Liberia Energy Project: Findings from the Final Evaluation of the Pipeline Sub-Activity

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Poonam Ravindranath, Paolo Abarcar, Matt Spitzer, Cullen Seaton, Candace Miller

Submitted to:

Millennium Challenge Corporation
1099 14th St., NW Suite 700
Washington, DC 20005
Project officer: Sarah Lane
Contract Number: 95332418C0094

Submitted by:

Mathematica
1100 First Street, NE, 12th Floor
Washington, DC 20002-4221
Phone: (202) 484-9220
Fax: (202) 863-1763

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Executive Summary

The Liberia Energy Project included an $18 million water pipeline sub-activity, which was designed to transport raw water from the Mount Coffee Hydro Power Plant (MCHPP) to the White Plains water treatment plant and improve the Liberia Water and Sewer Corporation's (LWSC's) capacity to serve more than one million customers across Monrovia, Liberia. The pipeline system was constructed to be fed by gravity to reduce the electrical cost associated with transmitting water to the treatment plant, decrease salinity by intaking water upstream from the St. Paul River, and provide a more consistent supply to the treatment plant. In turn, the pipeline was expected to increase the quantity and improve the quality and reliability of water supply to customers in Monrovia.

Mathematica's mixed-methods performance evaluation of the pipeline sub-activity assessed implementation and whether the sub-activity achieved outcomes articulated in the program logic, as well as examined asset maintenance. This evaluation conducted an ex-post thematic analysis of qualitative data sources including site visits, document review, and key informant interviews, and a pre-post analysis of quantitative administrative data. We also recalculated the economic rate of return and updated the pre-project cost-benefit analysis.

Key findings from the performance evaluation

- **The pipeline and other key program outputs were completed successfully despite delays in the pipeline design process and challenges related to preparing the resettlement action plan (RAP), the COVID-19 pandemic, and technical construction issues**. The sub-activity's key program outputs—design and construction of the raw water pipeline, training of LWSC staff on operations and maintenance (O&M), and construction and rehabilitation of community wells—were achieved. Implementation was completed in November 2020, about five months later than scheduled, due to a slow design process, challenges in preparing the RAP and ESIA documents, COVID-related delays, and technical construction issues.
- **The pipeline improved the reliability of the raw water supply and reduced electricity costs but did not increase the quantity of the raw water supply or decrease salinity and turbidity**. From December 2020, as the gravity-flow pipeline began transmitting raw water from MCHPP to the treatment plant, outages in raw water supply were eliminated, and electricity costs reduced for LWSC (estimated at $780,000 in savings annually). At the same time, the pipeline did not lead to other intended outcomes such as an increase in the quantity of raw water supply and reductions in raw water salinity and turbidity.
  - LWSC staff actively restrained the pipeline's water flow due to inadequate resources to process or treat additional water. As such, there was no substantive increase in the quantity of raw water supplied to the treatment plant.
  - Prior to January 2020, LWSC had occasionally observed increases in the salinity of raw water supply when salt-water from the ocean traveled up the St. Paul river during the dry season. LWSC staff believe that the pipeline's upstream intake location at MCHPP will prevent salt-water intrusion, however salt-water intrusion does not appear to be a major concern for raw water quality. LWSC did not recall any instances of salt-water entering the raw water supply due to dry season weather events in 2020 or 2021, before or after the pipeline was put into use. The administrative data also show no substantive changes in raw water salinity during the study period.

  - The pipeline was not able to reduce raw water turbidity, indicating that a design assumption that sediments would settle at the MCHPP reservoir, and therefore reduce turbidity in raw water supply, did not hold.

- **Consistent with the results on raw water supply, the pipeline did not improve the quantity or quality of treated water supply to LWSC's service areas**. As mentioned, LWSC resource constraints, including a shortage of treatment chemicals and electricity outages, limit LWSC's capacity to process additional raw water. Further, Liberia's old and decrepit water network impedes the expansion and improvement of water supply to service areas in Monrovia. As such, the pipeline has not yet increased the quantity or improved the quality or reliability of the treated water supply. Assumptions in the program logic that donors would improve treatment capacity at the plant and LWSC would have the infrastructure and operational capacity to deliver water to service areas have not yet come to fruition, despite some ongoing donor-funded projects to upgrade parts of the water infrastructure.
- **LWSC is not maintaining the pipeline, which risks the pipeline's ability to sustain outcomes**. The pipeline's maintenance plan—involving monitoring, inspections, leak detection tests, and management of access roads—has not been executed according to the O&M plan developed by the pipeline contractor. Stakeholders attribute this to a lack of management support for maintenance and a resource crunch, which hinders the procurement of even basic equipment to replace defective parts.

Key Takeaways

The evaluation results demonstrate that the program logic's assumptions about the pipeline design and the treatment plant's capacity were not fully accurate or realistic. Stakeholders reported that closer collaboration with technical staff at the treatment plant during the design stage and a deeper investigation of the treatment plant's constraints and needs could potentially have provided a more realistic picture of achievable outcomes.

Achieving long-term improvements to the treated water supply to Monrovia hinges heavily on explicit assumptions in the program logic that donors would improve treatment capacity at the plant and LWSC would have the capacity to deliver water to service areas. Donor-funded investments have upgraded the infrastructure at the treatment plant and aim to modernize the transmission and distribution infrastructure, but these activities are yet to be completed. The program logic did not sufficiently address LWSC's inability to fund operations at the treatment plant, which risks the sub-activity's achievement of long-term outcomes. Closer coordination and sustainability planning among the Liberian government, donors, and utility staff is recommended to ensure stakeholders gain a full understanding of infrastructure gaps and capacity constraints and ensure a viable path for achieving desired outcomes.

Finally, we recommend MCC conduct additional operations and sustainability planning, informed by a realistic assessment of the utility's organizational and financial situation, prior to investing in components of water infrastructure.

I. Overview of the Pipeline Sub-Activity

In 2015, the Millennium Challenge Corporation (MCC) and the Government of Liberia signed a Compact valued at $257 million ($238 million disbursed) to spur economic growth and reduce poverty. The Compact included the Mt. Coffee Support Activity (Activity 3), which aimed to address environmental and social risks associated with rehabilitating the Mt. Coffee Hydropower Plant (MCHPP). This evaluation report assesses construction of the White Plains Pipeline from MCHPP to the White Plains Water Treatment Plant. In this chapter, we provide an overview of the sub-activity, describe the theory of change, and present literature on water infrastructure investments and factors relevant to improving water outcomes. We describe the status of the Liberia Water and Sewer Corporation (LWSC) as context for the evaluation findings.

A. Overview of the water pipeline sub-activity

As part of the Liberia Energy Project, MCC aimed to restore and upgrade the raw water pipeline to the White Plains water treatment plant, which was destroyed during the civil war (1989-2003). The $18 million water pipeline sub-activity was expected to improve LWSC's capacity to serve more than one million customers across Liberia's capital city, Monrovia. The pipeline system was constructed to be gravity-fed to reduce the cost of pumping water to the treatment plant, improve raw water quality by substituting a less saline source than the previous location along the St. Paul River, and provide a more consistent supply of potable water.

The pipeline sub-activity aimed to replace the original 900-millimeter diameter pipe with a 1,200-millimeter pipe to meet the expanding demand for pipe-borne water. The sub-activity's budget of about $18 million (revised from an original estimate of $13.4 million) covered costs for pipeline design and construction, and other activities including environmental studies, procuring equipment for the treatment plant, compensating project-affected-persons, and constructing or rehabilitating wells in surrounding communities. After the completion of the feasibility and preliminary environmental studies, the design-build contract was executed in February 2019 and completed in November 2020. The pipeline began supplying raw water to the treatment plant in December 2020.

1. Technical aspects of the water pipeline sub-activity

The new pipeline was built to be 1,200 millimeters in diameter and approximately 4.7 km long. It was designed to carry water from the MCHPP to the White Plains water treatment plant and was required to deliver a flow of 0.9 m^3/second to 1.2 m^3/second. As shown in Figure I.1, the activity was split into two segments.

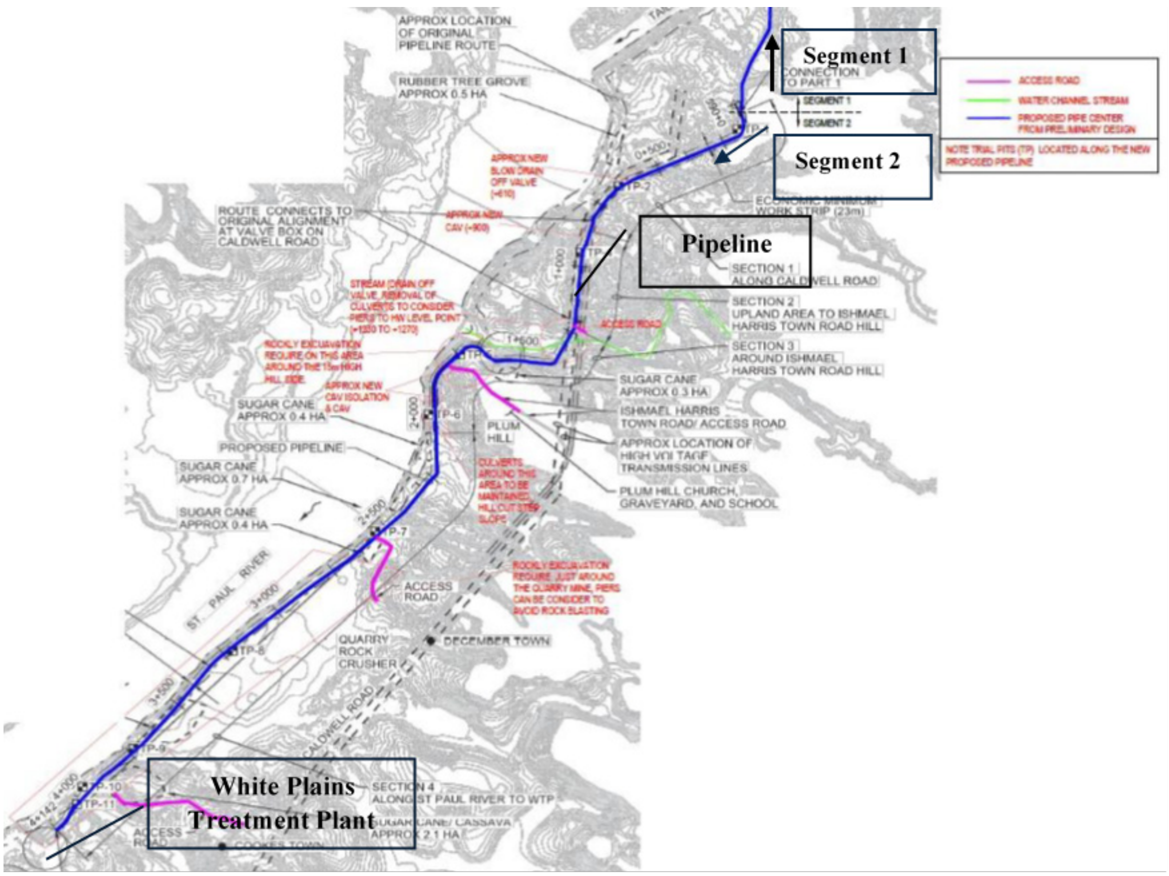
Segment 1 involved the provision of a short 0.9 km pipeline within the MCHPP property. This segment began at the current blank flanges, situated at the intake chambers of three of the four turbines at MCHPP, and rising to a valve chamber at the end of the Liberia Electricity Corporation (LEC) site for MCHPP. This segment comprised two parts:

- Segment 1A: Steel risers and valve manifold at the dam connection, an over-ground section of steel pipework, and a burst-control valve building
- Segment 1B: Buried pipeline to the boundary of MCHPP

Segment 2 involved the provision of a longer 3.8 km pipeline outside the MCHPP property boundary, running along the bank of the St. Paul River to the White Plains water treatment plant. This segment was divided into three parts:

- Segment 2A: Pipeline from the LEC MCHPP boundary to the Pipe Bridge near the treatment plant
- Segment 2B: Pipe Bridge with a steel pipe near the treatment plant
- Segment 2C: Pipeline from the Pipe Bridge to the treatment plant

