Food and Agriculture Organization
of the United Nations

Improved Water Resources Monitoring System/ Integrated Water Resources Management at regional level in Lebanon

MANAGING ASSETS OF THE IRRIGATION SYSTEM

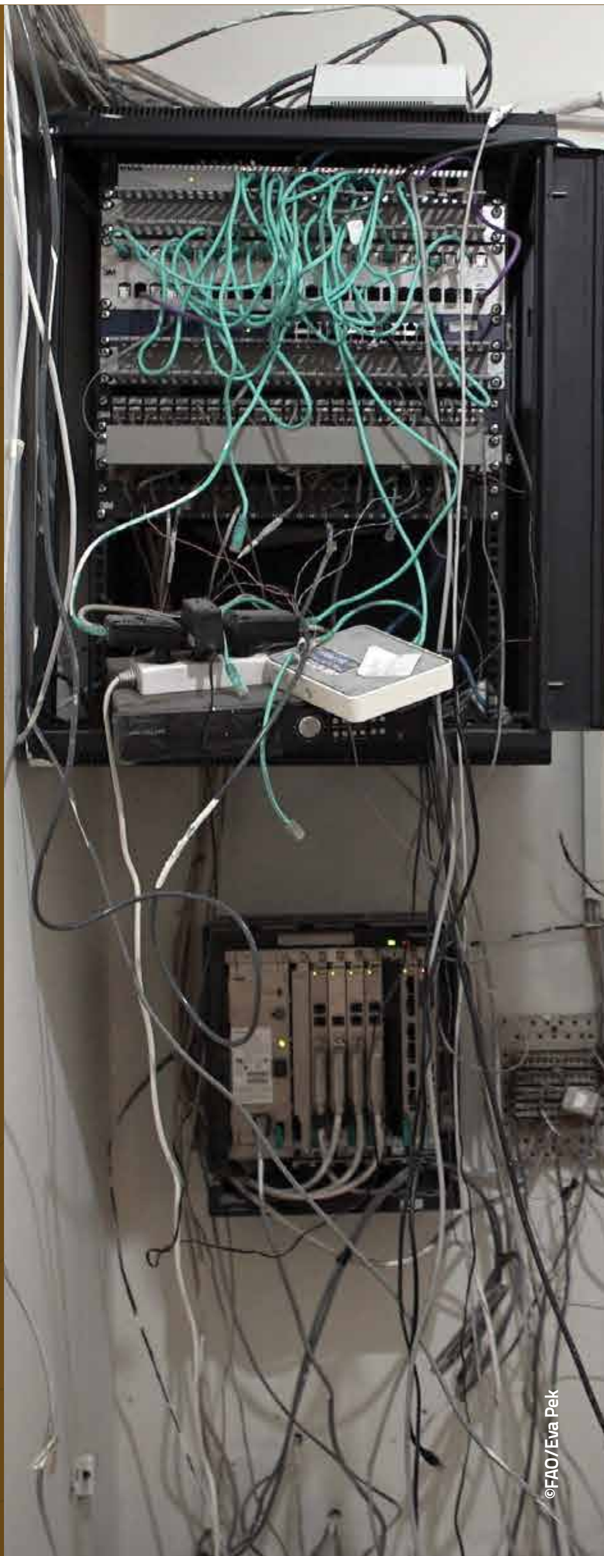
The project

In many areas of the world, including the Near East and North Africa (NENA) region and Lebanon, sustainable and reliable delivery of water for irrigation and municipal use has become increasingly complex. This issue also extends to affect the protection of the ecosystems from water pollution. Particularly, if the overall demand is outstripping supply, the delivery of water is often less about engineering, although it is still required. The issue is more often related to the governance of the resources to manage and protect them from pollution and over-abstraction, resolve conflicts over water, and ensure rights to water are respected. It is also about understanding water flow pathways in complex river basin systems. This is where water monitoring and accounting can play a crucial role to help water management institutions in managing complexity in light of the challenges facing the water sector.

In this context, the Food and Agriculture Organization of the United Nations, in collaboration with the North Lebanon Water Establishment (NLWE), which represents the Ministry of Water and Energy, is implementing the GCP/LEB/029/SWI project **'Improved Water Resources Monitoring System/Integrated Water Resources Management at regional level in Lebanon'**, funded by the Swiss Government. The main objective of the project is to strengthen Lebanon's water institutions improving their performance at regional level, thereby helping them to address the sector challenges for sustainable use of water resources.

In particular, Output (3) of the project '**Watershed Prototype Monitoring System is developed, management authorities empowered, and their capacity is enhanced to operate the system - including preparation of a business plan to operate the monitoring system**', aims at building institutional monitoring capacities, through:

- Linking the flow measurement devices to a central data collection unit in the NLWE.
- Developing a prototype monitoring system and train the professional staff of the NLWE on this system.



