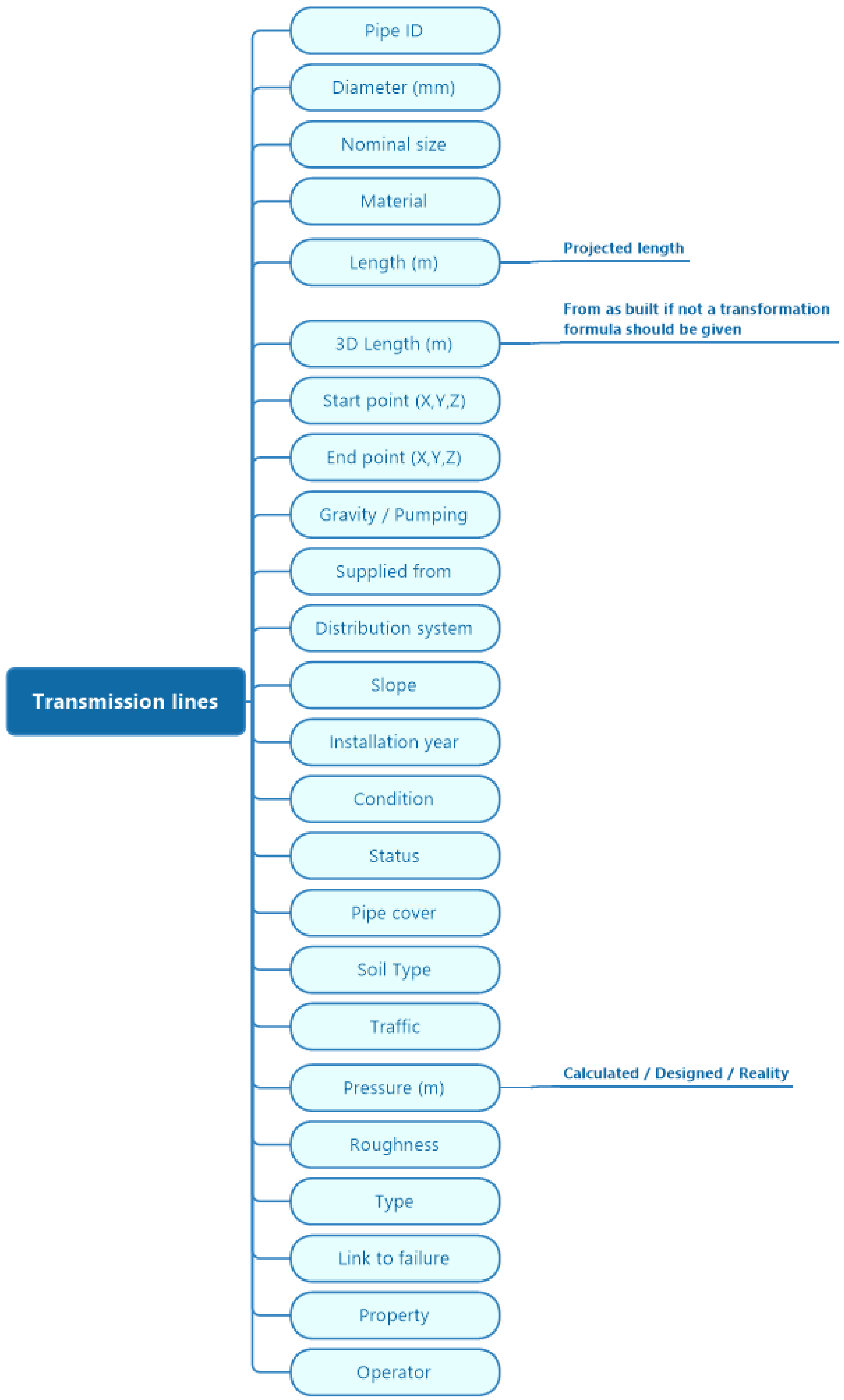


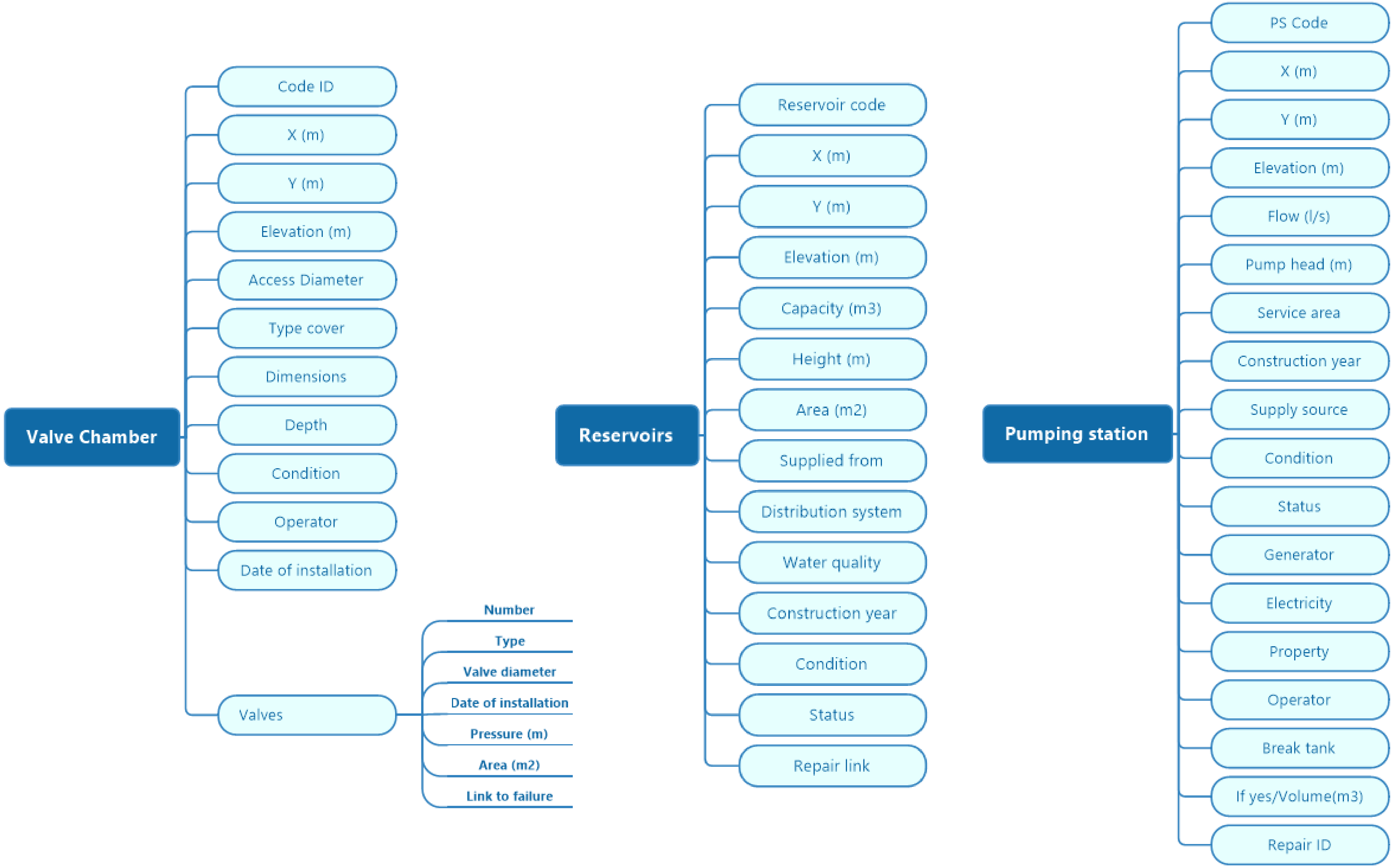
Figure 21 Integrated GIS platform and links with the different tools and business platforms

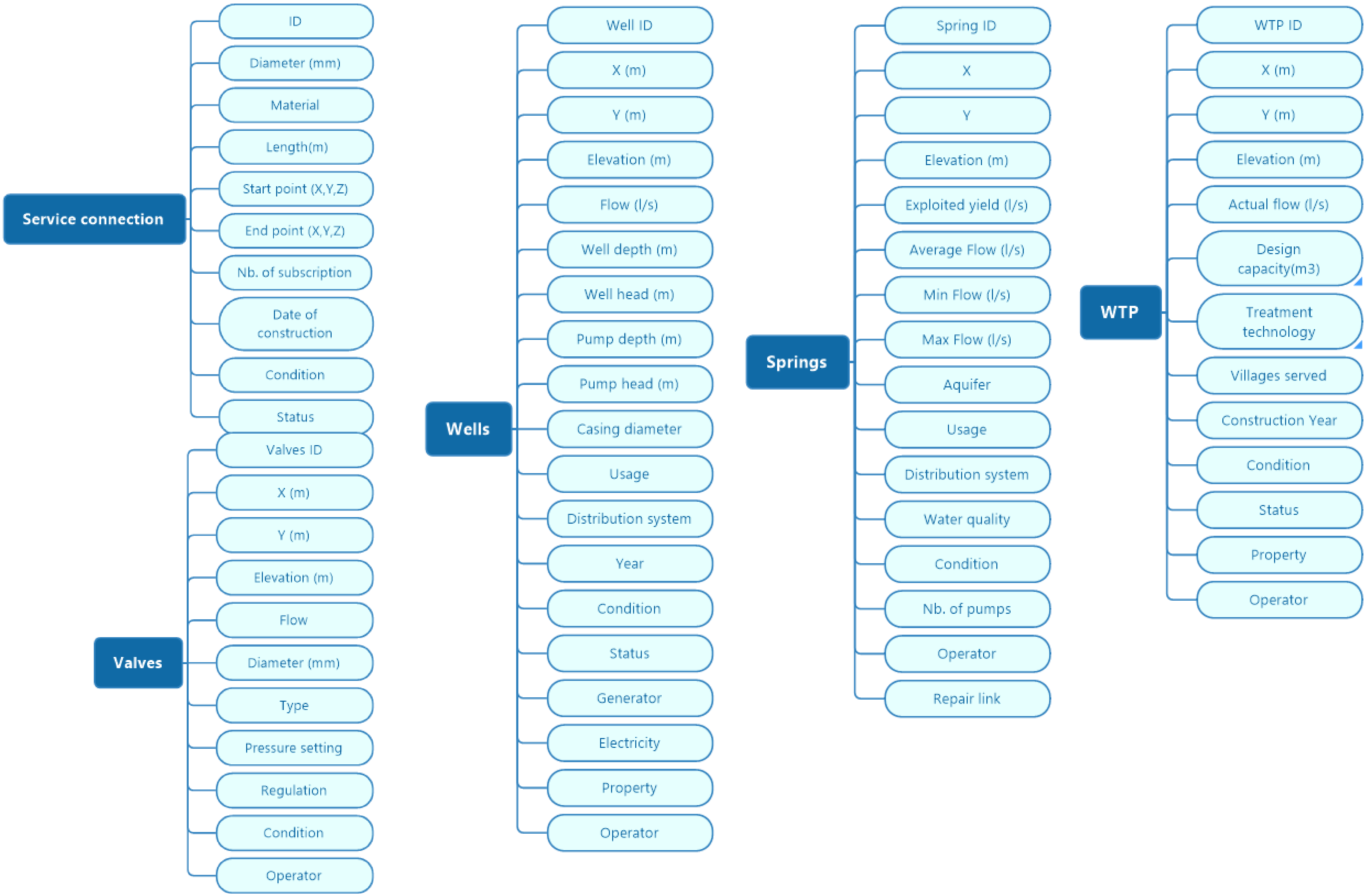
Table 9 Benefits of implementing the recommended GIS

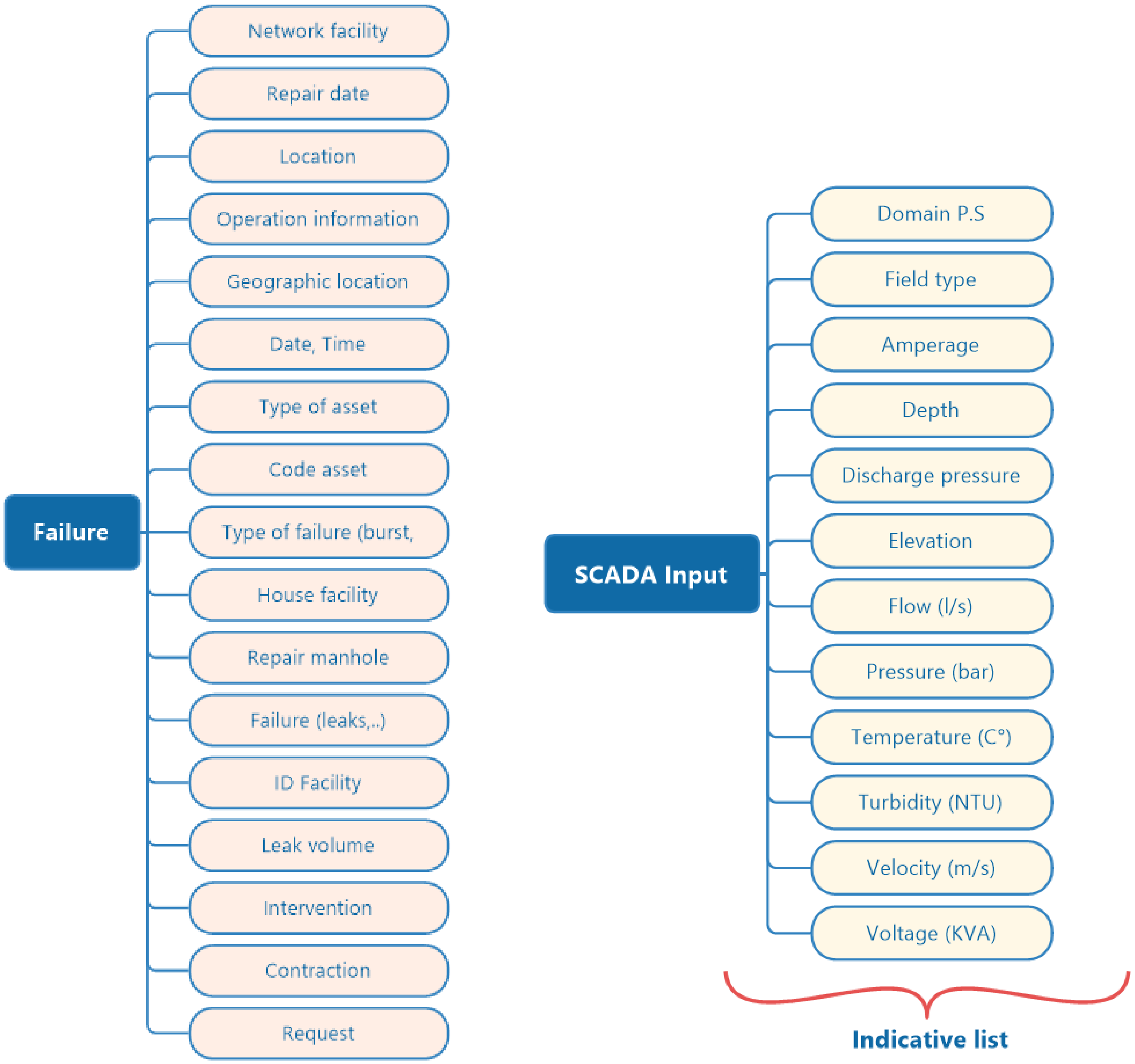
FROM **FRUITLESS**	**TO** **WINNING**
Problems of the past	**GIS Integrated Solutions**
Data management Tried to find assets Painful to update Duplicate efforts Different data pertaining to same assets Data error	***Data management*** Reduce time consuming quest for assets Easy to update and communicate with the different Information Systems Unique data across all Information systems Store details pertaining to the water system in an accurate manner
Mapping and schematic generation Difficulties in understanding relations with the different geographic data	***Mapping and schematic generation*** Facilitate understanding the location and relations with the different geographic parameters.
Tracking Monitoring and localization of asset Find assets using recollections and knowledge of employees	***Tracking Monitoring and localization of asset*** Track asset in real time
Analytics Subjective assessment and no possibility to predict	***Analytics*** Assess, plan and predict the behavior of assets to improve maintenance.
Design and planning Classic tool design	***Design and planning*** Generate scenarios and select optimized and sustainable solutions
NRW	***NRW*** Integrated GIS solution is an essential instrument for successfully implementing leakage reduction efforts.
