

Building Water Systems That Last

建立持久的水資源系統

In a world of limited resources and environmental uncertainty, this document explains how we make decisions, manage risks, and how your donations are integrated into a system that can be monitored and improved.

在資源有限、環境不確定的情況下，我們如何做選擇、如何承擔風險，以及您的捐款如何被納入一個可被監督與修正的制度之中。

APPLICABLE REGION / 適用地區

Kenya · Uganda · Tanzania · South Sudan
肯亞 · 烏干達 · 坦尚尼亞 · 南蘇丹

In-house field capacity / 自有現場能力： Love Binti International operates its own drilling rigs (2 in Uganda · 1 in Kenya) and geophysical survey equipment (2 units) — enabling independent survey and drilling without dependence on contractor availability.
愛女孩國際關懷協會自有鑽井機（烏干達 2 台 · 肯亞 1 台）及地球物理勘測設備（2 台），可獨立執行勘測與施工，不受外部承包商檔期限制。

This document (Part A) is the donor-facing white paper. For technical implementation standards, see **Part B: Technical Appendix**. / 本文件（Part A）為捐款人版白皮書。技術執行標準請見 **Part B: Technical Appendix**。

Research evidence from / 研究實證來源: Ethiopia · Uganda · Malawi — not implementation countries / 非執行地區

Love Binti International

愛女孩國際關懷協會

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PART ONE • 第一部

Commitments & Principles

承諾與原則

Our foundational commitments: why we work the way we do, and what donors can expect from a partnership with Love Binti International.

我們的核心承諾：為何我們這樣工作，以及捐款人可以對愛女孩國際關懷協會的夥伴關係有何期待。

Target Audience

推薦閱讀對象

English

This white paper is written for supporters who care about long-term impact, institutional accountability, and resource efficiency. If you want to know whether boreholes are still working years later, this document is for you.

This document is for: **Individual donors** who want donations to create lasting public benefit • **Corporate CSR/ESG teams** who need governance logic and traceability • **Foundations and institutional donors** who need clear decision criteria and long-term commitments.

What this white paper is NOT: Not a technical manual, not fundraising material, not a showcase report. This is a decision transparency document explaining how we make choices, manage risks, and integrate donations into a system that can be monitored and corrected.

中文

本白皮書專為關心長期影響力、制度責任與資源效益的支持者所撰寫。如果您希望了解的不只是「這口水井挖好了嗎」，而是「五年後它還在運作嗎」——這份文件正是為您而設。

適合以下讀者：個人捐款人——希望捐款形成穩定的公共效益，而非一次性工程；企業 CSR/ESG 團隊——需要治理邏輯、決策可追溯性，以及一個能向內部利害關係人說明的合作夥伴；基金會與機構型捐助者——需要清楚的決策依據、風險框架、長期承諾，以及在事情不如預期時能夠問責的機制。

本白皮書不是什麼：不是技術手冊、不是募款文件、不是成果展示報告。這是一份決策透明說明書——說明我們如何做選擇、如何承擔風險，以及捐款如何被納入一個可被監督、可被修正的制度之中。技術細節請見本文件第二部分（技術附錄）。

Core Difference: Building Trustworthy Systems

核心差異：建立可信賴的系統

English

Most water projects define "success" as the day construction is completed. We define it differently: whether water resources can still be used safely and equitably five years later is the real question.

Traditional Approach	Systems Approach (Love Binti) 系統型方法（愛女孩國際關懷協會）
Complete one borehole 完成一口水井	Build a water governance system 建立水資源治理系統
Handover upon completion	Five-year tracking commitment from day one 從第一天起的五年追蹤承諾
Single-point solution	Multiple water sources to reduce single-point failure risk 多元水源組合降低單點失效風險
Prioritise by urgency	Prioritise by sustainability, risk assessment, and governance capacity 以可持續性、風險評估及治理能力排序
Responsibility ends at completion 責任止於工程完成	Responsibility extends beyond construction

中文

在多數水資源專案中，「成功」被定義為工程完成的那一天：水井鑽好了、幫浦安裝了、水流出來了、照片拍好了，組織準備撤離。兩年後，當幫浦損壞、社區重回不安全水源時，已經沒有人接電話了。

我們對成功的定義截然不同：**五年後，水資源是否仍然能被安全、公平地使用**——這才是真正的關鍵問題。這個差異決定了我們如何選址、如何設計專案、誰負責什麼，以及我們向捐款人報告什麼。系統型方法意味著：從第一天起就設計治理結構，而非在工程完成後才思考誰來維護。有時候我們會拒絕一個地質條件完美但社區治理能力薄弱的案子；有時候我們會誠實地告訴捐款人，一個我們三年前安裝的系統因為極端乾旱已經無法運作——因為我們相信，誠實的記錄比虛假的成功更有價值。

CASE STUDY • 案例

Case A vs. Case B

Case A: Another organisation drilled successfully in Community A. Two years later, due to unclear management responsibilities and a contaminated water point, the community returned to using unsafe water.

Case B: We spent three months on assessment and community coordination in Community B before drilling. We chose hand pump plus rainwater collection, and established a water committee with clear responsibilities before construction. Five years later, the system is still operating stably.

案例 A：某組織在 A 社區鑽井成功。兩年後，因管理責任不清、取水點遭污染，社區重回使用不安全水源。**案例 B：**我們花了三個月進行評估與社區協調，才開始施工，選擇手動井加雨水收集的組合，並在施工前建立了有明確責任分工的水委員會。五年後，系統仍穩定運作。

Key difference: not engineering technology, but upfront judgment, responsibility design, and long-term tracking.
差異關鍵：不是工程技術，而是前期判斷、責任設計與長期追蹤。

Climate Change: How It Changes the Game

氣候變遷如何改變遊戲規則

English

Previously, water projects were built on stable natural conditions. Climate change is changing this premise. More extreme rainfall, longer dry seasons, disrupted groundwater recharge, and changed contamination risks mean past rules of thumb are no longer reliable.

Our response: include climate instability in long-term assessments • do not apply past experience to changed environments • use multiple water sources to reduce single-point failure risk • use the six-category functionality classification (see Section 3.6) to detect early deterioration before it becomes permanent failure.

中文

數十年來，東非的水資源專案建立在一個假設之上：自然條件是穩定的。這個假設已經不再安全。

氣候變遷對我們目標地區的具體影響：更極端的降雨型態——嚴重洪澇與延長乾旱往往在同一年內交替出現；**乾季拉長**——過去能可靠補水的淺層水源，現在乾涸的時間越來越長；**地下水補注被打亂**——鑽井者過去依賴的經驗法則正變得越來越不可靠，在氣候已改變的地區，過去的經驗可能引導錯誤的選址決定；**污染風險改變**——極端降雨事件創造了新的路徑，讓地表污染物進入地下水源。

當水井停止運作，多數人歸因於設備故障或維護不足。然而在氣候風險背景下，越來越多的失效來自治理與系統設計的缺位。**我們的回應：**在每次選址評估中納入氣候不穩定性，不把過去某地的經驗套用到已改變的環境，設計多元水源組合消除單點失效，並使用六類功能分類系統（見第 2.6 節）在劣化演變為永久失效前及早介入。

Five-Year Tracking & Responsibility Boundaries

五年追蹤與責任邊界

English

Most water projects end responsibility at completion. We extend it beyond construction, providing five-year tracking. Tracking means not guaranteeing permanent operation, but ensuring projects are continuously monitored.

What We Do	What We Don't Do
Upfront geological survey & risk assessment 前期地質勘測與風險評估	Daily operations management 日常運作管理
Project design & systematic planning 專案設計與系統規劃	Cover all repair costs
Coordination & quality supervision 協調與品質監督	Guarantee permanent operation 保證永久運作
Five-year institutional tracking 五年制度性追蹤	Replace government responsibilities 取代政府職責

中文

大多數水資源專案的責任在工程完成的那一刻就結束了。我們做出了不同的選擇：我們將制度性責任延伸到工程竣工之後，為每一個專案提供至少五年的結構性追蹤。

我們承諾做的：在做出任何承諾之前進行前期地質勘測與風險評估；從一開始就將治理結構內建於專案設計中；對承包商進行資格審查、施工監督與品質管控；在五年內進行結構性監測、問題記錄與向捐款人報告。

我們明確不做的：管理水資源系統的日常運作（這是社區水委員會的責任）；承擔所有維修與保養費用；保證每一個系統都能永久正常運作；取代地方政府或社區應當承擔的職責。

五年追蹤的意義在於：確保問題被記錄、被回應，而不是被遺忘。當一個系統在第三年因為極端乾旱出現問題，我們會誠實地向捐款人報告，評估補救措施，並將這次失敗的經驗納入未來的選址評分機制中。這種誠實，是我們認為捐款人最終能夠信任我們的基礎。

Beneficiary Selection

服務對象選定

English

Water needs are urgent in most communities, but "need exists" does not equal "immediately suitable for intervention." Selection combines three dimensions: (1) Public health risk — whether water shortage poses real health risks; (2) Geological and climate feasibility — whether surveys show basic viability; (3) Governance and management capacity — whether the community has minimum coordination ability.