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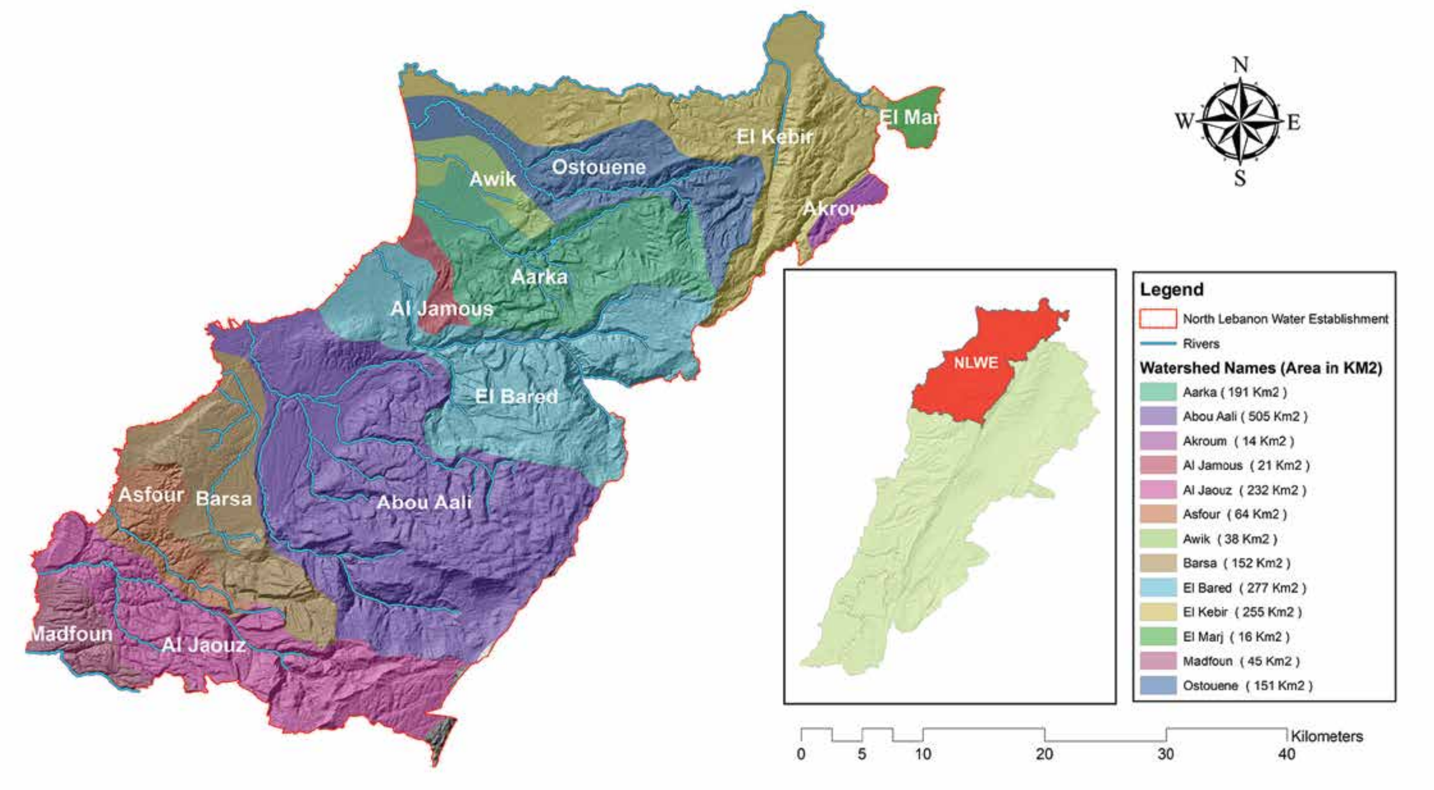
The command area

The project follows a pilot approach, whereby the regional Water Establishment has been selected through a Rapid Assessment driving to the greatest possible impact. Based on well-defined selection criteria, including water availability, level of irrigation development, water quality status, scope for institutional capacity building and scalability, the North Lebanon Water Establishment (NLWE) was chosen. The authority of the Establishment extends to the complex hydrological systems and diverse topography of Northern Lebanon. Amongst the involved watersheds, El-Bared is the second largest one, with its 277 km^2 catchment area and 24 km length.

Figure 1: Watersheds in North Lebanon



Source: Google Earth Pro v7.3.3.7786 (2020). Lebanon. 34°29'30 N, 35°58'33 E, elevation 40 m modified to comply with UN. 2020. Map of Lebanon, 4282 United Nations January 2010. https://www.un.org/Depts/Cartographic/map/profile/lebanon.pdf

The project design captures two adjacent open-canal systems supplied by El-Bared water dam, namely Akkar and El-Minieh. Both of them are peri-urban irrigation systems that are heavily exposed to human impacts. The irrigation service is facing several challenges, which impact the infrastructure conditions and the level of performance. One of the challenges is that the human interference leads to a severe deterioration of water infrastructures. More specifically, the irrigation canals are wrongly used as natural solid waste dumpsites and the households' plumbing systems are directly connected to the canals. Adding to the hurdle, the canals from the secondary level are heavily modified by farmers. The current irrigation infrastructures are becoming outdated and the conveyance infrastructures account for significant water loss. In order to address the growing need for irrigation water to supply the demand and adapt the climate change impacts, the improvement of management mechanisms is of vital interest.

