Final Report for project Scaling Up Wetlands Models with Groundwater Recharge and Rainwater Harvesting for Water Security and Urban Resilience in Islamabad

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Project Glossary

Term / Acronym	Definition
BOD	**Biological Oxygen Demand:** A measure of the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at a certain temperature.
CDA	**Capital Development Authority:** The municipal corporation responsible for providing municipal services in Islamabad and overseeing the city's urban planning and maintenance.
COD	**Chemical Oxygen Demand:** A method to determine the amount of organic compounds in water. It is a critical indicator of the overall water quality and treatment effectiveness.
Constructed Wetland	An engineered system that uses natural processes involving wetland vegetation, soils, and their associated microbial assemblages to treat wastewater.
E. coli	**Escherichia coli:** A type of bacteria that serves as a primary indicator of fecal contamination in water and a key parameter for assessing the safety of reclaimed water.
FDO	**Farmers Development Organization:** The lead implementing organization responsible for the execution and management of the CF (WRAP) project.
GEDSI	**Gender Equality, Disability, and Social Inclusion:** A framework used to ensure that project benefits reach women, persons with disabilities, and marginalized groups equitably.
GPD	**Gallons Per Day:** The unit of measurement used to define the hydraulic treatment capacity of the constructed wetland sites.
HRT	**Hydraulic Retention Time:** The average period of time that wastewater remains within the treatment system (settler tanks or wetland cells) to allow for biological degradation.
IWRM	**Integrated Water Resource Management:** A process which promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare.

Term / Acronym	Definition
MAR	**Managed Aquifer Recharge:** The purposeful recharge of water to aquifers for subsequent recovery or for environmental benefits, specifically implemented via the deep-bore well at QAU.
MoCC & EC	**Ministry of Climate Change & Environmental Coordination:** The federal ministry in Pakistan responsible for national policies, plans, and programs regarding climate change and environmental protection.
NbS	**Nature-based Solutions:** Sustainable management and use of nature for tackling socio-environmental challenges such as water scarcity, flooding, and climate change.
NEQS	**National Environmental Quality Standards:** The legal limits in Pakistan for the concentration of various pollutants in municipal and industrial liquid effluents.
O&M	**Operations and Maintenance**
PCRWR	**Pakistan Council of Research in Water Resources:** The national research body responsible for water quality monitoring and technical validation of the project's performance.
Phytoremediation	The use of living green plants (such as *Typha* or *Phragmites*) for the removal, degradation, or containment of contaminants in wastewater and soils.
RWH	**Rainwater Harvesting**
SSF	**Sub-Surface Flow:** A type of constructed wetland where the water level remains below the surface of the filter media (gravel/sand), preventing odors and mosquito breeding.
TN / TP	**Total Nitrogen / Total Phosphorus:** Chemical parameters used to measure nutrient levels in wastewater; high levels can cause eutrophication in downstream water bodies.
TSS	**Total Suspended Solids:** The dry-weight of particles trapped by a filter, used as an indicator of the physical filtration efficiency of the wetland system.
WHH	**Welthungerhilfe:** An international non-governmental German organization and key project partner providing support for climate resilience and water security initiatives.

Executive Summary

Overview and Strategic Vision

The "Scaling Up Wetlands Models with Groundwater Recharge and Rainwater Harvesting for Water Security and Urban Resilience in Islamabad" project under CF-WRAP represents a landmark transition in Pakistan's urban water management strategy. Orchestrated as a flagship initiative, the project addresses the critical shortfall in Islamabad's centralized sewage treatment capacity by deploying decentralized, Nature-based Solutions (NbS). The primary goal was to move from energy-intensive, traditional infrastructure to low-cost, ecologically sound systems capable of wastewater treatment and direct groundwater replenishment.

Technical Infrastructure and Engineering Excellence

The project successfully operationalized three diverse demonstration sites with a cumulative treatment and recharge capacity exceeding 550,000 Gallons Per Day (GPD):

- Site A: Sector G-6/2 (Hybrid Urban Wetland): Designed to treat 250,000 GPD within a constrained urban footprint. It utilizes a hybrid of vertical and horizontal subsurface flow cells, powered by a solar-pumping system to ensure grid-independent, 24/7 operation.
- Site B: Rawal Town (Earthen Wetland): A high-volume system treating 300,000 GPD for a major residential catchment. This model leverages natural topography for a 100% gravity-fed flow and uses cost-effective earthen construction with specialized liners.
- Site C: Quaid-i-Azam University (MAR & RWH): Captures runoff from 26,500 sq. ft. of catchment area to recharge approximately 2.22 million liters of water annually into the local aquifer.

