

## Article

# Governance Mechanisms and Barriers for Achieving Water Quality Improvements in Galapagos

Cristina Mateus <sup>1,2,\*</sup>, Melanie Valencia <sup>1</sup>, Kara DiFrancesco <sup>3,4</sup>, Valeria Ochoa-Herrera <sup>1,2</sup>, Todd Gartner <sup>5</sup> and Diego Quiroga <sup>1,2</sup>

<sup>1</sup> Instituto Biósfera, Colegio de Ciencias e Ingeniería, Universidad San Francisco de Quito, Diego de Robles y Vía Interoceánica, Quito 17-1200-841, Ecuador; melanievalenciav@gmail.com (M.V.); vochoa@usfq.edu.ec (V.O.-H.); dquiroga@usfq.edu.ec (D.Q.)

<sup>2</sup> Galapagos Science Center, Universidad San Francisco de Quito and University of North Carolina at Chapel Hill, San Cristobal, Galapagos 200150, Ecuador

<sup>3</sup> Wicked Water Strategies, Bend, OR 97702, USA; kara@wickedwaterstrategies.com

<sup>4</sup> Natural Resources, Oregon State University, Bend, OR 97702, USA

<sup>5</sup> World Resources Institute, Washington, DC 20002, USA; Todd.Gartner@wri.org

\* Correspondence: mcmateus@usfq.edu.ec; Tel.: +1-541-797-8822

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**Abstract:** Human activities contribute to the degradation of water quality on the Galapagos Islands, affecting human health and Galapagos' fragile ecosystem. Despite the numerous resources vested in water management, programs have yet to achieve measurable improvements in water quality. To identify the governance mechanisms and barriers to improving water quality, we applied a two-pronged strategy: a collaborative, bottom-up compilation and prioritization of technical specialists and stakeholders' concerns, and an evaluation of top-down government plans. The comparison of priorities and programs shows four major themes that require attention: barriers to better governance, community involvement, research, and policy. The islands lack a transparent method for accountability of the funds designated for water management, the efficacy of implementation, and results and progress beyond government periods. Government projects have included limited public participation, resulting in projects that do not meet stakeholder's needs and concerns. Furthermore, the majority of the programs have not been completed within the timeline or budgets allocated. We recommend implementing a participatory governance mechanism that responds to each island's context, balances socioecological and policy priorities and evaluates past projects to have adequate benchmarking, mitigating a planning fallacy. All programs should be accompanied by a transparent monitoring system that ensures accountability and evaluates water quality programs' efficiency and effectiveness, according to goals and indicators developed collaboratively. This research may aid practitioners in small island developing states (SIDS) around the globe that are struggling with similar water management and governance issues and who may benefit from taking a bottom-up and top-down approach to assessing technical specialists' and local stakeholders' concerns in relation to past, present and future government programs.

**Keywords:** water quality; sustainable water management; stakeholder participation; bottom-up decision making; Water Governance; small islands

## 1. Introduction

Worldwide, island communities face water management challenges due to their constrained capacity to obtain, allocate and treat freshwater. This issue is particularly relevant as many islands and small island developing states (SIDS) face contradictions in their sustainable development model

while trying to balance environmental, social and economic concerns [1] and how to adapt to the imminent impacts of climate change [2]. This study applies a combined bottom-up and top-down water governance approach to (i) better understand water quality management needs of local stakeholders, (ii) analyze technical specialists' recommendations, (iii) evaluate the effectiveness of government initiatives to address those concerns and recommendations, and (iv) identify the governance mechanisms and barriers to improving water quality and resiliency in three of the Galapagos Islands: San Cristobal, Santa Cruz and Isabela. This study looks at the governance or decision-making mechanisms that affect how water management occurs regarding operations and budget allocation.

Top-down governance approaches are characterized by more centralized, often remote and high-level decision making, while bottom-up approaches are more local, stakeholder-centric and negotiated. In Ecuador, water governance takes various forms, ranging from government-centric top-down approaches (primarily in urban areas) to community-based bottom-up approaches consisting of self-organized water boards (primarily in rural areas) [3]. The national water secretary, known as Secretaría Nacional del Agua (SENAGUA) establishes national-level water quality standards (top down), but, in rural areas of the mainland, local water basin boards define the details of water management both for agricultural and domestic uses (bottom up) [4].

The relatively small population of urban settings, its subsequent small footprint and, most importantly, the Galapagos economy's nature dependency, showcase the almost non-existent divide between rural and urban dwellers. Many economic activities occur in the National Park and rural areas. Despite the rural connections, water governance in Galapagos follows a top-down approach. Decision making is centralized in the Government Council of the Special Regime of Galapagos (CGREG), whose duty is to provide potable water and sanitation for the citizens of Galapagos [5]. CGREG issues regulations, plans and programs to establish sanitary infrastructure, including drinking water and sewerage systems, environmental sanitation, transportation and waste management [5]. To date, CGREG has not included stakeholders in any stage of the water management process.

The study follows a commonly used top-down and bottom-up water governance approach [6–10]. An uplift of global literature recommends a water governance methodology that includes all relevant stakeholders in water management decision making and evidences the enhanced quality, sustainability and equitability of such decisions through stakeholder participation [6–9,11–14]. Along these lines, local stakeholders shared their input during participatory workshops conducted on each island to identify and prioritize water quality related needs and concerns. Technical specialists provided knowledge through their published research, which helps water-related programs make informed, science-based decisions. We use relevant results from experts and technical specialists as a proxy to represent the needs of the ecological system, which lacks a direct voice to present an argument [15,16]. It is important to note that if there was a local indigenous population in the Galapagos, their insights and concerns would also have served as inputs to identify the ecological systems' needs [17]. Nonetheless, all Galapagos inhabitants are migrants from first up to fourth generation, hence the need to use the accounts from all technical specialists that have used qualitative and quantitative studies to assess the issues related to water quality in the islands. With the information gathered from local stakeholders and technical specialists via their publications, we evaluate whether government plans (Task 3) address those needs. The ultimate decision regarding which strategies to implement may lie with the government, but stakeholders' inputs can be made more explicit throughout the decision-making process. The applied method provides recommendations to design projects and plans that address water quality challenges. These recommendations should lead to tangible and measurable outcomes considering the budget allocation and the transparency in funds' use.

## 2. Methods

### 2.1. Study Area

The Galapagos Islands have experienced massive population growth and development in recent decades [18,19]. The local population increased 9.5% in the Galapagos islands between 2010 and 2015 [20] and the number of tourists visiting the islands increased 5% on average between 2007 and 2018 [21]. This growth has raised the local population's standard of living while simultaneously contributing to the deterioration of the fragile ecosystem [18].

The increased presence of humans on the islands has resulted in severe water quality issues due to the lack of infrastructure to treat and manage drinking water, wastewater and stormwater [22,23]. For example, the groundwater in Santa Cruz Island, the most populated island in the Galapagos Archipelago, is contaminated with fecal coliforms due to the lack of an adequate sewer system and the location of the basal aquifer beneath urban settlements [24]. The release of high concentrations of pollutants into the oceans is a significant source of nutrient input [25,26] that could lead to environmental damage, including eutrophication and mortality of marine organisms [27]. Additional population growth will only add to the amount of effluents generated in the islands [28].

Galapagos' economic dependence on the diverse natural environment puts the islands in a uniquely perilous position. Environmental contamination due to water quality issues and, thus, the loss of Galapagos biodiversity, directly impacts its local human communities, as most of the population depends on nature-based tourism, fisheries and agriculture for its livelihood [18,19].