Beyond the condition and performance related issues, the monitoring of water resources is also hampered by the situation. The monitoring system in such environment must consider the interactions that have the potential to cause unexpected changes in the structures and functioning.
The interferences, such as the improper water withdrawal, the unofficial gate installation, the wastewater discharge or the accumulated solid waste, might violate the water monitoring and eventually lead to data inconsistency.

Figure 2: Calibration of monitoring sites

Figure 3: A heavily deteriorated canal section

Another challenge is to ensure the long-term sustainability of the monitoring system. The sustainability largely depends on the appropriate operation and maintenance (O&M) of the monitoring devices and the surrounding environment. If the infrastructures and the equipment are not well-maintained, a further deterioration is foreseen. The declined conditions have also an impact not only on the level of service but on the reliability of the obtained data and information. While inappropriate irrigation service will lead to the farmers' reluctancy to contribute to the service provision, a poor data quality will hamper the evidence-based decision-making.

However, the adverse impacts are more diverse and extend to social, economic and environmental objectives. Amongst the most devastating ones, the following impacts are directly experienced in the pilot scheme:

Social
- Unequal distribution amongst water users
- Impact on the human health and safety
- Conflicting interest and competing demand amongst users and sectors

Economic
- Reduced performance
- Significant re-investment need in infrastructure
- Reduced lifespan
- Yield loss due to water stress
- Low natural resource efficiency/productivity

Environmental
- Natural resource contamination
- Soil erosion
- Natural resource degradation
- Decreased efficiency of freshwater

To address the aforementioned problems, the project has developed a rigorous 'asset management module" as non-traditional tool for business planning. The innovative approach of asset management has been emerging as the result of the combined efforts of practitioners, managers and scientists. The module is fully integrated into the central monitoring unit called prototype monitoring system (PMS). The PMS is a computer-based tool that integrates the core dimensions of a complex monitoring system. It is a versatile system to facilitate decision-making over water resources.

The approach

The irrigation asset management is defined as the processes and mechanism to manage irrigation assets to maximize and/or optimize their benefits. All types of infrastructures and equipment, including fixed and moveable, are considered as irrigation assets. A comprehensive and a well-designed asset management framework has multiple advantages to address challenges, such as:

- Increasing the performance of irrigation system.
- Improving return on investment.
- Enhancing cost efficiency.
- Achieving cost recovery and financial sustainability.
- Increasing the satisfaction of users.
- Reducing risk of failure.
- Avoiding devastating consequences of performance failure.

The concept of asset management has not been sufficiently trialled in irrigation systems so far. Moreover, the existing asset management systems in water sectors are mostly designed for urban water supply and wastewater management. As these networks usually require a high technological complexity, asset management systems are deployed to maintain their performance and condition, and to avoid the potential consequences of failure. However, irrigation asset management systems would still have their 'raison d'être". As the project added more to the already existing infrastructure and to the complexity of the irrigation system, the maintenance liability of NLWE amplified. In order to increase the investment efficiency from a management point of view and improve users' satisfaction by better performance, an asset management framework has been developed for NLWE.

The design of the asset management module is shaped by the conditions of Akkar and El-Minieh irrigation systems, notably the with following concerns:

Figure 4: Design restriction of the asset management module in NLWE

Factor	Restriction	Design requirement
Application in peri-urban irrigation system in public places	Communication devices for remote assessment in threat	Framework for a manually conducted assessment
Heavily deteriorated irrigation infrastructures and modified design	Low-level of service at the time of the introduction	Need for an individual asset-based assessment
Low collection efficiency of irrigation fees and under-resourced management	Restricted resources for financing asset management	Framework fitting into the existing financial and human resources
Lack of previous asset inventories	Lack of comprehensive performance assessment for the system as whole	Need for a disaggregated assessment
Social sensitivity	Restricted use for remote technologies (i.e. drones)	Need for in-situ assessment mechanisms
Manually operated infrastructure	Limited possibility for automated assessment (i.e. machine learning)	Need for expert observation-based assessment complemented with high-rigor protocol

During the development phase of an asset management tool, its scope must be aligned to the objectives of the irrigation system. In this particular case, the objective of the asset management module is to support the NLWE in proper O&M and management of irrigation systems, ensure the level of service for end-users, and provide financial sustainability. The framework is context-tailored and developed to the specific conditions of the irrigation systems. The condition-based asset management module involves a multilevel design, whereas each successive component contributes to the overarching objectives of the asset management module. The module consists of four components: inventory based on O&M protocol, assessment of the condition, assessment of criticality (performance and associated risk assessment strategy), and financing assets.