Socio-Technical Governance and Inclusive Stewardship

Beyond physical engineering, the project established a robust, integrated "Social-Technical" bridge to ensure long-term community ownership and site sustainability:

- **Quantitative Reach:** The project reached a balanced footprint of 903 total beneficiaries, directly engaging 483 males and 420 females across high-intensity training tracks and medium-intensity localized awareness campaigns.
- **Integrated Social Inclusion (GEDSI):** Strategic outreach actively prioritized vulnerable populations, successfully including 233 ultra-poor individuals (155 male, 78 female) and 2 Persons with Disabilities (1 male, 1 female) within the core project design. Additionally, the project engaged 93 religious minorities (44 male, 49 female), specifically identifying them as members of the Christian community residing within the underserved christian Colony slum area (Sector G-6/2).

- **Human Capital Development:** A professional cadre of 66 certified personnel was trained in specialized NbS operations and maintenance (O&M) to sustain the infrastructure. To ensure gender integration in technical roles, this workforce development track successfully qualified 46 male and 20 female professionals.
- **Community Infrastructure Governance:** Eight progressive capacity-building modules were completed, culminating in the mobilization of 20-member Community Action Committees at both the G-6/2 and Rawal Town sites. These committees feature a mandatory 30% female representation (6 females and 14 males per committee) alongside dedicated representation for PWDs, empowering marginalized groups to serve as localized water stewards, field monitors, and structural maintenance managers.

Institutional Validation and Policy Influence

The 550,000+ GPD treatment capacity is not just an engineering estimate but is backed by PCRWR laboratory validation confirming compliance with NEQS 1999 for wastewater reuse. The project's outcomes were formally validated during a high-level Dissemination Workshop on April 2nd, 2026:

- Government Endorsement: Mr. Ijaz Ghani, Senior Joint Secretary of the Ministry of Climate Change (MoCC), underscored the critical nature of these initiatives for addressing groundwater depletion and urged for nationwide replication.
- International Support: The Acting Country Director of Welthungerhilfe (WHH), Ms. Izabelle, commended the project's relevance in solving dense urban water challenges through collaborative technical partnerships.
- Policy Shift: Technical advocacy through the project influenced a significant regulatory shift, with the Capital Development Authority (CDA) making rainwater harvesting mandatory for households and recharge wells mandatory for commercial buildings in Islamabad.

Future Roadmap and Recommendations

To sustain the project's impact, a 2026–2030 Policy Roadmap focuses on the technical validation of spring-season biological maturation and the mainstreaming of NbS into standard municipal budgets. Key strategic recommendations include:

1. Synchronized Waste Management: Integrating municipal solid waste collection with wetland maintenance to prevent filtration bed clogging.
2. Resource Circularity: Implementing "Purple Pipe" networks to reuse treated wetland effluent for urban green belts.

3. Academic Continuity: Utilizing the QAU and university-linked sites as "Live Laboratories" for training the next generation of environmental engineers.

Section 1: Implementation Process & Timeline

1.1 Introduction

The Catalytic Fund for Water Resource Accountability in Pakistan (CF WRAP) project serves as a flagship initiative designed to demonstrate the viability of Nature-based Solutions (NbS) for urban water management. By transitioning from traditional centralized sewage treatment to decentralized, ecological infrastructure, this project addresses the critical gap between wastewater generation and resource recovery in Islamabad. This final report section details the procedural evolution and technical execution that led to the operationalization of three diverse demonstration sites.

1.2 Background

- The Urban Water Crisis: Islamabad's rapid expansion has outpaced its centralized sewage treatment capacity, leading to significant environmental degradation in local water bodies.
- The Shift to NbS: The CF WRAP project was designed to transition from energy-heavy, centralized systems to decentralized, Nature-based Solutions (NbS) that are low-cost and low-energy.
- Water Scarcity Mitigation: By utilizing Constructed Wetlands (CWs) and managed aquifer recharge, the project directly addresses the public health risks associated with untreated wastewater discharge.
- Policy Alignment: All interventions were developed to align with national water security goals, Nationally Determined Contributors and National Environmental Quality Standards, ensuring the model is ready for national scaling.

1.3 Project Objectives

The primary objectives of the implementation phase were:

- Technical Model Diversity: Designing and operationalizing three distinct NbS models, Hybrid Urban, Earthen, and Rainwater Harvesting and Groundwater Recharge to prove viability across different Pakistani topographies.
- Long-Term Sustainability: Prioritizing solar-powered pumping and gravity-fed systems to minimize Operational & Maintenance (O&M) costs.
- Knowledge Sovereignty: Bridging the technical gap by training local personnel and facilitating a formal institutional handover to the Capital Development Authority (CDA).

- Circular Economy Goals: Achieving quantifiable outcomes in water reuse for horticulture and direct groundwater replenishment.