Figure I.1. Schematic of proposed pipeline

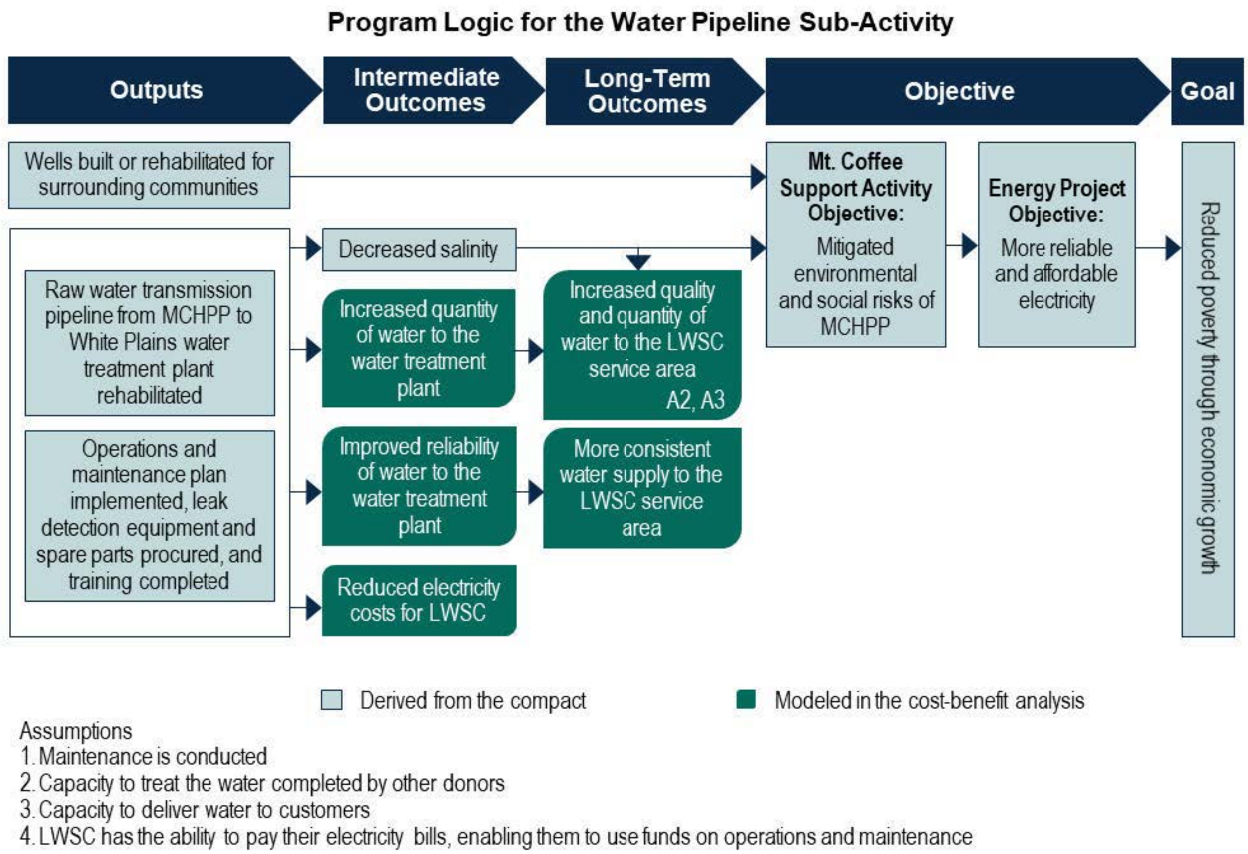


Source: Nicholas O’Dwyer (2019).

2. Theory of change

The program logic (Figure I.2) provided the rationale for investing in the pipeline sub-activity and the expected outcomes. The program outputs included the rehabilitation of the water pipeline, implementation of an operations and maintenance (O&M) plan, training for LWSC staff on O&M, and procurement of leak detection equipment and spare parts for the pipeline. These outputs would lead to intermediate outcomes of increased quantity, improved reliability and decreased salinity of raw water, and reduced electricity costs for the LWSC due to the gravity-fed pipeline system. In the long term, the increase in reliable raw water supply to the treatment plant and the decreased salinity of raw water would contribute to improving the quantity and quality of the water supply in LWSC’s service areas. Finally, well construction or rehabilitation in the communities surrounding MCHPP would improve access to potable water, reduce the risk that the pipeline limited access to the St. Paul River, and manage expectations about the pipeline's ability to supply water in these communities. The logic model does not establish a strong link to the objective of the Mt. Coffee Support Activity: mitigating the environmental and social risks associated with the rehabilitation of MCHPP. The sub-activity will replace the pre-war pipeline and address issues related to salt-water intrusion and reliability of water supply to the treatment plant, but it does not appear to address any direct impacts from the rehabilitation of MCHPP.

Figure I.2. LEC Training Activity theory of change



MCC's logic model does not adequately account for LWSC's extremely limited financial capacity to operate the treatment plant and the water network. The likely expectation was that intermediate outcomes would lead to long-term outcomes if LWSC had other donor support to bolster capacity to treat raw water and distribute treated water. While the African Development Bank (AfDB), the World Bank, and the United States Agency for International Development (USAID) have all invested in LWSC, the White Plains Treatment Plant, or the transmission and distribution water infrastructure, these agencies had no immediate plans for the investments needed to achieve the outcomes in MCC's logic model.

The program logic makes two assumptions about sustainability of the sub-activity: (1) LWSC would conduct regular maintenance, and (2) LWSC could pay for electricity given the reduced cost of transmitting water, leveraging gravitational flow, and could use reallocation funds for O&M. These assumptions appear flawed given LWSC's poor record in maintaining donor-funded water infrastructure, and LWSC's financial challenges, which make it difficult to pay for operating expenses at the treatment plant. It is unclear how the sub-activity would help meet the objective of mitigated environmental and social risks of MCHPP or contribute to the goal of reduced poverty through economic growth.

B. Literature review

To situate the findings of the evaluation in the broader literature, we highlight some of the most recent evidence on water infrastructure projects including that (1) access to clean water is fundamental to well-being, (2) certain types of public water system investments are important to equitable outcomes, (3) utility companies require cost recovery and financing, (4) assets require funds for O&M, and (5) policy reform, for example for tariff setting and regulations, is necessary to achieve outcomes.

First, access to clean water is fundamental to basic well-being. Yet despite progress in improving water sources in many low- and middle-income countries, in 2020, one in four people globally (2 billion people) still did not have access to safe drinking water[1] (World Health Organization [WHO] 2022). Liberia lags many of its West African neighbors in providing access to quality water. As of 2015, only 4 percent of urban households in the country had access to piped water on premises. Water accessible through public sources is especially poor (WHO and UNICEF 2018). In addition, access to basic drinking water is inequitable: the richest households have nearly five times the rate of access as the poorest households (WHO and UNICEF 2017). In 2016, researchers selected a random sample of drinking water sources around Monrovia and found that the majority contained fecal indicator bacteria and 22 percent contained nitrates exceeding regulatory standards. They attributed the poor water quality in large part to the prevalence of pit latrines and open defecation in the city (Kumpel et al. 2016).

The literature suggests that increasing the quantity and quality of water through infrastructure improvements can lead to numerous benefits including better health and economic empowerment:

- **Health.** There is broad consensus that poor quality drinking water increases the risk of diarrheal disease (Wolf et al. 2014). Several studies provide evidence for the health benefits of closer and more reliable access to water sources. One systematic review found that improved water quality is associated with a 17 percent reduction in the risk of diarrheal disease (Cairncross et al. 2010). This protective effect has also been shown to extend to other conditions such as pneumonia (Hennessy et al. 2008), avian influenza (Dinh et al. 2006), and various respiratory illnesses in young children (Luby and Hadler 2008).
- **Economic empowerment.** Studies show that access to improved water sources can greatly increase economic well-being by reducing health care costs and improving time use. Because improved water sources prevent end users from becoming sick, they seek less health care and therefore save money and time. Additionally, time previously spent retrieving water (including time for traveling, waiting in line, and drawing water) can be reallocated towards more productive purposes. As such, the World Bank estimates that the annual economic benefits of improving water supply and sanitation can amount to 4.3 percent of GDP in sub-Saharan Africa (Hutton 2012). The same study concludes that the benefit of achieving universal piped water access can outweigh the costs by a factor of 2.8.
- **Environmental risk mitigation (through reduced water salinity).** The environmental consequences of excess salinity in the water supply are well documented. Excess salinity damages the soil, affects irrigation, stunts plant growth, and reduces agricultural yields (Shahid et al. 2018).

[1] WHO defines safe drinking water as a water source that is located on the household's premises, available when needed, and free from contamination.

Salinity in the water supply makes it more expensive to treat to make it suitable for human consumption. In this context, infrastructure improvements in LEC's water transmission pipeline have the potential to reduce environmental risks by reducing salt-water intrusion.

Second, evidence suggests that the effects of water infrastructure interventions depend greatly on the section of the water supply system that is targeted. For example, an analysis in Nairobi, Kenya, found "upstream" public water systems focused on large-scale supply and "downstream" systems focused on distribution and payment. They suggest the upstream interventions primarily benefited high-income customers and equitable water system investments require careful attention to downstream sub-systems (Blomkvist and Nilsson 2017). Notably MCC's investment is an "upstream" intervention that is unlikely to improve the downstream distribution network to ultimately reduce poverty and promote economic development.

Third and fourth, investment in new infrastructure is only part of what is needed to sustain water access. Montgomery et al. (2009) highlight three components of sustainability for water infrastructure in low- and middle-income countries: (1) effective community demand, (2) local financing and cost recovery, and (3) dynamic O&M. Accessibility of spare parts for the infrastructure is critical for dynamic O&M. However, local technicians must be coordinated and supported to operate and maintain assets. Allocating funds for monitoring and evaluation (M&E) to identify and diagnose issues in operations early can help make maintenance successful.

Finally, sector reforms are critical to achieve milestones like increasing piped water access to households (GIZ 2019). However, these reforms take a long time to implement. Sector reform processes in Zambia, Burkina Faso, Kenya, Uganda, and Tanzania took over a decade—and in some cases two decades—between the initiation of water policy reform and regular and publicly available reporting on utility performance. Socio-economic conditions and investment in the water sector can influence the performance of the water utility but, according to case studies, the key factors that influence performance are sound governance and competent management of the utility (GIZ 2019).

The evaluation of the White Plains water pipeline sub-activity adds to the evidence base on the impacts of improving water infrastructure in sub-Saharan Africa. In addition, we hope this report will provide useful information to guide LWSC management, Liberian policymakers, and donors about future investments in the water sector. We also identify general lessons for MCC on how to maximize the benefits from water infrastructure investments not only in Liberia but also in other countries.

C. Liberia Water and Sewer Corporation

The LWSC, a state-owned institution created in 1973, is the sole Liberian entity responsible for public water treatment and distribution. As part of this role, LWSC treats raw water flowing from the pipeline to the White Plains Treatment Plant and distributing downstream to customers in the greater Monrovia area. Despite having rapidly grown its customer base from approximately 6,500 customers in 2017 to 20,000 customers in 2020 (World Bank 2022), the utility is considered among the most poorly run government entities in Liberia and faces severe challenges related to financing, investments, and O&M (Front Page Africa 2021).

Many water utilities in Africa face challenges but LWSC's performance stands out as especially poor. Despite employing several times more staff per connection than the global and regional average, the average duration of water supply per day is 9.5 hours, nearly half of the African average of 20 hours (World Bank 2021). LWSC's rate of water loss (or non-revenue water [NRW]) is 79 percent, over twice as high as the average in Africa of 34 percent (World Bank 2021), and is a result of water theft, leakages, and billing issues. The issue of NRW contributes to the utility's low revenue, due to which staff have gone unpaid for months. Without pay and with corruption at public utilities common in Liberia, some staff resort to theft. One former employee was arrested for issuing fraudulent receipts and collecting money himself that should have gone to the utility (LWSC 2022). LWSC's low revenue has also impacted operations at the White Plains Treatment Plant, where there is a severe shortage of treatment chemicals, fuel to operate equipment and pumps, and funds to replace defective equipment and purchase tools. A performance contract with the Government of Liberia to improve LWSC's performance metrics was in effect between 2015 and 2018 but none of the targets set out in the contract were achieved.

Liberia's water network faces numerous challenges with vast sections of the transmission and distribution infrastructure outdated and in disrepair. These issues have resulted in leakages and breakdowns that impair consistent water supply to Monrovia (World Bank 2019). In February 2019, the 36-inch main transmission line that transports water from the treatment plant to Monrovia burst, cutting off water supply to the city for about a week. Leaks in the transmission network have also resulted in water supply being turned off in some areas, sometimes for over a month. The number of infrastructure-related service interruptions is likely to increase without the rehabilitation and modernization of the water infrastructure. In addition to these challenges, the distribution network is limited within LWSC's service areas in Monrovia, impeding the expansion of water supply and the utility's customer base. LWSC's financial constraints impede its ability to make the necessary upgrades and repairs to the infrastructure. To address these infrastructural challenges, the World Bank, African Development Bank, USAID, and other donors are investing in water network rehabilitation and expansion.

One of the issues complicating LWSC governance is that the utility plays a dual role as both the provider and the regulator. They set the tariff, creating a conflict of interest (World Bank 2021). Separating these two functions could enable more efficient operation of the utility. Additionally, accountability is limited as there is no Government of Liberia ministry to which LWSC reports. Accountability can also take place through less than official channels. For example, the previous President of Liberia, Ellen Johnson Sirleaf, had a direct connection to LWSC's water line and would often report outages herself if she could not access water in her home (World Bank 2022).