Inventory based on O&M protocol: well-defined protocol on intentional operation and maintenance of the asset based on manufacturer and expert recommendations

Assessment of the condition: assessment through rigorous methodology compared to the condition at installation

Criticality: measurement of performance failure and consequency of failure

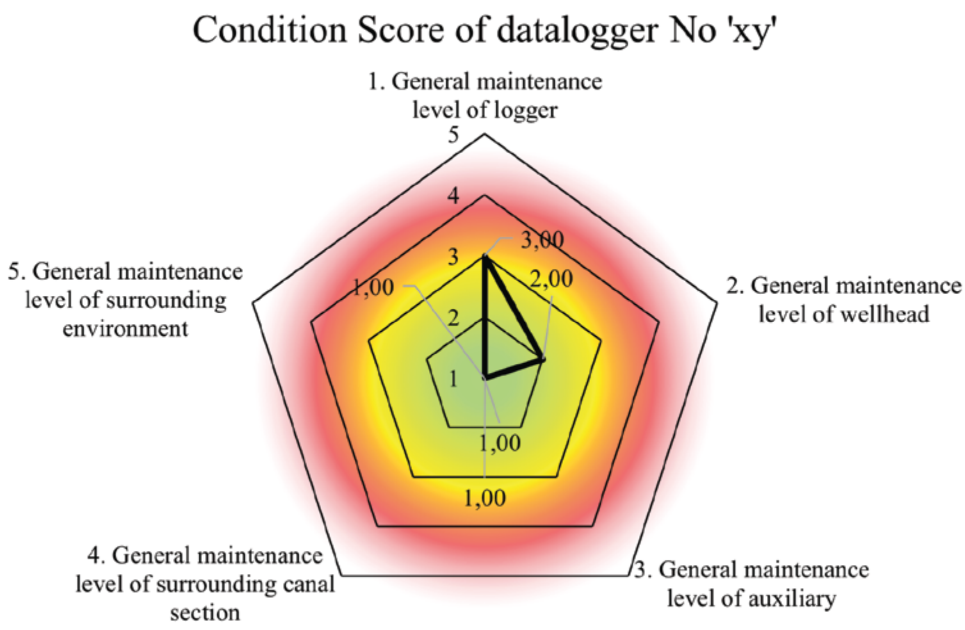
Financing asset: financial planning through the estimation of costs and revenues of assets

Although the asset management consists of consecutive steps, the analysis of assets must be carried out by integrating all information. This can help identifying causal relationship between a particular external or internal factor and the status of the asset. Such relationship is often not linear; therefore, the asset management module puts emphasis on the rigor of assessment through a pre-defined protocol.

Inventory based on O&M protocol: the component involves the identification of asset (ID) and its key features (type, location, installation date, responsible person, users, etc.). It defines the purpose and the function of the assets, as well as the relevant instructions on O&M (frequency, timing, data delivery method, etc.). The project has developed specific O&M guidelines to each asset types. Such guidelines support professionals in proper management of the infrastructures. It also helps having detailed stocktaking of the existing assets and the required load of work for O&M.

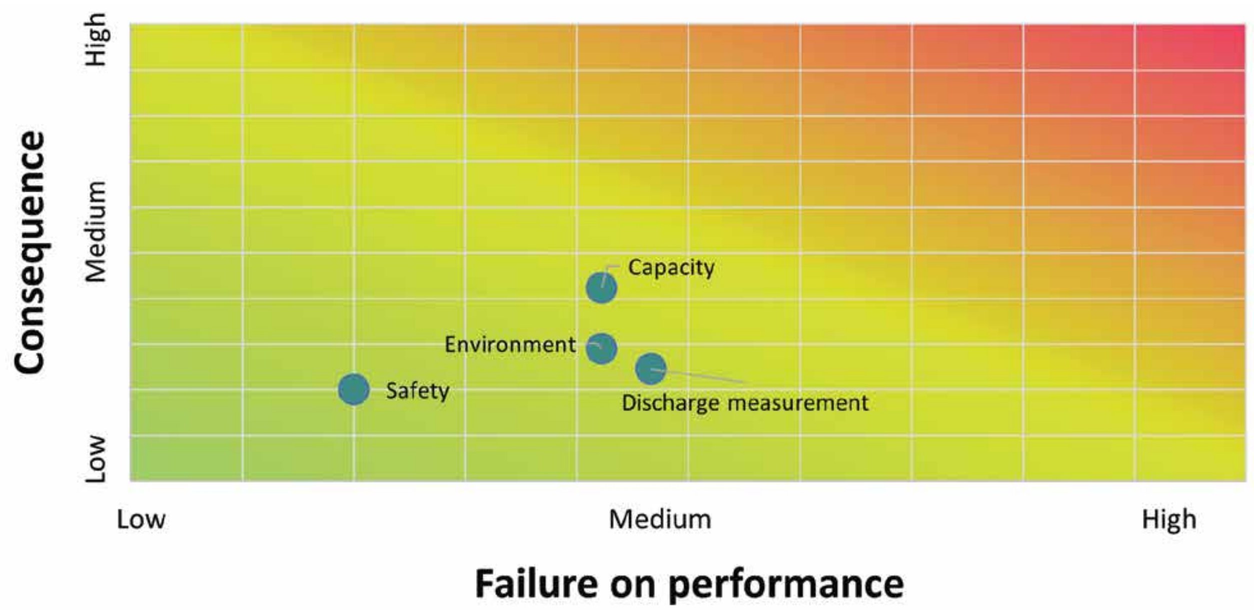
Assessment of the condition: the one-dimensional assessment of scoring is based on expert observations. The key items of the irrigation assets are evaluated independently through a 5-point Likert scale. A scoring scheme is developed for the responsible professionals to guide the scoring process and avoid the possible biasness. The scores of sub-items are aggregated into a final composite indicator called 'condition score". However, both the condition of the sub-items and the overall conditions of the assets are expressed in numeric and visual indicators in order to enable the detection of underperforming items. The condition score provides a clear understanding on the difference between desirable and actual condition of the assets. The decision-makers, then, are supported with realistic information on the required maintenance works.