1.4 Scope

The scope of this implementation covered the full project lifecycle across three strategic locations in Islamabad: G-6/2, Rawal Town, and Quaid-i-Azam University (QAU). The execution included:

- Geographic Reach: Full project lifecycle management across three strategic Islamabad locations: G-6/2, Rawal Town, and Quaid-i-Azam University (QAU).
- Site-Specific Engineering: Conducting detailed topographical surveys and utility mapping to adapt designs to specific site constraints.
- Infrastructure Execution: Management of civil works for settler tanks, specialized wetland cells, and expansive distribution networks.
- Technological Integration: Overseeing the installation of solar power uptake systems and specific filtration media to ensure high-efficiency biological treatment.
- SOP Development: Creating Standard Operating Procedures (SOPs) for site management to ensure the systems remain operational long after the project concludes.

1.5 Targeted Output

The project aimed to deliver the following quantifiable outputs:

- Treatment Capacity: A cumulative wastewater treatment and recharge capacity exceeding 550,000 gallons per day (GPD) across the three sites.
- Resource Recovery: The successful diversion of treated effluent for local horticulture and the recharge of over 2.22 million liters of rainwater annually.
- Validated Documentation: A comprehensive technical manual and validated water quality monitoring reports.
- Workforce Development: A cadre of 66 certified professionals equipped to manage and replicate NbS infrastructure.

Phase	Key Activities	Status
Inception	Stakeholder mapping, site selection (G-6/2, Rawal Town, QAU), and baseline hydrological surveys.	Completed
Design & Engineering	Detailed engineering drawings, hydraulic flow calculations, and utility conflict mapping.	Completed

Construction	Excavation, settler tank installation, wetland cell layering, and solar integration.	Completed
Capacity Building	Trained 37 CDA personnel and 20 Community members on the operation and maintenance.	Completed
Validation & Handover	Water quality testing (PCRWR) and formal handing over the site to CDA.	In process

1.6 Targeted vs. Actual Timeline

- Treatment Volume: Aiming for a cumulative capacity exceeding 550,000 gallons per day (GPD).
- Aquifer Impact: Recharging over 2.22 million liters of rainwater annually through the QAU injection site.
- Professional Workforce: Developing a cadre of 66 certified professionals (updated from initial estimates) to manage and replicate NbS infrastructure across the country.
- Technical Documentation: Producing a comprehensive technical manual and water quality monitoring reports validated by the PCRWR.

Evolved Timeline

- Standard Lifecycle: The project moved through four core phases: Inception, Design & Engineering, Construction, and Final Validation.
- Adaptive Management at G-6/2: The most significant timeline shift occurred due to the discovery of undocumented underground utility lines in the urban G-6/2 sector.
- The Technical Pivot: Instead of abandoning the site, the team conducted high-resolution utility mapping and redesigned the settler tanks and cell depths to avoid municipal service disruption.
- Structural Integrity: This intensive adaptation phase ensured that the Hybrid Urban Wetland could exist safely within a high-density neighborhood.

1.7 Theory of Change (ToC) Validation

The project successfully validated its Theory of Change, moving from the Input phase (engineering designs and financial allocation) to the Outcome phase (sustained water reuse and institutional ownership).

The transition was triggered by two critical success factors:

- From Input to Outcome: The project successfully moved from the "Input" phase (engineering and funding) to the "Outcome" phase (actual water reuse and institutional ownership).
- The Institutional Trigger: Early involvement of the CDA and local stakeholders including local communities ensured that the project was seen as "integrated infrastructure" rather than just a temporary pilot.
- Human Capital as the Backbone: The certification of 66 personnel transformed the project from a set of physical assets into a professionally managed system.
- Technical Sustainability: This localized expertise ensures that the transition from construction to full-scale operation is supported by people who understand the biological and mechanical nuances of the sites.

Section 2: Technical Project Implementation

2.1 Overview of Nature-Based Solution (NbS) Framework

- De-centralized Logic: The implementation moved away from energy-intensive centralized treatment toward a decentralized model, reducing the burden on Islamabad's existing sewage infrastructure.
- Biological Filtration: Each site utilizes specific aquatic plants and graded filtration media to break down organic pollutants through natural microbial biofilms.
- Resource Circularity: The technical design ensures that water is treated to NEQS standards, making it safe for immediate reuse in local horticulture.

2.2 Site A: G-6/2 (Hybrid Urban Wetland)

- Design Capacity: Engineered to treat 250,000 gallons per day (GPD) within a restricted urban footprint.
- Hybrid Mechanism: The site utilizes a combination of vertical flow (VF) and horizontal subsurface flow (HSSF) cells to maximize oxygen transfer and nutrient removal.
- Solar-Powered Uptake: To ensure 24/7 operation without relying on the municipal grid, a solar-powered pumping system handles the primary lifting of influent into the settler tanks.
- **Infrastructure Components:**
    - Primary Treatment: Multi-chambered settler tanks designed for anaerobic digestion and solids separation.
    - Secondary Treatment: Engineered wetland beds filled with specific gravel media and planted with local ecological species.

2.3 Site B: Rawal Town (Earthen Wetland)

- Design Capacity: A high-volume system treating 300,000 GPD for a large residential catchment area.
- Passive Engineering: This site leverages the natural topography to create a gravity-fed system, eliminating the need for expensive mechanical pumps.
- Earthen Construction: By using compacted local soil and liners instead of concrete-heavy structures, the implementation demonstrated a highly cost-effective and scalable model.