II. Evaluation Design

We conducted a performance evaluation, using pre-post analysis of quantitative data and ex-post thematic analysis of qualitative data, to assess implementation and whether the pipeline sub-activity achieved expected outcomes. We relied on quantitative data to examine if the pipeline sub-activity led to changes in the quantity, salinity, and reliability of water supplied to the water treatment plant. We conducted a document review to understand the context of LWSC, implementation, and outcomes; site visits to conduct interviews and observe the pipeline and treatment plant; and key informant interviews (KIIs) to understand stakeholder perceptions of implementation and outcomes. The evaluation also includes a recalculation of the economic rate of return (ERR) and updating the cost-benefit analysis.

A. Evaluation questions and methodology

1. Evaluation questions and approach

In Table II. 1, we summarize the evaluation questions, our approach to answering them, and the links to the program logic (shown in Figure II.1).

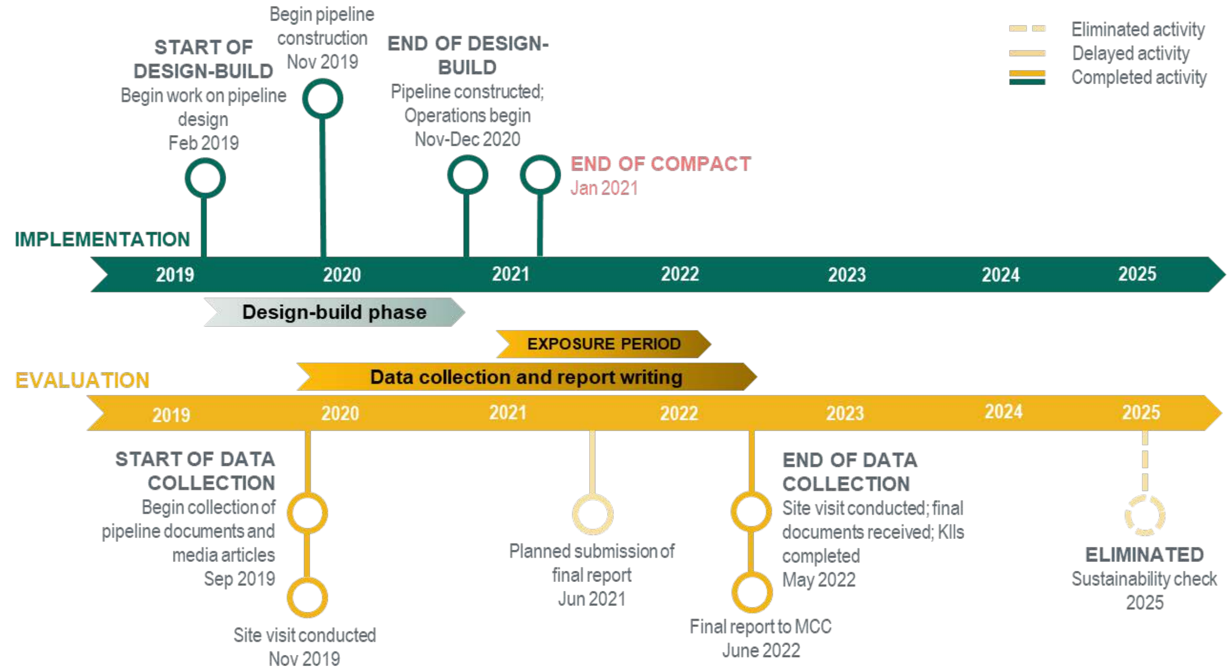
Table II.1. Overview of evaluation questions, evaluation approach, and link to program logic

Evaluation questions	Evaluation methodology	Link to program logic
1. Did implementation of the water pipeline sub-activity go according to plan?	Ex-post thematic analysis of the sub-activity's implementation using key informant interviews (KII), document reviews, and site visits	Program output
2. To what extent, if any, has the water pipeline increased the supply of water to the White Plains treatment plant, improved the reliability and quality of water supply, and reduced risks associated with salt-water intrusion?	Ex-post thematic analysis using document reviews, KIIs, and pre-post analysis of administrative data	Intermediate outcomes
3. Has the new pipeline design led to a reduction in electricity costs now that water is gravity fed at no cost?	Ex-post thematic analysis using document reviews and pre-post analysis of administrative data	
4. What is the status of the existing water network? To what extent can it accommodate the increased supply? Will the water pipeline improve the ability of LWSC to meet a growing demand for water?	Ex-post thematic analysis using KIIs and document reviews	Long-term outcomes
5. What is the cost-benefit analysis of the pipeline? (Recalculation and justification.)	Re-estimation of the ERR: Analysis of the model, with suggested revisions and justification	Cost-benefit analysis (not in program logic)
6. Is the asset being maintained?	Ex-post thematic analysis using document reviews and KIIs	Sustainability (assumption in program logic)

2. Changes to study design

The original evaluation design included a sustainability check in 2025 to assess the maintenance and sustainability of the pipeline activity. This sustainability check would contribute to evaluation questions 2, 3, 4, and 6. On January 20, 2022, MCC communicated their decision to change the evaluation plan because they felt that this report would satisfactorily address all the evaluation questions and subsequently eliminated the sustainability check from the design. Figure II.1 depicts these changes in study design.

Figure II.1. Implementation and evaluation timeline



3. Study timeline and exposure period

Data collection was originally planned for June 2021. However, given the COVID-19 pandemic and related travel restrictions, travel to Liberia to meet with LWSC staff, visit the White Plains Water Treatment Plant, and obtain all necessary administrative data from LWSC was paused. Due to these challenges, we completed data collection in May 2022.

The evaluation methodology aligns with MCC's theory of change, which assumes that the benefits from the sub-activity accrue immediately following completion of the sub-activity. The pipeline became operational in December 2020. We can measure short-term changes given that we collected administrative data spanning January 2020 to December 2021 and report a one-year exposure period (see Figure II.1).

B. Data sources and analysis

1. Data sources and analysis

We collected quantitative and qualitative data from various sources to answer the evaluation questions. In Table II.2, we provide details about each data source.[2]

Table II.2. Overview of data sources

Data type	Key content	Data source	Timing
Quantitative data			
Administrative data[a]	Examine trends in key outcomes before and after the pipeline became operational: • Capacity of the pipeline • Water flow (quantity, turbidity, salinity, outages) to the treatment plant, water salinity, etc. • Production of finished water at the treatment plant • End-user water consumption • Number of customers served by LWSC	• LWSC[3]	• LWSC data collected in January 2022 • LWSC data spans January 2020 to December 2021 (before and after the new pipeline became operational)
Qualitative data			
Key informant interviews (KIIs)	Stakeholder perspectives on: • Design and implementation of the pipeline, including successes and challenges • Implementation of the resettlement action plan (RAP) • Role of stakeholders in the sub-activity • Perception on project outcomes and costs • Sustainability of the pipeline	18 KIIs with: • MCC (3 KIIs) • MCA-Liberia (3) • Nicholas O'Dwyer (2) • Denys (1) • RAP consultant (1) • LWSC (7)[4] • World Bank (1)	• KIIs conducted from May 2021 to May 2022
Documents (project documentation, media articles, donor reports)	Information on: • Pipeline design • Progress reports and completion reports • Background and contextual factors on Liberia's water infrastructure and LWSC	Documents from: • MCC • MCA-Liberia • Denys • Nicholas O'Dwyer • World Bank	• Documents collected from late 2019 to May 2022

[2] The quantitative administrative data contained certain improbable figures that could not be verified and may be due to human record-keeping. We excluded this data from our analysis.
[3] As reported in the next chapter, LWSC does not maintain the pipeline per the O&M manual. This suggests that LWSC may not adequately calibrate and clean water testing equipment at the treatment facility, which can affect the accuracy of reported data. To mitigate this risk, we followed up with LWSC staff to confirm and provide context on findings observed in the administrative data.
[4] We held multiple iterative discussions with LWSC staff over the course of the evaluation.

Data type	Key content	Data source	Timing
Site visits	Observe implementation and operations at the water treatment plant Local perspective on project outcomes, pre-existing water infrastructure, challenges in operations and maintenance	Site visits to: • MCHPP • White Plains water treatment plant	• Site visits in November 2019 and April 2022

[a] We requested LWSC administrative data on electricity costs associated with transporting water to the plant. LWSC was unable to provide information. We relied on stakeholders' perspectives on how electricity costs changed at the water treatment plant due to the pipeline.

2. Cost-benefit analysis

MCC conducted a cost-benefit analysis using projected benefits and costs to estimate the ex-ante economic rate of return (ERR) for the water pipeline sub-activity. The ERR is a single metric that MCC uses to convey whether an investment's benefits are commensurate to costs. Projects must pass an ERR hurdle rate of 10 percent to be considered for investment. As part of this study, we used data collected from the evaluation to calculate an ex-post ERR by updating the parameters and assumptions MCC used in its ex-ante analysis. We also assessed the main assumptions underlying the original ERR model that led to our revised estimate.

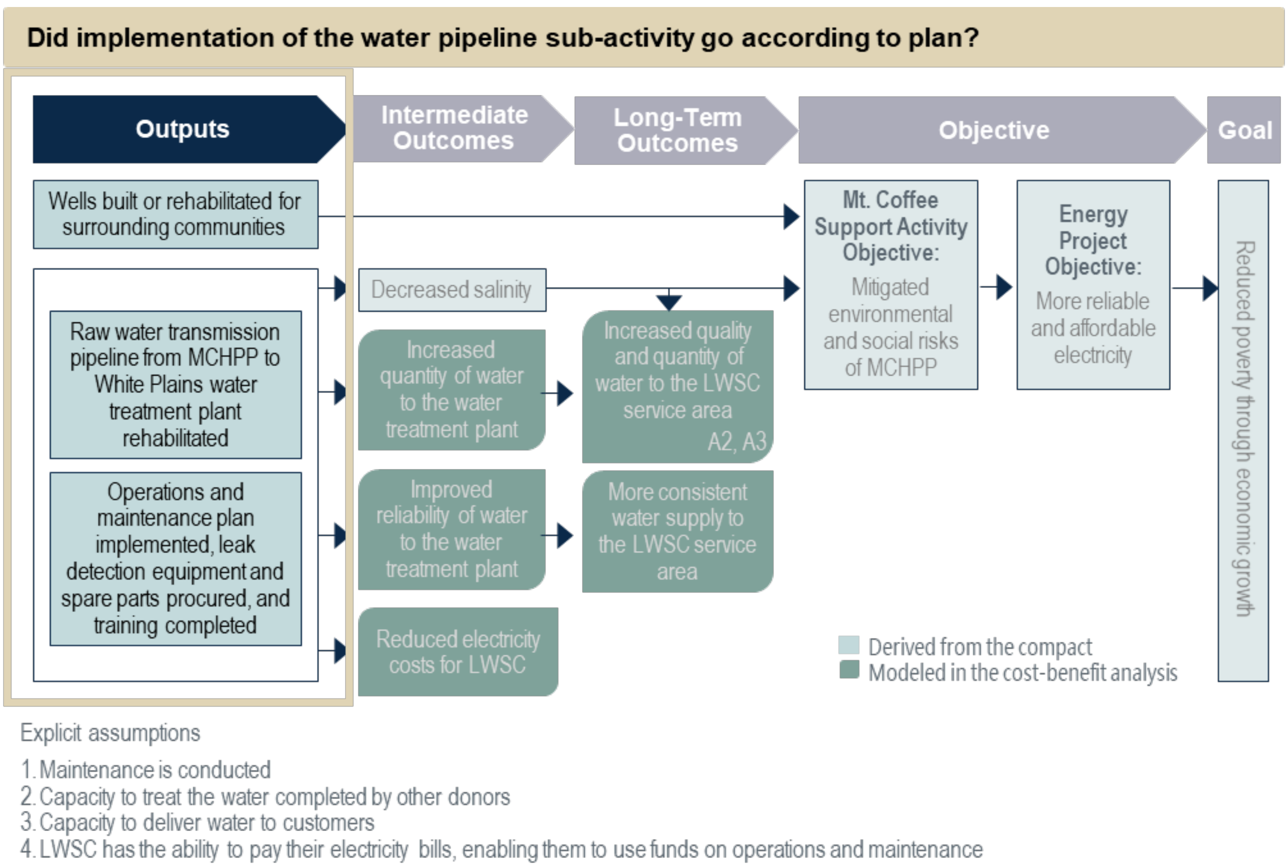
III. Findings from the Final Evaluation

Below, we organize findings into four key sections: pipeline implementation, project outcomes, cost-benefit analysis, and project sustainability. Each section begins with a summary of the key findings and an assessment of the relevant portion of the program logic.

A. Pipeline implementation

The pipeline sub-activity included (1) rehabilitation of a raw water transmission pipeline, (2) implementation of an O&M plan, (3) training of LWSC staff on O&M, (4) procurement of leak detection equipment and spare parts for the pipeline, and (5) construction or rehabilitation of wells in the communities surrounding MCHPP.