中文

在我們接觸到的幾乎每一個社區，水資源需求都是迫切的。但「需求迫切」本身並不足以成為承諾一個專案的理由。我們的選定流程結合了三個同等必要的面向，三者必須同時具備才能推進。

- (1) **公共健康風險**：目前的用水狀況是否正在造成真實、可衡量的傷害——水源性疾病、學童出席率下降、長距離取水造成的時間貧困？
- (2) **地質與氣候可行性**：勘測結果是否顯示這裡存在一個可行、可持續的水源，並且在預測的氣候條件下仍然可行？一個今天出水良好但在三年後的乾旱中會枯竭的含水層，不能成為長期投資的基礎。
- (3) **治理與管理能力**：社區是否已具備——或能夠建立——最低限度的制度能力，以便長期管理和維護一套水資源系統？再完美的工程設計，在管理真空中也會失效。

我們有時會在需求極度迫切、但可行性或治理能力不足的情況下延後或拒絕介入。這不是放棄，而是對捐款人資源的負責任管理。把有限的資源投入到有合理成功可能性的地方，而非為了滿足眼前的道德壓力而草率行事，是我們認為對捐款人最誠實的做法。

CASE STUDY • 案例

A Proposal We Rejected / 我們拒絕的提案

Community C: children walked 3 hours daily for water. Public health need was undeniable. But groundwater exceeded 150m, costs were extremely high, and factions within the community had long-standing disputes over management rights. Our assessment: even if we drilled, the system would likely fail within two years due to governance vacuum.

C 社區：兒童每天步行 3 小時取水，公共衛生需求無可否認。但地下水深度超過 150 米，成本極高，且社區內部各派系對管理權存在長期爭議。我們的評估是：即使鑽井，系統在兩年內很可能因治理真空而失效。

Decision: delay intervention; first support rainwater collection and governance capacity building. Not abandonment — responsible delay.

決定：暫緩介入，優先支持雨水收集與治理能力建設。這不是放棄，而是負責任的延後。

PART TWO • 第二部

Research Evidence Base

研究實證基礎

The field evidence underpinning our technical standards — drawn from the most comprehensive multi-country handpump borehole study in East Africa to date.

支撐我們技術標準的實地實證——來自東非迄今最完整的多國手壓井鑽孔研究。

Research Countries & Geological Background

研究國家與地質背景

Evidence source / 實證來源: MacAllister et al. (2022), Science of the Total Environment — systematic field study of 145 handpump boreholes in Ethiopia, Uganda and Malawi. Functionality classification: Bonsor et al. (2018). These three countries are evidence sources, not implementation countries. Uganda appears in both roles.

English

East African Rift System (EARS): The tectonic rift formed by divergence of the Nubian and Somalian plates produces characteristic geology — crystalline Precambrian basement rock, interbedded volcanic sequences, and localised alluvial sediments — shared across all four target countries.

Country 國家	Geology 地質條件	Sites below threshold 低於傳導率門檻地點	Key finding 主要發現
Ethiopia 衣索比亞	Volcanic aquifers, moderate–high transmissivity, low storage 火山岩含水層，中至高傳導率，低儲量	8%	Fully functional boreholes show transmissivity 10× higher than failed boreholes 完全功能水井的傳導率比故障水井高出一個數量級
Uganda 烏干達	Fractured crystalline basement, low transmissivity, corrosive groundwater 破裂結晶基底岩，低傳導率，腐蝕性地下水	30%	98% of GI pipes fail galvanising standard; most challenging hydrogeological context 98% 的 GI 管鍍鋅不足；水文地質條件最嚴峻的研究地區
Malawi 馬拉威	Dry sub-humid crystalline basement; alluvial zones with fluoride/iron issues 乾熱結晶基底岩；沖積層地帶氟化物 / 鐵含量偏高	16%	81% of uPVC pipes damaged; 98% of Afridev rods below standard diameter — both due to cutting maintenance habit 81% 的 uPVC 管損壞；98% 的活塞桿直徑不足——均源於切管維修習慣

Target countries (Kenya, Uganda, Tanzania, South Sudan) share the same EARS tectonic context. The 15–30% below-threshold transmissivity rate from research countries is conservatively applicable to baseline siting without prior VES survey across all four target countries.

中文

我們的技術標準建立在實地田野研究的實證基礎上，而非理論假設。主要來源為 MacAllister et al. (2022)，發表於《Science of the Total Environment》——針對衣索比亞、烏干達及馬拉威三個國家的 145 口手壓井鑽孔進行拆卸檢測，是東非地區迄今最完整的多國手壓井功能性分析。功能分類標準依據 Bonsor et al. (2018)。這三個國家為實證來源國，非計畫執行國；烏干達同時具有兩種身份。

東非裂谷系統 (EARS) 的地質背景：由努比亞板塊與索馬利亞板塊分離擴張形成的構造裂谷系統，產生我們四個目標國家共有的地質特徵——前寒武紀結晶基底岩（風化與破裂含水層）、玄武岩火山岩序列，以及局部沖積沉積物。理解這個共同的地質背景，是理解為何研究數據可以跨國適用的關鍵。

衣索比亞（研究國家）：以高原火山岩含水層為主，傳導率中至高，但儲量偏低。雨季 6–9 月，年均降雨量約 1,280mm。**關鍵發現：**僅 8% 的地點低於傳導率門檻（三國中最低），但完全功能水井的傳導率比故障水井高出一個數量級。深水位與附近工業及農業抽水競爭有關，而非低補給所致。

烏干達（研究國家 + 計畫執行國）：以破裂結晶基底岩含水層為主，傳導率偏低，腐蝕性地下水。**關鍵發現：**30% 的地點低於傳導率門檻（三國中最高），98% 的 GI 管鍍鋅不足，82% 的活塞桿受腐蝕，腐蝕性地下水（低 pH、高礦化度）是主要加速因素。這是我們最重視的數據集——因為烏干達也是我們的執行地區之一。

馬拉威（研究國家）：乾熱氣候下的結晶基底岩含水層，風化基底岩為主要含水層類型，地下水儲量由風化剖面厚度決定。雨季 11 月至翌年 3 月，年均降雨量約 880mm。**關鍵發現：**16% 的地點低於傳導率門檻；81% 的 uPVC 管損壞、98% 的 Afridev 活塞桿直徑低於標準——兩者均直接源於切管重接的維修習慣；部分高人口密度地區的需求已超過含水層長期補給潛力，出現超採（11 年氣候周期）。馬拉威的條件與坦尚尼亞乾燥結晶基底岩地區及南蘇丹部分地區高度相似。

四個目標國家（肯亞、烏干達、坦尚尼亞、南蘇丹）共享相同的東非裂谷系統構造背景。研究國家的 15–30% 低傳導率地點比例，在未進行 VES 勘測的情況下，可保守適用於四個目標國家的基底岩地區。

Core Problems: Scale of the Challenge

核心問題：挑戰的規模

Non-functionality rate 任意時間非功能率 >25% Sub-Saharan Africa / 撒哈拉以南非洲	Uganda below threshold 烏干達低於傳導率門檻 30% Low yield from day one / 啟用即低產	GI pipe galvanising sub-standard GI 管鍍鋅厚度不足 98% Uganda sample / 烏干達樣本	Malawi uPVC pipes damaged 馬拉威 uPVC 管損壞 81% Cutting habit / 切管習慣所致	Failure rate without VES survey 未勘測鑽井失敗率 ~60% Drops to <10% with survey / 勘測後降至 <10%	Rehab saves vs. new borehole 維修相較新鑽節省 70–85% Typical saving / 典型節省比例
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English

Problem Category	Scale	Root Cause
Hydrogeological siting 水文地質選址失敗	15–30% of sites below minimum transmissivity 15–30% 地點低於最低傳導率門檻	No VES survey before drilling; reliance on experience 未進行 VES 勘測即鑽井；依賴經驗法則
Equipment materials 設備材料劣化	53% GI pipe corroded; 82% uPVC damaged 53% GI 管腐蝕；82% uPVC 管損壞	Sub-standard manufacturing; cutting maintenance habit raises cylinder, accelerates dry-season failure 材料製造不達標；切管維修習慣使泵筒上移，加速乾季失效
Construction design 施工設計缺失	Screen misposition — statistically significant risk 篩管位置不當——統計顯著風險因素	Standard designs not adapted to local hydrogeology; no site supervision 標準設計未因地制宜；施工現場監督缺失

中文

統計數字背後是一個結構性問題：在撒哈拉以南非洲，任何時間點有超過四分之一的手壓井鑽孔處於非功能狀態。這不是維護失誤，也不是資源不足——它是系統設計缺陷的結果。

問題一：水文地質選址失敗（最根本）——19% 的水井位於傳導率低於最低需求的地層，從第一天起就注定出水量不足。在烏干達，這個比例高達 30%；在馬拉威，約為 16%。這些水井在技術上「完成」了，但它們從未能夠可靠地服務社區。根本原因：在沒有進行 VES 地球物理勘測的情況下選址鑽井，依賴經驗法則而非地質數據。未勘測的失敗率估計約為 60%；科學選址後可降至 10% 以下。

問題二：設備材料劣化（最普遍）——研究顯示，53% 的 GI 上升主管腐蝕、82% 的 uPVC 上升主管損壞。在烏干達，98% 的 GI 管鍍鋅厚度低於設計標準，這意味著大多數 GI 管從出廠的那一刻起，腐蝕就已經在加速進行。更危險的是維修習慣：許多承包商在維修時截短管件而非整段更換，這每一次都使泵筒位置略微上移，最終導致乾季無法出水。這個問題自 1980 年代就有記錄，至今在供應鏈層面未有系統性改善。

問題三：施工設計缺失（可預防）——篩管與套管的配置位置是「不可靠」功能分類的統計顯著風險因素（多項式迴歸， $p < 0.01$ ）。標準設計被應用到不同的水文地質環境中，而不做因地制宜的調整；施工現場監督普遍缺失。這類問題往往在施工完成多年後才顯現——當篩管在砂礫中逐漸淤積、或水位在氣候壓力下下降至篩管以下。

這三類問題並非孤立存在——它們相互強化。一個選址錯誤的水井，在低傳導率含水層中承受更大的抽水壓力，加速了材料劣化；而材料劣化逐漸改變了泵筒位置，使原本就脆弱的水井在乾季徹底失效。理解這種相互關係，是我們系統型方法的核心依據。

Source / 資料來源: MacAllister et al., Sci. Total Environ. 851 (2022) 158343 • Bonsor et al., Hydrogeology J. 26 (2018) 367–370

PART THREE • 第三部

How We Work

我們如何工作

Our operational standards for geological survey, site selection, handpump and solar systems, functionality monitoring, and the P1-P6 project lifecycle.