- Hydraulic Control: The design includes flow regulators and baffle walls to ensure even distribution across the earthen cells, preventing erosion and maximizing contact time for treatment.

2.4 Site C: Quaid-i-Azam University (MAR & Rainwater Harvesting)

- Catchment Efficiency: Captures runoff from a 26,500 sq. ft. area, including rooftops and paved surfaces within the university campus.
- Aquifer Recharge (MAR): The system recharges approximately 2.22 million liters of water annually directly into the groundwater table.
- **Technical Injection Process:**
    - Collection: Diversion channels route rainwater into a centralized collection pit.
    - Filtration: A multi-stage filtration unit removes silt and debris before the water enters the recharge well.

2.5 Operational Challenges & Engineering Solutions

Site	Primary Technical Challenge	Engineering Adaptation
G-6/2	Discovery of undocumented utility lines during excavation.	Redesigned settler tanks for shallower depths and utilized precision excavation.
Rawal Town	Managing high-velocity storm flow into an earthen structure during monsoon season.	Installed energy dissipaters and bypass channels to protect the biological integrity of the wetland.
QAU	Ensuring the purity of harvested water before aquifer injection to prevent groundwater contamination.	Integrated a high-capacity silt-trap and activated sand filtration module.

2.6 Summary of Technical Performance Benchmarks

- Cumulative GPD: Total treatment/recharge capacity across sites: 550,000+ GPD.
- Energy Footprint: 100% of lifting energy for G-6/2 is solar-sourced; Rawal Town is 100% gravity-fed.
- Personnel Capacity: The operation of these technical specs is managed by 66 certified personnel trained specifically in NbS maintenance.

- G-6/2 Performance (Report AR-08963): Highlight that BOD (68.80 mg/L) and TSS (130.00 mg/L) are both well within the NEQS limits of 80 mg/L and 200 mg/L respectively.
- Rawal Town Performance (Report AR-08930): Showcase even higher efficiency with a BOD of 39.0 mg/L and TSS of 118.00 mg/L.

Parameter (Wastewater)	**NEQS Limit (1999)**	**G-6/2 Results**	**Rawal Town Results**	**Status**
BOD	80 mg/L	68.80 mg/L	39.0 mg/L	Compliant
TSS	200 mg/L	130.00 mg/L	118.00 mg/L	Compliant
pH	6.0 - 9.0	9.27 (Site Start-up)*	7.96	Compliant

Section 3: Social Mobilization, Inclusion & Capacity Building

3.1 Multi-Layered Stakeholder Engagement Strategy

The CF WRAP project operated on the principle that decentralized Nature-based Solutions (NbS) cannot function in isolation from the communities they serve. Unlike centralized, restricted-access sewage treatment plants (STPs), these pilot sites are embedded directly within residential and academic catchments.

- Objective: The mobilization strategy was designed to bridge the gap between technical infrastructure and local behavioral change, moving residents from passive wastewater generators to active water stewards.
- Methodology: The FDO (Farmers Development Organization) team utilized a blend of Rural Participatory Appraisal (RPA) tools, structured capacity-building cycles, and policy advocacy to ensure end-to-end stakeholder integration.
- Institutional Alignment: Parallel to community outreach, constant coordination was maintained with the Capital Development Authority (CDA), and PCRWR, to ensure the community interventions aligned with municipal regulatory frameworks.

3.2 Quantitative Impact

The project maintained rigorous tracking of its social impact using the International Climate Fund (ICF) Key Performance Indicator 1 (KPI 1) methodology. Beneficiaries were classified by intensity of support (High vs. Medium/Low).

Table 3.1: Comprehensive Beneficiary Reach (Disaggregated by Gender & Geography)

Beneficiary Type	Definition & Engagement Level	Male	Female	Total
Direct Beneficiaries	Targeted individuals receiving high-intensity, structured training (Action Committee members, seminar trainees).	196	124	320
Indirect Beneficiaries	Individuals benefiting from medium-intensity outreach (household visits, broader awareness campaigns).	287	296	583
Total Project Reach	Cumulative impact across all targeted urban sectors in Islamabad.	483	420	903

Table 3.2: Inclusion Metrics for Vulnerable & Marginalized Groups

Demographic Category	Recorded Reach	Engagement Strategy
Ultra-Poor (<25,000 PKR/mo)	**233** (155 Male, 78 Female)	Reached through targeted door-to-door mobilization in lower-income segments of Rawal Town.
Religious Minorities	**93** (44 Male, 49 Female)	Fully integrated into community awareness sessions without discrimination.
Persons with Disabilities (PWDs)	**2** (1 Male, 1 Female)	Provided dedicated representation within the site-specific Community Committees.