Figure III.1. Evaluation question and link to program outputs



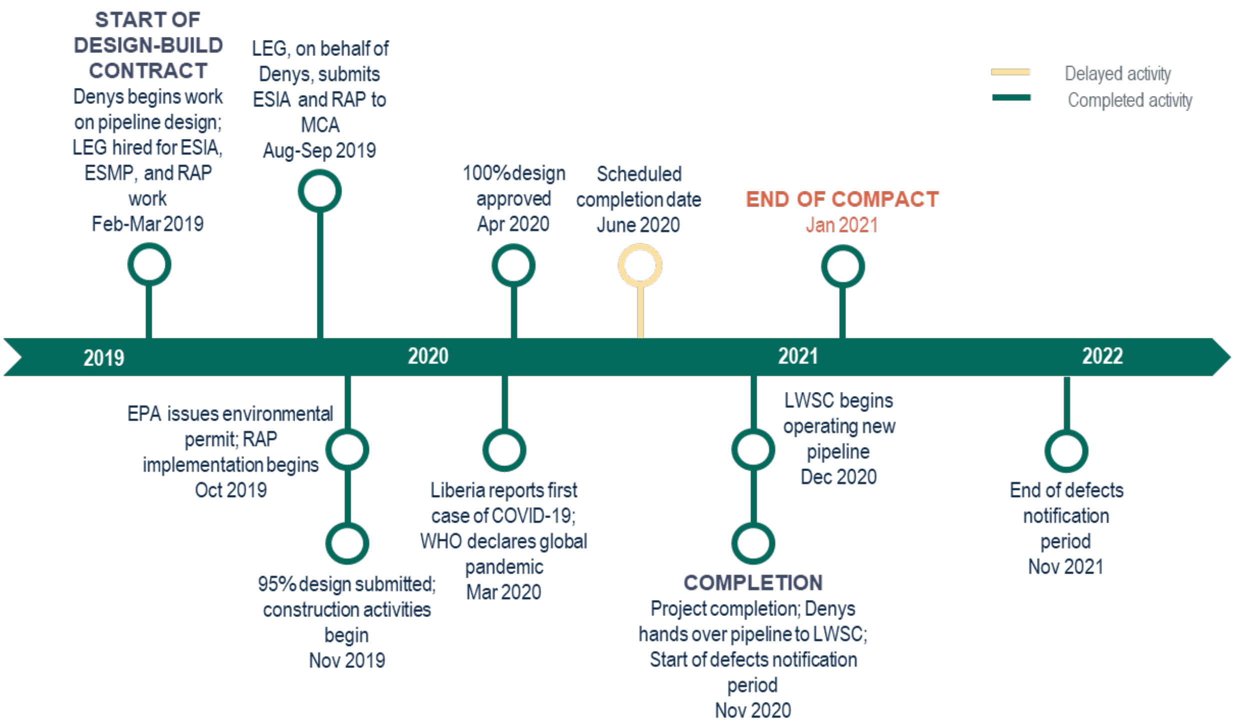
1. Implementation summary

The implementation of the pipeline sub-activity began in 2016 when MCA-Liberia hired a consulting firm, CH2M Hill, and an environmental specialist to conduct a feasibility study, perform an environmental and social impact assessment (ESIA), and develop an environmental and social management plan (ESMP) and a resettlement policy framework (a precursor to a resettlement action plan

[RAP]). In early 2019, following the completion of these deliverables, MCA-Liberia contracted Denys, an infrastructure construction firm, to design, build, and commission the pipeline that would transport raw water from MCHPP to the treatment plant. Denys' scope of work included an ESIA, ESMP, and RAP, which needed to be updated to comply with international practices and Liberian law. Nicholas O'Dwyer, an engineering firm, served as the Owner's Engineer to supervise Denys's work. MCA-Liberia was responsible for the overall implementation and management of the sub-activity, while MCC provided oversight and relied on the U.S. Army Corps of Engineers for technical reviews and support. Below, we summarize the design process, construction of the pipeline, preparation and implementation of the RAP, and handover of the asset to LWSC.

Figure III.2 highlights key implementation milestones.

Figure III.2. Key milestones in pipeline implementation



Note: LEG = Liberia Engineering and Geo-Tech Consultants; EPA = Environmental Protection Agency

Pipeline design. Denys hired Bergstan Africa, an engineering consultant, to serve as the designer of record and develop the pipeline design specifications. Denys and Bergstan conducted detailed site investigations in early 2019. They reviewed satellite images, the feasibility study, preliminary design, and topographic surveys and conducted site visits and stakeholder discussions to develop the pipeline technical specifications. The draft pipeline design report was submitted in June 2019 and the final design report was submitted in August 2019. Following stakeholder reviews (by Nicholas O'Dwyer, U.S. Army Corps of Engineers, MCC, and MCA-L) and subsequent revisions, various components of the design were approved by Nicholas O'Dwyer in November 2019. A final updated design report with construction drawings was approved in April 2020.

The Environmental and Social Impact Assessment (ESIA), Environmental and Social Management Plan (ESMP), and Resettlement Action Plan (RAP). Denys hired the Liberia Engineering and Geo-Tech Consultants (LEG) to conduct the ESIA, prepare the ESMP, and develop the RAP. LEG collected baseline environmental data and conducted field assessments, a document review, and discussions with community members, government officials, and the pipeline consultants (Denys, Nicholas O'Dwyer). LEG submitted the (1) ESIA, which assessed environmental and social impacts and recommended mitigation measures; (2) ESMP, to guide Denys in minimizing the environmental and social impacts of construction; and (3) RAP to compensate those financially affected by the pipeline. Denys also hired an environmental, health and safety consultant, to support the ESIA, ESMP, and RAP design and implementation. After extensive review and revisions, the ESIA report and RAP were submitted to Nicholas O'Dwyer in August 2019 and September 2019. Upon Nicholas O'Dwyer's approval, the documents were submitted to Liberia's Environmental Permit Authority, which issued the necessary environmental permit in October 2019.

Figure III.3. Finished pipeline segment

Source: Millennium Challenge Corporation

RAP implementation. LEG and the environmental consultant began RAP implementation in October 2019. The consultants implemented RAP activities while the pipeline design and construction were underway and completed this work in October 2020. As part of the RAP, farmers whose crops were affected by the pipeline or construction and landowners whose land was leased or acquired to serve as the permanent right-of-way were compensated. The implementation team also conducted financial management training for community members, organized a campaign to raise awareness about HIV/AIDs and malaria, constructed eight community wells with hand pumps, and rehabilitated two existing wells.

Pipeline construction. Denys set up offices at the water treatment plant, brought in construction equipment, and procured materials and ductile iron pipes from February to October 2019. While project startup was delayed due to the design process, RAP implementation, and procurement of clearances and permits, construction began slowly in November 2019 and was progressing at full pace by January 2020. Construction was completed by November 2020 with outstanding works expected during the subsequent defects notification period.

Pipeline handover to LWSC. Denys completed various tests of the pipeline, for example, water pressure tests, and prepared to officially transfer the pipeline to LWSC between September and November 2020. Denys developed an O&M manual, and subsequently conducted an O&M training for LEC and LWSC staff. The pipeline was officially transferred to LWSC ownership on November 24, 2020. Nearly a month after handover, LWSC began using the pipeline to transport water from MCHPP to the water treatment plant. The defects notification period began on the date of handover and expired November 23, 2021. During this period, Denys worked on the outstanding implementation items and resolved minor defects identified by the engineer during monthly inspections.

2. Implementation analysis

Did implementation of the water pipeline sub-activity go according to plan?

Key findings	Assessment of program logic
(+) The sub-activity was completed successfully, with stakeholders noting that the pipeline was built using high-quality materials and sound construction practices.	Program outputs achieved include the following: (+) The raw water transmission pipeline from MCHPP to the treatment plant was constructed.
(−) Implementation concluded in November 2020, about five months after scheduled completion. This was largely due to a slow design process, delays in preparing the resettlement action plan (RAP) and ESIA, COVID-related logistical challenges, and technical construction issues.	(+) (−) Maintenance equipment and spare parts were provided to LWSC and staff were trained on O&M. Note that LWSC faces challenges implementing the O&M plan (see Section 4) (+) Eight community wells were constructed; two existing wells were rehabilitated.

(+) = positive finding, (−) = negative finding

Most key program outputs were executed successfully, but LWSC has been unable to implement the pipeline's O&M plan. Nearly all program outputs were successfully implemented, including designing and constructing the raw water transmission pipeline from MCHPP to the treatment plant, providing LWSC equipment to detect leaks and spare parts to maintain the pipeline, developing an O&M plan and training LWSC staff, and constructing and rehabilitating community wells near the treatment plant. The sub-activity also included implementing the pipeline's O&M plan to maintain the pipeline system. LWSC staff report that maintenance activities such as regular inspections of the pipeline components and leak detection tests are not being performed in compliance with the O&M plan because LWSC's management does not sufficiently prioritize pipeline maintenance. Hence, LWSC has not designated staff to conduct maintenance activities. In addition, the utility has been unable to procure replacement parts for the pipeline and conduct repairs (covered in further detail in Section 4).

A long communication chain, slow response by Denys, and a redesign of some pipeline components delayed the design process. The project's circuitous chain of communication led to delays in finalizing the pipeline design specifications. Stakeholders report that feedback and responses on design had to be communicated through a chain of command, from Denys and its consultants to Nicholas O'Dwyer, followed by MCA-Liberia, MCC, and the U.S. Army Corps of Engineers. There was no direct communication between MCC and Denys or Nicholas O'Dwyer. MCA-L tried to overcome this issue by coordinating on feedback and responses between MCC and other implementation stakeholders, but more direct communication between the contractors and MCC might have enabled swifter resolution of design issues. Some stakeholders also noted that Denys was particularly slow in responding to feedback and did not deliver documents on time, which slowed the process. LEC objected to some design specifications during the final design conference, and it was decided that some portions required full redesign.

"With the benefit of hindsight, there should have been more direct communication, such as meetings, to resolve issues. MCA did an excellent job of channeling communication through to MCC and consultants. Because of course we formally had no direct line of communication with MCC or their consultants."◢

The resettlement plan was completed successfully despite challenges in preparing the RAP and ESIA documents and establishing land ownership. Stakeholders noted that LEG's ESIA and design of the RAP, Denys' management of RAP implementation, and Nicholas O'Dwyer's supervision did not meet expectations. First, stakeholders reported that the RAP and ESIA documents submitted by LEG were of poor quality, with both deliverables receiving extensive negative feedback from stakeholders. For example, one stakeholder noted that some of the submitted materials were not tailored to the pipeline and the Liberian environmental and legal context and did not meet MCC's requirements. Due to these quality issues, the deliverables required extensive revisions, with MCC stepping in to rewrite large sections of both documents. Given these issues, MCC recommended that Denys bring on an environmental consultant who had previously worked on the RAP for the rehabilitation of Mt. Coffee (Activity 1), and stakeholders noted that RAP implementation improved thereafter. Second, in addition to report issues, the implementation team faced challenges in disbursing compensatory payments to some project-affected landowners as they lacked legal documentation (for example, property deeds or title) to prove land ownership, while in other cases fake deeds were used to claim compensation payments. To overcome these issues, the team had to work extensively with community leaders and landowners to establish land ownership.

"This (RAP design and implementation) was the weakest point of work in general. The quality of material produced by the consultants was not very good initially. They also created expectations in communities around the pipeline for wells and access to water that ultimately needed to be managed. This led to the construction of wells."◢

The pipeline was built using high-quality materials and sound construction practices. Nearly all stakeholders reported that Denys' materials and practices were high quality. Nicholas O'Dwyer's onsite staff and quality assurance processes included regular monitoring and quality control tests that Denys conducted. Stakeholders noted that MCA-L managed the construction work effectively and both Denys and Nicholas O'Dwyer benefitted from MCA-L's leadership in coordinating and resolving construction-related issues.

LWSC's involvement in implementation was weak and limited. Senior LWSC management participated in the pipeline design process but provided minimal input on most aspects of the design. Mid-level technical staff from the treatment plant were included late in the design process, but report that their feedback was not incorporated into the design, which later had implications for pipeline O&M. For example, LWSC staff members suggested designing the pipeline with a solar-powered flowmeter instead of an electricity-powered meter, but MCA-Liberia did not accept this suggestion to avoid redesigning components and further delays. However, since the pipeline became operational in late 2020, LWSC staff have reported that they are unable to measure water and estimate the quantity of chemicals required for treatment during power outages, a frequent occurrence in Liberia. Most stakeholders noted that LWSC was not adequately involved in the construction stage of implementation. LWSC's limited participation in this process was due to the utility's financial situation, which constrained the appropriate utility staff from commuting to the treatment plant and limited access to computers and communication equipment. Some stakeholders felt that LWSC staff did not gain sufficient first-hand knowledge of the pipeline system during the construction phase, and this may potentially hamper its ability to conduct repairs and maintenance in the future.

