Water Security in a changing world – Transitioning to evidence-based, proactive and resilient water resources planning: A case study from Seychelles.

Dr. Mark Futter, Senior Principal Hydrologist, MWH now part of Stantec and Dr. Evan Dollar, Technical Director, MWH now part of Stantec.

Correspondence address:

Dr. Mark Futter,
MWH
Buckingham Court, Kingsmead Business Park
Frederick Place, London Road
High Wycombe, HP11 1JU
UK

Tel: +44(0)1494 557580
Email: mark.futter@mwhglobal.com

Abstract

The resource efficiency programme for the Seychelles water sector (REPSWS), supported by the European Union, is an accompanying measure to a major water & wastewater investment programme funded by the European Investment Bank and Agence Française de Développement, working with the Seychelles Public Utilities Corporation (PUC). It addressed three key challenges in the Seychelles water sector:
1) enhancing energy efficiency across the PUC's water supply systems;
2) future water demands and water security, and;
3) developing water supply measures for the main islands to 2030.

The PUC recognized the need to move towards a proactive approach to water planning and water security. REPSWS therefore sort to move decision making on future risk management onto an evidence based, forward looking and more resilient foundation.

A water resources planning approach was developed and applied across the main populated islands that included the first use of a strategic, integrated water resources planning model. Combined with REPSWS developed demand projections, this supported the estimation of supply-demand balances of the existing water supply systems to 2030. Where supply demand balance deficits were identified, long lists of potential supply-side options that included run-of river abstractions, surface water storage, coastal lagoons, ground water with managed aquifer recharge, and desalination plants, were screened. The resulting short lists of preferred options were further assessed, using a multi-criteria analysis (MCA) approach. The MCA framework considered cost, supply reliability, climate change adaptability and environmental and social equity.

The results from application of this approach presented a series of recommendations for the further investigation of new water resources for the main islands. In addition

to this, an important secondary set of recommendations were presented on the need for investment in data collection, with archiving and data management to support future analysis.

REPSWS has demonstrated that the adoption of a water resources planning approach, with the use of appropriate water modelling and planning tools, supports the development of a strategic understanding of water delivery systems. The adoption of this approach, facilitates proactive decision making on where to focus future investments that offers adaptable, reliable and equitable solutions. The framework adopted in Seychelles is readily transferable to other countries facing similar challenges to move their water resources planning onto a more resilient basis.

REPSWS also recommended the parallel development of an enabling water policy and strategy framework. Such a framework should include a strong role for public consultation, and give due consideration to wider issues of water sector resilience, energy efficiency and water demand management.

Implementation of the adopted water resources planning approach, within such a policy and strategy framework, supports the provision of answers to questions related to water security that are based on inputs from science and engineering. This results in investment decisions that deliver robust solutions, but also the identification of where to focus additional investment. This is so that in the future, remaining uncertainties associated with these decisions can be reduced and the science and engineering "building-blocks" are progressively improved going forward, strengthening water policy and strategy implementation.

Introduction and Background

The Republic of Seychelles (Seychelles) is a 115 island archipelago located in the western Indian Ocean. It has a population of 91,000, the vast majority of which inhabit the islands of Mahé, Praslin and La Digue. Seychelles is classified by the United Nations as a Small Island Developing State (SIDS).

The tropical maritime climate of the Seychelles archipelago is strongly influenced by the ocean, especially through changes in monsoonal winds, ocean currents and sea surface temperature patterns. Two distinct seasonal patterns are associated with the dominant wind regimes. The southeast monsoon which blows from May to October is associated with the dry season. The northwest monsoon, with the tropical cyclone season over the southwest Indian Ocean (November to March), is associated with the wet season. Synoptically, the main system which governs weather over Seychelles is the Inter-Tropical Convergence Zone (ITCZ). Hence, complex and highly interactive processes control the Seychelles' climate system.

The mean daily temperature is relatively constant, varying from 26°C in July and August to 28°C in March, April and May. There is an average of seven hours of sunshine per day varying from 5.0 hours in January to 8.2 hours in May. Relative humidity averages at 79.7%, and like temperature, is relatively stable. From May to October, trade winds blow from the southeast, associated with typical mean monthly wind speeds of between 7.9 to 12.1 knots. During November to April, the winds are from the northwest, and have lower mean monthly speed, varying from 5.0 to 6.4 knots. Nevertheless, during this period, the ITCZ can generate periods of convective activity, associated with the tail-end of tropical cyclones, and thus high wind speeds.

Rainfall shows a strong seasonal pattern, which based on the rain gauge record at the Seychelles International Airport, varies from a monthly mean value of 78 mm in July to 408 mm in January. In addition to this seasonality, the topography of the Seychelles strongly influences the spatial pattern of rainfall. For example, on Mahé, mean annual rainfall varies from less than 2,000 mm on the coastal plains to over 3,500 mm at the highest elevations of over 700 mASL.

The main island of Mahé has a total area of 154 km^2, Praslin covers 38 km^2 while La Digue has a land area of 10 km^2. The mean catchment areas on Mahé, Praslin and La Digue are 0.57 km^2, 0.35 km^2 and 0.27 km^2 respectively.

Given the small, steep sided catchments that are typical of each of these islands, especially Mahé, the catchment river flow regimes are characterized by a very “flashy” response. The geology on all three of these islands is dominated by granites, with limited superficial deposits. Thus, hydrograph recession following rainfall events is typically steep, with low flows experienced in these catchments soon after the cessation of rainfall events.