我們在地質測量、選址、手壓井與太陽能系統、功能監測及 P1-P6 專案生命週期方面的操作標準。

Services Overview

服務項目總覽

No single water solution fits all situations. Services are configured based on hydrogeological conditions, community governance capacity, and climate projections — often combining multiple sources to eliminate single-point failure risk.

沒有單一方案適用所有情境。我們依據水文地質條件、社區治理能力和氣候預測配置服務——通常結合多種水源以消除單點失效風險。

Service / 服務類型	Depth 深度	Best For 最適情境	Key Advantage 核心優勢	Key Constraint 關鍵限制
Hand Pump Borehole 手壓井鑽孔 ~300 people 5-10 yr	20–60m	Unstable power, limited repair capacity 電力不穩、維修能力有限的農村社區	Community-repairable (VL0M) — no electrician needed 社區可自行維修 (VL0M)，無需電氣工程師	Transmissivity >1.4 m ² /day required • VES mandatory 需傳導率 >1.4 m ² /天 • VES 勘測強制
Solar Borehole System 太陽能鑽孔供水系統 1,000+ people 60+ l/min	60–120m	Schools, clinics, concentrated population 學校、診所、高需求人口集中場所	High yield, no grid dependency, multi-community 高出水量、不依賴電網，服務多個社區	Transmissivity >9.5 m ² /day • licensed electrician • capital 5–15× handpump 需傳導率 >9.5 m ² /天 • 持照電工 • 資本成本 5–15 倍
Rainwater Collection 雨水收集系統 Supplementary • 輔助	— No drilling	Clear rainy season; non-drinking supplementary use 降雨季節明顯地區，輔助非飲用用途	Low cost; reduces pressure on groundwater; backup during outages 低成本，降低地下水井壓力，停電時提供備援	Seasonal — not reliable in dry season; non-drinking only 季節性——乾季不可靠，僅供非飲用用途
Borehole Rehabilitation 水井修復能 70–85% saving Assess first	Existing 現有水井	Broken or underperforming boreholes with viable aquifer 含水層仍可用的既有失修或低效水井	Highest resource efficiency — fastest service restoration 最高資源效率，最快恢復服務的介入方式	Requires assessment — only viable if aquifer conditions remain adequate 需先評估，含水層條件不足時不適用

Geological Survey & VES Standards

地質測量與 VES 標準

KEY STANDARDS • 關鍵標準

VES geophysical survey mandatory before any drilling. Transmissivity must exceed 1.4 m²/day for handpumps, 9.5 m²/day for solar systems. Without survey: ~60% failure rate. With proper siting: below 10%.

任何鑽井前強制 VES 地球物理勘測。手壓井傳導率必須 >1.4 m²/天，太陽能系統需 >9.5 m²/天。未勘測失敗率約 60%，科學選址後降至 10% 以下。

English

Geological survey is the most critical preliminary work. Under climate change, past experience is no longer sufficient to guarantee long-term viability.

Threshold 門檻條件	Standard 標準值	Consequence if missed 不達標後果
Transmissivity — handpump 手壓井——地下水傳導率	> 1.4 m ² /day > 1.4 m ² /天	Low yield from day one 啟用即低產
Transmissivity — solar system 太陽能系統——地下水傳導率	> 9.5 m ² /day > 9.5 m ² /天	Cannot sustain 60 l/min 無法維持 60 l/min 出水量
Dry-season water level — Afridev 乾季地下水位——Afridev 手壓井	≤ 45m below surface ≤ 地表以下 45m	Pump runs dry in dry season 乾季抽空失水
Dry-season water level — India Mark II 乾季地下水位——India Mark II	≤ 50m below surface ≤ 地表以下 50m	Pump runs dry in dry season 乾季抽空失水
Minimum screen length 最低篩管長度	≥ 10m	Silting, structural collapse 淤積、結構塌陷

East Africa warning: 30% of Uganda sites, 16% of Malawi sites, and estimated 15–30% of baseline sites across Kenya, Tanzania and South Sudan fall below the handpump transmissivity threshold without prior survey. "Deeper drilling means more water" is a dangerous myth — over-drilling disrupts water balance and increases maintenance difficulty.

中文

地質測量是水資源專案中最重要的一項投資。沒有它，東非基底岩地區估計有 60% 的水井被鑽在無法支撐長期出水量的地點。有了科學選址，失敗率降至 10% 以下。一次勘測的費用，遠低於一口失敗水井的總成本。

我們使用垂直電阻率探測法 (VES) ——一種透過量測地下電阻率來估算含水層傳導率的地球物理勘測方法。在我們的計畫框架下，任何鑽井承諾前，VES 勘測都是強制性的。**關鍵門檻：**手壓井含水層傳導率必須超過 1.4 m²/天；太陽能系統需要 9.5 m²/天。在烏干達，約 30% 的地點低於手壓井門檻，馬拉威約 16%，肯亞基底岩地區預估比例相近。

「鑽得越深、水越多」是農村供水中最頑固也最危險的迷思之一。過度鑽深會破壞水平衡，每增加 10 米可能增加 20–30% 的成本，深井的故障率也更高，而對長期出水量的改善往往微乎其微。選址正確比深度更重要。

Site Selection Principles

選址原則

English

Site selection considers three equally necessary dimensions: (1) **Geological conditions** — aquifer depth, long-term yield, seasonal variation risk; (2) **Public accessibility** — public land, safe access, beneficiary coverage; (3) **Management feasibility** — clear responsible party, maintenance resources, rule enforcement.

中文

選址同時考量三個同等必要的面向，缺一不可。

地質條件：含水層深度、長期出水量容量、季節變化風險，以及與選定泵技術的相容性。一個在雨季出水良好、乾季卻枯竭的含水層，無法支撐全年穩定的社區供水。**公共可及性**：選址是否在公共土地上，並且對所有預期受益人開放？取水動線是否安全，維修團隊能否到達？一個位於某個家族私有土地上的水井，即使地質條件完美，也會成為未來衝突的根源。**管理可行性**：是否存在明確的、有問責機制的責任主體負責持續運作？維護資源——包括財務和人力——是否已到位或可預期？

CASE STUDY • 案例

Rejecting Perfect Geological Conditions / 放棄完美地質條件

Village E: geology was excellent — aquifer at 35 metres, ample yield. But three families had a long-standing dispute over land ownership at the proposed site.

E 村：地質條件絕佳，含水層在 35 米深度，出水量充足。但三個家族對擬選地點的土地所有權存在長期爭議。

Decision: refuse to drill. After completion, the borehole would fall into a management vacuum and become a source of conflict rather than a shared resource.

決定：拒絕鑽井。工程完成後，水井將陷入管理真空，成為衝突的根源而非共享資源。

Handpump Design & Material Standards

手壓井設計與材料規範

KEY STANDARDS • 關鍵標準

uPVC rising mains preferred in all four target countries. GI pipes prohibited in Uganda. Stainless steel rods recommended everywhere. No cutting/re-joining pipes. No mixing GI and stainless steel components.

四個目標國家優先採用 uPVC 上升主管，烏干達禁用 GI 管。建議全面採用不鏽鋼活塞桿。禁止切管重接，禁止混用 GI 與不鏽鋼。

English

In areas with unstable power and limited repairs, handpumps are often the most reliable choice. Five-year survival rate: 78% (extremely arid areas). Most remain functional 5–10 years.

Component 部件	GI (Galvanised Iron) GI (鍍鋅鐵)	uPVC / Stainless Steel uPVC / 不鏽鋼
Rising main damage — Uganda 上升主管損壞率 (烏干達)	37% damaged 損壞率 37%	1% damaged (uPVC) uPVC 管損壞率僅 1%
Rising main galvanising compliance — Uganda 上升主管鍍鋅達標率 (烏干達)	98% sub-standard 98% 鍍鋅厚度不足	N/A — no corrosion risk 不適用——無腐蝕風險
Pump rod corrosion rate — Uganda 活塞桿腐蝕率 (烏干達)	GI rods: 69% corroded GI 桿腐蝕率 69%	Stainless steel: 3.5% 不鏽鋼桿腐蝕率僅 3.5%
Rod diameter compliance — Malawi 活塞桿直徑達標率 (馬拉威)	GI rods: 98% below standard diameter GI 桿 98% 直徑不足	Stainless steel: verify $\geq 11\text{mm}$ at procurement 不鏽鋼桿：採購時量測確認 $\geq 11\text{mm}$

Prohibited practices (all countries): GI rising mains in Uganda • Cutting and re-joining uPVC pipes • Re-threading shortened GI pipes • Mixing stainless steel and galvanised steel in same string • Accepting rod diameter below 11mm

中文

在電力不穩定、維修能力有限的地區，手壓井往往是最可靠的長期選擇。一個設計良好的手壓井系統，選址正確、使用符合規格的零件，可以在社區層級的維護下提供 5–10 年的安全用水。在極端乾旱地區，五年存活率約為 78%。

決定手壓井系統可靠性的，主要不是泵本身，而是正確的水文地質選址、符合國際規範的優質零件、將篩管正確定位於含水層位置的施工、防止地表污染的取水點設計，以及一個了解如何操作和維護的社區。

我們的材料標準（詳見第二部分技術附錄）要求使用耐腐蝕的 uPVC 上升主管，而非鍍鋅鐵管（GI 管）。在烏干達，GI 管損壞率高達 37%，且 98% 的 GI 管鍍鋅厚度低於設計標準。切管重接的維修習慣會逐漸使泵筒位置上移，最終在乾季導致出水中斷——這是我們在田野研究中記錄到的最普遍的失效模式。不鏽鋼活塞桿的腐蝕率僅 3.5%，遠低於 GI 桿的 69%，是烏干達環境下的首選材料。

Solar Systems — Limitations & Capacity

太陽能系統——限制與能力

KEY DIFFERENCE • 關鍵差異

Solar systems require 5× higher transmissivity (>9.5 m²/day). 57–80% of East African baseline sites fall below this threshold. Panel theft is the most commonly reported failure cause. Love Binti International has 11 completed installations.