Pipeline construction took longer than expected due primarily to the COVID-19 pandemic. The pipeline was commissioned and LWSC took ownership in November 2020, about five months after the expected date of completion. Construction work was postponed by delays in pipeline design and RAP completion, long communication and approval processes, the COVID-19 pandemic, and unanticipated construction issues. For example, COVID-19 presented both logistical and supply-chain challenges. While Denys implemented a risk mitigation plan based on MCC's official guidance, allowing the site to remain open and free of outbreaks, materials and equipment procured from across Europe were delayed given national and transportation shutdowns and closures. Further travel restrictions prevented construction staff from Cote D'Ivoire from entering Liberia as well MCC and the U.S. Army Corps of Engineers staff. MCC relied on Nicholas O'Dwyer's documents, photos, and video footage and email and virtual meetings to review progress and provide feedback. Additionally, Denys had to clear large and unexpected quantities of rock along sections of the pipeline route, which eventually required hydraulic rock splitters. Also, some worksites were flooded during construction due to a sudden increase in the discharge of overflow water from MCHPP.

The pipeline cost more than originally planned. As mentioned in Chapter I, the pipeline budget increased from $13.4 million to about $17 million because MCC decided to expand the original 900 mm pipe design to 1,200 mm so that the pipeline could meet a growing demand for water in Monrovia. Second, the initial estimate did not include adequate funds for preparing and implementing the RAP or contingency funds to deal with unexpected issues during implementation. Further, issues with contractor performance increased costs. MCA-L had first hired CH2M Hill (an engineering firm now known as Jacobs Engineering Group), to conduct a pre-feasibility study and work on the ESIA and resettlement policy framework. These deliverables did not meet Liberia EPA standards and the work had to be redone and included in Denys' scope of work.

B. Project outcomes

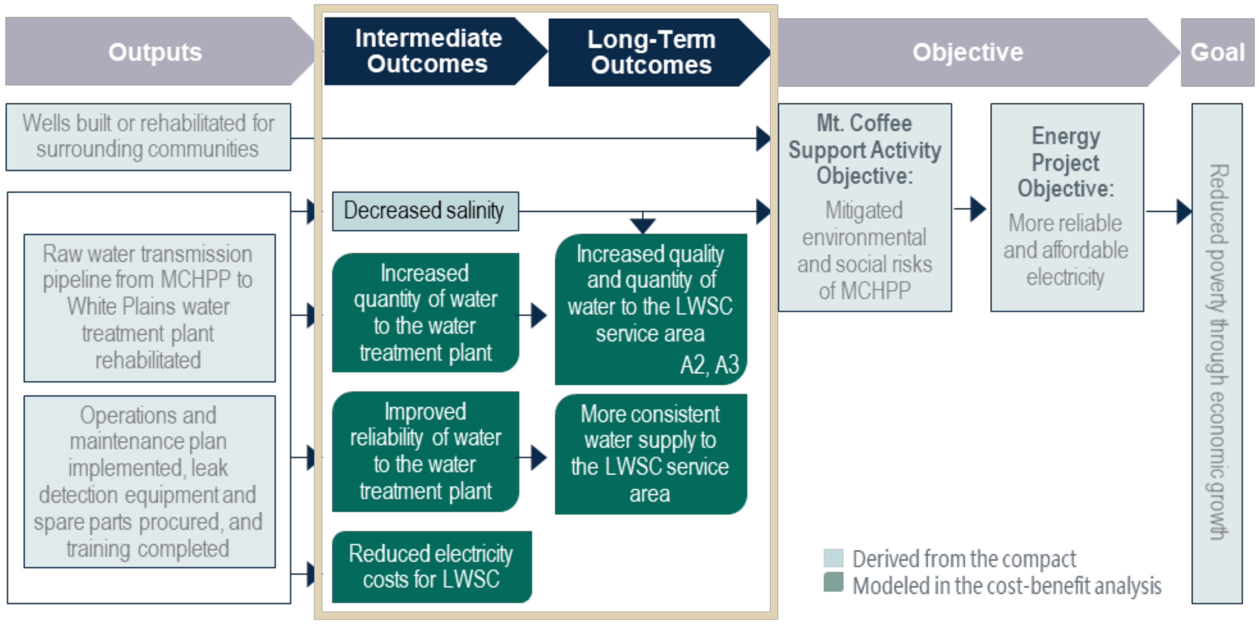
The pipeline program logic suggests that the pipeline increases water supply to the treatment plant, improves water supply reliability and quality, and reduces salt-water intrusion. The gravity-fed design reduces electricity costs associated with transporting water to the treatment plant. Long term, these raw water supply improvements increase the quantity, quality, and reliability of water supply to customers in Monrovia.

Figure III.4. Evaluation questions and link to intermediate and long-term outcomes

To what extent, if any, has the water pipeline increased the supply of water to the White Plains treatment plant, improved the reliability and quality of water supply, and reduced risks associated with salt-water intrusion?

Has the new pipeline design led to a reduction in electricity costs now that water is gravity fed at no cost?

What is the status of the existing water network? To what extent can it accommodate the increased supply? Will the water pipeline improve the ability of LWSC to meet a growing demand for water?



Explicit assumptions

1. Maintenance is conducted
2. **Capacity to treat the water completed by other donors**
3. **Capacity to deliver water to customers**
4. LWSC has the ability to pay their electricity bills, enabling them to use funds on operations and maintenance

Implicit assumptions

1. **The amount of raw water supplied to the treatment plant is a limiting constraint to increasing treated water supply to LWSC's service areas in Monrovia.**
2. **The gravity-fed pipeline design removes dependence on fuel and grid electricity for transporting raw water to the treatment plant and improves reliability of raw water supply.**
3. **The pipeline's upstream intake point will reduce risk of salt-water intrusion from the ocean.**
4. **Raw water turbidity will decrease as sediments settle down at MCHPP reservoir.**

1. Findings on quantity, reliability, and quality of water supply; salt-water intrusion in raw water

To what extent, if any, has the water pipeline increased the supply of water to the White Plains treatment plant, improved the reliability and quality of water supply, and reduced risks associated with salt-water intrusion?

Implicit assumptions in program logic:

- The amount of raw water supplied to the treatment plant is a limiting constraint to increasing treated water supply to LWSC's service areas in Monrovia.
- The gravity-fed pipeline design removes dependence on fuel and grid electricity for transporting raw water to the treatment plant and improves reliability of raw water supply.
- The pipeline's upstream intake point will reduce risk of salt-water intrusion from the ocean.
- Raw water turbidity will decrease as sediments settle down at MCHPP reservoir.

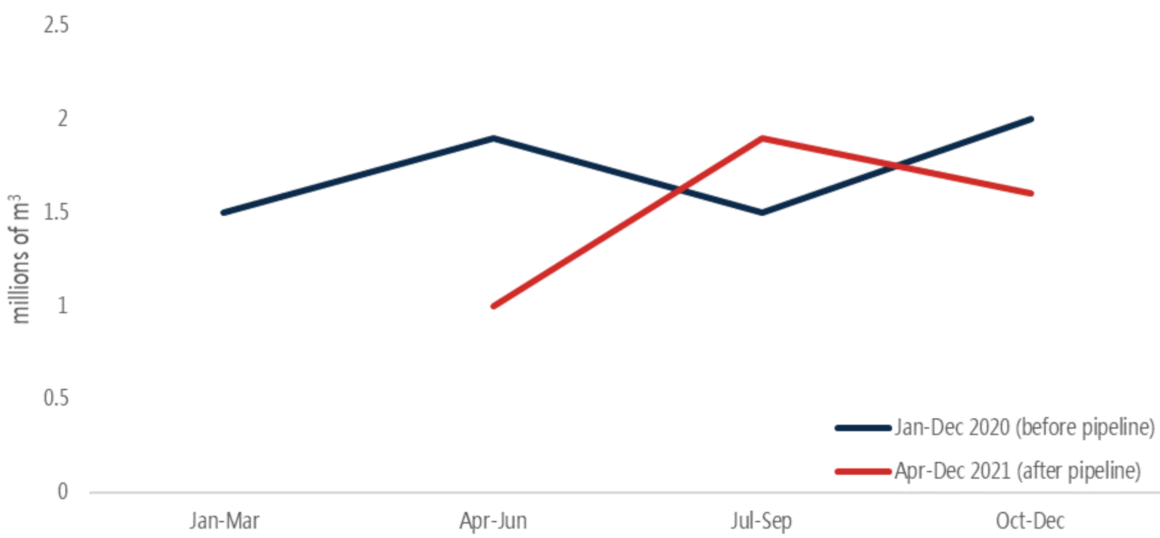
Key findings	Assessment of program logic
(−) The supply of raw water to the treatment plant has not changed substantively. LWSC limits water intake from the pipeline due to operational constraints and limited capacity to process additional raw water at the treatment plant.	(−) Intermediate outcome of increased raw water supply to the treatment plant is yet to be realized as LWSC does not utilize the full capacity of the pipeline. Raw water supply is not a primary limiting constraint at the treatment plant.
(+) The number of outages in raw water transmission to the treatment plant reduced from about seven per month to zero, which improved the reliability of raw water supply.	(+) Improved reliability of raw water supply has been achieved. Gravity-fed pipeline eliminates electricity-related transmission outages in raw water supply.
(−) LWSC data do not show changes in salinity of raw water as there were no instances of salt-water intrusion related to dry season conditions during the study period. However, (+) LWSC and other stakeholders indicate that the pipeline can prevent increases in raw water salinity if salt-water intrusion events occur in future dry seasons.	(~) Program logic on decreased water salinity due to upstream location of pipeline's intake point cannot be assessed as ocean-based salt-water intrusion occurs sporadically and was not observed in the data during the study period (January 2020 to December 2021).
(−) Raw water turbidity increased after the pipeline, in the latter months of 2021, due to rainy season storms and floods and LWSC not draining the pipeline of sediments towards the end of each year of operations as per the O&M plan.	(−) Pipeline's intake location below the MCHPP reservoir does not reduce turbidity in raw water supply.

(+) = positive finding, (−) = negative finding, (~) = could not be assessed

There were no changes in the quantity of raw water supply; LWSC restricted water intake from the pipeline due to inadequate capacity at the treatment plant to process additional quantities of raw water. The pipeline was designed to have a diameter of 1,200 mm and deliver a flow of 0.9

m^3/second to 1.2 m^3/second, against the pre-war pipeline's flow capacity of 0.9 m^3/s and the treatment plant's prevailing capacity of 0.03 m^3/s. Given the pipeline's larger capacity, the sub-activity was supposed to increase the quantity of water supplied to the treatment plant. Yet, administrative data on quarterly measures of water flow to the treatment plant show no significant change in water supply due to the pipeline (see Figure III.5). Between January and December 2020, the average quantity of water supplied to the treatment plant was 1.7 million m^3 per quarter, versus 1.5 million m^3 per quarter after the pipeline was utilized. LWSC staff indicate that supply through the pipeline is actively restricted due to operational constraints such as scarcity of treatment chemicals, power outages, and limited operating hours at the treatment plant, which hinder treatment of additional quantities of raw water. As such, the pipeline's flow capacity is currently underutilized at the treatment plant, suggesting that the program logic and the pipeline investment did not sufficiently address the underlying causes of low water supply.

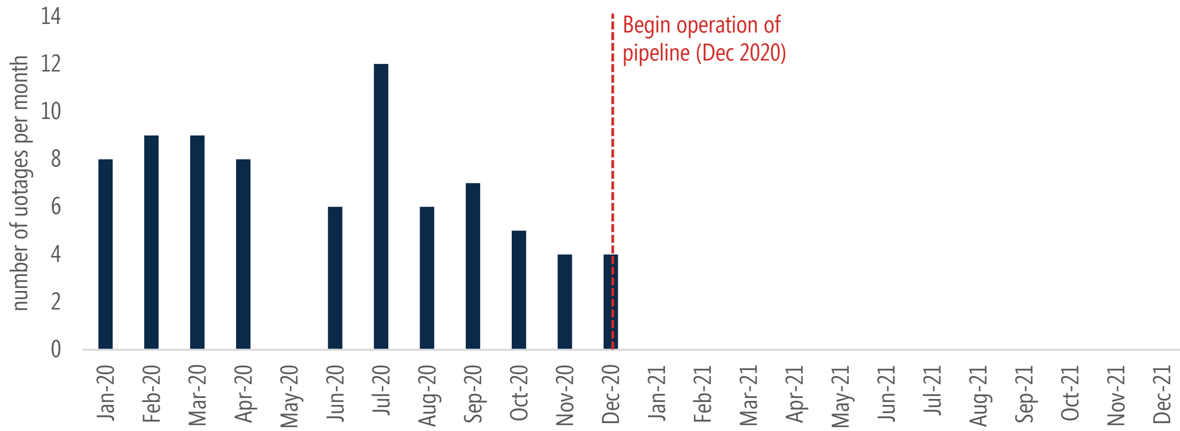
Figure III.5. Water flow to the treatment plant, before and after the pipeline



Note: We do not report on data for January–March 2021 as the figure does not accurately capture water flow to the treatment plant through the pipeline.