The development of water resources / water supply systems of the three main islands reflect these physical constraints, and have developed through a series of master planning exercises and detailed studies since the 1960s. On the main island of Mahé, the water resources / water supply system consists of two impounding reservoirs (La Gogue and Rochon), with a raw water transfer between them, thirty run of river abstractions (“barrages”) and four desalination plants (including Providence, Anse Boileau, Ile Perseverance and Belombre). Water supply on Praslin is provided by six barrages and a single desalination plant (Baie Ste. Anne). On La Digue, groundwater represents an important supply source, reflecting the presence of a relatively large coastal plain, as well as a five number of barrages and a single desalination plant (La Passe). There has been significant recent development in desalination plant capacity across the three islands since 2012. This was in response to a serious drought experienced that year.

The resource efficiency programme for the Seychelles water sector (REPSWS), supported by the European Union (EU), was an accompanying measure to a major ongoing water & wastewater investment programme funded by the European Investment Bank and Agence Française de Développement (AFD), working with the Seychelles Public Utilities Corporation (PUC). It addressed three key challenges in the Seychelles water sector:

- Enhancing energy efficiency across the PUC’s water supply systems;
- Future water demands and water security, and
- Developing water supply measures for the main islands to 2030.

The PUC recognized the need to move towards a proactive approach to water planning and water security, particularly following responses to the 2012 drought.

REPSWS therefore aimed to help move decision-making around water security towards an evidence-based, resilient model.

Water Resources Planning Approach

In response to this identified need, a water resources planning approach was developed and applied across the three main islands that included the use of a strategic, integrated water resources planning model. Combined with REPSWS-developed demand projections, this supported the estimation of supply-demand balances of the existing water supply systems to 2030. Where supply demand balance deficits were identified, long lists of potential supply-side options that included run-of river abstractions, surface water storage, coastal lagoons, ground water with managed aquifer recharge (MAR), and desalination plants, were screened. The resulting short lists of preferred options were further assessed, using a multi-criteria analysis (MCA) approach. The MCA framework considered cost, supply reliability, climate change adaptability and environmental and social equity. The application of this approach to the main populated islands of Seychelles is summarised in this paper.

Adoption of this approach, with the use of appropriate water modelling and planning tools, supported the development of a strategic understanding of water delivery systems. The adoption of this approach, facilitated proactive decision-making on where to focus future investments that offer adaptable, reliable and equitable solutions. The framework adopted in Seychelles is readily transferable to other countries facing similar challenges to move their water resources planning onto a more resilient basis.

Water Resources Planning Models

Water resources planning models based on the Water Evaluation and Planning (WEAP) platform (Stockholm Environment Institute, 2017) were developed and subject to calibration, one for each island. This was the first time that integrated water resources planning models had been developed for Seychelles. These models were used to estimate baseline yield / deployable output (DO) for a range of Levels of Service (LoS) (1 in 50-year, 1 in 30-year, 1 in 20-year) and for safe yield / DO.

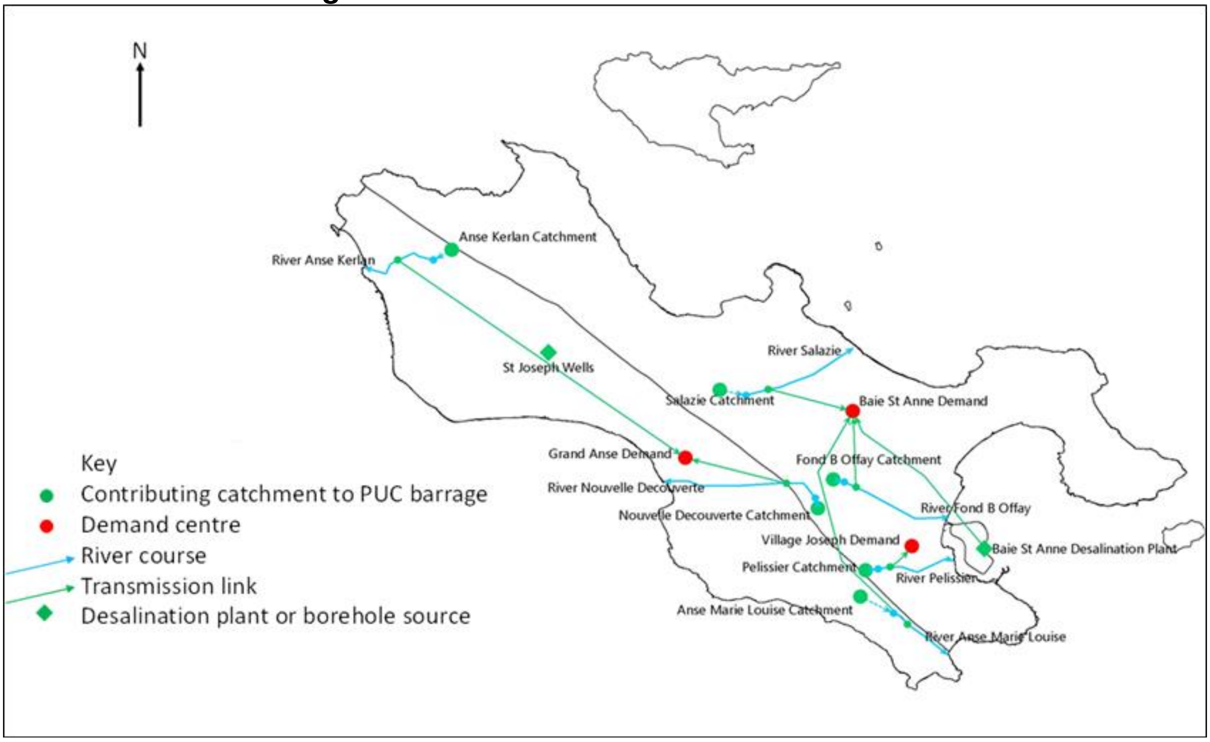
LoS was defined as being the frequency of supply interruption to customers within a defined water resources zone, while DO reflects the volume of water that can be produced by a water resources system, constrained by hydrological yield (water availability) and engineering constraints, such as pumping station, transmission pipeline or WTW capacity limits. Accordingly, DO on any one day is equal to the minimum of water availability and engineering capacity, where water is delivered by a system from source to a WTW and then into supply.