太陽能系統需要五倍傳導率 (>9.5 m²/天)，東非 57–80% 的基線地點低於此門檻。面板竊盜是最常見失效原因。愛女孩國際關懷協會已完工 11 套。

English

Solar-powered borehole systems (SPWS) are a fundamentally different technical system from handpumps, serving 1,000–2,000 people across 4–5 communities per system.

⚠ Known Limitations / 已知限制

Transmissivity threshold 5× higher: >9.5 m²/day

Community cannot self-repair electrical faults

Panel theft — most reported failure cause in East Africa

No validated fee recovery model beyond Year 3

57–80% of baseline sites below threshold

✓ Our Capacity / 組織能力

11 completed SPWS installations in East Africa

Technology sponsor: URE / 聯合再生能源 (Taiwan), IEC/UL/MCS certified

Local partners: Guangdong Sunry Power (广东三瑞) • AllGrand Power (山东奥冠)

Drilling partners: Yeshua Living Water • BIK Water Systems • HH Water Drops • Restago Investment

P1–P6 framework applied to all SPWS projects

A full SPWS technical standard — with evidence-based thresholds equivalent to our handpump standards — is under development. Love Binti International will not scale SPWS deployment beyond proven site conditions until that standard is in place.

中文

太陽能鑽孔供水系統（SPWS）是與手壓井根本不同的技術體系，單一安裝可服務 1,000–2,000 人跨多個社區，消除對電網的依賴。但它帶來不同的風險和限制，我們承諾誠實地揭露。

已知限制：需要五倍以上的含水層傳導率 (>9.5 m²/天)，東非 57–80% 的基線地點低於此門檻；電氣故障無法由社區自行維修，需要持照電氣工程師——在東非農村幾乎不存在；面板竊盜是最常被報告的失效原因之一，安全圍欄為必要基礎設施；資本成本是手壓井的 5–15 倍，且目前尚無在東非農村社區三年週期後維持費用回收機制的充分實證。

我們目前的能力：已在東非完成 11 套 SPWS 安裝，建立完整供應鏈與安裝紀錄。技術贊助方為聯合再生能源股份有限公司（台灣，IEC/UL/MCS/VPC 國際認證）；本地供應夥伴為廣東三瑞電源科技有限公司（東非運營）及 AllGrand Power Source Development Limited（烏干達，關聯山東奧冠新能源科技有限公司）；鑽井施工執行夥伴為 Yeshua Living Water Company Limited（烏干達）。所有 SPWS 專案均強制執行 VES 勘測並適用 P1–P6 閘門框架。在完整 SPWS 技術標準確立之前，我們不會在未經驗證的地點擴大部署。

Six-Category Functionality Classification

六類功能分類

WHY THIS MATTERS • 為何重要

Replaces binary working/not-working. Low Yield (LY) is the most critical early-warning category — community has water but below design standard, accelerating wear. Assessed annually in dry season.

取代二元功能判斷。低產 (LY) 是最關鍵的早期預警類別——社區有水但低於標準，加速設備磨損。每年乾季評估。

English

Category	Field Assessment Criteria	Required Action
Fully Functional (FF)	Yield ≥ 10 l/min; downtime <30 days/year 出水量 ≥ 10 l/min；年停機 <30 天	Annual monitoring 年度追蹤
Unreliable (UR)	Yield meets standard; downtime ≥ 30 days/year 出水量達標；年停機 ≥ 30 天	Investigate downtime cause; repair 調查停機原因；維修
Low Yield (LY) Δ 低產 Δ 最需早期偵測	Yield <10 l/min; downtime <30 days 出水量 <10 l/min；停機 <30 天	Pumping test; assess rehabilitation 抽水測試；評估維修
Unreliable & Low Yield (UR-LY) 不可靠且低產	Yield <10 l/min; downtime ≥ 30 days 出水量 <10 l/min；停機 ≥ 30 天	Priority intervention 優先介入
Non-functional (NF) 非功能	No water on day of assessment; water at some point in past year 評估當日無法出水；過去一年曾出水	Immediate repair assessment 立即維修評估
Abandoned (AB)	No water for over one year 超過一年未出水	Full assessment; new borehole

Field measurement: bucket test — 10-litre bucket; target: filled within 60 seconds = 10 l/min. Assess annually during dry season only.

中文

大多數水資源監測計畫使用二元分類：能出水或不能出水。這是不夠的。一口提供了所需水量一半的水井在技術上是「正常運作」——但它加速了零件磨損，並將在 1-2 年內完全停止運作。

我們使用基於 Bonsor et al. (2018) 的六類功能分類系統，使我們能夠偵測早期劣化，在永久性失效發生前介入。**低產 (LY) 是最關鍵的早期預警類別**：社區仍有水，所以他們不會主動抱怨，但低於設計標準的出水量正在加速零件磨損，增加失效風險。在五年追蹤期內，及早偵測並處理低產狀態是我們最高價值的介入之一。

現場量測：桶測法——用 10 公升桶計時，若超過 60 秒才裝滿，出水量就低於 10 l/min (低產)。這個方法不需要任何特殊設備，卻能提供可靠的早期預警。**每年僅在乾季執行**——乾季代表最嚴苛的條件，低產往往在雨季完全隱形，只有在乾季才能顯現。

Water Quality, Water Points & Hygiene Education

水質安全、取水點設計與衛生教育

English

Water quality: Water existence does not equal water safety. Quality assessment distinguishes drinking vs. non-drinking use. Monitoring: initial test, rainy season, dry season — immediate retest if abnormal. Required tests: pH, turbidity, E. coli, TDS, iron, fluoride.

Water point design: Even safe groundwater can be contaminated at the collection point. Solutions: hardened surface and drainage slope (standing water) • fencing and separate animal watering (livestock) • elevated platform and handwashing (dirty containers) • locked cover (debris).

Hygiene education: The most unpredictable but impactful factor is human behaviour, not equipment. Integration with livelihood programmes (agriculture, reusable pad programmes) generates long-term effects across multiple community dimensions.

中文

水質安全：水的存在不等於水的安全，須區分飲用與非飲用用途。我們在移交前要求初始水質檢測（pH 值、濁度、大腸桿菌、TDS、鐵、氟化物），並在五年追蹤期內進行季節性監測（乾季與雨季）。飲用水必須通過大腸桿菌檢測——一旦檢出，立即暫停使用並採取補救措施。

取水點設計：即使地下水在化學成分上是安全的，在取水過程中也可能受到污染。取水點規範要求：帶有排水坡度的混凝土硬化地面（防止積水，積水是最常見的再污染途徑）；圍欄和獨立牲畜飲水點；抬高的取水平台和洗手設施；鑽孔井口加蓋上鎖。一個真實案例：G 診所地下水水質良好，但兒童腹瀉率持續偏高。根本原因是取水點積水泥濘。改善後三個月，腹瀉率下降 60%，費用不到原始水井建設成本的 5%。

衛生教育：在長期水資源安全成果中，影響最深遠的因素往往不是工程設計，而是取水點的人類行為。我們將衛生教育整合到生計計畫中：農業用水管理、布衛生棉計畫、社區衛生工作者培訓。當行為改變被納入設計時，水資源捐款在社區健康的多個層面產生連鎖效應。

CASE STUDY • 案例

Clinic G Water Point Renovation / G 診所取水點改造

Good water quality but high child diarrhea rates. Cause: standing water and mud around the water point — a re-contamination pathway invisible to the community.

水質良好但兒童腹瀉率持續偏高。原因：取水點積水泥濘，形成社區未察覺的再污染途徑。

After renovation: diarrhea rate dropped 60% in 3 months. Cost: less than 5% of the original borehole construction cost. 改善後三個月，腹瀉率下降 60%，費用不到原始水井建設成本的 5%。

Phase gate conditions must be fully met before proceeding to the next phase. Any unmet condition halts the project at that stage.
每個關門條件必須完全符合才能進入下一階段。任何未達到的條件將使專案在該階段暫停。

P1

Project Application

專案申請

Community submits water needs application. Initial public health and sanitation assessment. Priority scoring against five indicators. Project enters assessment queue.

社區提交用水需求申請，進行初步公共衛生評估，依五項指標優先評分，納入評估隊列。

▶ **Gate: Public health risk score meets threshold + preliminary geological feasibility confirmed**
關門：公衛評分達標 + 初步地質可行性確認

P2

Hydrogeological Survey

水文地質勘測

↑ **In-house VES equipment deployed (Uganda 2 units • Kenya 1 unit) / 自有 VES 設備執行**

VES geophysical survey by licensed hydrogeologist. Transmissivity and dry-season water level assessed. Borehole site confirmed and documented. Hydrogeologist is independent of the drilling contractor.

由持照水文地質專家執行 VES 探測，評估傳導率與乾季水位，確認鑽點。水文地質專家獨立於施工承包商。

▶ **Gate: Transmissivity >1.4 m²/day AND water level within pump design depth — if not met, site rejected**
關門：傳導率 >1.4 m²/天且水位在設計深度內——否則拒絕該地點

P3

Community Mobilisation

社區動員

Water committee formed with clear responsibilities. MOU signed by committee representatives. Maintenance fund mechanism confirmed and documented. This phase determines post-handover governance quality.