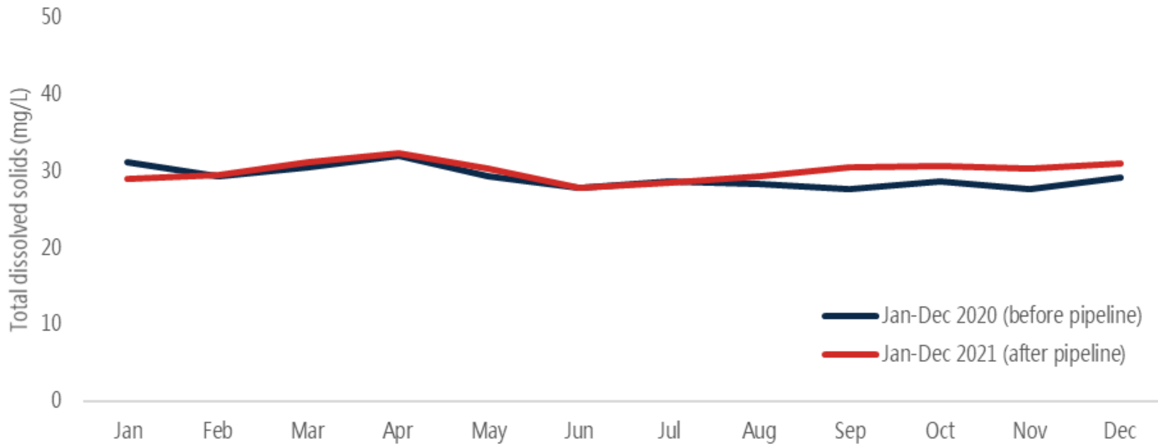
The pipeline improved the reliability of water supply to the treatment plant, with the average number of transmission outages falling from about seven per month to zero. Prior to the pipeline, LWSC relied on an electric pump system to transport water from the St. Paul River to the treatment plant. Powered by electricity, the system was prone to interruptions when grid electricity or fuel was unavailable. The gravity-fed pipeline design was expected to mitigate this problem by reducing the need for constant power supply. Between January and December 2020, LWSC reported an average of nearly seven outages per month in water supply to the treatment plant. These outages typically lasted a few hours and were primarily due to electricity outages that prevented pumping of water to the treatment plant. In contrast, there have been no outages in water supply to the treatment plant since the pipeline became operational in December 2020 (see Figure III.6). LWSC staff also note that the most substantial benefit of the pipeline is the increased reliability of water supply to the treatment plant.

Figure III.6. Number of outages per month in water flow to the treatment plant, before and after the pipeline



Data show minimal variation in raw water salinity; LWSC and other stakeholders report that the pipeline could decrease salt-water intrusion during the dry season. LWSC had historically reported sporadic instances of saltwater intrusion in raw water supply during the dry season from December to April. These intrusions occurred due to high tides and low water flow in the St. Paul River, which allowed saltwater to enter the river and move upstream. As the treatment plant originally drew from a river intake point about 20 kilometers upstream of the ocean estuary, high levels of raw water salinity occurred when ocean-based salt-water intrusion took place. The new pipeline intake is located about 4.7 kilometers further upstream from the treatment plant at MCHPP and about 20 meters above sea level to reduce this risk. To assess this outcome, we studied monthly maximum values of total dissolved solids (TDS) in raw water supplied to the treatment plant between January 2020 and December 2021. Figure III.7 illustrates that the monthly maximum TDS values were generally around 30 mg/L, well within the water salinity standard set by the World Health Organization (WHO) (600 mg/L), indicating that salt-water intrusion does not appear to be a major risk to the quality of raw water supply. There were also minimal changes in water salinity during this two-year period. LWSC staff explained that there have been no instances of salt-water intrusion since 2019, possibly due to above average rainfall during the dry season, which prevented salt-water from the ocean moving upstream of the St. Paul River. As such, we are unable to detect whether the pipeline reduced the risk of salt-water intrusion. However, LWSC and other stakeholders believe that the pipeline would likely prevent any future instances of salt-water intrusion as envisioned in the program logic.

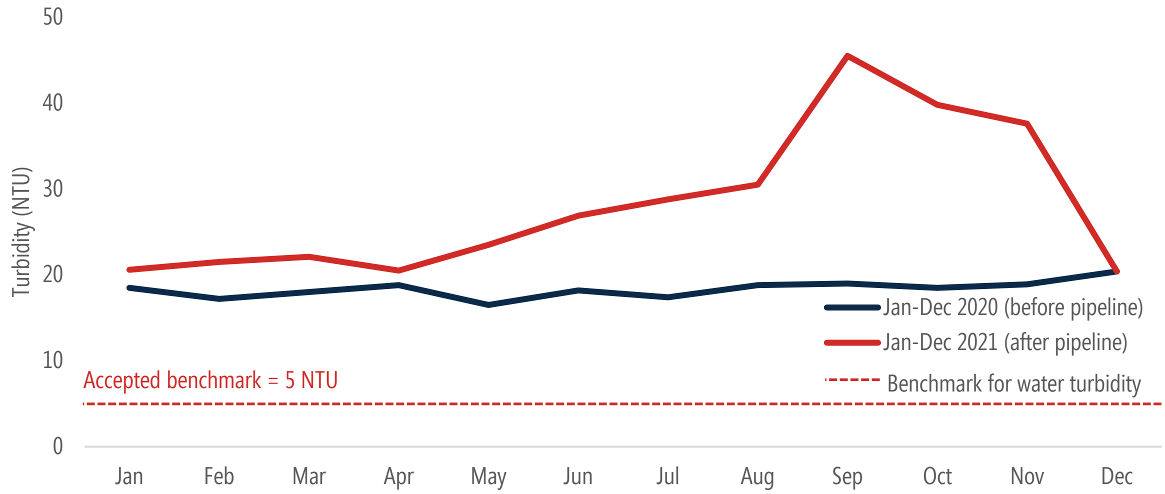
Figure III.7. Salinity of water flow to the treatment plant, before and after the pipeline



The pipeline did not reduce raw water turbidity. Turbidity is the presence of solid particles in water and can indicate the presence of harmful chemical and microbial contaminants. Nearby mining activities and rainy season storms and floods raise the raw water turbidity, creating challenges for water treatment. The pipeline aimed to alleviate this issue as sediments were expected to settle at the MCHPP reservoir prior to reaching the pipeline inlet, and as a result improve the quality of raw water. Figure III.8 shows that monthly maximum values for raw water turbidity increased after the pipeline was operationalized in December 2020, with turbidity levels well above the accepted benchmark of 5 Nephelometric Turbidity unit (NTU).[5] Maximum turbidity levels spiked sharply during the rainy season months from May to November 2021. LWSC staff explain that periods of unusually high rainfall kicked up sediments and increased raw water turbidity during this period. Additionally, transmitted raw water mixed with sediments accumulated at the bottom of the pipeline as LWSC did not flush the pipeline of sediments towards the end of 2021. The O&M plan states that the pipeline should be flushed annually. This resulted in the higher monthly maximum values observed towards the end of the rainy season of 2021. LWSC staff also report that such high turbidity levels in raw water necessitate the use of large amounts of treatment chemicals (for example, aluminum sulphate), which is particularly challenging for the resource-constrained utility.

[5] These data are based on measurements of turbidity in raw water samples collected from the pipeline's flow meter. LWSC also tests water samples from upstream of the St. Paul river, close to the intake point at MCHPP, regularly. LWSC staff report that these tests show that turbidity at the intake point is similar to turbidity levels observed after raw water enters the pipeline. However, we did not receive this data and were unable to independently verify this information.

Figure III.8. Turbidity of water flow to the treatment plant, before and after the pipeline



2. Findings on electricity costs

Has the new pipeline design led to a reduction in electricity costs now that water is gravity fed at no cost?

Implicit assumption in program logic: Gravity-fed design of pipeline reduces electricity costs for the treatment plant.

Key findings	Assessment of program logic
+ LWSC staff report a reduction in electricity costs at the treatment plant.	+ Intermediate outcome of reduced electricity costs at the treatment plant realized.

+ = positive finding

LWSC staff indicate that the gravity-flow design of the pipeline has reduced electricity costs. The pipeline was designed to supply water through gravity flow and replace the pump system. As LWSC was unable to provide electricity usage and cost data, we could not quantify the savings. However, LWSC staff confirm that the pipeline transports water at no cost, reducing the plant's electricity usage, potentially saving the utility up to $780,000 per year (Afrik21 2019). As discussed in Chapter I, LWSC faces severe financial constraints. The utility is unable to pay its electricity bills, and instead relies on a Ministry of Finance and LEC agreement to use grid electricity at the treatment plant. Because the flow meter used to measure the raw water supply is powered by electricity, LWSC staff cannot measure water flow, and consequently estimate the amount of treatment chemicals required to process water during LEC outages.

3. Findings on the water network and increasing water supply to LWSC service areas

What is the status of the existing water network? To what extent can it accommodate the increased supply? Will the water pipeline improve the ability of LWSC to meet a growing demand for water?

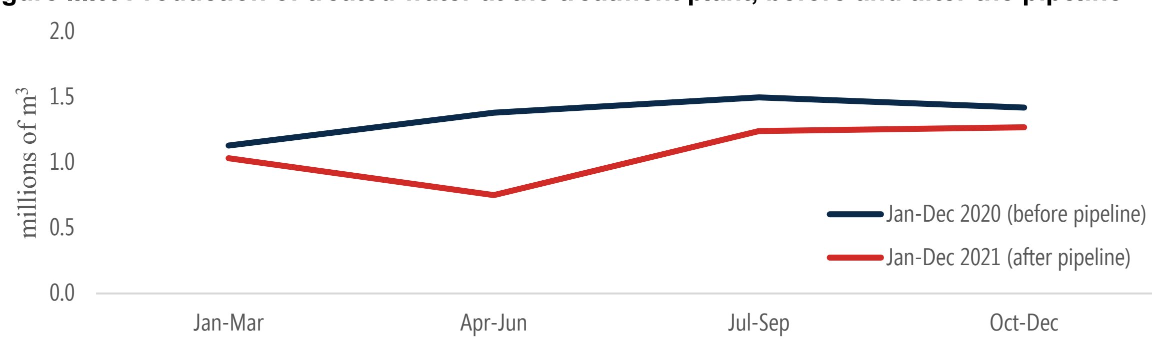
Explicit assumptions in program logic:

- Capacity to treat the water completed by donors.
- There is capacity to deliver water to customers.

Key findings	Assessment of program logic
(−) The pipeline has not increased the quantity and consistency of treated water supply to LWSC service areas. Findings on water quality are mixed, as data show a decrease in treated water turbidity and an increase in water salinity	(−) Long-term outcomes in the program logic related to the quantity and quality of treated water supply to LWSC service areas have not been realized.
(−) Large segments of Liberia's water network are old and decrepit. Significant investments are needed to modernize the downstream infrastructure and accommodate increased water supply from the treatment plant.	(+) (−) Donors have upgraded the treatment capacity of the plant but there is inadequate funding for treatment operations at the White Plains facility.
(−) Although the pipeline potentially increases LWSC's access to raw water, the treatment plant faces significant operational challenges that hinder the production and supply of treated water supply.	(−) LWSC lacks the infrastructural, operational, and financial capacity to increase water supply to customers.

(+) = positive finding, (−) = negative finding

Figure III.9. Production of treated water at the treatment plant, before and after the pipeline



Long-term outcomes such as increased quantity and improved consistency of water supply to LWSC service areas have not happened; water salinity has increased marginally, while turbidity levels have dropped. As seen in Figure III.9, there have not been meaningful changes in the production of treated water (intended for supply to customers in Monrovia) between January 2020 and December

2021 (1.3 million m^3 in 2020 versus 1 million m^3 in 2021).[6] These data are consistent with the lack of changes in raw water supply to the treatment plant during this period. Again, monthly maximum values for water salinity increased slightly in 2021 although this is still well below the accepted benchmark of 600 mg/L. LWSC staff attribute the increase to issues in treating water salinity at the treatment plant. We observed improvements in the monthly *maximum* turbidity of treated water, which dropped from the 2021 level. This result is inconsistent with the findings on the turbidity of raw water, which worsened after the pipeline became operational, indicating that the improvement in water turbidity is likely due to other operational factors at the treatment plant. While we do not have data on transmission outages, documents, news articles, and stakeholder perspectives suggest that customers in Monrovia continue to experience service interruptions, due to infrastructural and operational challenges faced by LWSC.

Liberia's water network requires rehabilitation and upgrades to increase access to water supply and improve service delivery to customers. MCC's program logic theorized that the project's intermediate outcomes, if realized, would increase the quantity and quality of water supply to customers, as well as provide more consistent water supply in LWSC's service areas in the long term. This logic depended on a couple of assumptions, including LWSC's capacity to deliver water to customers. As described previously, vast portions of the water network are outdated and in disrepair. These issues have resulted in leakages and breakdowns that impair consistent water supply to Monrovia (World Bank 2019). Additionally, the limited reach of the distribution network impedes the expansion of water supply and the utility's customer base (see Figure III.8). Although donors like the World Bank, African Development Bank, and USAID are investing in water network rehabilitation and expansion, the water network needs significant additional investments to modernize the infrastructure and ensure that LWSC has sufficient infrastructure capabilities to accommodate potential increases in water supply from the treatment plant.