Safe yield / DO was calculated as the maximum yield that a system can support through the simulation period without registering an unmet demand. Safe yield / DO is here reported in cubic metres per day (m^3/d) or megalitres per year (Ml/yr). The yield / DO estimates were calculated for each water resource zone (WRZ) and for each island. The WRZ were defined as those geographical areas where customers are subject to the same risk of supply interruption.

The models were built using information provided by the PUC and reflect the status, connectivity, conjunctive use and operation of PUC's water supply assets at the end of 2014. This incorporated all PUC investments to December 2014 including, for example, upgrades to existing desalination plants and water supply engineering works. Hydrological inputs to the models were generated in WEAP based on information developed earlier in the programme, including water supply catchment areas as well as estimated annual average rainfall.

By way of example, the WEAP calibration model structure for Praslin is presented in Figure 1.

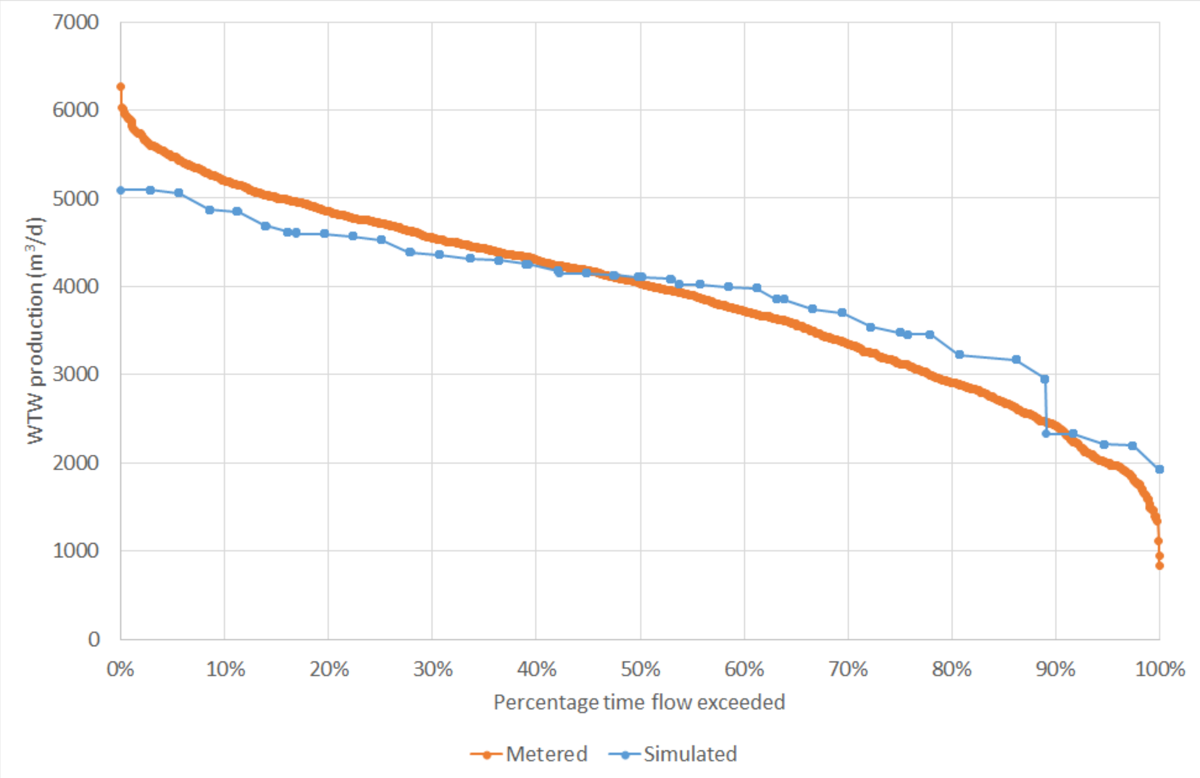
Figure 1: Praslin WEAP model schematic



The activities of others in catchments where the PUC abstracts water were not explicitly included in the WEAP models developed here. This was because of the lack of information and data about these other abstractions (licenced and un-licenced). Accordingly, the models developed under the REPSWS programme represent a first step of a potential programme to address a number of uncertainties associated with the PUC's own data, but also associated with other water users in these same catchments.

In the absence of reliable, daily flow data, WEAP model output data were necessarily calibrated against PUC production data for 2012, 2013 and 2014. The approach adopted here sought to match observed and WEAP-simulated WRZ production data at both a WRZ level and at an individual Water Treatment Works (WTW) level. Successful calibration was achieved on an annual basis. However, calibration at the 'high' and 'low' production percentile values was less satisfactory, particularly at the smaller WTWs. In the 'low' production range (i.e. low flows), this reflects a tendency to (potentially) overestimate available resources particularly at run-of-river sources, most noticeably on Mahé. This mirrors the uncertainty in the simulated hydrology (and possibly abstraction efficiency). A typical WEAP model calibration result for Mahé is presented in Figure 2 for an example WRZ.

Figure 2: Comparison of example WRZ metered and simulated daily production duration curves 2012 to 2014



Following calibration, the WEAP models were used to estimate yield / DO for a series of baseline scenarios across each island. Here, the simulation period was extended to cover the period 1972 to 2014, i.e. a daily simulation of 43 years. This is greater than the duration of the 30-year cycle identified in the Seychelles rainfall record.