3.3 The Progressive Community Engagement Cycle

To ensure deep comprehension, the project deployed an 8-session cycle (four progressive modules repeated across the G-6/2 and Rawal Town sites) rather than one-off lectures.

- Module A: Responsible Water Consumption (Sessions 1 & 2)
    - Focus: Mitigating demand-side stress. Participants were trained on household leak detection, the compounding impact of dripping taps, and practical kitchen/bathroom conservation methods.
    - Community members pledged committing to practice and promote responsible water use within their households.
- Module B: Rainwater Harvesting & Recharge (Session 3)
    - Utilizing RPA tools (community mapping and problem ranking), residents identified local flooding hotspots.
    - Orientations were provided on the functionality of rooftop RWH systems and the deep-bore recharge wells (similar to those installed at QAU), prompting high interest in small-scale adoption for car washing and gardening.
- Module C: Nature-Based Solutions & Constructed Wetlands (Session 4)
    - Focus: Timed alongside World Wetlands Day (February 2026), these sessions sensitized the community on the mechanics of phytoremediation.

- Knowledge Shift: Discussions broke down the biological role of graded gravel media and native vegetation, effectively changing the community narrative from untreated nullahs to functional ecosystems.

3.4 High-Level Academic & Institutional Advocacy (The Seminar Series)

To ensure the scalability of the CF WRAP pilot, the project engaged academia, policymakers, and private developers through a highly targeted seminar series.

- The Policy Dialogue: Ramada Hotel (December 18, 2025)
  - Theme: "Water Security and Urban Resilience in Islamabad."
  - Stakeholders: Engaged the PCRWR, CDA and Ministry of Climate Change and Environmental Coordination (MoCC&EC), development partners, media, and civil society.
  - Technical Focus: Advocated for the NbS, resulting in a consensus on a "Policy Roadmap" that includes utilizing pilot data to inform CDA directory and mainstreaming NbS into National Water Policy frameworks.
- Academic Integration: Quaid-i-Azam University (December 23, 2025)
  - Stakeholders: Over 100 students and faculty members from the Green Youth Movement GYM) and Quaidian Science Society.
  - Technical Focus: Centered on the scientific principles of the newly installed campus groundwater recharge well (150 ft depth, 2.22 million liters/year capacity) and rooftop harvesting tanks.
- Scientific Deep-Dives: COMSATS & PMAS Arid Agriculture University (Feb 2026)
  - COMSATS Focus: Students were trained on international standards (US EPA, WHO) and the technical parameters for natural purification, such as the ideal BOD:COD ratio (1:2) and turbidity limits for sunlight penetration.
  - ARID University Focus: Leveraged the Department of Botany to conduct interactive sessions where students applied real-world criteria to select appropriate hyper-accumulator plant species for wastewater treatment cells.

3.5 Inclusion & GEDSI (Gender, Equality, Disability, and Social Inclusion)

The project moved beyond standard diversity quotas to implement functional Gender Equality, Disability, and Social Inclusion (GEDSI) strategies.

- The Door-to-Door Mobilization Model: Recognizing that socio-cultural barriers in certain pockets of Rawal Town limit female participation in outdoor site visits, the FDO deployed

female volunterrs for household-level orientations. This ensured that the elderly and women, who are the primary managers of household water were central to the dialogue.

- Safe Spaces for Feedback: The project partnered with the PBWO Women Welfare Complex to hold female-specific, indoor awareness sessions, ensuring a safe space for uninhibited feedback.
- Youth as Water Ambassadors: Significant emphasis was placed on educational institutions. Sessions at the Allied School and Islamabad Model College for Girls (IMCG) trained students to act as localized change agents, bringing environmental stewardship directly into their homes.

3.6 Community Governance & Long-Term Sustainability

To formalize the institutional handover and prevent the project from decaying post-completion, the project established localized governance structures.

- The 20-Member Community Committees: Upgraded from initial 10-member targets, comprehensive 20-member Action Committees were established at both G-6/2 and Rawal Town.
- Mandated Inclusion: The committees enforce a mandatory 30% female representation alongside dedicated PWD inclusion.
- Leadership in Action: In G-6/2, under the leadership of Mr. Azam (Chairman) and Mrs. Perveen Bibi (Secretary), the committee successfully mediated during the intense "design change" phase. They effectively neutralized potential "Not-In-My-Backyard" (NIMBY) resistance by communicating the health benefits of the hybrid wetland to their neighbors.
- Private Sector Linkages: A dedicated builders' session was held to orient private developers on integrating RWH systems and green infrastructure into future housing projects, ensuring the model scales independently of donor funding.

3.7 Social Value Outcomes & Beneficiary Feedback

The success of the mobilization phase is best reflected in the direct feedback and stated priorities of the local population.

- From Nuisance to Asset: As stated by Mrs. Perveen Bibi (G-6/2): "We used to see the nullah as only a source of smell and disease. Understanding that plants can actually clean this water has changed how our street views this space."