LWSC's financial challenges constrain operations at the treatment plant and risks achievement of outcomes. The long-term outcomes set out in the program logic also depended on the assumption that donors would provide the capacity to treat raw water and LWSC would be able to pay electricity bills. However, these assumptions have not fully come to fruition and MCC may have underestimated the consequent risks to the program logic. Despite donor-funded upgrades to the treatment plant's infrastructure, stakeholders report that LWSC produces treated water at 25 percent of the plant's capacity. This is partly because LWSC does not have adequate financial resources to procure chemicals for treating water at the treatment plant. LWSC staff report that the equipment to supply chlorine for water treatment is damaged, necessitating manual dosing of the chemical. LWSC has sometimes paused water supply to Monrovia for a week or more due to inadequate funding for purchasing treatment chemicals, which in turn negatively affects their revenue. Staff are not provided the tools needed to do their jobs and often use their own personal funds to purchase gear required for work. Stakeholders also report that several pieces of equipment that were upgraded through donor investments, including circulators and pumps, are not functioning properly due to poor maintenance. LWSC lacks the financial resources to upgrade the faulty equipment and procure adequate chemicals. Additionally, LWSC faces financial challenges in procuring fuel for generators to

> "Some assumptions from MCC were a little off, especially about challenges and outcomes. Most people agreed that the raw water pipeline was important and necessary, but it is only part of the process. It is a lot more important to make sure that water gets to the people. Some LWSC staff were careful in describing places where design could have been somewhat better and were frank about challenges. And the thinking around sustainability could have been better."◢

[6] The production of treated water was slightly lower in 2021, particularly in the second quarter of the year, as the treatment plant had inadequate chemicals and fuel for treatment of raw water.

conduct operations during the dry season and when there are outages in LEC current. Although the World Bank has previously supported the treatment plant's operational expenses, currently there is no dedicated funding stream to enable smooth operations at the treatment plant. Therefore, while the pipeline can potentially increase raw water supply, LWSC's limited financial capacity constrains the achievement of long-term outcomes in the program logic.

C. Cost-benefit analysis

We conducted a cost-benefit analysis (CBA) of the water pipeline to estimate the extent to which the project's benefits were commensurate with its costs. We updated MCC's ex-ante CBA, with revised estimates of costs and benefits using findings from our evaluation. We found that the water pipeline had **a net present value (NPV) of negative $12,216,505 and an economic rate of return (ERR) of negative 18 percent.** This NPV and ERR are substantially lower than MCC's original estimates of positive $5,481,675 and positive 17 percent, mostly because the primary benefit stream of increased water consumption did not materialize.

1. The CBA model

We used MCC's ex-ante CBA model, which identified the primary pipeline beneficiaries as LWSC customers who were expected to benefit from increased water to the treatment plant and receive more reliable water supply. The primary benefit stream is the increase in these customers' water consumption resulting from the new pipeline. We valued water consumption using a consumer surplus approach relying on a willingness to pay estimate of $0.65 per m^3 from Ayslbat et al. (2013), and tariffs of $0.1 per m^3 of water in Monrovia. The model includes the cost of pumping water to the treatment plant, water treatment, supplying water to consumers, and MCC's initial investment. Net benefits are calculated by comparing the total benefits and costs under two scenarios: the expected outcomes with and without the pipeline. These net benefits are calculated over a 20-year period, as is customary for MCC investments.

Table III.1 shows MCC's original costs and benefits forecast before construction alongside our revised estimates based on the evaluation. Our NPV and ERR estimates are negative and substantially lower than the original forecast for the following reasons:

- **The primary benefit stream of increased water consumption envisioned in the original forecast did not materialize**. MCC expected that LWSC customer water consumption would increase by more than double its baseline level, from 5.52 million to 17 million cubic meters per year. We found no evidence that this happened—there was no detectable increase in water transmission to customers after pipeline construction. Consumption would have needed to increase by about 10 million cubic meters per year for the project to have cleared MCC's ERR hurdle rate of 10 percent.
- **While the new pipeline eliminated the costs of pumping raw water into the water treatment plant as envisioned, this improvement was small relative to the costs of the overall investment**. LWSC no longer incurs the costs of pumping water into the water treatment plant because the raw water is now gravity fed. However, these cost savings are minimal compared to the overall costs of the investment, and other costs to operate the water treatment plant and supply the water to customers did not change.
- **The cost of new pipeline construction was 25 percent higher than expected.** Based on the feasibility design, MCC expected to invest $13.4 million, but actual costs were $18 million.

Our CBA indicates that the project had overoptimistic assumptions about its impact without other investments in the transmission and distribution infrastructure and operational capacity.

Table III.1. Parameter values in MCC's pre-investment CBA and Mathematica's CBA

Outcomes	Expected value based on MCC's pre-investment forecast		Actual value based on evaluation findings
	Without project	With project	With project
Benefits			
Amount of water supplied to consumers in Monrovia	5.52 million m^3 per year	17 million m^3 per year	5.52 million m^3 per year
Costs			
Pumping water to treatment plant	0.025 USD per m^3	0 USD per m^3	0 USD per m^3
Water treatment	0.02 USD per m^3	0.02 USD per m^3	0.02 USD per m^3
Supplying water to Monrovia	0.04 USD per m^3	0.08 USD per m^3	0.04 USD per m^3
MCC investment costs	USD 0 million	USD 13.4 million USD	USD 18 million

Source: MCC ex-ante CBA calculations and authors' calculations.

Notes: In the CBA, the increased amount of water consumed is valued using a consumer surplus approach relying on a willingness to pay estimate of $0.65 per m^3 from Ayslbat et al. (2013), and tariffs of $0.1 per m^3 of water in Monrovia. We do not have an exact value for the cost of supplying water to Monrovia from the evaluation, but we estimate this would remain unchanged from the scenario without the project because the pipeline did not increase or decrease the amount of water supplied to customers.

D. Project sustainability

In this section, we provide an overview of the O&M plan, assess the extent to which maintenance activities are being conducted, and identify the key risks to project sustainability.

Is the asset being maintained?

Explicit assumptions in the program logic: Maintenance will be conducted; LWSC can use funds saved from the reduction in electricity costs for operations and maintenance

Key findings	Assessment of program logic
⊖ Both technical and non-technical components of the pipeline are not being maintained. LWSC staff have not conducted regular inspections, tests, and other maintenance activities described in the O&M plan.	⊖ Lack of pipeline maintenance can lead to failure in raw water supply and risks the sub-activity's ability to sustain intermediate outcomes and achieve long-term outcomes.
⊖ Lack of support from LWSC's senior management and financial constraints are the key impediments to implementing the maintenance plan and procuring parts for repairs. This contributes to concerns about the long-term health and operations of the pipeline and the sustainability of outcomes related to raw water supply.	⊖ Program logic assumption that LWSC can use funds for O&M does not hold.

⊖ = negative finding

1. Overview of O&M plan

Denys developed a manual with instructions to operate and maintain the pipeline's technical components (such as the main ductile iron pipe and steel piping, concrete chambers with steel pipes and valves, and the bridge at the treatment plant) and non-technical components of the project (such as the permanent fencing along the pipeline corridor and access roads to the right-of-way for the pipeline). As part of the handover process, Denys conducted a 10-day training for LEC and LWSC staff in October 2021 and provided spare parts. LWSC staff are responsible for executing the O&M plan, which involves conducting regular inspections of the pipeline components (chambers, valves etc.), carrying out regular maintenance activities for the access roads to the pipeline and vegetation management, and completing emergency maintenance and repairs.

> "LWSC needs to maintain the access roads so that they can maintain the wash-out chambers and air valve chambers. There are three access roads and LWSC should be able to get easy access to all parts of the pipeline using these roads. It is important to maintain these roads so that you can find the relevant valve chamber and make sure the vegetation is not overgrown."◢

2. Findings on maintenance and project sustainability

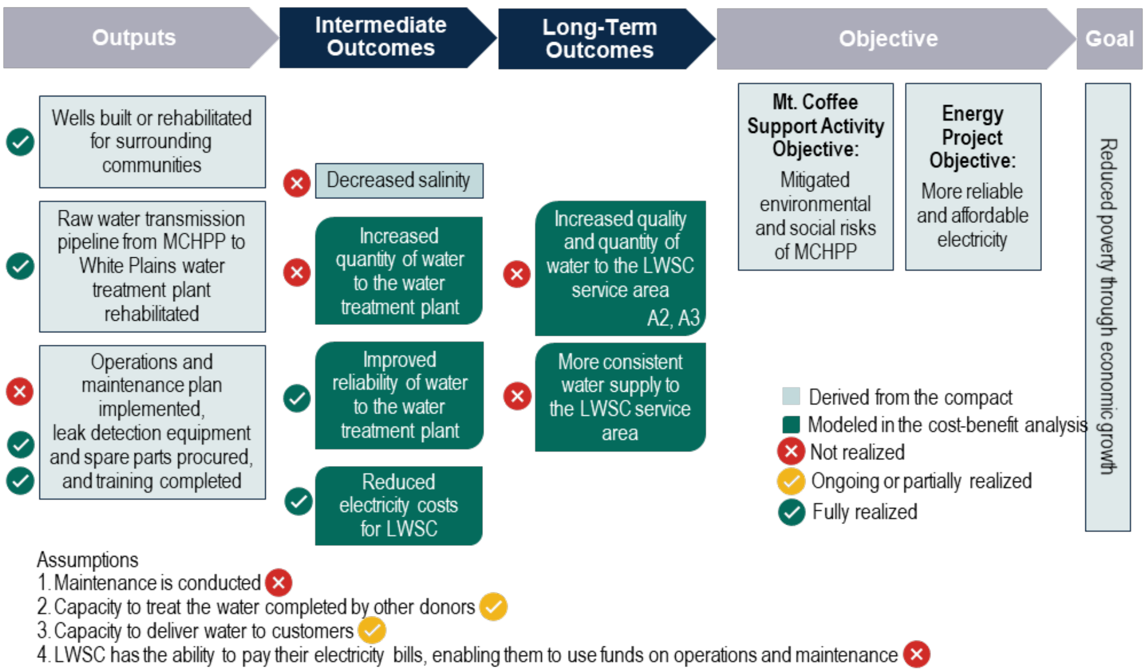
LWSC is not conducting maintenance activities on the technical and non-technical aspects of the pipeline. LWSC staff report that maintenance activities outlined in the O&M manual, such as inspection of parts, leak detection tests, and pipe drainage, are not being conducted regularly and are likely to cause serious maintenance problems in the future. Stakeholders also report that the access road to the pipeline has overgrown vegetation, which impedes inspection of the pipeline and makes it challenging to conduct leak detection tests. Many sections of the pipeline's perimeter fencing have been stolen for use as building material and the bridge component of the pipeline has been vandalized. LWSC's subsequent request for resources to rehabilitate the vandalized section of the fence and assign security personnel to prevent further theft was not approved by the government. However, lower level staff at LWSC report that, while they have the capacity to conduct O&M, little to no action has been taken to curb these issues and senior management do not prioritize maintenance activities.

LWSC faces serious financial constraints, which could lead to the failure to replace equipment and retain trained staff to execute the maintenance activities as set out in the O&M manual. LWSC's severe resource constraints and lack of consistent funding present a key challenge for the sustainability of the pipeline investment. Stakeholders note that the pipeline O&M activities are low effort given the gravity-flow design and absence of electrically operated pumps. Valves are used to imitate water flow through the pipeline and control the quantity of water supplied to the treatment plant. However, LWSC needs to follow the maintenance protocol set in the O&M plan to ensure the long-term health of the pipeline. LWSC staff note that some spare parts were provided as part of the handover process, but this may be inadequate as LWSC's resource crunch makes it difficult to procure any additional parts. For example, staff noted that a valve used to flush the pipeline of sediments has been damaged, but due to resource constraints and lack of management support for maintenance, they have yet to procure this equipment. Some stakeholders also feel that staff trained by Denys on O&M may leave the utility as they have not received wages for the past four months. Overall, these challenges contribute to concerns that lack of maintenance may result in damaged parts, threaten the long-term health and operations of the pipeline, and risk the sustainability of outcomes such as the reliability and quality of raw water supply.

IV. Conclusion

As illustrated in Figure IV.1, the evaluation results indicate that the sub-activity was able to complete nearly all program outputs but did not achieve several outcomes in the program logic. The pipeline has not increased raw water intake at the treatment plant or reduced the turbidity of raw water supply, which indicate that some inherent assumptions about the pipeline design and the treatment plant's constraints did not hold true. Stakeholder perspectives suggest closer collaboration between MCC, MCA-Liberia, and technical staff at the treatment plant during the design stage and a deeper investigation of the treatment plant's constraints and needs might have provided a more realistic picture of achievable outcomes. In the future, MCC could deepen local stakeholder engagement during the feasibility and design phases of work to tailor activities to the local context and constraints.