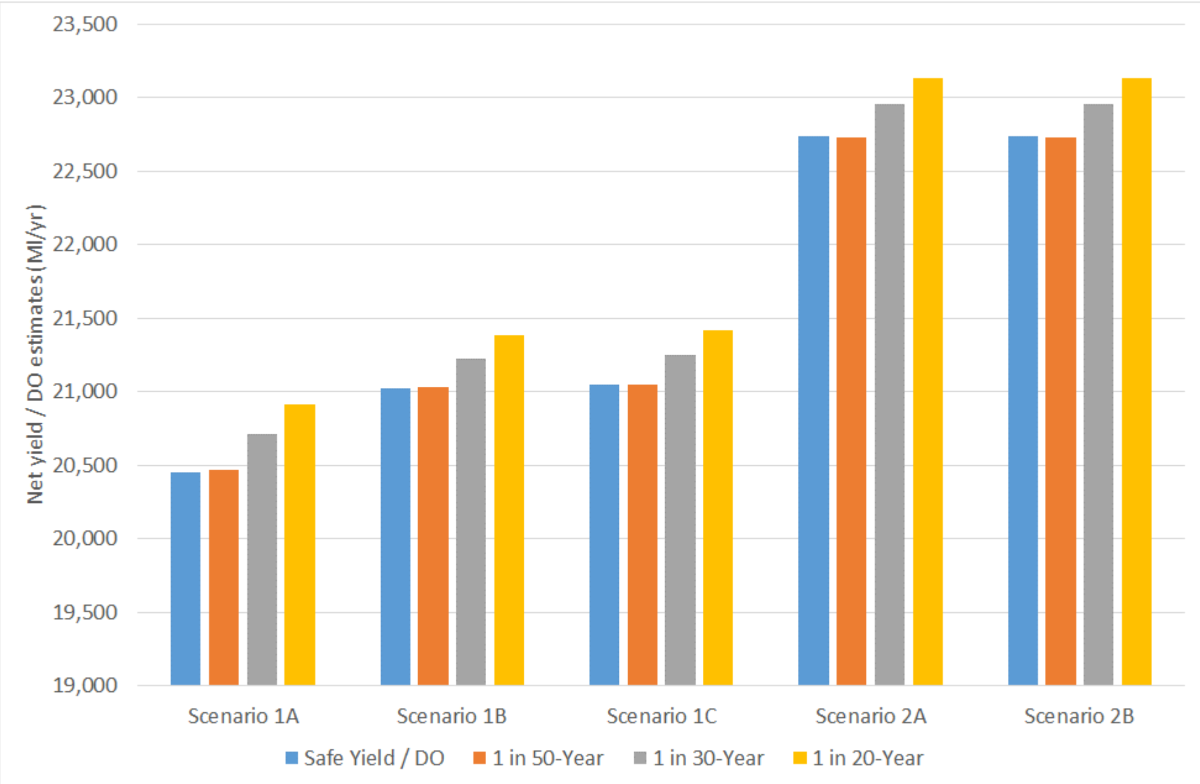
For Mahé, the following baseline scenarios were developed:

- Scenario 1A - retaining existing calibration set-up.
- Scenario 1B - removal of operational constraints imposed to achieve the calibration.
- Scenario 1C - as per Scenario 1B, but combining the 7 No. WRZs to reflect increased connectivity as a result of PUC investments. This resulted in 4 No. zones (where customers within each zone have the same level of risk of supply interruption, i.e. LoS):
  - West and South (merging of three existing WRZs).
  - East (merging of two existing WRZs).
  - Le Niol WRZ.
  - Cascade WRZ.
- Scenario 2A - as per Scenario 1C, but revised to include the increased active storage (to 1,455 Ml) of La Gogue Dam as a result of the planned +6 m dam raising and associated new WTW (4,200 m^3/d).

- Scenario 2B - as per Scenario 2A, but revised to include planned additional transfer (assumed to be 500 m^3/d) from northern catchments to supplement inflows to La Gogue Dam.

Figure 3 presents a summary of the Mahé LoS net yield / DO estimates. Values are in Ml/yr.

Figure 3: Mahe LoS Scenario Net Yield / DO Estimates



The results presented in Figure 3 are in the order of 5,000 Ml to 7,000 Ml higher than the total Mahé metered production for the years 2012 to 2014. This difference can be explained by a combination of factors, including production / DO measurement uncertainties, hydrological simulation uncertainties, WEAP optimising / maximising the use of all sources (including the call on the desalination plants) and increased desalination plant production. For example, for Providence desalination plant, production capacity increased from 2,000 m^3/d at the start of 2012 to 11,500 m^3/d at the end of 2012. Similarly, Ile Perseverance desalination plant was commissioned in 2013 with a production capacity of 2,000 m^3/d, while Belombre desalination plant was commissioned in August 2013 with a production capacity of 1,130 m^3/d. Given these uncertainties, and that fact that desalination plants 'mask' climate change impacts (on flows), it was recognised that some caution must be exercised when considering the SDB for Mahé.