The islands' water supply is insufficient to meet the growing demand of the Galapagos population [23,29,30], creating the need for integrated water resource management within the towns. The contamination by solid, organic waste and garbage also affects the superficial freshwater resource in streams or gullies, resulting in deficient natural recharge of the aquifers generated by impervious areas [31]. As each island has its own characteristics and water-related issues, it is essential to look at each island individually (bottom up) to understand their own needs and priorities better. Understanding each islands' needs and context will not only lead to a sustainable management of water but also maximize ecosystems' health, economic wellbeing and social welfare.

### 2.2. Study Approach

Each island has a unique hydrogeology characteristic and faces different issues related to water quantity and quality. To better understand the differences between islands, this study focused separately on three of the four populated islands: Santa Cruz, San Cristobal and Isabella islands (Table 1). The methodology consisted of five steps (Figure 1):

- Task 1. Identified water resource concerns and current knowledge gaps based on existing scientific research by technical specialists (Circle A in Figure 1).
- Task 2. Used local stakeholder input gathered during participatory workshops to identify and prioritize needs and concerns (Circle B in Figure 1).
- Task 3. Revised government plans' and used technical specialist and stakeholders' inputs to identify completed and ongoing water resource plans, projects and initiatives (Circle C in Figure 1).
- Task 4. Evaluated areas of agreement in the needs identified by local stakeholders, technical specialists and established or proposed government programs to address those needs (overlapping circles A, B and C in Figure 1).
- Task 5. Evaluated each island's results to propose alternate actions to generate information for decision making, develop plans and implement projects for water management and resiliency.

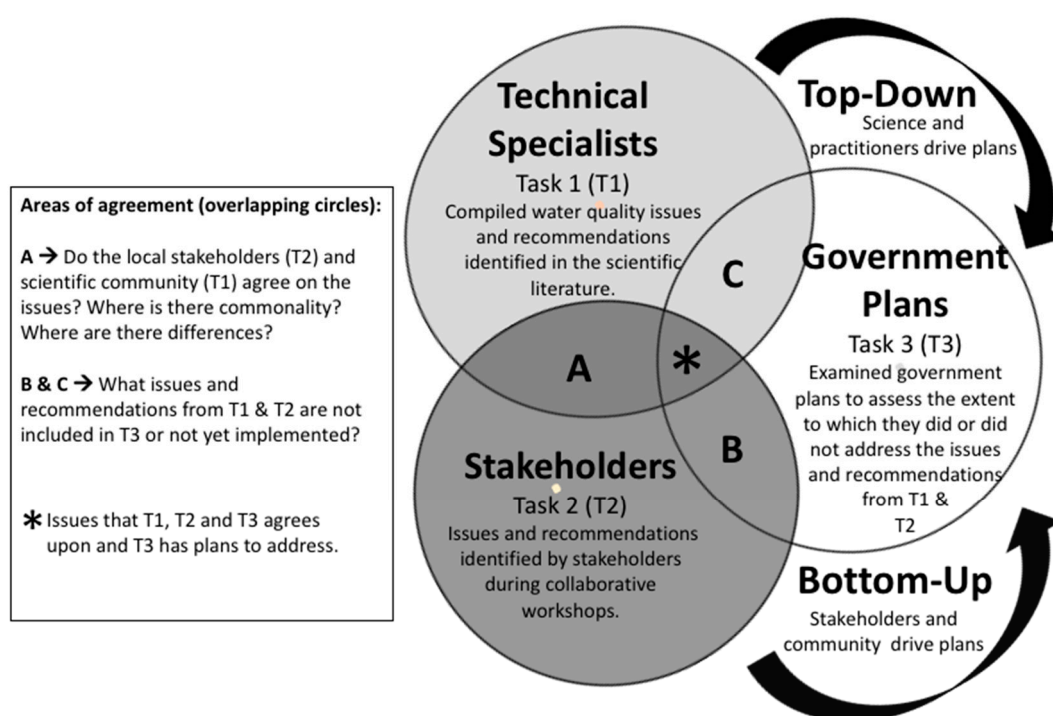
During Task 1, we completed an extensive literature review to better understand technical specialists' assessment of the Galapagos' hydroclimatic conditions, freshwater sources and water management systems. This process entailed a literature search performed on Web of Science and SCOPUS for peer-reviewed articles related to water quality between January 01, 2010 and June 18, 2020, using the keywords described in Table A1. The search yielded 259 publications, of which we reviewed the 30 most-cited articles. We expanded our search radius following the method known as "pearl growing" citation chasing [32] by reviewing the reference lists of all the 30 papers selected during the online search. In addition to peer-reviewed publications, this effort uncovered relevant white papers and reports with crucial data about water management in the Galapagos Islands not published in scientific journals. A total of 134 articles were included in the analysis, representing the perspective of technical specialists. It is noteworthy that some technical specialists were also present during Task 2 activities but weighing in their recommendations coming from a broader range of publications of specialists that might not necessarily live in the Galapagos is a relevant contribution of this method. Furthermore, this form of including technical specialists voices through their published work avoids that the saliency of specific themes or availability bias that comes from participation in one event or recent campaigns overrun all other contributions from the literature and prior research that could be relevant [33,34].

For Task 2, researchers from the Universidad San Francisco de Quito (USFQ) and the Galapagos Science Center (GSC) in collaboration with representatives from World Resources Institute (WRI), Oregon State University (OSU) and Wicked Water Strategies (WWS), conducted a workshop for each island to assess key local stakeholders' perspectives on the current water management strategy. The workshops were conducted on May 21, May 23 and June 13, 2018, in San Cristobal, Santa Cruz and Isabela, respectively. Workshop organizers aimed to include stakeholders currently involved in Galapagos' water management, who would significantly contribute and remain engaged throughout the design and implementation of the water strategy selected. The GSC initially identified prominent organizations and the sampling followed a snowball referral approach [35] pointing to actors working in water management throughout the islands until reaching saturation when the same actors were mentioned. Of note, the level of seniority amongst participants greatly varied.

**Table 1.** Area, population, urban areas and current water status for Santa Cruz, San Cristóbal and Isabela islands.

Island	Area	Population [20]	Main Urban Areas	Water Sources	Sewerage Network	WWTP
Santa Cruz	986 km <sup>2</sup>	15,393	1. Puerto Ayora 2. Bellavista 3. Santa Rosa	<ul style="list-style-type: none"> <li>• Four aquifers for municipal water supply (mainly brackish)- La Camiseta, Pozo Bellavista, Grieta Ingala, Vertiente Santa Rosa-</li> <li>• Seven aquifers for irrigation water supply</li> </ul>	<ul style="list-style-type: none"> <li>• No sewerage network.</li> <li>• 97.2% connected to septic tanks - 1.9% to the public sewerage network</li> </ul>	None
San Cristóbal	558 km <sup>2</sup>	7199	1. Puerto Baquerizo Moreno 2. El Progreso	<ul style="list-style-type: none"> <li>• Two main sources for municipal water supply (freshwater) - La Toma with El Progreso Drinking Water Plant and Cerro Gato with Las Palmeras Drinking Water Plant.</li> <li>• Three main sources for irrigation water supply</li> </ul>	<ul style="list-style-type: none"> <li>• Existing system connected to 99% of households.</li> </ul>	Yes, since 2012

Isabela	4640 km <sup>2</sup>	2164	1. Puerto Villamil 2. Tomas de Berlanga	• Three aquifers for municipal water supply (mainly brackish) - Chapin 1, Chapin 2, Grieta San Vicente. Desalinization plant since 2014.	• Existing system connected to 30% of households  Yes, since 2015
				• Five aquifers for irrigation water supply	