Figure IV.1. Assessment of program logic



The sub-activity has not achieved long-term outcomes on improving water supply to LWSC's service areas either. These outcomes are heavily dependent on assumptions that donors would improve treatment capacity at the plant and LWSC would have the capacity to deliver water to service areas. Although donor-funded projects have improved the treatment plant's capacity and would upgrade vital parts of the water infrastructure, the program logic does not account for LWSC's inability to pay for operational expenses (purchase of chemicals, tools, etc.) at the treatment plant. Stakeholders agree that the raw water pipeline is an essential investment but note that the sub-activity needed to address other factors, such as lack of funds for operations, to improve water supply to Monrovia.

Finally, the sub-activity did not adequately address the risk to sustainability of the investment. LWSC does not prioritize asset maintenance or perform maintenance activities for the pipeline. Given LWSC's organizational problems and financial issues, MCC could have considered other arrangements, such as short-term maintenance contracts, to ensure the sustainability of the investment in the near term and to transition the utility into performing maintenance activities long term.

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Appendix A

Documentation of the comments/feedback from country and MCC stakeholders

Table A.1. Stakeholder comments and evaluator responses

Reviewer Role/ Institution	Page Number	Comment	Evaluator Responses
M&E Lead	Page v, second paragraph	Please include the identification strategy, in this case, ex post and pre-post.	We have specified the identification strategy in this paragraph and the evaluation design chapter.
M&E Lead	page 1, "The pipeline sub-activity aimed to replace the original 900-millimeter pipe with a 1,200-millimeter pipe to meet the expanding demand for water. "	Can you clarify that the 900 and 1,200 are the diameter of the pipe?	We have clarified that this refers to diameter.
M&E Lead	Page 7, first paragraph	Explicitly state the identification strategy. SP: Refer to EMG for PE methodologies. Is this pre-post?	We added the identification strategy to this paragraph and clarified this in Table II.1.
M&E Lead	Page 11, Logic diagram	Minor point but using the color red makes me think the output weren't achieved. Can you consider a more neutral color here?	Figures III.1 and III.4 have been updated to replace red with a neutral color.
M&E Lead	Page 14	Can you color code the positive/negative findings in the box?	The colors have been updated - green for positive, red for negative.
M&E Lead	Page 16 ". Also, some worksites were flooded during construction due to a sudden increase in spillway discharge from MCHPP."	What is "spillway discharge"?	Spillway discharge refers to the release of overflow water from the dam. We have modified this sentence to make it clear.
M&E Lead	Page 17, Program Logic	Same comment about the color red.	The figure has been updated.
M&E Lead	Page 18, "The amount of raw water supplied to the treatment plant is a limiting constraint"	This is a little confusing. A constraint to what? Can you provide some additional clarity?	The assumption has been updated to say that raw water supply is a limiting constraint to treated water supply.
M&E Lead	Page 18, Implicit assumptions	It might make sense to also include the implicit assumptions with the logic.	This has been added to the logic model figure.
M&E Lead	Page 18	Can you color code the positive/negative findings in the box?	The findings have been color coded: green for positive, red for negative, grey for outcomes that could not be assessed.

Reviewer Role/ Institution	Page Number	Comment	Evaluator Responses
M&E Lead	Page 18, "LWSC data do not show changes in salinity of raw water as there were no instances of salt-water intrusion during the study period. LWSC and other stakeholders indicate that the pipeline will potentially prevent salt-water intrusion into raw water in future dry seasons"	If LWSC thinks that salinity will go down in future dry seasons, was there a reason it wasn't detected now?	LWSC data does not show increases in water salinity since salt-water intrusion due to dry-season events (tides, low levels of water in the St. Paul River), which occurred occasionally, did not take place during the study period (Jan 2020-Dec 2021). In KIIs, LWSC did not recall salt-water intrusion events during this two-year period and confirmed that the data was accurate. Hence, we were unable to confirm using quantitative data that the pipeline reduced the risk of salt-water intrusion. At the same time, LWSC and other stakeholders indicate that if such events were to occur in the future, the pipeline's upstream intake location would prevent salt-water intrusion and increases in raw water salinity. It is also worth noting that the pipeline was not expected to decrease water salinity outside of these sporadic salt-water intrusion events and salt-water intrusion is not a major risk to the quality of raw water supply. We have modified this text to provide more clarity.
M&E Lead	Page 19	In Figure III.5, there is no key for the red line.	The legend indicates that the red line is for Apr-Dec 2021 (after pipeline)
M&E Lead	Page 19	If the outages have reduced from 7 per month to 0, how is there not more water getting to households? Do we know anything about the duration of these outages?	This finding corresponds to outages in raw water supply. The findings on treated water supply show that despite improvements in the reliability of raw water supply, LWSC does not have the capacity to process additional amounts of raw water and increase treated water supply to customers in Monrovia. Before the pipeline, outages typically lasted a few hours. We have added this detail to the findings.
M&E Lead	Page 20, Figure III.6	This figure should be with the outage text rather than the salinity.	We have moved this figure.
M&E Lead	Page 21, Figure III.7	The legend should include the red line. Are the values for dissolved solids 0? This graphic doesn't add much for me.	We have revised the figure to make the values for pre- and post-pipeline salinity clear. The accepted benchmark is now indicated in the findings text.
M&E Lead	Page 22, Figure III.8	The legend should include the red line.	We added the legend to the figure.
M&E Lead	Page 23, Figure III.9	The legend should include the red line.	We added the legend to the figure.

Reviewer Role/ Institution	Page Number	Comment	Evaluator Responses
M&E Lead	Page 23, Figure III.9	Why is the treated water so much lower in April-June?	LWSC faced challenges in producing treated water in 2021, particularly in the second quarter, due to inadequate chemicals and fuel for treatment of raw water. The situation improved once they received donor funding for treatment operations. We have clarified this in footnote 5.
M&E Lead	Page 25	What is the actual ERR? You say it is negative, but don't explicitly state it.	The text states that the ERR is negative 18 percent.
M&E Lead	Page 26	Is the implicit assumption that LWSC will you the cost savings for maintenance?	The logic model had an explicit assumption that LWSC would save funds through reduced electricity costs, enabling it to conduct maintenance. This is clarified in the summary box.
M&E Lead	Page 27	since O&M is not happening, what are the implications for the life of the infrastructure?	Stakeholders have indicated that in the short term the pipeline will largely continue to function as designed. In the long-term, however, lack of maintenance may lead to damaged parts that need extensive repairs or replacement, risk the pipeline's basic functions, and negatively impact the sustainability of outcomes such as reliability and quality of raw water supply. We have revised the summary box and findings text to provide more detail.
ESP	Page v, Exec. Summary	Bullet #2: As documented in this report LWSC does not perform periodic maintenance per guidance manuals, which likely includes calibration and cleaning of water quality laboratory and monitoring equipment. This affects the quality and reliability of the data reported and it would be appropriate to make note of this caveat in this report.	We have documented this in footnote 3 in the evaluation design chapter.
ESP	Page v, Exec. Summary	Bullet #2, Sub-bullet #2: LWSC and local media outlets reported and documented one case of high salinity during the compact period. The saltwater intrusion that occurs in the river adjacent to the treatment plant cannot advance beyond MCHPP, so the pipeline DOES eliminate the incidence of periodic intrusion events when saline water would have been encountered pre-pipeline.	We have noted that salt-water intrusions did occur prior to 2020. Although there were no salt-water intrusions during the study period (2020-2021), the findings clarify that the pipeline will prevent increases in raw water salinity if salt-water intrusions occur in the future.

Reviewer Role/ Institution	Page Number	Comment	Evaluator Responses
ESP	Page v, Exec. Summary	Bullet #2, Sub-bullet #3: Turbidity levels at the treatment plant are influenced by sediment accumulating in the pipe itself, particularly if LWSC is not flushing the line per the O&M plan. Therefore, measuring turbidity at the end of the pipe does not accurately depict the turbidity of raw water entering the pipe at the reservoir, making this conclusion suspect.	LWSC has tested water samples from upstream of the St. Paul river, before water enters the pipeline, on a regular basis. We did not have access to this data (now noted in footnote 4). Staff at the treatment plant say that these measurements showed that turbidity of water entering the pipeline was similar to turbidity levels observed in water samples collected after entering the pipeline. As per LWSC, the O&M plan requires the pipeline to be flushed once a year. In KIIs, staff explained that increased sediments during the rainy season from May to November, and not flushing the pipe towards the end of 2021 as per the O&M plan, contributed to the spike in turbidity during the final months of 2021. However, it does not explain the lack of improvement in raw water turbidity observed in other months of 2021.
ESP	Page v, Executive Summary, Page 12 and 13	RAP and ESIA delays: The RAP and ESIA delays stemmed initially from the poor performance of the local firm hired by DENYS. After numerous failed attempts, MCC requested that DENYS hire a resettlement/EHS expert who had worked for the PIU to improve the quality of the ESIA and RAP to MCC requirements. MCC also stepped in to re-write huge sections of both. Ironically, while this was blamed for the delay, DENYS was largely at fault, even though they made a case that was accepted for a claim to MCA and the SE. On top of that, designs were not even done, so that was more the driver behind the delays. As for implementation of the RAP, some of the payments had to be increased due to delays in construction associated with DENYS because the payments had been for temporary impacts that went beyond the compensation agreements, so a supplemental payment was made. The narrative infers that the blame for the delays is Resettlement or ESIA work, when then is not really the case.	Thanks for providing these details. We had noted issues with LEG's performance in preparing these deliverables in the detailed findings, and we have now revised to clarify that this was a significant reason for the initial RAP and ESIA delays. The bullet and detailed findings also clarify that other factors including the design process contributed to delayed project completion.

Reviewer Role/ Institution	Page Number	Comment	Evaluator Responses
ESP	Page 24	First paragraph: This indicates that the salinity measurements were taken post-treatment and does not provide a clear comparison of the raw water pre- and post-pipeline.	The comparison of pre- and post-pipeline salinity of raw water is covered in a previous section (Chapter III Section B.1).
Evaluation Lead/MCC	Page v, Exec. Summary (also applies to page 1 intro)	First sentence - question for MCC staff and then the report - was the transfer of water from Mt. Coffee to the treatment plant expected to increase the supply of water for other purposes? Or was Mt. Coffee taking water that previously went to communities and the pipeline ensured that the water could be reused? I'm trying to understand the purpose of the investment in relation to the Mt. Coffee component.	The pipeline's logic model does not establish a strong link to the objective of the Mt. Coffee Support Activity: addressing the social and environmental risks associated with the rehabilitation of Mt. Coffee. The pipeline sub-activity will replace the pre-war pipeline and address issues related to salt-water intrusion in raw water supply to the water treatment plant. However, MCC indicated that it does not address any direct impacts from the rehabilitation of MCHPP. We have noted this in the narrative on the logic model.
Evaluation Lead/MCC	Page vi, Executive Summary	Missing word: has not been executed according to the O&M plan developed by the pipeline contractor.	Thanks for catching this. We have fixed this sentence.
Evaluation Lead/MCC	3, logic	Related to my previous comment, it would be helpful if the report could explain how the pipeline mitigated environmental and social risks for Mt. Coffee. In one or two sentences only, not looking for a deep discussion. This doesn't have to go into the logic diagram, but it should be clearer to the reader what that objective box means.	As mentioned above, we have noted this in the narrative on the logic model.
Evaluation Lead/MCC		Nice job on the summary visuals!	Thanks!
DCO IEPS	Page 19,20	There appears to be a repeat of the paragraph that begins "Data show minimal variation in raw water salinity…". This paragraph appears twice.	We removed this paragraph.
DCO IEPS	Page 21, Figure III.7	The graphic for this figure does not appear to be showing up correctly in the report. There is no data in the graph.	This graph should appear correctly now.

Appendix B

Evaluation Gender Type

Background

MCC originally developed the following typology to document which of its independent evaluations produced "gender data" in accordance with its 2015 commitment to publish all such data in support of the Data 2X initiative.[5] These categories were later included in the agency's Women's Economic Empowerment Learning Agenda, which was adopted in 2019, to help identify and consolidate findings about the extent to which gender issues have been incorporated into the design, implementation, evaluation, and learning related to MCC's investments.

A Gender Type will be assigned by the MCC Evaluation Management Committee (EMC) for each MCC evaluation at two points in time:

1. Upon approval of Evaluation Design Reports (EDRs)
2. During review of final evaluation reports in case changes to the program or evaluation have implications for the original assignment

This assignment will be recorded in MCC's evaluation pipeline database for management and reporting purposes.

Definitions of MCC's Gender Types

- **Type 1:** Gender is/was part of the logic and evaluation design of the program being evaluated[6]
- **Type 2:** Gender is/was not part of the logic of the program being evaluated, but the evaluation design incorporates gender issues, e.g., in the evaluation questions or data collection methods
- **Type 3:** Gender is/was not part of the logic or evaluation design of the program being evaluated, but sex-disaggregated data will be/were collected
- **Type 4:** Gender is/was not part of the logic or evaluation design of the program being evaluated, and sex-disaggregated data will not be/were not collected
- **N/A:** This applies if interventions will not be evaluated or if an evaluation is canceled before an Evaluation Design Report has been approved

Assigned Gender Type

At the time of final evaluation report completion, the EMC determined the Liberia Pipeline Sub-Activity evaluation's Gender Type to be Type 4 based on the definitions above.

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