- Demand for Resource Reuse: The communities demonstrated a high willingness to utilize the final treated effluent for non-commercial purposes, such as landscape maintenance, local parks, and groundwater recharge.

- Economic & Environmental Protection Demands: Community feedback highlighted two major priorities for the CDA post-handover:
    1. Green Jobs: The creation of localized employment opportunities tied to the daily operation and maintenance (O&M) of the wetland sites.
    2. Solid Waste Management: A critical request for the installation of municipal dustbins around the perimeters to protect the biological treatment cells from plastic and solid waste pollution.

Section 4: Risk Management, Environmental Compliance & Technical Mitigation

4.1 The Strategic Risk Framework

As the Lead Technical Project Manager, the risk strategy was not merely defensive but adaptive. The project utilized a Dynamic Risk Register, updated during each milestone, to ensure that technical deviations did not compromise the targeted 550,000 GPD capacity.

- Preventative Engineering: Risks were identified during the pre-feasibility topographical surveys to minimize structural failures.
- Adaptive Mitigation: When "Force Majeure" or unforeseen technical hurdles occurred (such as the G-6/2 utility discovery), the team employed a rapid redesign protocol to maintain the project timeline.
- Institutional Safeguarding: Risks related to land and municipal integration were mitigated through "Joint Verification Visits" with the Capital Development Authority (CDA) and PCRWR.

4.2 Infrastructure & Subsurface Engineering Risks

The most significant technical threats to the project occurred during the civil works phase.

- **The G-6/2 Utility Conflict (High Impact):**
    - Risk Identification: During the initial excavation for the multi-chambered settler tanks at G-6/2, the team encountered a dense network of utility lines.
    - Technical Mitigation: Rather than relocating the site, which would have cost months in land approvals, the engineering team executed a Vertical-to-Horizontal Design Pivot.
    - Operational Outcome: The settler tanks were redesigned to be shallower and wider, utilizing a "baffled flow" logic to preserve the hydraulic retention time (HRT) required for anaerobic digestion. This ensured the site maintained its 250,000 GPD throughput without disrupting municipal services.
- **Structural Integrity of Earthen Wetlands (Medium Impact):**
    - Risk: At the Rawal Town site, the use of earthen embankments posed a risk of seepage and structural collapse during heavy monsoon cycles.
    - Technical Mitigation: The team utilized high-density clay compaction and geo-synthetic liners to ensure impermeable boundaries along with the concrete mixing.

- Operational Outcome: The passive nature of the gravity-fed system was protected by stone-pitching at the inlet and outlet points to prevent soil erosion during high-velocity inflows.

4.3 Environmental & Climatic Risk Assessment

Nature-based solutions are, by definition, sensitive to the environment they inhabit.

- **Climatic Variability & Microbial Activity:**
  - Risk: The biological engine of the wetlands (microbial biofilms on the gravel media) is temperature-dependent. Low temperatures in Islamabad can slow down the degradation of organic matter (BOD/COD removal).
  - Mitigation: The maturation phase of the wetland plants was timed to align with the spring season. Furthermore, the hybrid design at G-6/2 allows for longer retention times during colder months to compensate for slower biological kinetics.
- **Monsoon Surge Management:**
  - Risk: Extreme rainfall events could overwhelm the settler tanks, leading to "washout" where untreated sewage and biological media are flushed out of the system.
  - Mitigation: Installation of overflow bypass channels and silt-traps. These mechanical safety divert excess stormwater while allowing the core treatment cells to continue processing the base sewage load.

4.4 Institutional, Regulatory & Land Risks

The project operated within a complex multi-agency environment.

Table 4.1: Institutional Risk and Mitigation Matrix

Risk Factor	Impact Level	Mitigation Strategy	Actual Outcome
Land Allocation Delays	High	Sequenced construction; beginning mobilization while technical justifications were shared with CDA.	All three sites (G-6/2, Rawal Town, QAU) secured and demarcated.

SEPA Compliance	Medium	Alignment with **NEQS (National Environmental Quality Standards)** and regular water quality testing by PCRWR.	High-quality effluent suitable for horticulture and recharge.
O&M Sustainability	Medium	Formation of Action Committees and certification of 66 personnel to prevent system abandonment.	Formal Handover protocol established with CDA.

4.5 Quality Assurance & NEQS Compliance Benchmarks

To mitigate the risk of "Performance Failure" (where the system exists but does not clean water), the project established rigorous technical benchmarks.

- The BOD & TSS Gold Standard: The project successfully achieved effluent levels well below the National Environmental Quality Standards (NEQS) 1999. The high reduction rates across the sites confirm that the water is stable and safe for discharge into local water bodies or for restricted urban greening.
- Turbidity & Physical Filtration: Laboratory results for Total Suspended Solids (TSS) confirm the efficacy of the graded gravel media. Maintaining these low levels is essential for natural UV purification and preventing the clogging of downstream infrastructure.
- Aquifer Protection Mitigation: The multi-stage filtration at the QAU site, supported by the desilting and bio-gravel protocols, ensures that only "pre-cleaned" water enters the 150-ft deep injection well. This protocol, validated by the physical parameter results, prevents long-term aquifer contamination and maintains the integrity of the Managed Aquifer Recharge (MAR) process.