Figure 5: Condition score example



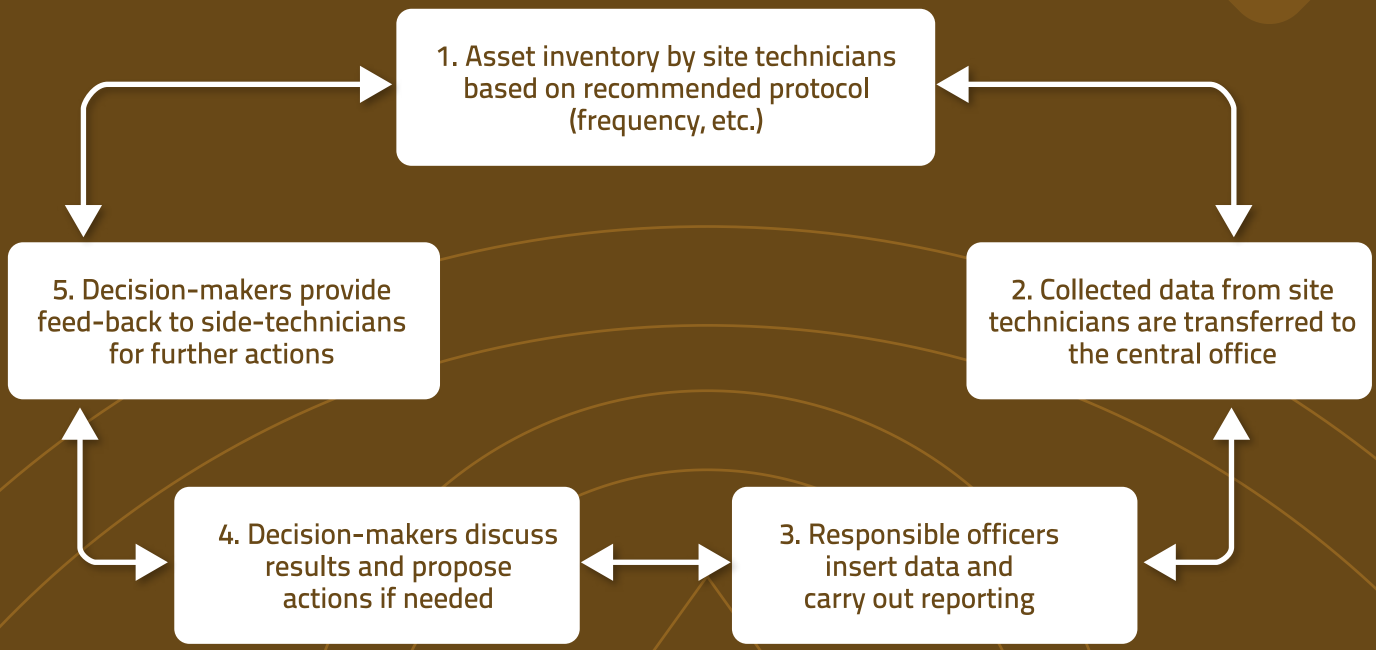
Assessment of criticality: the criticality assessment consists of two sub-indicators: failure on performance and consequence of failure. Similar to the condition assessment, specific features of performance and consequences are defined, and a scoring scheme is developed for both sub-indicators. The scoring scheme is based on a 5-point Likert scale and aggregates the sub-scores into the two sub-indicators. The multidimensional criticality score, then, consists of the aggregated scores of failure on performance and the consequence of failure. As failure on performance and consequence of failure do not necessary correlate, the two sub-indicators must be evaluated separately. The criticality score is expressed as numeric indicators and visualized in heat map. The criticality score alerts decision-makers on the decrease in the level of service and the potential impact on issues such as the functionality, the human safety and the environment. Therefore, the criticality score is equally suitable for a performance assessment and a risk management.

Figure 6. Example of criticality score heatmap



Financing assets: the final step of financial assessment and business planning is based on the pre-assumption that O&M works are properly carried out and no performance decline is encountered. The financial assessment is based on life-cycle cost analysis method (LCC). A specific equation is developed to involve each cost element that might occur during the asset lifespan. The cost breakdown defines the major cost types that involve both deterministic and stochastic variables: capital investment, maintenance cost, operation cost, replacement cost, and cost of failure. The LCC calculates the total cost based on the lifespan, number of assets within the asset type and adjusted discount rate. The calculation scheme, then, computes the total cost per asset type. The LCC provides critical information for the business planning. The proper stocktaking of costs helps mitigate the overspending and ensure financial sustainability. It also identifies the avoidable costs, thus improving the cost-effectiveness and cost-recovery of the irrigation infrastructure.