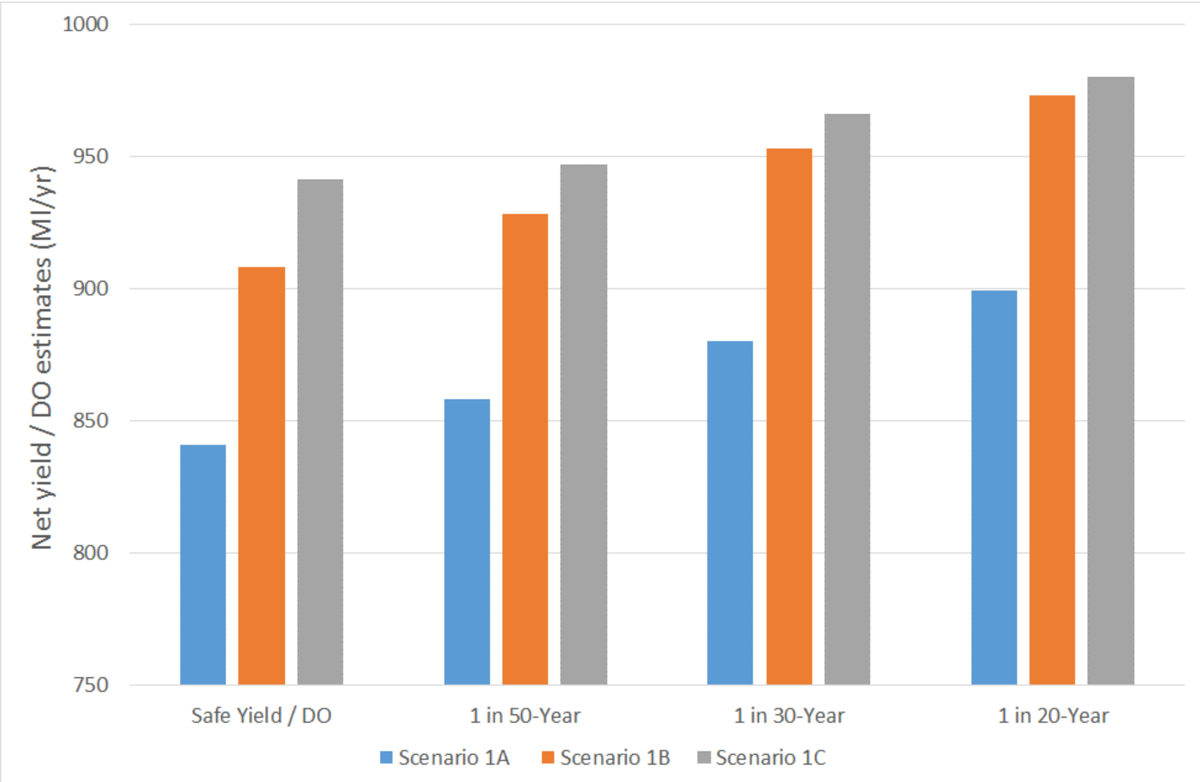
For Praslin, the following baseline scenarios were developed:

- Scenario 1A - retaining the existing Grand Anse, Baie Ste. Anne and Village Joseph (a very small isolated zone) WRZs as separate, unconnected zones.

- Scenario 1B - combining the Grand Anse and Baie Ste. Anne WRZs to reflect the commissioning of a treated water link between the water treatment works that serve these two WRZs.
- Scenario 1C - as per Scenario 1B, but with operational constraints removed to allow WEAP to optimise the call on different resources.

Figure 4 presents a summary of the Praslin net yield / DO estimates; for Scenario 1A this shows the sum of the yield estimates for the separately modelled Grand Anse and Baie Ste. Anne WRZs, while for Scenarios 1B and 1C these are the results for the combined WRZ. Values are in Ml/yr.

Figure 4: Praslin LoS Scenario Net Yield / DO Estimates

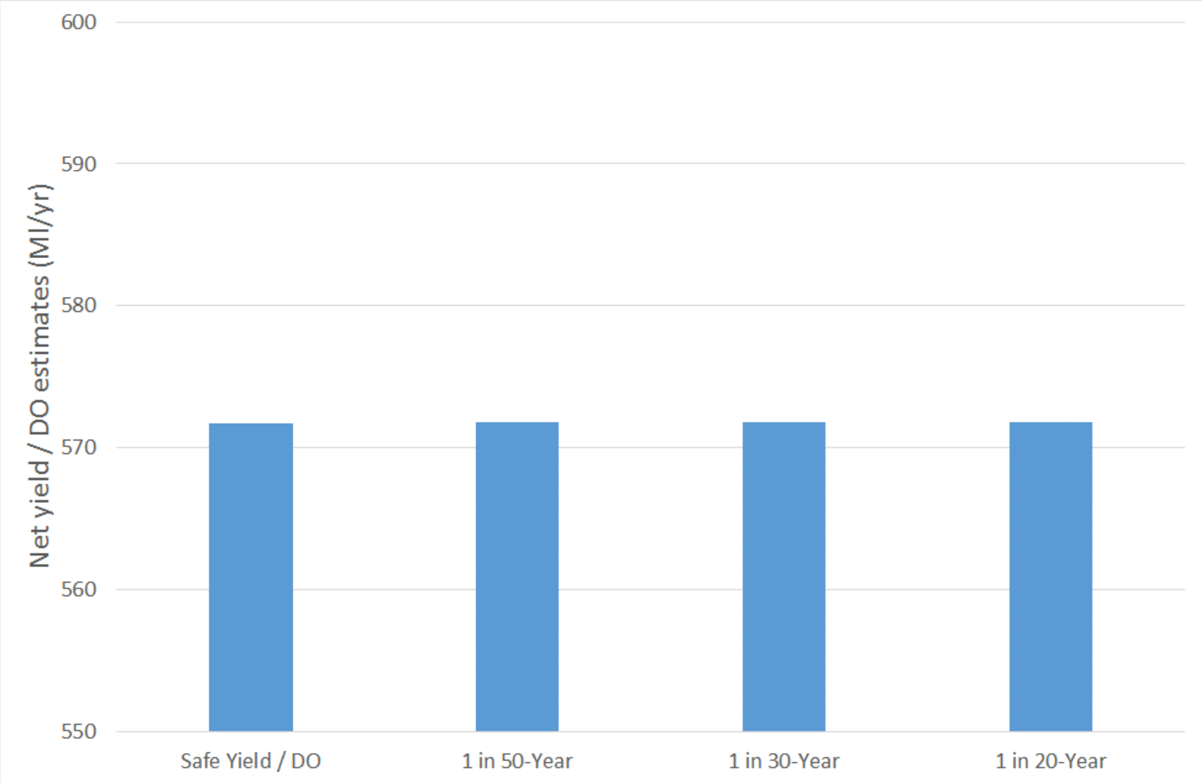


For La Digue, the following baseline scenario was developed:

- Scenario 1A - retaining the calibration set up.