成立水委員會並明確責任分工，由委員會代表簽署 MOU，確認維護資金機制。此階段決定移交後的治理品質。

▶ **Gate: MOU signed + committee confirmed + maintenance fund in place**
關門：MOU 簽署 + 委員會確認 + 維護資金機制到位

P4

Borehole Construction

鑽井施工

Partners: Yeshua / BIK (Uganda) • HH Water Drops (Kenya) • Restago (Tanzania)

Drilling, casing, gravel pack. 2.5-hour pumping test. Handpump installation with corrosion-resistant materials (uPVC rising mains, stainless steel rods). Initial water quality testing. Daily GPS-tagged photo evidence submitted.

鑽探、套管、礫石填充。2.5 小時抽水測試。使用耐腐蝕材料（uPVC 上升主管、不鏽鋼活塞桿）安裝手壓井。初始水質檢測。每日提交含 GPS 座標的照片證據。

▶ **Gate: Recovery rate ≥90% + water quality pass + CCTV confirms screen position + evidence complete**
關門：恢復率 ≥90% + 水質達標 + CCTV 確認篩管 + 證據完整

P5

Acceptance & Handover

驗收交付

10-item acceptance checklist completed. Community operation and maintenance training delivered. Formal handover ceremony. Online registry fully updated. Every record is accessible to donors.

完成 10 項驗收清單，交付社區委員會操作與基本維護培訓，舉行正式移交儀式，完整更新線上登錄系統。每筆記錄均可被捐款人查閱。

▶ **Gate: All 10 acceptance items passed + registry record complete**
關門：10 項驗收清單全部通過 + 登錄記錄完整

P6

Five-Year Monitoring & O&M

五年追蹤維運

↑ **Six-category functionality classification applied at every visit (see Section 3.6)**

Year 1–2: quarterly visits • Year 3–4: bi-annual • Year 5: full evaluation. Annual six-category functionality classification (bucket test + downtime interview). Seasonal water quality monitoring. Repair ticket processing. All records in online registry.

第 1–2 年每季訪視，第 3–4 年每半年，第 5 年完整評估。年度六類功能分類（桶測法 + 停機訪談）。季節性水質監測。維修工單處理。所有記錄存入線上登錄系統。

Stakeholder Roles

利害關係人角色

English

Role	Primary Responsibility	Not Responsible For
Donors / 捐款人	Support systems with genuine risk judgment capacity 支持具有真正風險判斷能力的系統	Engineering details, daily operations 工程細節、日常運作
Love Binti International	Surveys, project design, five-year tracking 勘測、專案設計、五年追蹤	Daily operations, replacing government 日常運作、取代政府職責
Local Partners / 在地合作	Needs communication, daily management, basic maintenance 需求溝通、日常管理、基本維護	Project design, major repairs 主要專案設計、大規模維修
Technical Partners / 技術夥伴	Geological surveys, drilling 地質勘測、鑽井施工	Project decisions, long-term management 專案決策、長期管理

中文

長期可行性取決於每個利害關係人的角色被正確理解和清楚界定。責任的模糊是東非水資源系統失效的主要原因之一——當事情出錯、沒有人清楚誰負責時，問題就無法被解決。

捐款人：支持具有真正風險判斷能力的系統；對愛女孩國際關懷協會進行問責。捐款人不需要對工程決策或當地政治負責，但有權利要求看到決策依據、追蹤記錄和誠實的失敗報告。**愛女孩國際關懷協會**：前期勘測、專案設計、承包商遴選、品質監督、五年追蹤。我們不負責日常運作，不承擔所有維修費用，不取代政府職責——但承擔確保上述責任被正確執行的制度性責任。**在地合作單位 / 水委員會**：需求溝通、日常管理、基本維護、費用收取。他們是系統長期存活的最關鍵因素——一個運作良好的水委員會可以讓一套平凡的工程系統持久；一個管理真空可以讓一套完美的工程系統在兩年內崩潰。**技術夥伴**：地質勘測、按規格施工、品質報告，不負責長期的專案決策或社區管理。

Contractor Qualification & Supply Partners

承包商資格標準與供應夥伴

English

We use an invitation-based qualification model. Two hard requirements: valid drilling licence and pumping test competency. All other criteria are trainable. Four-step process: expression of interest → technical assessment → training → trial project.

Partner 夥伴	Role 角色	Country 國家 / 地區
Yeshua Living Water Company Limited	Borehole drilling execution partner — P4 construction in Uganda 鑽孔施工執行夥伴——烏干達 P4 施工	Uganda • 烏干達
BIK Water Systems Ltd	Borehole drilling execution partner — P4 construction in Uganda 鑽孔施工執行夥伴——烏干達 P4 施工	Uganda • 烏干達
HH Water Drops	Borehole drilling execution partner — P4 construction in Kenya 鑽孔施工執行夥伴——肯亞 P4 施工	Kenya • 肯亞
Restago Investment Co. Ltd	Borehole drilling execution partner — P4 construction in Tanzania 鑽孔施工執行夥伴——坦尚尼亞 P4 施工	Tanzania • 坦尚尼亞
United Renewable Energy (URE / 聯合再生能源)	Solar panel technology sponsor / 太陽能面板技術贊助	Taiwan • IEC/UL/MCS certified
Guangdong Sunry Power (广东三瑞电源科技)	Solar system local supply / 太陽能系統本地供應	Guangdong, China • East Africa operations 廣東, 中國 • 東非運營
AllGrand Power Source Dev. Ltd (山东奥冠新能源)	Solar system local supply / 太陽能系統本地供應	Uganda-registered • Shandong, China 烏干達註冊 • 山東, 中國

IN-HOUSE FIELD EQUIPMENT • 自有現場設備

Equipment / 設備	Quantity / 數量	Location / 地點	Purpose / 用途
Drilling rig 鑽井機	2 units • 2 台	Uganda • 烏干達	P4 borehole construction • P4 鑽孔施工
Drilling rig 鑽井機	1 unit • 1 台	Kenya • 肯亞	P4 borehole construction • P4 鑽孔施工
Geophysical survey equipment (VES) 地球物理勘測設備 (VES)	2 units • 2 台	Uganda / Kenya	P2 hydrogeological survey • P2 水文地質勘測

What this means in practice: Love Binti International is not solely a coordination organisation. We can execute geological surveys (P2) and borehole drilling (P4) using our own equipment, independent of external contractor availability. This reduces programme timeline risk and enables internal training and quality control at the equipment level.

這在實際執行上意味著：愛女孩國際關懷協會不只是協調型組織。我們能以自有設備執行地質勘測 (P2) 與鑽孔施工 (P4)，不受外部承包商檔期影響。這降低了計畫時程風險，並使我們能夠在設備層面進行內部培訓與品質管控。設備同時作為人員培訓平台——協助當地技術人員建立標準化的勘測與施工能力。

中文

我們採用邀請型承包商資格評估模式——目前不完全符合所有標準的承包商仍受鼓勵申請，並獲提供培訓路徑。兩項不可以培訓取代的硬性要求：有效的鑽井執照和抽水測試能力。

鑽井施工執行夥伴 (三個目標國家)： Yeshua Living Water Company Limited、BIK Water Systems Ltd (烏干達)、HH Water Drops (肯亞)、Restago Investment Co. Ltd (坦尚尼亞)——三個目標國家的 P4 鑽孔施工核可執行夥伴，各自在所在國負責實際鑽探作業、套管安裝與手壓井安裝，均在計畫監督下執行。**聯合再生能源股份有限公司 (URE, 台灣)：** 太陽能面板技術贊助單位，台灣上市公司，前身為新日光能源等三家公司於 2018 年合併而成，持有 IEC (歐洲)、UL (美國)、MCS (英國)、VPC (台灣) 等國際認證。**廣東三瑞電源科技有限公司：** 在東非運營的中國太陽能供應商，提供潛水泵、安裝系統、逆變器及現場售後技術支援。**AllGrand Power Source Development Limited (烏干達)：** 烏干達註冊公司，關聯山東奧冠新能源科技有限公司 (中國)，提供相同類型的本地供應服務。

Project Scoring & Prioritisation

專案評分與排序

English

With limited resources, "which project first" is itself an accountability question. We use a transparent scoring logic that can be reviewed.

Indicator / 指標	Weight / 權重	Assessment Content / 評估內容
Public health risk / 公共衛生風險	30%	Water-borne disease incidence / 水源性疾病發生率
Geological & hydrological feasibility / 地質水文可行性	25%	Aquifer stability, VES results / 含水層穩定性
Climate stability / 氣候穩定性	20%	Seasonal variation risk / 季節變化風險
Community governance capacity / 社區治理能力	15%	Responsible party, management track record 責任主體、管理過往紀錄
Long-term impact / 長期影響力	10%	Beneficiary population, demonstration effect 受益人口規模、示範效果

中文

資源有限的情況下，「先做哪個」本身就是一個責任問題。我們使用透明、可被稽核的評分機制——捐款人可以審閱每一個評分決定及其依據。

公共衛生風險（30%）：水源性疾病發生率、學童出席率、取水時間負擔——需求的緊迫程度。**地質水文可行性（25%）**：含水層傳導率、季節性出水量穩定性、VES 結果。一個公衛風險極高但地質條件極差的地點，可能得分低於地質條件優良的地點——因為在地質條件極差的地方投入資源，成功的可能性太低。**氣候穩定性（20%）**：降雨變異性、乾旱頻率、補給可靠性。在氣候快速變化的地區，過去的成功紀錄不再是未來成功的可靠預測指標。**社區治理能力（15%）**：水委員會的過往紀錄（若有）、管理責任的清晰度。**長期影響力潛力（10%）**：受益人口規模、示範效果或可複製性潛力。

Online Registry & Transparency

線上登錄與透明

English

We maintain an online registry recording each project from application to five-year tracking. Every decision has a traceable basis. Your supported project does not disappear after completion.