The developed asset management module follows a stepwise approach and requires the individual assessment of each asset. Due to the fact that irrigation system has manual equipment and devices, the implementation involves a wide range of stakeholders from site engineers to decision-makers. The inventory and scoring plans are based on field observations, while the computation, validation and potential intervention are carried out by the central management unit.

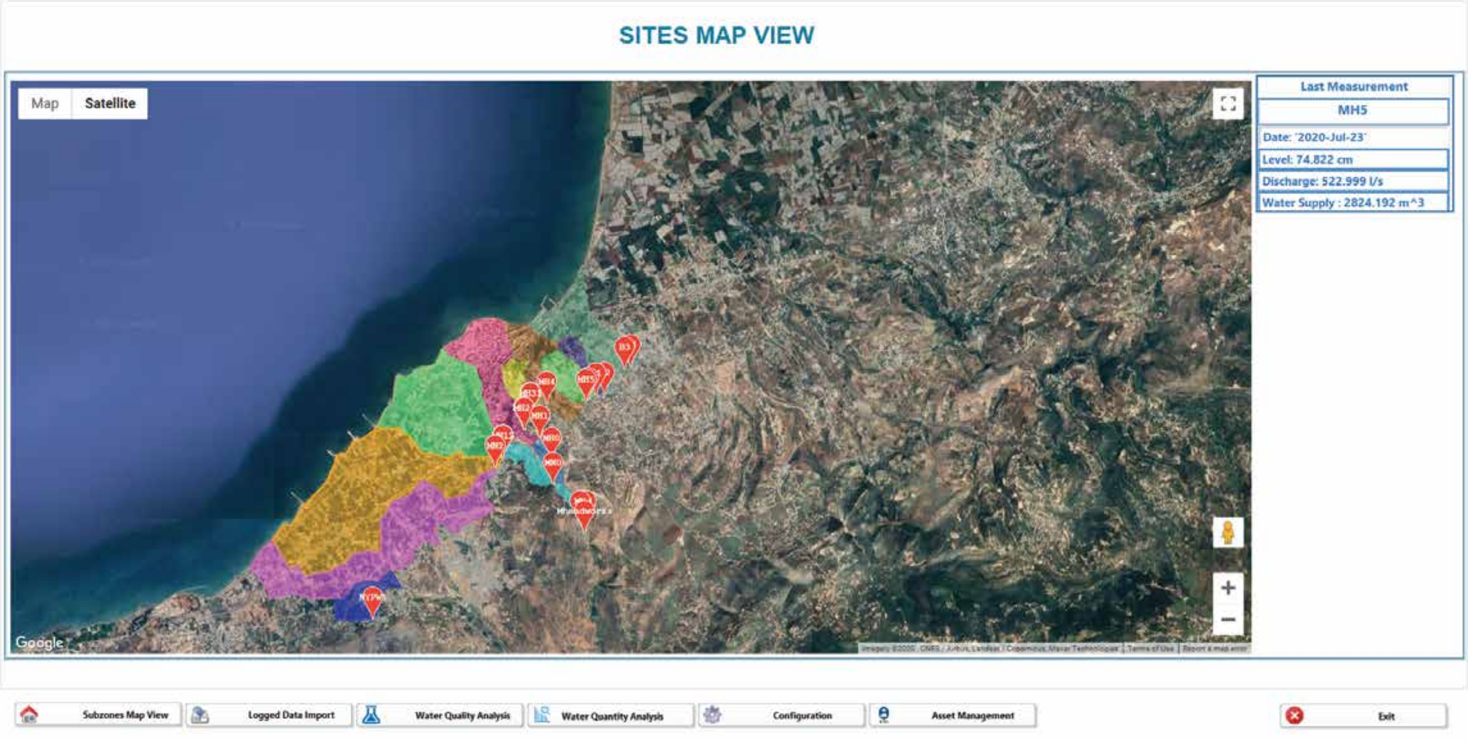


The asset management module is fully integrated into the PMS, as it is essential part of data-driven water management. Also, the integration enables the validation of the monitoring results. If data inconsistency occurs due to the condition or the performance of the asset (i.e. malfunction, backwater effect, etc.), the asset management module indicates the possible reasons, thus preventing the data misinterpretation.

The outcome

The asset management module is designed in a user-friendly way in an integrated manner. It also works as independent module of the PMS. The PMS provides a map-view interface, whereas each asset can be traced. The visual interpretation of assets contributes to the identification of potential hotspots. Therefore, asset IDs are displayed in the main monitoring sites. The software databases also include a repository for picture upload and download.