**Figure 1.** A bottom-up and top-down water governance approach for the Galapagos Islands.

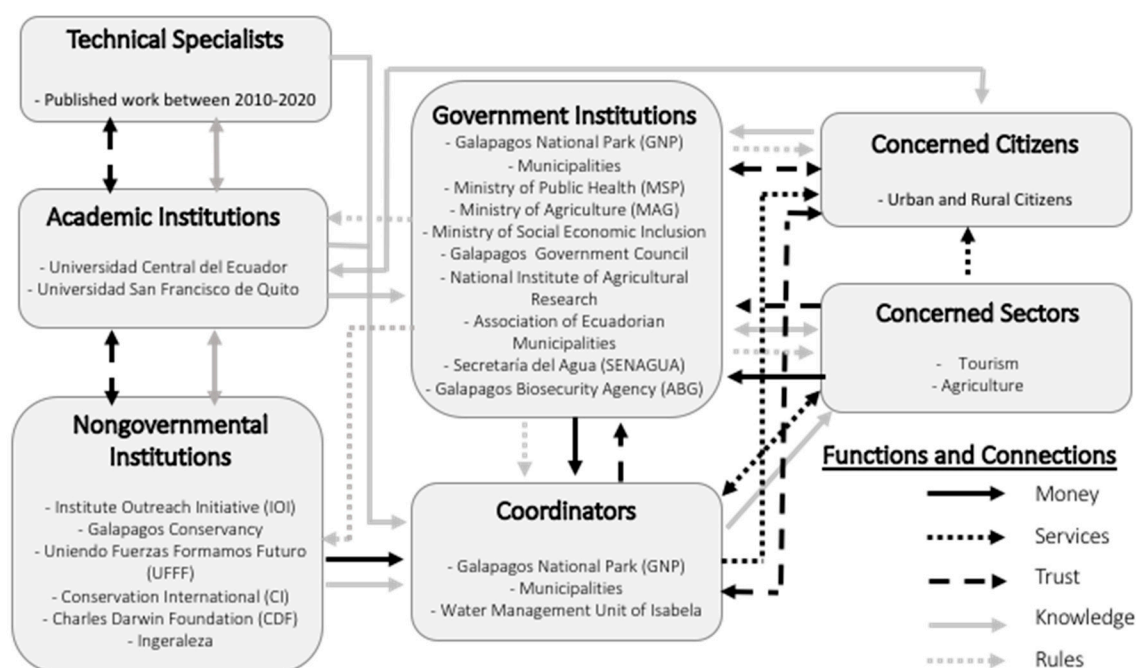
Participants and organizations that attended the workshops included representatives from government institutions, non-governmental organizations and civil society organizations (Figure 2). All the mentions of local stakeholders throughout this document refer to the participants listed in Figure 2. Government institutions provide funding and approve regulatory requirements or measures. Non-governmental institutions, academic institutions and technical specialists generally provide technical knowledge and assistance to help programs make informed, science-based decisions. While non-governmental institutions can provide funding and create programs, academic institutions generally conduct research and establish education and monitoring programs. In this context, coordinators include primary administrators of water programs and funds. Concerned citizens also participated in the workshops. They provided vital insights into impacts on their

communities. Concerned sectors represented those more affected by water management decisions, including tourism and agriculture. Many international organizations and foreign aid agencies that act as financial agencies in Galapagos such as the Japanese Agency for International Cooperation (JAICA), Korea International Cooperation Agency (KOICA), Interamerican Development Bank (IDB), among others, did not participate in the workshops because they were not present in the islands.

The workshop followed the World Café method [36]. After a brief introduction to the workshop's scope and a keynote presentation covering the latest research in water management in Galapagos, the active participation portion of the workshop began. It consisted of three activities:

1. Identify issues, challenges and opportunities: Workshop organizers divided participants into three tables, ensuring a diverse group of sectors was represented at each table. A theme was assigned for each table—water quality, water quantity, or climate change strategies—and, organizers facilitated a discussion on: (1) what is currently working well, (2) what is not working and (3) what improvements could be made. Participants then rotated through all the tables/themes and organizers clustered all the ideas to obtain key insights for the next activity.
2. Identify financial and technical resource flows: Using the same rotational system as in the first activity, organizers asked participants to identify financial and technical resource flows related to insights from the first activity, including existing projects and the organizations involved.
3. Prioritize issues and identify initiatives to address these: Within each table, participants prioritized the most pertinent challenges and opportunities from Activity 1 and the resources available to address the challenges identified in Activity 2. Then, organizers asked them to identify two or three priorities for the island. All groups shared their results through an interactive plenary session. Organizers and participants combined redundant strategies and developed new ones to fill gaps; then, each participant voted for the highest priority initiatives.

Task 3 entails the analysis of government planning, using the report on the Development and Zoning Planning, known as “Plan de Desarrollo y Ordenamiento Territorial” (PDOT) for each island [31]. The Ecuadorian Constitution of 2008 established a methodology created by the National Secretary of Planning (SENPLADES) to develop each PDOT [37]. Each island goes through a different process and makes plans for different periods that define priorities and budgeting. The latest documents include the following: Santa Cruz 2012–2027 [38], San Cristobal 2012–2016 [39] and Isabela 2012–2016 [40]. Each PDOT includes an assessment of environmental, economic, human settlement and mobility/energy systems. The analysis described in this study considers any strategy that mentioned water or climate as a problem. It is important to note that the plans listed in PDOTs can become obsolete before implementation occurs.



**Figure 2.** Participants and organizations that attended the workshops and their typical roles in water governance in the Galapagos Islands regarding resource flows. The figure is based on the framework by [41].

Task 4 identified where agreement exists in priorities and needs identified by technical specialists (Task 1) and local stakeholders (Task 2), represented in Figure 1 as area A. It then evaluated whether or not established and proposed government plans (Task 3) address those needs (overlapping areas B and C and asterisk in Figure 1). In order to systematically classify the priorities identified in Tasks 1, 2 and 3, they were thematically coded inductively [42], finding the following five categories: research, policy, community, infrastructure and capacity building. Though in this regard, the codes were not used to develop theory, this process allowed for the comparison of the findings from the three previous tasks to proceed into evaluating the categories of priorities that have been addressed by government plans and those that have been neglected.

Finally, based on the results from Task 4, Task 5 evaluated the positive attributes and flaws in the current governance structure and proposed an alternate bottom-up structure to secure funding, develop plans to address water quality concerns and evaluate and ensure the effectiveness of sustainable water management and resiliency where the priorities from technical specialists, local stakeholders and government plans coincide (circle with the asterisk sign in Figure 1). Furthermore, recommendations from experiences in other relevant contexts were added to the discussion that can be useful for the Galapagos Islands and have not necessarily been considered despite the similar needs to be addressed.

### 3. Results

Results indicate that several research and governmental initiatives have examined and identified water quality challenges that the Galapagos Islands face. However, the progress achieved so far has been insufficient despite many initiatives, plans and programs and the funding allocated to them. As a result, insufficient water supply and contamination remain a problem in all three islands. Results are discussed in detail for each island in the sections below.

#### 3.1. Santa Cruz

Technical specialists identified contaminated groundwater near populated areas in Santa Cruz Island as a significant concern. The leading causes for poor water quality include recent economic development and population growth [22,23], lack of effective wastewater treatment [26], seawater

intrusion [23] and saline water for agriculture [43]. Both technical specialists and local stakeholders recommended policy actions towards a better water management system and improved water infrastructure while recognizing the importance of research to improve water quality monitoring and identify pollution sources (Table 2).