Stage	Recorded Content
Application	Needs description, preliminary survey, whether entering assessment
Scoring	Five indicators, composite score, delay or rejection reasons
Execution	Site selection, drilling depth, water quality tests, completion date
Five-year tracking	Periodic review, issue reports, maintenance records 定期訪視、問題報告、維修記錄

中文

我們建立並維護一個線上登錄系統，記錄每一個專案從最初申請到五年追蹤期結束的完整歷程。每一個關鍵決策都有可追溯的依據。支持特定專案的捐款人可以追蹤其完整生命週期——包括遇到的問題以及問題如何被處理。

登錄系統記錄：申請階段的需求描述與初步勘測發現；評分與排序的五項指標詳細評分、若被拒絕的原因；施工階段的選址座標、鑽井深度、抽水測試結果、水質證書、承包商身份、GPS 照片證據；移交階段的驗收清單完成情況；以及五年追蹤期的年度功能分類、水質結果、發現的問題、完成的維修和向捐款人提交的報告。

您支持的專案不會在完工後消失於記錄中。這是我們對捐款人透明度承諾的核心：不只是在事情進展順利時分享好消息，也在事情不如預期時誠實報告問題和我們的回應。

Risk Management

風險控管

English

Water projects cannot guarantee zero failure. We assume problems may occur and design response mechanisms in advance.

Type	Characteristics	Response
Repairable technical	Equipment ageing, component damage	Initiate repair assessment
Management problems	Use conflicts, management vacuum 使用衝突、管理真空	Coordination, mediation, governance reset 協調、調解、治理重啟
Structural failure	Geological conditions changed, aquifer depleted, climate-driven 地質條件改變、含水層耗竭、氣候驅動	Record cause, termination recommendation

中文

水資源專案無法保證零失敗。我們不假裝可以。相反，我們在設計時就假設問題會發生，並從一開始就將回應機制內建於專案結構中。

可修復的技術性失敗（設備老化、零件損壞、正常磨損）：啟動維修評估，動員維護資源，這是最常見的問題，也是五年追蹤期的主要干預對象。**管理層面的崩潰**（委員會解散、費用收取失敗、使用衝突）：協調、調解、治理重啟，這類問題往往是漸進的，可以透過定期監測在早期發現並介入。**結構性失效**（地質條件改變、含水層耗竭、氣候驅動的失敗）：誠實記錄原因，評估終止或補救選項，並將這次失敗的學習納入未來的選址評分機制。

當結構性失效發生時，我們不隱瞞它。一個被誠實記錄和理解的失敗，比一個什麼都沒教給我們的虛假成功更有價值——對捐款人如此，對我們服務的社區更是如此。

CASE STUDY • 案例

Facing Failure Honestly / 誠實面對失敗

Community K: borehole yield dropped sharply in year 3. Cause: two consecutive years of extreme drought beyond modelled climate parameters — a structural failure, not a maintenance failure.

K 社區水井第三年出水量驟降，原因：連續兩年極端乾旱，超出氣候建模參數——屬於結構性失敗，而非維護失誤。

Response: honest report to donors, assessment of remedial options, findings incorporated into future site scoring criteria.

回應：誠實向捐款人報告，評估補救方案，並將此次失敗的學習成果納入未來選址評分標準。

Five-Year Tracking Mechanism

五年追蹤機制

English

Phase	Frequency	Focus
Year 1-2	Every 3 months	Early issue detection, management structure establishment, six-category baseline 早期問題偵測、管理結構建立、六類分類基線
Year 3-4	Every 6 months	Long-term stability, seasonal variation, low yield (LY) detection 長期穩定性、季節變化、低產 (LY) 偵測
Year 5	Full evaluation	Continue, extend tracking, or honest closure with documented learnings 繼續、延長追蹤，或以誠實記錄結案

After five years: stable operation → recorded as success • needs continued attention → assess extended tracking • failed → honest documentation of cause, fed back into future decisions.

中文

五年追蹤不是形式上的定期拜訪，而是結構化的問責機制。每一次訪視都遵循標準化的評估流程，並記錄於線上登錄系統中。

第 1-2 年（每季密集追蹤）：重點是早期問題偵測和管理結構的建立。新移交的系統最脆弱，社區水委員會仍在學習如何運作，任何設計或施工上的遺漏問題在這個階段最容易顯現。**第 3-4 年（每半年穩定觀察）**：重點轉向長期穩定性、季節性變化和低產 (LY) 的早期偵測——這個類別在雨季往往完全隱形，只有在乾季的追蹤訪視中才會顯現。**第 5 年（完整評估）**：全面評估：系統是否繼續穩定運作？是否需要延長追蹤？還是應當誠實地記錄原因並結案？無論結果如何，第五年的評估報告都會向捐款人完整披露。

PART FIVE • 第五部

Impact & Partnership

成果與合作

Case studies, impact measurement, scalability, and how donors can engage effectively with Love Binti International.

案例摘要、影響力衡量、可複製性，以及捐款人如何與愛女孩國際關懷協會有效合作。

Case 1 — Community L • Hand Pump System

案例一：社區 L • 手壓井鑽孔系統

M&E MONITORING FRAMEWORK • 監測與評估框架

Indicator / 指標	Baseline / 基線值 Before / 介入前	Target / 目標值 Year 5 / 第 5 年	Actual / 實際值 Latest / 最近	Source / 來源
Dry-season yield (l/min) 乾季出水量	—	≥ 10 l/min	—	Bucket test • 桶測法
Annual downtime (days) 年度停機天數	—	< 30 days	—	Committee log • 水委員日誌
Functionality category (FF/UR/LY...) 功能分類	—	FF	—	P6 annual visit • P6 年訪
E. coli (dry season) 大腸桿菌 (乾季)	—	Not detected • 未檢出	—	Lab cert • 水質報告
Water-borne disease rate 水源性疾病發生率	—	≥ 30% reduction ≥ 30% 下降	—	Clinic records • 診所記錄
Water committee active 水委員會運作狀況	—	Active + fee collecting 運作中 + 持續收費	—	Governance review • 治理評估
Beneficiaries with daily access 每日可取水受益人口	—	—	—	Community census • 人口普查
Self-completed repairs (no.) 社區自行完成維修次數	—	≥ 1 by Year 3	—	Maintenance log • 維修日誌
Women's programme participation 婦女農業計畫參與率	—	—	—	Programme records • 計畫記錄

Assessment frequency / 評估頻率: Y1–2 quarterly 每季 • Y3–4 bi-annual 每半年 • Y5 full evaluation 完整評估

CASE 1 • 案例一 • HAND PUMP SYSTEM

Community L — Remote Village • 偏遠社區 L

Approximately 350 people in a remote mountain community. Intervention: hand pump borehole + water point contamination prevention + integrated women's agriculture programme. Pre-intervention: community walked 2+ hours daily for unsafe water. Assessment confirmed viable geology and strong governance capacity before commitment. 山區偏遠社區，約 350 人。介入方式：手壓井鑽孔 + 取水點污染防治 + 整合婦女農業計畫。介入前：社區每日步行 2 小時以上取用不安全水源。承諾介入前已確認地質條件可行且社區治理能力達標。

5-year outcomes: yield stable at 600 l/hr • community independently completed 3 repairs • child diarrhea rate down 65%
五年成果：出水量穩定維持 600 公升 / 小時 • 社區獨立完成 3 次維修 • 兒童腹瀉率下降 65%

Case 2 — School M • Solar + Rainwater System

案例二：M 小學 • 太陽能深井 + 雨水收集系統

M&E MONITORING FRAMEWORK • 監測與評估框架

Indicator / 指標	Baseline / 基線值 Before / 介入前	Target / 目標值 Year 5 / 第 5 年	Actual / 實際值 Latest / 最近	Source / 來源
Dry-season yield (l/min) 乾季出水量	—	≥ 10 l/min	—	Bucket test • 桶測法
Annual downtime (days) 年度停機天數	—	< 30 days	—	Committee log • 水委員日誌
Functionality category (FF/UR/LY...) 功能分類	—	FF	—	P6 annual visit • P6 年訪
E. coli (dry season) 大腸桿菌 (乾季)	—	Not detected • 未檢出	—	Lab cert • 水質報告
Water-borne disease rate 水源性疾病發生率	—	≥ 30% reduction ≥ 30% 下降	—	Clinic records • 診所記錄
Water committee active 水委員會運作狀況	—	Active + fee collecting 運作中 + 持續收費	—	Governance review • 治理評估
Beneficiaries with daily access 每日可取水受益人口	—	—	—	Community census • 人口普查
School illness-related absence 學生因病缺課率	—	≥ 50% reduction	—	Attendance records • 出勤記錄
Rainwater share of daily demand 雨水供水佔日需求比例	—	≥ 40% (wet season)	—	Tank level log • 水槽記錄
Solar system downtime (days/yr) 太陽能系統停機天數	—	< 10 days/year	—	System log • 系統日誌

Assessment frequency / 評估頻率: Y1-2 quarterly 每季 • Y3-4 bi-annual 每半年 • Y5 full evaluation 完整評估

CASE 2 • 案例二 • SOLAR + RAINWATER SYSTEM

School M — 600 Students • M 小學，600 名學生

600-student school with unreliable municipal supply. Intervention: solar deep borehole + rainwater collection system + zone-based management. The rainwater system was designed to reduce pressure on the deep borehole during the rainy season — extending equipment lifespan and reducing energy consumption.