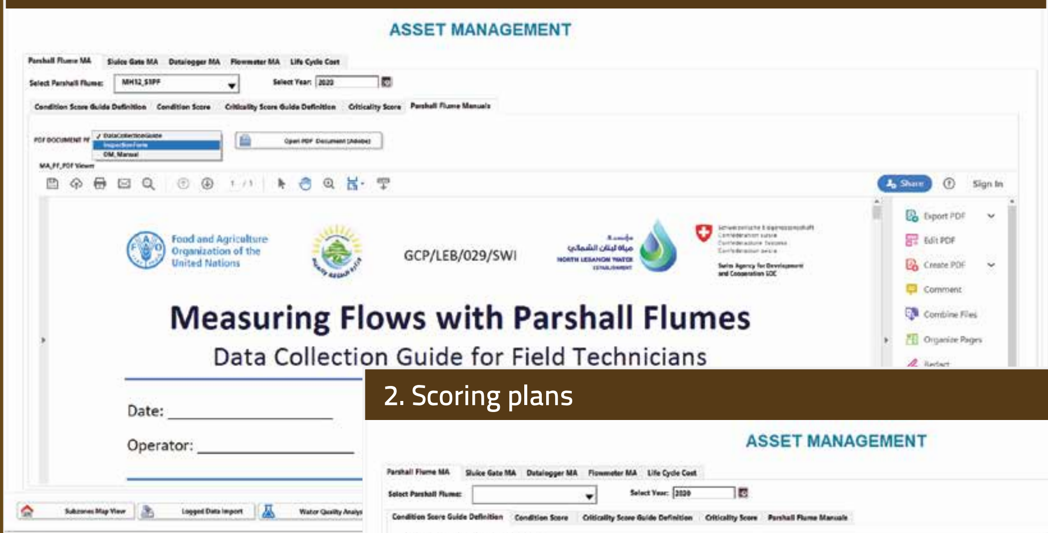
Figure 7: The interface of the Prototype Monitoring System (PMS)



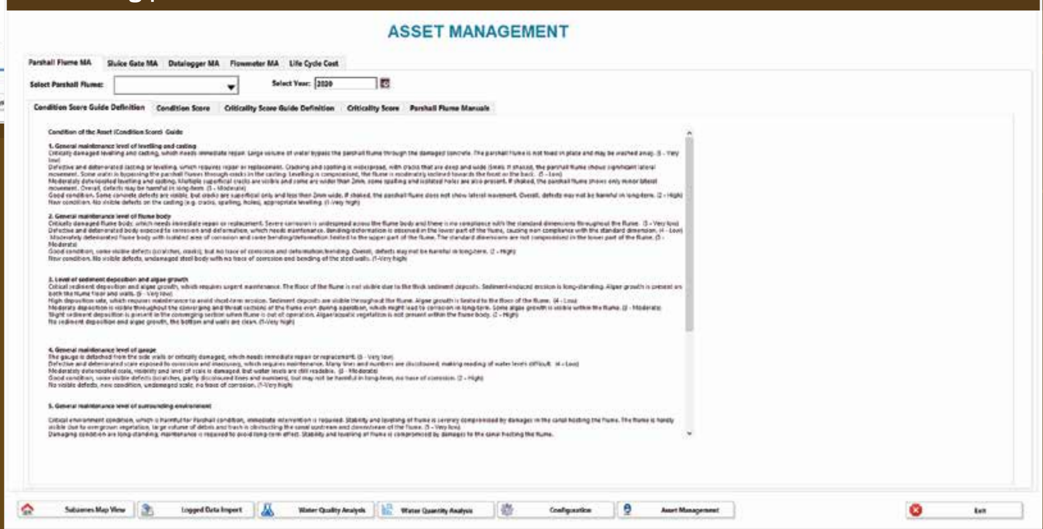
Source: Google. 2020. Lebanon. Retrieved from https://www.google.com/maps. Complys with UN. 2010. Map 4282 United Nations. https://www.un.org/Depts/Cartographic/map/profile/lebanon.pdf

The current framework sets the scope of the assets developed by the project, namely gates, parshall flumes, flowmeters and pressure sensors. The module has also a user guide that helps conducting the full assessment from inventory to cost calculation.