Figure 5 presents a summary of the La Digue net yield / DO estimates. Values are in Ml/yr.

***Figure 5:* La Digue LoS Scenario Net Yield / DO Estimates**



Here the La Passe desalination plant buffers against climatic variability, and therefore provides a potentially reliable supply to La Digue.

Water Demand Forecasts

Baseline demand forecasts to 2030 were prepared for Mahé, Praslin and La Digue utilising models developed by REPSWS, informed by the results of a fixtures and fittings survey undertaken in 2015.

Further, implementation of water demand measures across the three islands and their potential efficacy in reducing consumption were estimated. These were based on a list of agreed demand measures (e.g. rainwater tanks, development codes, education programmes) which were grouped as scenarios - low, medium and high. **Table 1** presents the estimated total 2030 water savings of the low, medium and high scenarios in comparison (as a percentage) to the 2015 baseline demand forecast. It is evident that these scenarios result in small savings (1-4 %) relative to the baseline forecast. Reducing Non-Revenue Water (NRW) delivers the largest saving.

Table 1: Water demand forecasts in 2030 for Mahé, Praslin and La Digue as percentage change against 2015 baseline estimates

Demand scenario	Mahé	Praslin	La Digue
Demand estimate at 2015 (Ml/yr)	13,279	1,141	483
Percentage change at 2030 planning horizon			
Baseline incl. NRW reduction	-30%	-11%	-3%
Scenario 1 - low savings scenario	-1%	-1%	-1%
Scenario 2 - medium savings scenario	-2%	-3%	-2%
Scenario 3 - high savings scenario	-3%	-4%	-4%

To improve confidence in the demand management results and to make more informed programme investment decisions, it was recommended that an audit is performed of the existing metering system, including meter accuracy, data collection and database quality (including meter locations). This, together with an audit of the existing production data and a targeted survey to estimate persons per account, it was recognised, will enable a higher-confidence prediction of current and future demands and associated NRW. This will also support a higher-confidence estimate of SDBs across the three islands.

Supply Demand Balance

The baseline yield / DO estimates were assessed against the demand projections (to 2030) to provide a SDB for each island at 2030.

For Mahé, baseline supply Scenario 2A was applied, for Praslin, baseline supply Scenario 1C was applied, for La Digue, baseline supply Scenario 1A was applied.

While SDB balances were prepared by comparing the safe yield / DO, 1 in 50-year yield / DO, 1 in 30-year yield / DO and 1 in 20-year yield / DO against the baseline demand, the baseline demand including NRW targets, low, medium and high demand scenarios to provide a range of SDBs, a conservative approach was adopted here whereby the SDB at a 1 in 30-year LoS with no NRW targets (i.e. NRW at levels calculated for 2015) was taken forward for further assessment.

For Mahé, a positive balance was calculated. For Praslin, a deficit of 421 Ml/yr was calculated at 2030. For La Digue, a deficit of 112 Ml/yr was calculated at 2030.

An initial assessment of the potential surface water storage required to meet the deficits on Praslin and La Digue was calculated based on dry period (June, July and August) demand and dry period yield / DO. These preliminary calculations indicated storage requirements in the order of 66,500 m^3 to 105,000 m^3 for Praslin to 22,500 m^3 to 28,000 m^3 for La Digue. These values were taken forward for further assessment to identify potential supply side options to address the identified SDB deficits.

Surface Water Storage Options

Surface water storage options were developed to resolve the identified supply deficits at 2030. This was achieved by developing a long-list of potential surface water measures derived utilising a three-stage desktop analysis (using GIS working with the REPSWS developed Digital Terrain Models (DTM) for each island), local knowledge and previous studies. This allowed for the identification of site-specific surface water storage measures.

For Praslin, the developed long-list of measures included four river regulation reservoirs, two run-of-river sources / barrages, off-line storage reservoirs, off-line storage tanks, desalination plant capacity increase and MAR.

For La Digue, the long-list of measures included one river regulation reservoir, an off-line storage reservoir, an off-line storage tank, desalination plant capacity increase and MAR.

The long-list of measures was screened to propose a refined set of measures for further assessment. Run-of-river / barrages were screened out on the basis that they provide only a small yield / DO benefit of around 0.1 Ml/d at 1 in 30-Year LoS. Off-line storage reservoirs were screened out on the basis that a previous report could not identify suitable locations (confirmed by the REPSWS study). Off-line storage tanks were screened out as being high risk and high cost, as these would effectively require the construction of new impoundments to capture and transfer ‘quick-flows’ which would be sediment-laden (amongst other undesirable factors). Multiple small-scale options were screened out as they were considered to have high costs and programme delivery risks (including multiple environmental and planning challenges) compared with a single, larger strategic storage solution. MAR was screened out as it provides only a marginal benefit (~0.1 Ml/d at the 1 in 30-Year LoS). Screened-in measures included river regulation reservoirs and desalination plant capacity increases.