600 名學生的學校，市政供水不可靠。介入方式：太陽能深井 + 雨水收集系統 + 按區域分流管理。雨水系統的設計目的之一是在雨季降低深井負荷——延長設備壽命並降低能源消耗。

5-year outcomes: rainwater reduced borehole pressure by 40% • water-borne illness absence days down 70% • only 8 days total downtime in 5 years

五年成果：雨水系統降低深井壓力 40% • 水源性疾病缺課天數下降 70% • 五年內總停機天數僅 8 天

Case 3 — Clinic N • Borehole Rehabilitation

案例三：N 診所 • 水井維修復能

M&E MONITORING FRAMEWORK • 監測與評估框架

Indicator / 指標	Baseline / 基線值 Before / 介入前	Target / 目標值 Year 5 / 第 5 年	Actual / 實際值 Latest / 最近	Source / 來源
Dry-season yield (l/min) 乾季出水量	—	≥ 10 l/min	—	Bucket test • 桶測法
Annual downtime (days) 年度停機天數	—	< 30 days	—	Committee log • 水委員日誌
Functionality category (FF/UR/LY...) 功能分類	—	FF	—	P6 annual visit • P6 年訪
E. coli (dry season) 大腸桿菌 (乾季)	—	Not detected • 未檢出	—	Lab cert • 水質報告
Water-borne disease rate 水源性疾病發生率	—	≥ 30% reduction ≥ 30% 下降	—	Clinic records • 診所記錄
Water committee active 水委員會運作狀況	—	Active + fee collecting 運作中 + 持續收費	—	Governance review • 治理評估
Beneficiaries with daily access 每日可取水受益人口	—	—	—	Community census • 人口普查
Diarrhea consultations/month 腹瀉就診次數 (每月)	—	≥ 40% reduction	—	Clinic records • 診所記錄
Rehab cost vs. new borehole (USD) 維修費用對比新鑽孔	New: \$ _____	Saving ≥ 60%	Actual: \$ _____	Cost report • 費用報告
Staff hygiene compliance 員工衛生規範遵守率	—	≥ 80%	—	Hygiene audit • 衛生稽核

Assessment frequency / 評估頻率: Y1-2 quarterly 每季 • Y3-4 bi-annual 每半年 • Y5 full evaluation 完整評估

CASE 3 • 案例三 • BOREHOLE REHABILITATION

Clinic N — Rehabilitation • N 診所維修復能

Clinic borehole non-functional for 3 years, serving 800 potential beneficiaries. Intervention: borehole rehabilitation + water point upgrade + hygiene education for staff and patients. Assessment confirmed the underlying aquifer remained viable — only pump components and the water point required replacement. No new drilling needed.

診所水井失修 3 年，800 名潛在受益人。介入方式：水井維修復能 + 取水點升級 + 針對員工及患者的衛生教育。評估確認底層含水層仍然可用——只需更換泵件與取水點，無需新鑽。

Outcome: USD 1,200 vs. USD 8,500 for new borehole — 86% saving • full function restored • diarrhea consultations down 55% • 800 beneficiaries

結果：費用 \$1,200 對比新建 \$8,500，節省 86% • 功能完全恢復 • 腹瀉就診下降 55% • 800 人受益

Impact Measurement

影響力衡量

English

Traditional Output Indicators 傳統輸出指標	Our Outcome Indicators 我們的結果指標
Built X boreholes 建了 X 口水井	X% communities with stable, safe water access
Drilling depth X metres 鑽井深度 X 米	Dry-season yield maintained at X litres/hour 乾季出水量維持在 X 公升 / 小時
Served X population 服務 X 人口	Water-borne disease rate down X% 水源性疾病發生率下降 X%
Equipment operating X years	% still functional after 5 years

中文

停留在輸出指標層面的影響力衡量——挖了幾口井、服務了多少人——無法反映真實改變。我們從「做了什麼」轉向「改變了什麼」。

我們追蹤的結果指標：**X% 的社區在五年後仍然擁有穩定安全的水資源**（而不是完工當天）；**乾季出水量維持在 X 公升 / 小時**（最嚴苛條件下的表現，而非最理想條件）；**水源性疾病發生率下降 X%**（需與當地衛生部門合作追蹤，但它是直接反映實際健康影響的指標）；**五年後仍然功能正常的系統比例**（以六類分類衡量，這是我們最核心的績效指標）。這些指標更難被美化，也更難在單一的竣工報告中展示——但它們才是捐款人真正應該關心的問題的答案。

Scalability & Replicability

可複製性與擴展

English

Not Replicable 不可複製	Replicable 可複製
Drilling depth from one site directly applied to another 某地鑽井深度直接套用到另一地點	Risk assessment methodology and VES survey protocol 風險評估方法論和 VES 勘測協議
Community management model from one context imposed on another 某社區管理模式強加於另一社區	Decision scoring framework and weighting logic 決策評分框架和權重邏輯
Wet-season design applied to an arid area 雨季豐沛設計用於乾旱地區	Governance structure, water committee formation, MOU framework 治理結構、水委員會組建、MOU 框架

中文

「複製成功案例」往往被誤解為複製工程設計。在一個地點成功的鑽井深度，對地質條件不同的另一個地點毫無預測價值。

不可複製的：某地點的鑽井深度直接套用到另一地點；某社區的管理模式強加於另一社區；雨季豐沛設計用於乾旱地區；在低腐蝕性環境下適用的零件規格用於烏干達。**可複製的：**風險評估方法論和 VES 勘測協議；決策評分框架和權重邏輯；治理結構、水委員會組建流程、MOU 框架；六類監測系統和五年追蹤協議；以及誠實面對失敗、從失敗中學習並調整未來決策的制度文化。這些才是我們在東非各個目標國家之間可以移植的核心資產。

Donor Guide

捐款人指南

English

Option	Suitable For	How It Works
Support the system 支持整體系統	Trust our judgment; maximum impact per dollar 信任我們的判斷；每筆捐款產生最大影響力	Funds allocated via scoring to highest-priority projects 透過評分機制分配至最高優先專案
Specify a project 指定特定專案	Wants deeper engagement with a specific community 希望與特定社區有更深連結	Choose from assessed and approved projects 從已通過評估的專案清單中選擇
Support early-stage survey 支持前期探勘	Supports "invisible work" that determines success 支持決定成敗的「看不見的工作」	Fund geological surveys and risk assessments 資助地質勘測和風險評估
Long-term partner 長期夥伴	Corporates, foundations, institutional donors 企業、基金會、機構型捐助者	3-5 year collaboration framework, agreed funding pipeline 3-5 年合作框架，商定資助管道

FAQ: How long until a borehole is completed? Hand pump ~2-4 months; solar system ~6-9 months. Why is early-stage survey important? It determines 90% of success probability. Careful siting; failure rate below 10%. Without assessment: can reach 60%.

中文

根據您的目標、可用資源和偏好的參與深度，有四種與我們合作的方式。

支持整體系統：適合信任我們判斷、希望每一筆捐款產生最大影響力的捐款人。資金透過評分機制分配到優先度最高的專案，您收到的是橫跨所有資助專案的投資組合報告。**指定特定專案：**適合希望與特定社區有更深連結的捐款人。從已通過評估和核准的專案清單中選擇，在整個 P1-P6 生命週期中收到個別專案更新。**支持前期探勘：**適合理解「看不見的工作才是決定成敗之處」的捐款人。資助地質勘測和風險評估——每一次勘測要麼使一個專案成為可能，要麼阻止了一次糟糕的投資，兩者都有價值。一次 VES 勘測的費用往往不及一口失敗水井成本的十分之一。**長期夥伴：**適合企業、基金會和機構型捐助者，提供 3-5 年合作框架、商定的資助管道和年度審查。

常見問題：手壓井從承諾到交付大約需要 2-4 個月；太陽能系統約 6-9 個月。為什麼要資助勘測而非施工？因為地質勘測決定了一口水井 90% 的成功可能性，資助一次阻止了壞水井被建造的勘測，與資助一口好水井同樣有價值——只是前者更難在捐款報告中展示。

Conclusion

結語

English

Climate change and social shifts are creating unprecedented uncertainty for water projects. The truly difficult part is not finding water, but making responsible choices: where to intervene, how to intervene, and when not to intervene.

We believe: Water resources are not a one-time project but a patient public investment • Real impact is measured by how many systems are still functioning five years later • Honestly facing failure matters more than manufacturing false success • Donors deserve a partner that learns and corrects.

We don't just build boreholes. We build water systems people can trust.

中文

氣候變遷、社會不穩定與資源日益稀缺，正在為東非的水資源專案製造前所未有的不確定性。技術挑戰是真實的、有文件記錄的。治理挑戰往往更難被看見，但同樣決定成敗。

水資源開發真正困難的部分，不是找到水。而是做出負責任的選擇：在哪裡介入、如何介入，以及——同樣重要的——什麼時候不介入。

我們相信：水資源不是一次性工程，而是需要耐心的長期公共投資。真正的影響力不以完工當天衡量，而以五年後有多少系統仍在穩定運作衡量。誠實面對失敗，比製造虛假成功更重要。捐款人值得一個從失敗中學習的合作夥伴——而不是一個把失敗埋藏在結案報告中的組織。

本文件的第二部分——技術附錄——包含支撐這些承諾的操作標準、材料規格、承包商資格標準、現場檢查表和術語表。兩份文件合在一起，代表我們完整的問責框架。

We don't just build boreholes. We build water systems people can trust.

我們不只是挖水井，我們建立人們可以信賴的水資源系統。

PART B • 第二部分

Technical Appendix

技術附錄

Borehole Technical Standards, Contractor Management & Supply
Chain Specifications

鑽孔技術標準、承包商管理與供應鏈規範

Love Binti International • 愛女孩國際關懷協會 • 2025

Borehole Technical Standards, Contractor Management & Supply Chain Specifications

鑽孔技術標準、承包商管理與供應鏈規範

A technical supplement to the Love Binti International Water Resources White Paper. Provides evidence-based operational standards for hydrogeological site assessment, borehole construction, component material specifications, six-category functionality classification, and contractor qualification for handpump borehole programmes in East Africa.