Decision making Management and planning decisions are subjective	***Decision making*** Integrated GIS solution constitute an efficient tool for management and planning for water establishment. It helps managers and the direction in testing the impact of decisions.
Communication and awareness GIS is used for simple and inter-departments operations (Asset localization and info related, etc.)	***Communication and awareness*** Maps and apps generated by the integrated GIS solution will be the base for communication and sharing information with customers and stakeholders through embedded maps on net and social media;
Governance GIS is not able to identify with accuracy the assets of the WE	***Governance*** Integrated GIS for WE gives responsible insight that can pinpoint assets, diagnosis, and plan.
Shared data Redundancy of data for same assets Data cannot be used if shared with others	***Shared data*** Unique data Shared data will be beneficial to cover missing info


Distribution lines
Pipe ID
Diameter (mm)
Material
Length(m)
Projected
3D Length (m)
From as built if not a transformation formula should be given
Start point (X,Y,Z)
End point (X,Y,Z)
Distribution system
Installation year
Condition
Status
Location description
Pipe cover (m)
Soil type
Traffic
Pressure (m)
Calculated / Designed / Reality
Roughness
Type
Link to failure
Property
Operator


Transmission lines
Pipe ID
Diameter (mm)
Nominal size
Material
Length (m)
Projected length
3D Length (m)
From as built if not a transformation formula should be given
Start point (X,Y,Z)
End point (X,Y,Z)
Gravity / Pumping
Supplied from
Distribution system
Slope
Installation year
Condition
Status
Pipe cover
Soil Type
Traffic
Pressure (m)
Calculated / Designed / Reality
Roughness
Type
Link to failure
Property
Operator


Valve Chamber
Code ID
X (m)
Y (m)
Elevation (m)
Access Diameter
Type cover
Dimensions
Depth
Condition
Operator
Date of installation
Valves
Number
Type
Valve diameter
Date of installation
Pressure (m)
Area (m2)
Link to failure
Reservoirs
Reservoir code
X (m)
Y (m)
Elevation (m)
Capacity (m3)
Height (m)
Area (m2)
Supplied from
Distribution system
Water quality
Construction year
Condition
Status
Repair link
Pumping station
PS Code
X (m)
Y (m)
Elevation (m)
Flow (l/s)
Pump head (m)
Service area
Construction year
Supply source
Condition
Status
Generator
Electricity
Property
Operator
Break tank
If yes/Volume(m3)
Repair ID


Service connection
ID
Diameter (mm)
Material
Length(m)
Start point (X,Y,Z)
End point (X,Y,Z)
Nb. of subscription
Date of construction
Condition
Status
Valves
Valves ID
X (m)
Y (m)
Elevation (m)
Flow
Diameter (mm)
Type
Pressure setting
Regulation
Condition
Operator
Wells
Well ID
X (m)
Y (m)
Elevation (m)
Flow (l/s)
Well depth (m)
Well head (m)
Pump depth (m)
Pump head (m)
Casing diameter
Usage
Distribution system
Year
Condition
Status
Generator
Electricity
Property
Operator
Springs
Spring ID
X
Y
Elevation (m)
Exploited yield (l/s)
Average Flow (l/s)
Min Flow (l/s)
Max Flow (l/s)
Aquifer
Usage
Distribution system
Water quality
Condition
Nb. of pumps
Operator
Repair link
WTP
WTP ID
X (m)
Y (m)
Elevation (m)
Actual flow (l/s)
Design capacity(m3)
Treatment technology
Villages served
Construction Year
Condition
Status
Property
Operator


Failure
Network facility
Repair date
Location
Operation information
Geographic location
Date, Time
Type of asset
Code asset
Type of failure (burst,
House facility
Repair manhole
Failure (leaks,..)
ID Facility
Leak volume
Intervention
Contraction
Request
SCADA Input
Domain P.S
Field type
Amperage
Depth
Discharge pressure
Elevation
Flow (l/s)
Pressure (bar)
Temperature (C°)
Turbidity (NTU)
Velocity (m/s)
Voltage (KVA)
Indicative list