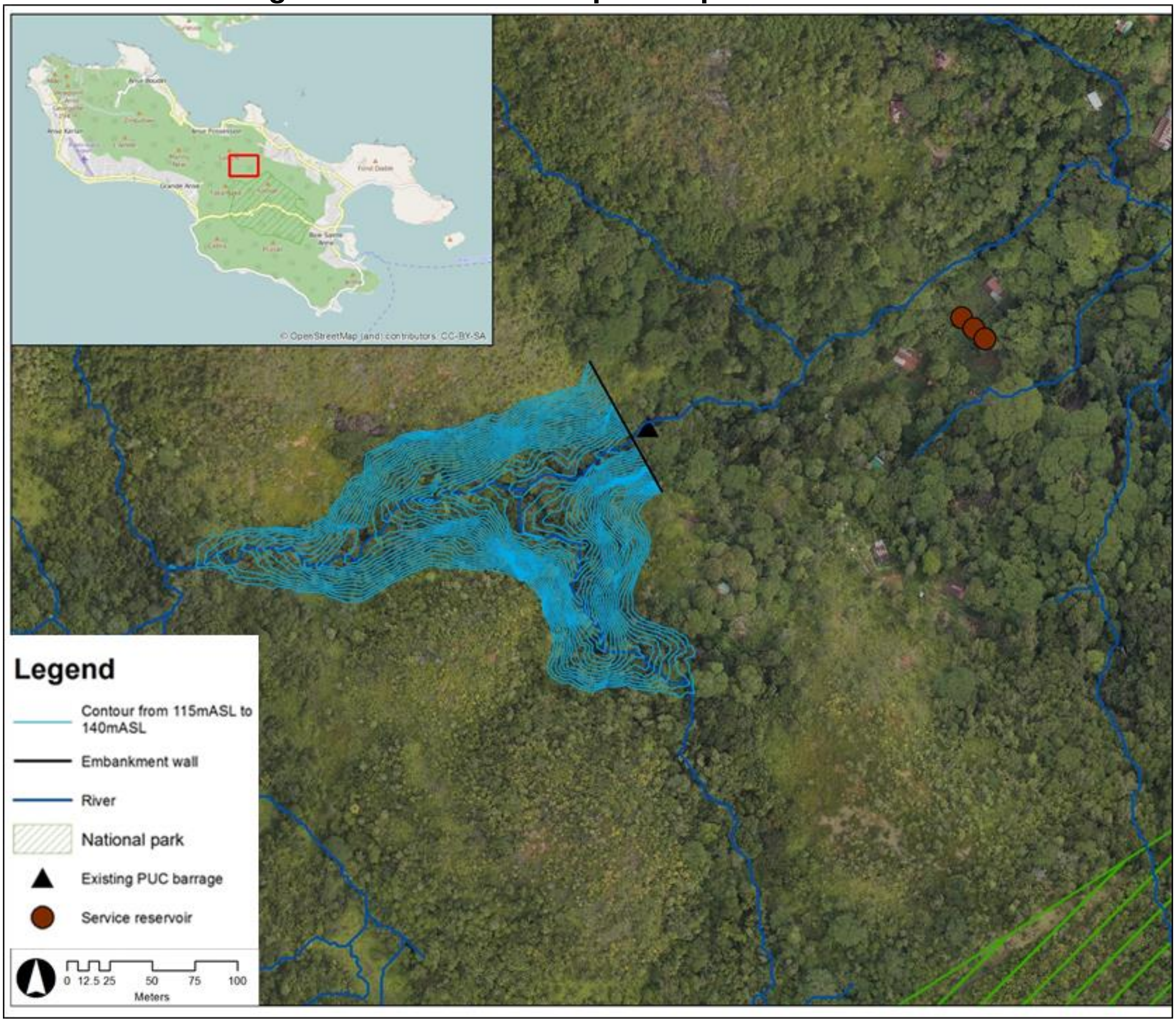
The screened-in measures were subject to further assessment. For the river regulation reservoirs, GIS tools were used together with the REPSWS-developed DTMs to generate the following information:

- Dam base elevation (mASL).
- Gross storage at Top Water Level (TWL) (m^3).
- Depth-capacity table (m^3).
- TWL elevation (mASL).
- Inundation area at TWL (m^2).

This information was taken forward for further assessment by considering inundation extent, impounding reservoir dimensions and catchment characteristics (human habitation, structures, assets and environmental designations). The potential impounding reservoirs were then optimised using WEAP to meet the required SDB deficit (i.e. 421 Ml/yr in Praslin and 112 Ml/yr on La Digue).

Inundation maps were produced for each of the refined measures. An example from Praslin is presented in Figure 6.

Figure 6: Inundation map example from Praslin



High-level capital and operational costs were estimated for each screened-in measure. Operational costs were estimated based on energy costs per m^3 of production.

Multi-Criteria Assessment

The screened-in options were assessed using a simple, weighted scoring system based on a MCA approach with the following criteria:

- Cost (Capex & Opex).
- Environment.
- Social.
- Risk & resilience.
- Policy.

The highest ranked option for Praslin was the River Nouvelle Decouverte at the existing PUC barrage. This was achieved due to this option having the highest environmental and joint highest social, risk and resilience and policy scores, with the second highest overall cost criteria score. The desalination plant capacity increase scored relatively low, principally due to higher OPEX costs and a low environment / policy score.

The outcome of the assessment for La Digue was the development of additional desalination plant capacity. This was only marginally higher than the score for the Grand Anse reservoir.

Storage Optimisation and Conjunctive Use

The potential for storage optimization and conjunctive use was explored as part of the water resources planning approach. The only significant storage on the three islands is on Mahé - Rochon and La Gogue dams. In undertaking the water resources assessment, use was made of WEAP's in-built capabilities to operate the water resources systems in each WRZ conjunctively, as well as using WEAP's optimization rules and tools.

Conjunctive use is traditionally focussed on maximising groundwater storage through resting abstractions from this source during average and wet periods to support recharge, with a call upon the stored water during times of drought when surface water resources are under stress. This concept also applies to surface water storage where inflows to impounding or pumped storage type reservoirs are maximised during times of plenty to ensure refill in readiness for dry periods and seasons.