Based on the information obtained from the PDOTs [38], approximately USD 70 million was allocated for water related projects in Santa Cruz between 2012 and 2016. The funding was directed towards research, infrastructure, community, policy and capacity building (Table A2). The projects' portfolio only addresses a portion of the water quality issues or have not been completed to the point of achieving benefits. For example, the wastewater treatment facility will only serve a small portion of the island's population (Bellavista and Mirador). The plant is designed to provide primary treatment, rather than the secondary treatment recommended by technical specialists and local stakeholders (Table 2).

Approximately USD 16 million was allocated in 2013 to construct an integrated sanitary sewer system and expansion and improvement of drinking water systems for Puerto Ayora [38]. However, by 2017 only 31% of the project was completed and 44% of the allocated money was disbursed [44]. An additional USD 7 million was invested in 2016 for the desalination plant located 2.8 km from Puerto Ayora [44]. This plant was supposed to treat brackish water extracted from La Camiseta crevice (a well that provides access to groundwater) and supply the town of Puerto Ayora with water that meets the standards for drinking water [45]. However, as of March of 2020, the plant is still in its testing phase and is being operated by the contractor. Furthermore, in 2017 a credit of USD 4.8 million was given to the municipality to improve and expand the drinking water system and build sanitary and storm sewer systems in Bellavista [44]. Until now, this project is still in its first stages (contracting and disbursements) [44]. Despite the significant financial investment, none of these plans have been finalized and there have been no measurable improvements to water quality.

In 2005, the Galapagos National Park (GNP) implemented a regular monitoring water quality program to provide information on possible sources of contamination and necessary mitigation measures [22]. Government plans last budgeted for the water monitoring program in 2013 and the program conducted by the GNP ended in 2015. An analysis of the data collected by the GNP between 2005 and 2015 provided valuable information of the water quality status in Santa Cruz and can serve as a baseline for effective water management and the future control of pollution [24]. Both technical specialists and local stakeholders emphasized the importance of implementing an effective water quality monitoring of municipal water supplies (Table 2).

While government plans also include construction and maintenance of wetlands, local stakeholders nor technical specialists identified this as a priority. Two artificial wetlands operated by the municipality to treat the effluent from food processing and manufacturing plants have been proposed as long-term solutions to control contamination of water and groundwater sources [23]. However, no further information could be found regarding whether this plan is moving forward or if money has been allocated for its implementation.

Education and awareness campaigns are generally recognized by technical specialists, but stakeholders did not identify them as a priority. The government has proposed a plan, but there is no clear information about the budget and its implementation.

**Table 2.** Priorities and concerns identified by technical specialists (Task 1) and key local stakeholders (Task 2) for each island.

	Santa Cruz	San Cristobal	Isabela
Task 1	<p><b>Policy:</b> Finding suitable areas for wastewater management and system collection prior to urbanization. Other recommendations include closure of contaminated water sources, leakage reduction, use of septic tanks and sterilization of jugs used for drinking water.</p> <p><b>Research:</b> Implementing an effective water quality monitoring program of the distribution system.</p>	<p><b>Infrastructure:</b> Improved water and sanitary infrastructure. Construction of neighborhood-level cisterns to shift maintenance and cleaning responsibility of piped drinking water from residents to the municipality level and thus, increasing the frequency of post-treatment and improving water quality. Provide a safely managed drinking water source where limited freshwater quantities result in intermittent flow and require storage at the household level. <b>Research:</b> Water quality monitoring and evaluating the impacts of tourism on drinking water infrastructure.</p> <p><b>Community:</b> Education and awareness of the importance of water resource conservation.</p>	<p><b>Infrastructure:</b> Construct a new sewer system in Puerto Villamil, since the current system and pipe conditions may be sources of contamination. The drinking water treatment plant currently works but could be improved with chlorination.</p> <p><b>Policy:</b> Closure of contaminated water sources and mitigation actions to recover those water sources.</p> <p><b>Community:</b> Local stakeholders' involvement and participation on regional water and wastewater plants to ensure success.</p>
	<p><b>Research and infrastructure:</b> Bioremediation of domestic effluents in the Galapagos, for example, include a secondary wastewater treatment using native microorganisms to stabilize organic matter and remove nutrients.</p> <p><b>Policy:</b> Establish a sanitary water management system to monitor water quality and protect water sources.</p>	<p><b>Infrastructure, Policy and Community:</b> Implementing alternatives for capture, treatment, use, reuse and final disposal of water at the household and municipal levels.</p> <p><b>Infrastructure:</b> Upgrade the WWTP for water reuse.</p> <p><b>Policy:</b> Foster the continuity of the water quality monitoring program and its scaling to other islands.</p>	<p><b>Community:</b> Awareness campaigns about the maintenance of septic tanks and waste management and their effects on water quality.</p> <p><b>Infrastructure:</b> Increase infrastructure for runoff and wastewater treatment facilities as well as reservoirs.</p> <p><b>Capacity Building:</b> Training to have adequate human resources for water quality control.</p>

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**Community:** Inter-institutional collaboration focused on using infrastructure for participatory monitoring.

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### 3.2. San Cristobal

Drinking and wastewater research and management are significant concerns for local stakeholders and a central focus of technical specialists in San Cristobal Island (Table 2). Recent management actions, including the construction of a Wastewater Treatment Plant (WWTP) in 2012 and the implementation of two drinking water treatment plants in 2013, have led to improved water quality. However, significant issues remain.

While the potable water treatment plant generally produces high-quality drinking water, the distribution system remains inefficient and does not reach the entire population [46]. It has been demonstrated [47] that the water leaving the treatment plants meets Ecuadorian standards for human consumption and domestic use [48]. However, some samples taken at households contained elevated levels of total *E. coli*, suggesting contamination and/or regrowth during distribution and storage. Old distribution pipes along the boardwalk allow contaminated groundwater to seep into the system and allow treated water to leak out [47]. On the other hand, water is only available during a few hours each day, forcing inhabitants to store water in reservoir tanks that are often not maintained or cleaned consistently, affecting drinking water quality [49].

In 2014, the company IMPROSOAM recommended to carry out actions to mitigate contamination caused by the drinking water network in Puerto Baquerizo Moreno [50]. Their recommendations involved: washing the pipes with chemical hydrocarbon removers, washing the cisterns at the household level and periodic water quality sampling and testing for quality control. The approval and authorization for the execution of the plan are available since October 2014. No information about the project execution, success or failure is available.

Before the WWTP began operations in 2012, each household had to rely on a septic tank to treat wastewater, many of which leaked into the groundwater. The installation of the WWTP has mitigated this issue but challenges remain. People often flush oil, trash and other waste products that cannot be adequately treated by the WWTP [46]. All the treated effluents should meet Ecuadorian guidelines before they are discharged approximately 100 m off the shoreline between the beaches of Punta Carola and Las Tijeretas. However, when there is an emergency, such as extreme precipitation events, lack of electricity, or any damage in the WWTP, wastewater is let out near Playa de Oro and Punta Carola beaches without previous treatment (personal communications with engineers at the WWTP, 2018). In October of 2019, the WWTP was shut down for maintenance and it is expected to start operating by the first semester of 2020 (Personal communication with the Mayor of San Cristobal, December 10 of 2019).