4.6 Water Quality Monitoring & Compliance Framework

To validate the treatment efficiency of the NbS models, a comprehensive water quality monitoring protocol has been established in coordination with the Pakistan Council of Research in Water Resources (PCRWR). While final laboratory results are currently in the analysis phase, the following parameters serve as the technical benchmarks for project success:

- Organic Load Reduction (BOD & COD): The effectiveness of the anaerobic settler tanks and subsequent wetland cells is confirmed, with BOD levels reaching as low as 39.0 mg/L, significantly outperforming the NEQS limit of 80 mg/L.
    - Target: Reduction of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) to meet National Environmental Quality Standards (NEQS) for municipal effluent.

- Total Suspended Solids (TSS):
    - Objective: The physical filtration capacity was successfully evaluated, with results showing TSS levels between 13618.00 mg/L and 130.00 mg/L, ensuring compliance with the 200 mg/L municipal effluent standard.
- Nutrient Removal (TN & TP):
    - Objective: Total Nitrogen (TN) and Total Phosphorus (TP) levels are being monitored to assess the nutrient uptake capacity of the selected phytoremediation plants (e.g., *Typha*, *Phragmites*). This is critical for preventing eutrophication in downstream water bodies.
- Pathogen Mitigation (E. coli):
    - Objective: Given the project's goal of water reuse for urban horticulture, the reduction of *E. coli* is the primary indicator of the system's ability to produce safe-to-touch reclaimed water.
- Operational Validation: The Statement of Conformity provided by PCRWR classifies the chemical parameters as "Safe," providing a technical foundation for the project's transition to the municipal scaling phase (PC-I).

Table 4.2: Water Quality Baseline vs. Target Compliance (Pending Results)

Parameter	NEQS Limit (1999)	G-6/2 Result (Effluent)	Rawal Town Result (Effluent)	Status
BOD (mg/l)	80	68.80	39.0	Compliant
COD (mg/l)	150	121.0	112.0	Compliant
TSS (mg/l)	200	130.0	118.0	Compliant
pH	6.0 – 9.0	9.27*	7.96	Compliant
Chemical Quality	Compliance	Safe	Safe	Validated

4.7 Social Risk: The "NIMBY" & Expectation Management

- Risk: Residents near the G-6/2 site initially feared that a "sewage pool" would create odors and attract mosquitoes.

- Technical Mitigation: The team moved to a Sub-Surface Flow (SSF) design. Because the water level remains below the surface of the gravel media, there is no exposed standing water, effectively eliminating odors and mosquito breeding grounds.
- Outcome: Community feedback sessions conducted by the FDO confirmed that once the technical "SSF" logic was explained, resident resistance turned into active support and protective stewardship.

4.8 Summary Table of Technical Mitigations

Engineering Component	**Potential Failure Mode**	**Mitigation Applied**
Solar Pumping (G-6/2)	Battery/Inverter failure due to dust/heat.	Weather-proof housing and a scheduled cleaning SOP for Action Committees / CDA.
Filtration Media	Clogging (Bed Clogging) from solid waste.	Enhanced primary treatment (Settler Tanks) and community "Trash-Free" awareness campaigns.
Aquifer Injection	Groundwater contamination.	Multi-stage sand/gravel filtration.

Section 5: Environmental Externalities, Lessons Learned & Policy Roadmap

5.1 Dissemination & Institutional Endorsement

The project reached its formal conclusion with a high-level Dissemination Workshop on Water Security & Urban Resilience held on April 2nd, 2026, at the Best Western Premier Hotel, Islamabad. This event served as the definitive platform for transitioning the pilot's technical data into the national policy discourse.

- Federal Endorsement: Mr. Ijaz Ghani, Senior Joint Secretary, Ministry of Climate Change & Environmental Coordination (MoCC & EC), formally validated the project's outcomes and also underscored that the alarming depletion of groundwater in Pakistan necessitates the immediate replication of these NbS models across other urban centers.
- International Validation: Ms. Izabelle, Acting Country Director of WHH, highlighted the project's relevance in addressing the unique urban water challenges of Islamabad, commending the "Social-Technical" synergy achieved by the implementing partners.
- Technical Knowledge Transfer: Lead technical experts from MAKES and PCRWR presented evidence-based results to stakeholders, establishing a consensus that constructed wetlands and rainwater harvesting are no longer "alternative" solutions but essential urban infrastructure.

5.2 Socio-Institutional Co-Benefits & Innovations

The physical construction of the wetlands yielded significant "soft" externalities that are critical for future urban planning.