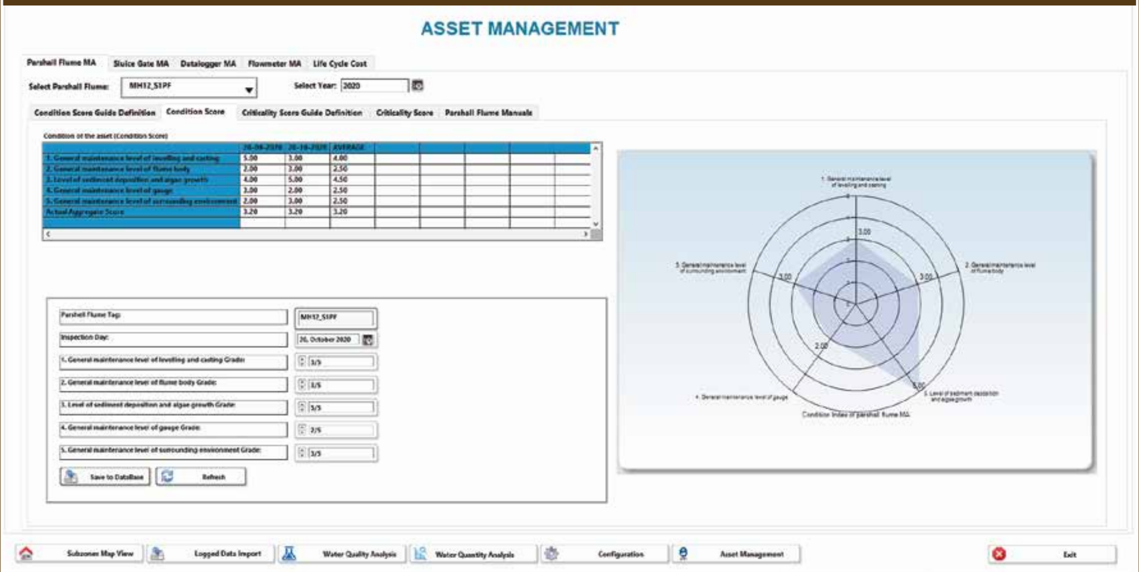
1. Downloadable inventory guides



2. Scoring plans



3. Condition score



4. Criticality score

5. LCC

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The following key futures improve the applicability and facilitate the use of the module:

- Scalability: The module design is highly scalable. The databases can be easily extended by involving additional assets and/or command area.

- Generated timeseries: In order to keep track of the change in conditions or criticality, the module stores the historical data. This function is essential for future assessments to reveal a causal relationship amongst the indicators and their impact on cost.

- Reporting function: The reporting function includes both numeric and visual interpretations to support the timely decision-making.

- Flexible methodology: Institutional and social priorities dominate the objectives of irrigation assets. Therefore, the methodology of scoring plans requires certain flexibility. Unlike prefixed algorithm to measure the condition and performance (i.e. machine learning methods, pre-defined meta-analysis methods, etc.), the current methodology is based on a qualitative evaluation. A validation campaign was organized at the initial phase of the module installation. The campaign relied on the concerted efforts of experts, scientists and development specialists. Future validation campaign might further shape the scoring plans. Therefore, the scoring guides are formulated in a way that gives a room for future adjustments.

- Participatory management: The implementation of asset management components is built on a consultative process and requires the cooperation over the reporting line of the irrigation system management. Such process strengthens the collaboration amongst stakeholders, thus improving the institutional data-sharing mechanism from field to office.

The asset management module fully reflects on the need of the NLWE and provides a novel case study for future replication and scale-up.

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The lessons learned - best practices

The first phase of the project drew lessons from the design and implementation of the asset management module within the PMS. Such lessons can be categorized under three dimensions: financial sustainability, water service and risk management.

Financial sustainability	Water service	Risk management
The asset management systems facilitate the proactive and long-term planning of institutional budget, thus avoiding merely contingency planning. **A proper asset management framework provides information on the expected and unforeseen costs, thus improving the institutional capacity.** **By having a rigorous stocktaking of costs, cost recovery can be achieved. Based on the due account of emerging costs, decision-makers can prepare a fair pricing mechanism to finance the irrigation system management** **The collection efficiency of irrigation fees often remains low, therefore, an asset management framework can help estimate the sufficiency of budget and the income foregone.** **The asset management systems are effective tools to facilitate the return of investment.**	The asset management systems aim at improving the performance of the irrigation system, thus the betterment of the water service for users. A proper O&M based on inventory and inspection improves the performance, increases the asset lifespans, and reinforces the objective of the asset. The asset management systems build a baseline for condition and performance, therefore the actual changes can be measured over time. The condition and the criticality of an asset are not necessarily correlated, therefore, advanced asset management systems provide an option to evaluate these two indicators separately but also allows the comparability. A better level of service of the assets can considerably improve the users' satisfaction, thus prompting them to contribute to the management. A pre-fixed scoring scheme for condition and criticality can help avoid the biased scoring, and give realistic picture about the status of the system. The asset management module contributes to the performance of the water monitoring system by pinpointing the condition-driven data inconsistency.	The asset management systems help identify the deterioration of the asset condition and/or performance, thus enabling the timely action. Although the condition and performance contribute to a better water service, the consequence of failure must be evaluated to understand the potential impacts. A risk management strategy must be built on the consequence of failure in a multidimensional manner, involving critical aspects, such as human safety and environment. While condition deterioration puts a risk on financing, the performance decline poses risk to the level of water service and the surrounding environment, including human livelihood or the ecosystem.

Figure 8: Inception of installed gate with farmers

Lessons-learnt related to asset management and O&M of irrigation system are critical to maintain the achieved results. Training of professional staff is key to reach long-term sustainability of established monitoring system and maintain gains.

The long-term vision of the project anticipates the scaling-up of implemented and demonstrated practices, both within the boundaries of the NLWE, and beyond, extending to other establishments. Dissemination is a built-on complex strategy with multiple publication outlets to reach wide audiences. The scaling-up is phased into three successive steps:

Piloting	▪ Select pilot sites based on multiple-criteria ▪ Design and implement novel approaches ▪ Draw lessons from implementation
Learning	▪ Train professional staff on traditional and non-traditional methods ▪ Extend the training to potential stakeholders at national level
Scaling-up	▪ Demonstrate results and assess replicability ▪ Implement the developed approach

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