To address some of these issues, the Gobierno Autonomo Descentralizado (GAD) of San Cristobal proposed creating and implementing an ordinance for wastewater management as a program for pollution control in 2017 [51]. Some strategies proposed in the ordinance are revamping operations of the sewage pumping stations, WWTP and underwater discharge in Punta Carola. They also considered the provision of new sewer systems in Puerto Baquerizo Moreno, Puerto Velasco Ibarra and El Progreso.

Several studies [47,52,53] highlight the importance and value of water quality monitoring programs. Local stakeholders also expressed this need during local workshops (Table 2). Better use of existing monitoring data could help identify the primary sources of contamination (i.e., distribution system and storage) and provide updated water quality status and valuable information for public policy and decision making. However, while researchers from USFQ-GSC have been

monitoring the WWTP performance since 2015, the government has not used this available data to improve its efficiency.

Inadequacies in the current wastewater and potable water systems have required additional investment to maintain and upgrade existing components and build new infrastructure. Approximately USD 2.3 million have been invested by the GAD San Cristobal [39] in infrastructure for a new sewerage system and maintenance of the WWTP, the cleaning of drinking water pipes and water quality monitoring between 2014 and 2017 (Table A3). Around USD 200,000 were proposed in 2012 for the implementation of an integrated water management plan to ensure monitoring, control, remediation and recovery of water resources considering zones for capture, recharge and runoff [39], there is no evidence of actions taken towards the completion of this plan. Despite the recent government investments in potable and wastewater management, both technical specialists and key stakeholders emphasized the need to find alternatives for wastewater treatment, use and reuse, and improve rainwater capture techniques.

Nearly USD 2.4 million of funding were proposed in 2012 to construct a storm sewer network (Table A3). While stakeholders propose water capture alternatives in case of drought, such as reservoirs in the highlands and rainwater capture systems in urban areas, no plans that consider capture and storage of stormwater during precipitation events were proposed. These strategies would not only mitigate urban flooding, soil erosion and beach destruction but would also prevent contaminated water reaching the ocean coast by storing runoff that contains human-made contaminants as well as natural forms of pollution [54].

Technical specialists suggested the importance of community education and awareness for water resources conservation [55]. However, local stakeholders and government plans did not identify this as a priority.

### 3.3. Isabela

There is a general agreement on water quality priorities and concerns among all three stakeholders' groups (Tables 2 and A4). They all highlight the importance of (i) improving infrastructure for a new sewerage system and freshwater collection systems, (ii) controlling, preventing and mitigating water contamination, and (iii) increasing the involvement and participation of all social actors to secure the effectiveness of an integrated water resource management plan. Unfortunately, information about funding allocation, project development and project status from Isabela PDOTs is not available. Hence, the plans and priorities presented in Table A4 were taken from the proposed plans and projects in development with no further information [40,56]. We assume the plans have been proposed but not yet implemented.

There is unanimous concern about water quality and sewer infrastructure among technical specialists for Isabela Island (Table 2) [22,52,57,58]. There is also consensus among them that community, infrastructure and policy actions are needed. Like San Cristobal and Santa Cruz, Isabela is also experiencing rapid urban development [19] without an effective sewerage network or a potable water supply [18,30].

The recharge of groundwater reservoirs in Isabela Island passes through crevices that separate freshwater from rainwater. However, a few meters deep, the water is brackish and salty [46]. Brackish water is extracted from several of these crevices and used for municipal tap water. The water extracted from the water sources is distributed through a piped network in Puerto Villamil, the main urban area, and with tank trucks at the highlands [19]. The limited groundwater supply available at lower elevation gets contaminated with rainwater that percolates downhill from the agricultural land in the highlands and saltwater intrusion that results from over pumping [19]. In 2010, it was reported that municipal tap contaminated water was the cause of approximately 70% of local illnesses in Puerto Villamil [19]. Fecal coliform contamination has been reported in crevices such as El Manzanillo [22]. Thus, inhabitants rely on rainwater collection, desalinization plants and water from other islands for potable water.

Water from the desalinization plant is pumped to two storage tanks with 300 m<sup>3</sup>/day and then distributed throughout Puerto Villamil's water grid for 3 h in the morning and 3 h in the evening. However, the treated water runs out within a couple of hours of distribution and the municipality ends up distributing untreated water during the remaining hours (personal communications with the municipality, 2019). Plans to increase the storage capacity of treated water to 600 m<sup>3</sup>/day by 2020 and 1000 m<sup>3</sup>/day by 2025 [46] have not been funded.

Furthermore, due to the lack of maintenance of the pipes, the potable water running through the grid is often contaminated with seawater intrusion and sometimes holes and leaks can be found at the household level. While Puerto Villamil has a piping system that collects wastewater from households and takes it to the WWTP, contamination of groundwater sources remains an issue. Ideally, the water that has been treated in the WWTP is discharged into the ocean. However, this is not always the case. The sewage system on the island continually collapses, causing not only strong odors and unsanitary conditions in the neighborhoods but also contaminating water sources. Even worse, in those neighborhoods without a sewerage system, the wastewater goes directly into the crevices [46].

#### 4. Discussion and Recommendations

We base our discussion on actions identified by technical specialists and local stakeholders not yet addressed in government plans found during Task 4 (Table 3). While each island has their own water needs and priorities, they all highlighted the need for an integrated freshwater management plan to address water quality issues by (a) building or improving infrastructure for freshwater collection systems and sewerage; (b) monitoring, controlling, preventing and mitigating water contamination; (c) evaluating the impact of water quality on the public health of local people; and (d) actively enlisting the participation of all social actors.

Government plans have limitedly addressed the needs and concerns expressed by technical specialists and local stakeholders; thus, measurable impacts on water quality have not yet been attained on any of the three islands. Multiple factors contribute to current water quality issues, including the limited freshwater resources, the lack of an effective wastewater treatment plant and sewerage systems [26,59], the lack of cleaning and maintenance of distribution systems, water storage and pipes [60], the lack of access to these services [31], and lack of transparency and political problems [61,62]. Government efforts along with some technical experts' recommendations have focused on infrastructure solutions. While many of these efforts have not yielded successful results, to our knowledge, this is the first study to look at why these have failed. Our research highlights the need to holistically examine research and policy, and community focused recommendations alongside infrastructure solutions.

Recommended initiatives from technical specialists and local stakeholders that the government still needs to address fall under four main interconnected categories: infrastructure, research and policy, and community (Table 3). Based on the workshop and the analysis of the PDOTs, a fourth category of barriers to governance was added as an overarching theme.

**Table 3.** Issues and actions identified as priorities by technical specialists and local stakeholders that the government still needs to address.

Island	Initiative	Actions
Santa Cruz	Infrastructure	Develop a biological wastewater treatment plant to stabilize organic matter, remove nutrients and improve water quality overall.
		Create and maintain constructed wetlands for water quality control
	Research and Policy	Implement water quality monitoring programs. Study the impact of degraded water quality on the health of local people and the environment. Improve water management system.
San Cristobal	Infrastructure	Develop reservoirs and natural infrastructures such as wetlands for capture and storage of stormwater and improved quality control.
		Strengthen the operability of the water treatment plants and the wastewater treatment plant.
	Research and Policy	Examine alternatives for water treatment, use and reuse. Ensure the continuity of an effective water quality monitoring program.
		Study the impact of degraded water quality on the health of local people and the environment.
		Develop a water ordinance that addresses the functionality of running water and wastewater treatment facilities. Implement policy requiring the cleaning and maintenance (i.e., prevent leaks) of drinking water pipes.
Isabela	Infrastructure	Develop a new sewerage system and freshwater collection systems (reservoirs and rainwater collection systems). Strengthen the operability of the water treatment plants.
	Research and Policy	Study the impact of degraded water quality on the health of local people and the environment. Control, prevent and mitigate water contamination.
	Community	Increase the involvement and participation of all social actors to secure the effectiveness of an integrated water management plan.