Application of this concept to the management of water resources in Seychelles is already in place by PUC. However, REPSWS recognised that there is merit in exploring further optimization potential across the three islands. This first requires addressing the following uncertainties in the existing models and data:

- Hydrological simulations.
- Production data.
- Raw water transfers.
- Treated water transfers.
- Consumption data and its geographical distribution.
- Costs - capital, fixed operating and variable operating.

For Mahé, further optimization was explored as follows:

- Desalination plant control rules with respect to the Rochon-La Gogue system.
- Raw water transfer capacity from La Gogue Dam to Hermitage WTW.
- Mare aux Cochons transfer to La Gogue Dam.

For Praslin, further optimization was explored as follows:

- Relative call on source pairs in the Baie Ste. Anne and Grand Anse WRZs.
- Potential for MAR.
- Groundwater model build and link to WEAP.

For La Digue, further optimization was explored as follows:

- Potential for MAR.
- Groundwater model build and link to WEAP.

It was also recommended that future use of the WEAP models is supported by the enhancement and calibration of the Mahé hydraulic network model also developed by REPSWS. In combination, these two tools provide a powerful basis for future optimization and evidence-based decision-making.

REPSWS Conclusions and Recommendations

A series of recommendations for further study to assess the potential surface water measures identified earlier and the potential for MAR were also presented. These are summarised below:

For Mahé:

- Data quality audits and enhancements.
- Revisiting the WEAP model following enhanced data collection.
- WEAP optimization using enhanced data, including operation and energy costs.

For Praslin, as for Mahé, but extended to including following recommendations:

- Pre-feasibility studies for impounding reservoirs on the rivers Nouvelle de Couverte, Salazie and Pasquiere.
- Pre-feasibility studies on additional associated WTW capacity.
- Pre-feasibility studies for increasing desalination capacity at Baie Ste. Anne.
- Pre-feasibility studies on the potential for MAR on the Amitie Plain.

For La Digue, as for Mahé, but extended to including following recommendations:

- Pre-feasibility studies for an impounding reservoir on the Grand Anse River.
- Pre-feasibility studies on additional associated WTW capacity.
- Pre-feasibility studies for increasing desalination capacity at La Passe.
- Pre-feasibility studies on the potential for MAR on La Digue.

A number of further recommendations were also presented by REPSWS associated with the work summarised here. In summary, these were as follows:

- Consideration of the LoS that will be provided to customers through customer engagement.
- Full comparison of all water resources planning options (including NRW targets) against a common and consistent baseline situation to ensure that costs of options are consistent and comparable (cost per kL of water saved / generated).
- Development of a water policy / strategy to provide strategic direction, allowing for integrated planning and decision-making and ensuring water security within the islands.

Finally, recommendations for further assessment for each island are presented in Table 2 for the short-term (1 to 3 years), medium-term (3 to 5 years) and long-term (5+ years).

Table 2: Recommended short, medium and long term water resources planning actions for Mahé, Praslin and La Digue

Action Period	Recommended planning actions
Short-term (1 to 3 years)	• All islands, enhance data collection, data quality and data audits. • All islands, develop water policy / strategy. • For Praslin and La Digue, further options assessment. • For Praslin and La Digue, target demand measures at tourism sector
Medium-term (3 to 5 years)	• All islands, revise SDB using updated data and appropriate models. • All islands, full comparison of all water resources planning options. • For Praslin and La Digue, build hydraulic network model; for Mahé, update hydraulic model network • For Mahé, Optimise storage for Rochon-La Gogue system using WEAP.
Long-term (5 + years)	• All islands, Implement 5-year water resources management planning cycle.

Wider Considerations and Conclusions

REPSWS has demonstrated that the adoption of a water resources planning approach, with the use of appropriate water modelling and planning tools, supports the development of a strategic understanding of water delivery systems. The adoption of this approach, facilitates proactive decision making on where to focus future investments that offers adaptable, reliable and equitable solutions. The framework adopted in Seychelles is readily transferable to other countries facing similar challenges to move their water resources planning onto a more resilient basis.

REPSWS also recommended the parallel development of an enabling water policy and strategy framework. Such a framework should include a strong role for public consultation, and give due consideration to wider issues of water sector resilience, energy efficiency and water demand management.

Implementation of the adopted water resources planning approach, within such a policy and strategy framework, supports the provision of answers to questions related to water security that are based on inputs from science and engineering. This results in investment decisions that deliver robust solutions, but also the identification of where to focus additional investment. This is so that in the future, remaining uncertainties associated with these decisions can be reduced and the science and engineering “building-blocks” are progressively improved going forward, strengthening water policy and strategy implementation.

Acknowledgements

The authors would like to thank both the European Investment Bank and the Seychelles Public Utilities Company for their permission to prepare this paper.

The views expressed in this paper present the views of the authors and should in no way be inferred to represent the views of MWH, the European Investment Bank or the Seychelles Public Utilities Company.

References

Stockholm Environment Institute (2017) *Water Evaluation and Planning System* (WEAP). Available from: http://weap21.org/index.asp?action=200 [Accessed 22 January 2017].

Sir Alexander Gibb & Partners (1988) *Mahé Integrated Water Supply Development Plan Study: Final Report, Volume I Main Report, Volume II Appendices*. Report prepared for Republic of Seychelles, Department of Environment, Public Utilities Corporation: Water and Sewerage Division. September 1988.

Ministry of Home Affairs, Environment, Transport and Energy, Government of Seychelles (2011) *Seychelles' Second National Communication under the United Nations Framework Convention on Climate Change*. Available from: http://unfccc.int/essential_background/library/items/3599.php?rec=j&priref=7716#beg [Accessed 22 January 2017].