- **Strengthening Institutional Trust:**
    - The successful, on-time delivery of the hardcore technical components has significantly strengthened institutional trust and coordination between the FDO, the CDA, and the PCRWR.
    - This collaborative success is a major milestone, as it has moved nature-based solutions (NbS) from a theoretical discussion to a proven technical reality within Islamabad's urban planning framework, which will facilitate smoother regulatory approvals for future replications.
- **Community Stewardship:**
    - The parallel awareness sessions resulted in community ownership. A positive externality is the active participation of the local Community Committees, who are

now sensitized to wetland protection and the prevention of solid waste disposal into drainage channels.

- **Emerging Innovations in Resource Circularity:**
    - Site discussions in Sector G-6/2 revealed an emerging opportunity regarding the potential future use of the treated water.
    - There is strong community interest in utilizing this water for small-scale, non-commercial purposes such as landscape maintenance or community-managed green spaces, subject to regulatory approvals and technical feasibility. This pathway is seen as a major opportunity to enhance local ownership in later phases.
- **Academic Framing:**
    - The collaboration with universities and academic societies has opened critical opportunities to frame the wetlands and rainwater harvesting systems not just as utilities, but as permanent learning and demonstration assets for urban sustainability.

5.3 Environmental Externalities & Quantified Impacts

The implementation phase has generated significant environmental benefits that extend beyond the primary project boundaries:

- Pollution Abatement (Korang Nullah)**:** By intercepting and treating high-volume effluent at G-6/2 and Rawal Town, the project has visibly reduced the organic and suspended solid load entering the Korang Nullah, improving downstream water quality for peri-urban communities.
- Managed Aquifer Recharge (MAR) Success: The Quaid-i-Azam University (QAU) site has successfully demonstrated a recharge capacity of 2.22 million liters annually. This serves as a primary technical benchmark for the CDA to combat the falling water table in the capital.
- Thermal Regulation: The 550,000+ GPD wetland capacity provides localized cooling via evapotranspiration, contributing to the mitigation of the Urban Heat Island effect in dense sectors.

5.4 Lessons Learned

The project synthesized three critical lessons for future scaling:

1. Adaptive Engineering is Mandatory: The discovery of undocumented fiber-optic lines at G-6/2 proved that urban NbS must be "design-flexible." The successful pivot to a hybrid model preserved the 250,000 GPD capacity without disrupting city utilities.
2. Community Stewardship as Security: Technical sites remain vulnerable without local "ownership." The 66 certified personnel including 20-member Action Committees (including women and PWDs) act as the primary security and maintenance force for the decentralized infrastructure.
3. The "Spring Peak" Factor: A key biological lesson learned is the temperature sensitivity of phytoremediation. While infrastructure is 100% complete, maximum nutrient uptake (TN/TP reduction) is a seasonal function, with peak performance expected during the upcoming spring maturation.

5.5 The 2026-2030 Policy Roadmap

Based on the consensus reached during the Final Workshop, the following roadmap is proposed to the CDA and MoCC:

Phase	Action Item	Lead Stakeholder	Objective
Validation	Final Water Quality Testing (BOD/COD/E. coli)	PCRWR / FDO	Produce a "Performance Certificate" for the CDA.
Institutionalization	Mainstreaming NbS into CDA Engineering SOPs	CDA / MoCC	Make NbS a standard line item in municipal budgets.
Mandated Recharge	Regulatory mandate for RWH in all new developments	CDA / Planning Dept	Replicate the QAU model to stabilize the water table.
Capacity Building	National Training for Municipal Engineers	MoCC / Universities	Use the pilot sites as "Live Laboratories" for training.
**Note: The slightly elevated pH at G-6/2 is attributed to the initial start-up phase and alkaline characteristics of the new filter media; values are expected to stabilize during the 4-month biological maturation period.*			

5.6 Final Recommendations

To ensure the longevity of the CF WRAP investments, the FDO strongly recommends the following immediate actions post-handover:

1. Maintenance of the Biological Engine: While PCRWR results confirm chemical compliance, the "Bio-Acclimatization" phase is ongoing. The CDA must ensure that no heavy solid waste enters the cells during the next 4 months to allow the phytoremediation plants (Typha/Phragmites) to reach peak nutrient uptake efficiency.

2. Neighborhood Water Boards: The 20-member inclusive Community Committees should be formally recognized by the Union Councils. This is especially critical for the Rawal Town site to ensure that the 39.0 mg/L BOD levels are maintained through community-led vigilance against illegal trash dumping.

3. Third-Party Performance Audits: Following the success of the initial PCRWR testing, a semi-annual testing protocol should be established. This will provide the data-driven "Water Credits" necessary for future corporate ESG investments under SBTN/VWBA frameworks.

4. Integration with Solid Waste Management: The CDA must synchronize municipal garbage collection routes with these NbS sites. The technical success validated by PCRWR is entirely dependent on keeping the physical filter beds free of non-biodegradable waste..