#### 4.1. Water Infrastructure

As previously mentioned, the significant amount of money towards new potable and wastewater systems currently only benefits a small portion of the islands' population or projects have not been fully implemented. Failure of proposed projects to improve both wastewater treatment and the supply of drinking water services is likely related to the lack of effective planning, as discussed below in this section or the lack of funding and adequate governance, as discussed in Section 4.4.

While all islands still have water quality issues, recommendations should be very specific for each one depending on its current water status and infrastructure. For example, a new sewerage system should be prioritized in urban and rural areas that lack basic services such as Puerto Ayora and Santa Rosa in Santa Cruz Island and Puerto Villamil and settlements in the highlands of Isabela Island. This will not be a priority for San Cristobal Island since they have a sewerage system. In San Cristóbal, there is a need to develop stormwater infrastructure to capture and store water during intense precipitation events to prevent runoff contamination. Another example would be WWTPs and drinking water treatment plants' infrastructure and operations. While there is no need for new infrastructure in San Cristobal and Isabela Islands, that should be a priority in Santa Cruz Island.

Nevertheless, biological WWTPs are urgently needed to stabilize organic matter, remove nutrients and to preserve and improve water quality in all islands.

In addition to new infrastructure on some islands, the operability of existing potable and wastewater systems should be evaluated and more consistently monitored on all the inhabited islands to improve and better maintain existing water infrastructure. For example, the water quality for the two drinking water treatment plants in San Cristobal varies because it comes from two sources. Therefore, there is a need to optimize the system to understand and improve the treatment process itself to respond to the characteristics of each plant [47]. The situation is different for Isabela, where the existing infrastructure is only working partially since they do not have enough treated water storage capacity to meet the population's demands. Thus, they need to first increase storage capacity and then develop optimization plans. The situation is complex in Santa Cruz since it is the most populated island but lacks good quality potable water. While it has a desalinization plant, it is still not operational and thus the water that is distributed is considered brackish. The challenge on this island is to make sure the existing infrastructure works as intended.

In recent years, population and tourism expansion has led to increases in impervious areas [18]. As a result, the amount of forested lands, wetlands and other open spaces that absorb, slow and filter stormwater in the natural system has decreased. Therefore, construction and maintenance of systems to collect and treat stormwater such as water tanks, reservoirs and natural infrastructure like wetlands are also recommended. While government plans are aware of these needs, significant progress on these actions is not yet noticeable. We recommend that all new construction should identify its impact on stormwater runoff and evaluate how they can mitigate any negative impacts. Policies such as those in the City of Portland, Oregon, USA, that requires any new development to reduce, delay, or improve the quality of stormwater runoff, through actions such as infiltration bioswales, green roofs, pervious pavement, trenches, sumps, among other practices, could be used as an example [63].

#### 4.2. Community

Community involvement and participation of all social actors to secure the effectiveness of an integrated water resource management plan is recommended for all three islands. Involving communities in all stages of decision making such as policy and plan formulation and project and program implementation (bottom-up approach) encourages local stakeholders to work together and provides capacity building and empowerment opportunities to communities [64–66]. Local stakeholders are considered experts of their local environment. Therefore, their knowledge of the system as well as specific needs and priorities concerning local water access and management should be considered. Furthermore, the participation of local stakeholders is crucial, not only at the design stages but for monitoring of the development of projects to guarantee their execution and transparency of the use of funds. Methods of fiscal accountability to assess the progress of these projects should be considered key features in any future planning for water quality programming in the Galapagos.

There are multiple options to foresee the involvement of community members in water quality investment by the government and other institutions. One option can be to establish a platform for pledges, budgets and dates that visualize the progress of investment as it relates to water quality. This strategy would be reminiscent of the Toxic Releases Inventory through which companies in the United States share the data of their releases and autoregulate based on the social pressure created to not be at the top of the list of polluters [67]. In this case, municipalities could reveal this information and compare across islands, even beyond the Galapagos; pressure can be created from the community and the media about the timeliness and efficacy of the use of funds. For this type of strategy to work, the data should be clear and accessible. Now, PDOTs are easily obtained and downloaded but the data are not presented with a citizen-centered design that would make the documents easy to read.

Another option to get community participation and continued engagement can be using the citizen science (CS) tools. CS can also help keep participants engaged, while community members

learn more about water quality monitoring and become more interested in this process. Technical specialists can be part of knowledge sharing that can aid in capacity building. In this manner, the government has real-time signals on what to act upon, strengthening collaboration among sectors and further building community engagement and transparency [68,69]. This option is also discussed further in the policy section (4.3).

Additionally, there is a need to strategically emphasize information, awareness and education for the local community regarding water management's importance. Some key issues to be addressed are waste management and improving the effective maintenance of storage tanks and septic tanks at the household level.

#### 4.3. Research and Policy

Long-term water quality monitoring programs are recommended for all islands. While technical specialists have made significant contributions to establish baseline information on water quality in all three islands [23,24,47], the government needs to re-establish funding programs for monitoring and use the data more effectively, especially in Santa Cruz and Isabela. These monitoring programs should evaluate the efficiency and effectiveness of treatment plants to meet Ecuadorian environmental legislation for (i) water leaving the drinking water treatment plants according to the NTE INEN 1108 standard for drinking water [70], (ii) the water distribution systems by testing the water as it enters households, and (iii) water leaving the wastewater treatment plants for physical-chemical and microbial parameters according to wastewater discharge limits required to enter a water body [48]—in this case, the ocean. Furthermore, these monitoring programs should focus on monitoring both the water resource and the users' actions acknowledging water as a common good, setting adequate sanctions [71]. Information obtained from these monitoring programs can be used as background data for environmental impact assessments to validate monitoring data, identify water bodies in need of protection, evaluate the effectiveness of water management plans and take corrective actions in terms of the operation, provide data for decision making and comply with environmental regulations.

Capacity building at the local level is also recommended for Isabela and Santa Cruz Islands. This will not only allow for carrying out analysis locally but will also reduce costs by not sending water samples to the continent, reduce analysis times and guarantee the quality of the results [47]. Furthermore, a local laboratory would also promote local citizens' training, generating professionals trained in the state-of-the-art analysis of samples.

In terms of policy making, creating and implementing an ordinance for pollution control for each populated island can only be as useful as it is reinforced. To promote water quality improvements, there is the need to

- Develop measurable water quality objectives and get community participation in continuous monitoring, using strategies such as CS. In this case, getting community participation for collecting and analyzing water samples is not initially about obtaining quality data, but about getting concerned citizen participation and a sense of ownership and responsibility [69], consistent with managing commons. This process should be accompanied by researchers or officials collecting and sharing data while also educating citizens to improve data quality.
- Identify participatory approaches to monitor discharges of domestic sewage into communal sewers or water bodies. A concerned citizen brought up the issue of inadequate water discharges from septic tanks during one of the workshops. Though he proposed enhanced regulation, he also described his strategy to deliver the water for adequate treatment at a low cost. Positive deviance, where community members find creative solutions and whose ideas are uplifted and shown to other members, could be an adequate next step rather than focusing on sanctioning [72]. Further research would be required to pursue this option but would take a behavioral outlook, such as applying social pressure into policy-making, where citizens are rewarded for good practices [73]. This strategy could be particularly useful where funding for reinforcement is scant.

- Develop funding strategies to sustain these programs such as (i) adding a small fee to water bills for monitoring; (ii) designating a portion of the national park entrance fee to water projects; (iii) engaging university students in aiding community education and monitoring efforts.

#### 4.4. Barriers Towards Progress, Water Governance and Transparency

Large funds have been allocated to address water needs and concerns in the Galapagos Islands, but it is challenging to detect progress towards addressing identified problems. Evidence suggests that barriers to progress towards the Galapagos' water and sanitation goals resemble governance shortcomings found throughout the developing world. These challenges include budget inefficiencies and misallocation, lack of transparency, lack of prioritization and coordination, lack of local participation and buy-in (discussed in Section 4.2), lack of consideration towards local capacity, and lack of understanding island-specific needs and building capacity (discussed in Section 4.1).

Of these barriers, we found several instances of inefficiencies and misallocation of budgets for projects to improve the supply of drinking water and wastewater services. For example, in December 2003, the Ministry of Housing (MIDUVI) signed a contract with the company Eptisa-Entemanser to design and construct a drinking water plant for the four inhabited islands of the Archipelago [62]. The project was expected to deliver drinking water to 30,000 inhabitants for 20 years. The project's total cost was approximately USD 13 million, of which, by 2018, the Ministry has already paid USD 7.6 million [61]. However, until now, there is no evidence of this project. Furthermore, according to the Anticorruption National Secretary, the plans proposed by the company Eptisa-Entemanser do not correspond to the environmental or demographic reality of the Archipelago and, thus, using this technology would be extremely expensive to produce drinking water [61]. Another similar case occurred in 2016, the Municipality of Santa Cruz with the contribution of the State Bank invested USD 20 million for a water purification project to supply drinking water service for the inhabitants of Santa Cruz [69]. Nonetheless, there is no access to information about this project's development or status and drinking water is still an issue there. The desalination plant built in 2016 in Santa Cruz Island is another example of a project in which a significant amount of money has been invested (approximately USD 7 million) [44] but until March of 2020, it cannot be determined if the system is fully operational.

According to the Organization for Economic Cooperation and Development (OECD)'s strategy for water governance [74], Latin and Central America have the lowest average implementation levels of water infrastructure, at 35% [69]. Consistent ongoing communication among participants and institutional support in the form of facilitation, coordination and continuity by organizations have resulted in successful water governance processes [75]. Therefore, there is a need for a method for accountability of the funds being used in water management and implementation efficacy. Results should be accessible for monitoring by all stakeholders and citizens according to pre-defined performance indicators. This information should be accompanied by adequate timelines that can show progress beyond government periods (one mayor to the next), serving the institutionalization of water governance to improve water management and transcend projects. Furthermore, a thorough revision of previous plans, prior to proposing new ones can provide insight into the true timelines and budgets required for similar projects within the Galapagos or other relevant contexts. This exercise can be used as the "outside view" as referred to by Kahneman and Tversky to set benchmarks and avoid a planning fallacy due to optimism bias [76]. This benchmark can also aid in managing expectations of the financing institutions that generally define key performance indicators, the multiple stakeholders invested in water management and the expected beneficiaries.

An integrated water resources management plan is needed in Galapagos to protect its natural environment. Overexploitation of groundwater resources, a changing climate and increased demands can exacerbate water scarcity issues in this already vulnerable system. Thus, it is first necessary to represent the ecological reality of each island by accounting for the environment's needs through including not one technical representative but the multiple studies published about water quality efforts. Moreover, stakeholders must understand the water cycle in the islands and its vulnerabilities and find ways to accommodate current conditions and plan for future changes. These

changes include the impacts of climate change alongside the increased water demand consumption due to population and tourism growth and the subsequent effluents.

Local capacity, more oversight and knowledge building must be considered to guarantee water management projects success. For example, various actions have been proposed to solve wastewater management issues in Santa Cruz; however, those projects faced a slow implementation due to technical difficulties [26]. The centralized sewage system that was proposed and implemented in Puerto Ayora failed to take into consideration the challenges of doing it in an already densely urbanized town, with proximity to the sea and located on top of volcanic soil that makes it difficult for deep excavations [26]. Actions to solve this issue have been proposed [26] in which the sewer system is connected to a semi-centralized treatment system instead of a centralized one. This semi-centralized system consisted of constructed wetlands and Imhoff tanks (a simple system used for primary and secondary wastewater treatments without energy use) that eventually will end up in a centralized plant for disinfection. The proposed plan considers that deep excavations are not possible in that area and uses technologies that have been effective in other areas requiring minimum maintenance.

All these examples highlight the need for a participatory governance strategy that involves multiple stakeholders in designing, implementing and evaluating water management projects. Community integration in understanding water management, alongside technical specialists' insights representing the environments' needs, can better inform policy and balance social and environmental concerns while developing adaptive and resilient water governance [77]. When compared and balanced with the budget allocation as performed in Task 4, they present the socioecological reality to account for in planning; these are the strengths of this method. Engaging technical specialists beyond participation in workshops by using their publications also constitutes an improvement for top-down and bottom-up approaches. Moreover, the transversal evaluation of funds' usage and timelines in programs can provide increased transparency that may lead to faster and better outcomes to improve water quality. This historical analysis of projects success or failure represents an important contribution to regular top-down and bottom-up approaches that are only used for planning and designing but generally do not consider past failures to implement within the timeframe and budget allocated.

The methodology presented from Tasks 1 to 4 can be used iteratively as an overarching governance mechanism to not only design strategies but monitor efforts in water quality improvements, the advancement of science in the region and the awareness in the population. More actors may become engaged considering the high interest presented by current stakeholders in collaborating in projects when invited to the workshops for Task 2. Considering all the priorities related to 'Community', it would be ideal that as community members become more engaged, they would become direct participants in Task 2 and validate the results of Tasks 4 and 5 to move forward with a co-creative approach to solutions and program development. As a general recommendation for practitioners, if there had been an indigenous community, their perspective should also be balanced with the technical specialists' priorities to represent the ecological priorities. Unfortunately, the funding and time constraints for this stage of the project did not allow for engaging local stakeholders to validate the results of Tasks 4 and 5. However, these actions will take place in later stages of this project.

Finally, as mentioned in Section 4.1, plans to solve drinking water problems are unique for each island since each island has its own specific needs and priorities. Therefore, prioritization and coordination of island-specific needs will lead to tangible, measurable outcomes that are socially, financially and technically feasible.

## 5. Conclusions

Despite the specific focus on the Galapagos Islands, this study and methodology can provide insights and guidance to other islands facing similar constraints in achieving water quality objectives. The Galapagos Archipelago is exceptionally vulnerable to disturbance resulting from human activity. This study examines water quality needs and priorities for the three main inhabited islands in the

Archipelago. A collaborative bottom-up and top-down governance approach was applied to evaluate water quality plans. The methodology considers water resource challenges, concerns and plans identified by the scientific literature, practitioners and local community and evaluates the effectiveness of proposed and implemented programs to address those needs. Therefore, the study provides a valuable governance mechanism that can be used as a baseline for improving current and future water management, considering how funds are used to respond to societal requirements following the ecological reality presented by technical specialists representing the environment's needs. The vastly different results in the islands reveal the need to understand the socioecological context and stakeholders' perspectives to adequately prioritize programs to improve water quality in each island. This participatory approach offers an opportunity for dynamic water governance that can be responsive to the challenges faced currently, but also in the future, particularly with the pending impacts of climate change.

More research is needed to understand the hydrogeological and socioeconomic conditions that lead to different stakeholders' and budgetary needs and the execution differences. All groups highlighted the need for (a) building or improving infrastructure for sewerage systems and freshwater collection systems; (b) monitoring, preventing and mitigating water contamination; and (c) the involvement and participation of all social actors to secure the effectiveness of an integrated water management plan. Considerable funds have been allocated to address infrastructure needs. However, most of these projects have not yet been completed or only address a portion of the water quality issues. By looking at why these actions have failed, this study highlights the need to holistically examine research and policy, and community focused recommendations alongside infrastructure solutions. A method for accountability of the funds being used in water management, the efficacy of implementation and results and progress beyond government periods should also be consistently accessible for monitoring by all stakeholders. This will guide future policy and inform potential funders of tangible, feasible and measurable outcomes. Combining these governance strategies can aid the Galapagos Islands and other islands worldwide in improving water quality and building climate resilience.

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## Appendix A

**Table A1.** Peer reviewed articles from Web of Science and SCOPUS between 1 January 2010 and 18 June 2020.

KEYWORDS	SCOPUS	WEB of SCIENCE
Water and quality and Galapagos	21	24
Water and resources and management and Galapagos	14	22
Wastewater treatment and Galapagos	1	1
Water contamination and Galapagos	1	6
Water issues and Galapagos	6	8
Water distribution and Galapagos	52	70
Water access and Galapagos	12	21

**Table A2.** Government plans addressing water quality issues in Santa Cruz Island <sup>1</sup>.

Initiative	Funding allocation	Year	Project Status	PDOT Description
Research	USD 14,250	2013	Proposed	Payment or Contract for water samples analysis and monitoring. Responsible: Dirección General de Ambiente (DGA), Gobierno Autónomo Centralizado (GAD) Santa Cruz
	No information		Proposed	Implementation and monitoring of water distribution and sewerage systems.
Infrastructure	USD 69,752,346	2012 – 2016	Running/ Executed	Construction of: (1) a primary wastewater treatment facility in the community of Bellavista and Mirador; (2) an integrated sanitary sewer system and improvement of the potable water system in Puerto Ayora; (3) main potable water networks of El Mirador (executed); (4) a cistern in the rural area of Santa Rosa; (5) reservoir in Bellavista. Responsible: GAD Santa Cruz
	USD 508,500	2013	Proposed	Implement ecological systems for sewerage systems: Provide water to Miramar and Bellavista, resources maintenance, La Camiseta aquifer maintenance, sewerage for Barrio La Unión, water distribution system maintenance, construction of water networks. Responsible: Dirección de Obras Públicas (DOOPP) and DGA
	No information		Proposed	Maintenance of artificial wetlands.
	No information		Proposed	Environmental education and communication campaigns and awareness campaign for the sustainable use of water.
Community	USD 228,184	2012	Executed	Integrated Water Resource Management. Responsible: GAD Santa Cruz
	USD 82,419	2016	Executed	Creation of a guide with norms for environmental building and technology implementation according to the natural environment of the island: sustainable mobility system. Responsible: GAD Santa Cruz
Policy	USD 25,000	2014 – 2015	Proposed	Creation of a guide with norms for environmental building and technology implementation according to the natural environment of the island: ecological regeneration of coastal public spaces. Responsible: DOOPP and Secretaría Técnica de Planificación y Desarrollo Sustentable (STPDS)
	No information		Proposed	Creation and implementation of ordinances for wastewater management.
	USD 252,308	2012	Executed	Capacity building for the monitoring and control of sources of pollution: recovery of Las Ninfas Lagoon. Responsible: DOOPP and GAD Santa Cruz
Capacity Building	USD 136,000	2013 – 2016	Proposed	Capacity building for the monitoring and control of sources of pollution: consulting and recovery of Las Ninfas Lagoon, maintenance of Camiseta, Pozo Profundo and Mirador aquifers, maintenance of dry wetlands (PEA), wastewater treatment. Responsible: DOOPP, STPDS and Dirección General de Ambiente y Servicios Públicos (DIGAS)
<b>Total Invested</b>		<b>USD70,315,257</b>		

**Total Proposed**                      **USD 683,750**

<sup>1</sup> Information obtained from Plan de Desarrollo y Ordenamiento Territorial (PDOT) for Santa Cruz Island [38].

**Table A3.** Government plans addressing water quality issues obtained from PDOTs in San Cristobal Island <sup>1</sup>.

Initiative	Funding allocation	Year	Project Status	PDOT Description
Infrastructure	USD 2,037,379	2014–2015 & 2017	Executed	Sanitary sewer system for Manzanillo, Las Palmeras and el Gran Maestro. Responsible: GAD, Banco del Estado.
	USD 15,500	2014	Executed	Cleaning and mitigation of drinking water pipes in Puerto Baquerizo due to contamination of the pipeline with some type of hydrocarbon. Responsible: GAD.
	USD 49,964	2014	Executed	Strengthening the operability of the water treatment plants: remodeling of the laboratory area and septic tank; Sanitary batteries and septic tank in drinking water plant in Las Palmeras; drainage relocation of the water treatment plant in the Las Palmeras. Responsible: GAD.
	USD 17,000	2014	Executed	Water quality monitoring. Responsible: SENAGUA.
	USD 208,840	2015–2016	Executed	Strengthening of drinking water and sanitary sewerage services in San Cristóbal canton, Galápagos. Responsible: GAD.
	USD 2,000,000	2012	Proposed	Construction of storm sewer network. Responsible: GAD, MIDUVI, ONGs.
	USD 400,000	2012	Proposed	Constructions of water tanks for Soledad, Goteras and Cerro Verde. Responsible: GAD, MIDUVI, ONGs.
	No information	2016	In progress	Water quality monitoring in El Progreso. Responsible: PNG, GAD. Wastewater treatment plant and potable water plant monitoring (El Progreso and Las Palmeras). Responsible: GAD.
Policy	USD 200,000	2012	Proposed	Integrated Water Management: Ensure the management, monitoring, control, remediation and recovery of water resources considering zones for capture, recharge and runoff.
	No information		Proposed	Program for Pollution Control: Creation and implementation of ordinance for wastewater management.
<b>Total Invested</b>		<b>USD 2,328,683</b>		
<b>Total Proposed</b>		<b>USD 2,600,000</b>		

<sup>1</sup> Information obtained from Plan de Desarrollo y Ordenamiento Territorial PDOT) for San Cristobal Island [39].

**Table A4.** Government plans addressing water quality issues obtained from PDOTs in Isabela Island <sup>1</sup>.

Initiative	Funding allocation	Year	Project Status	PDOT Description
Policy	No information	2012–2016	Proposed	Control, prevention and mitigation of the contamination of water as a contribution to the improvement of the quality of life and to guarantee the right to live in a healthy and ecologically balanced environment.
	No information	2012–2016	Proposed	Comprehensive water resource management program and water access plan.
	No information	2012–2016	Proposed	Pollution control program
Community	No information	2012–2016	Proposed	Promote the participation of all social actors in the cantonal environmental management through the coordinated work between the sectional governments and the national environmental authority.
Infrastructure	No information		In progress - No information	Develop a potable water system that guaranteed the health of Isabella residents.
	USD 10,000.00	2012–2013		Implementation of freshwater collection systems, reservoir tanks. Responsible: GAD Isabela.

<sup>1</sup> Information obtained from Plan de Desarrollo y Ordenamiento Territorial PDOT) for Isabela Island [40].

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