本文件為愛女孩國際關懷協會水資源白皮書之技術補充，提供東非手壓井計畫在水文地質評估、鑽井施工、管件材料規格、六類功能分類及承包商資格審核方面的實證操作標準。

APPLICABLE REGION / 適用地區

Kenya · Uganda · Tanzania · South Sudan
肯亞 · 烏干達 · 坦尚尼亞 · 南蘇丹

Research evidence from / 研究實證來源：Ethiopia · Uganda · Malawi (MacAllister et al., 2022) — not implementation countries / 非執行地區

About This Document & Research Evidence Base

關於本文件及研究實證基礎

English

This document draws on the most comprehensive field-based study of handpump borehole functionality in East Africa to date: MacAllister et al. (2022), published in *Science of the Total Environment*. The study dismantled and examined 145 handpump boreholes across three countries — Ethiopia, Uganda and Malawi — assessing hydrogeology, borehole construction, and pump component condition. The research was conducted under the UPGro Hidden Crisis project, funded by NERC, FCDO and ESRC (UK).

Functionality classification standards are based on Bonsor et al. (2018), *Hydrogeology Journal*. All technical thresholds (transmissivity, recovery rate, component dimensions) are derived directly from peer-reviewed evidence. This document translates that evidence into operational standards for programme implementation across Kenya, Uganda, Tanzania and South Sudan.

Note on research countries: Ethiopia, Uganda and Malawi are the three countries where the primary field research was conducted. They are evidence sources, not implementation countries. Love Binti International's programme operates in Kenya, Uganda, Tanzania and South Sudan. Uganda appears in both roles — as a research country providing the most challenging hydrogeological data, and as an active implementation country.

關於研究國家的說明：衣索比亞、烏干達及馬拉威為主要實地研究執行地區，屬於實證來源國，而非計畫執行國。愛女孩國際關懷協會的計畫在肯亞、烏干達、坦尚尼亞及南蘇丹執行。烏干達同時具有兩種身份——既是提供最嚴峻水文地質數據的研究國家，也是現行計畫執行國。

中文

本文件以東非地區迄今最完整的手壓井功能性實地研究為基礎：MacAllister et al. (2022)，發表於《*Science of the Total Environment*》。該研究針對衣索比亞、烏干達及馬拉威三個國家的 145 口手壓井進行拆卸檢測，評估水文地質條件、鑽孔施工品質與泵件狀況，隸屬英國 NERC、FCDO 及 ESRC 共同資助的 UPGro Hidden Crisis 研究計畫。功能分類標準依據 Bonsor et al. (2018)，《*Hydrogeology Journal*》。所有技術門檻均直接來源於經同行評審的研究證據，並轉化為可在肯亞、烏干達、坦尚尼亞及南蘇丹實施的操作標準。

Research Countries — Geology & Key Findings / 研究國家——地質條件與主要發現

Ethiopia / 衣索比亞

Geology: Volcanic aquifers (highland areas) with moderate to high transmissivity but low storage capacity. Seasonal rainfall June–September; mean annual rainfall ~1,280mm. Water levels deepest among the three countries (median 20.4m in dry season).

Key findings: 8% of sites below transmissivity threshold (lowest of the three countries). Median transmissivity of fully functional boreholes was 684 m²/day — an order of magnitude higher than other categories. Deep groundwater levels linked to competition from nearby industrial and agricultural abstraction, not low recharge. India Mark Extra Deep pumps used at depths >50m increase corrosion risk due to extended GI component strings.

地質：高原地區以中至高傳導率的火山岩含水層為主，但儲量容量偏低。雨季為 6–9 月，年均降雨量約 1,280mm，乾季水位在三國中最深（中位數 20.4m）。

主要發現：8% 的地點低於傳導率門檻（三國中最低）。完全功能類別的中位傳導率達 684 m²/天，比其他類別高出一個數量級。深水位與附近工業及農業抽水競爭有關，而非低補給所致。深度 >50m 採用 India Mark Extra Deep 泵會因延長 GI 管柱而增加腐蝕風險。

Uganda / 烏干達

Geology: Fractured crystalline basement aquifers — highly weathered, often clay-rich, with low transmissivity and storage. Rainfall year-round; heaviest March–May and September–November; mean annual rainfall ~1,290mm.

Key findings: 30% of sites below transmissivity threshold — the highest proportion of the three countries. Median transmissivity only 3.4 m²/day. GI pipe galvanising thickness sub-standard in 98% of samples; pipe wall thickness below standard in 93%. 82% of pump rods corroded. Corrosive groundwater chemistry (low pH, high mineralisation) is a primary accelerant. India Mark II pumps (non-VLOM) make community-level repair more difficult, compounding the maintenance gap.

地質：破裂結晶基底岩含水層，高度風化，常含黏土，傳導率與儲量均偏低。全年有雨，3–5 月及 9–11 月最為集中，年均降雨量約 1,290mm。

主要發現：30% 的地點低於傳導率門檻，三國中比例最高；傳導率中位數僅 3.4 m²/天。98% 的 GI 管樣本鍍鋅厚度不足，93% 管壁厚度不足，82% 活塞桿腐蝕。腐蝕性地下水（低 pH、高礦化度）是主要加速因素。India Mark II 泵（非 VLOM 型）使社區層面維修更加困難，加劇維護缺口。

Malawi / 馬拉威

Geology: Primarily crystalline basement (dry sub-humid conditions) with weathered and fractured aquifer zones. Developable aquifers are weathered basement (saprolite/saprock) and alluvium. Groundwater storage controlled by weathering profile thickness. Wet season November–March; dry season April–October; mean annual rainfall ~880mm. Shares Kilimanjaro aquifer (volcanic alluvium) and Lake Tanganyika Basin with Tanzania.

Key findings (MacAllister et al., 2022; Smith-Carington & Chilton, 1983; Mkandawire, 2004): 16% of sites below transmissivity threshold.

Afridev handpumps used throughout; 81% of uPVC rising mains damaged — primarily due to maintenance practice of cutting and re-gluing pipe sections rather than full replacement. 98% of Afridev rods below standard diameter. Screens typically positioned in the mid-section of boreholes rather than opposite the most productive aquifer zones. Water quality: elevated fluoride and iron in alluvial zones. In some high-density population areas, demand now exceeds long-term aquifer recharge potential (11-year climate cycle), causing overdraft during dry-cycle years (Robins et al., 2013).

地質：以乾熱氣候下的結晶基底岩為主，含水層為風化與破裂帶。可開發含水層主要為風化基底岩（腐殖土層 / 腐岩層）與沖積層，地下水儲量受風化剖面厚度決定。雨季 11 月至翌年 3 月，乾季 4–10 月，年均降雨量約 880mm。與坦尚尼亞共享乞力馬扎羅含水層（火山沖積層）及坦噶尼喀湖盆地。

主要發現 (MacAllister et al., 2022; Smith-Carington & Chilton, 1983; Mkandawire, 2004)：16% 的地點低於傳導率門檻。全國採用 Afridev 手壓井；81% 的 uPVC 上升主管損壞，主因是維修時慣於切管黏合而非整段更換。98% 的 Afridev 活塞桿直徑低於標準。篩管通常置於鑽孔中段，而非對應最高產含水層位置。水質問題：沖積層地帶氟化物與鐵含量偏高。部分高人口密度地區需求已超過含水層長期補給潛力（11 年氣候周期），乾旱年份出現超採 (Robins et al., 2013)。

Sources / 來源: MacAllister et al., *Sci. Total Environ.* 851 (2022) 158343 • Bonsor et al., *Hydrogeology J.* 26 (2018) 367–370 • Smith-Carington & Chilton (1983), *Groundwater Resources of Malawi* • Mkandawire (2004), *Groundwater Resources of Malawi* • Robins et al. (2013), *Groundwater Supply and Demand from Southern Africa's Crystalline Basement Aquifer* • BGS Earthwise, *Hydrogeology of Malawi*

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Core Problems Identified by Research

研究揭示的核心問題

CHAPTER SUMMARY · 章節摘要

Research identifies three structural problem categories responsible for >25% non-functionality in Sub-Saharan Africa: hydrogeological siting failures, equipment material deterioration, and construction design deficiencies. Uganda (30% below transmissivity threshold), Malawi (16%) and the 98% GI pipe sub-standard galvanising rate define the scale of the challenge.

研究揭示三類結構性問題：水文地質選址失敗、設備材料劣化及施工設計缺失，共同造成撒哈拉以南非洲逾 25% 的水井在任意時間點非功能。烏干達 30%、馬拉威 16% 的地點傳導率不足，以及 98% 的 GI 管鍍鋅不達標，說明問題規模。

<p>Non-functionality rate 任意時間非功能率</p> <p>>25%</p> <p>Sub-Saharan Africa / 撒哈拉以南非洲</p>	<p>Sites below transmissivity threshold 傳導率低於門檻地點比例</p> <p>30%</p> <p>Uganda sample — low yield from day one / 烏干達樣本，啟用即低產</p>	<p>GI pipe galvanising sub-standard GI管鍍鋅厚度不足比例</p> <p>98%</p> <p>Uganda sample / 烏干達樣本</p>
<p>Malawi uPVC pipes damaged 馬拉威 uPVC 管損壞率</p> <p>81%</p> <p>Caused by cutting practice / 切管維修習慣所致</p>	<p>Malawi Afridev rods below standard 馬拉威活塞桿直徑不足</p> <p>98%</p> <p>At procurement / 採購時即不達標</p>	

Regional applicability / 地區適用性： Research data from Ethiopia (volcanic aquifers), Uganda (crystalline basement), and Malawi (basement and sedimentary). All four target countries — Kenya, Uganda, Tanzania and South Sudan — share the East African Rift System tectonic context: Precambrian crystalline basement with weathered/fractured aquifer zones, interbedded volcanic sequences, and localised alluvial deposits. The 30% below-threshold transmissivity figure from Uganda is conservatively applicable to basement rock zones across all four countries without prior VES survey. Kenya (basement zones), Tanzania (basement zones) and South Sudan (southwest Precambrian basement) present comparable low-transmissivity challenges. / 研究數據來自衣索比亞（火山岩含水層）、烏干達（結晶基底岩）及馬拉威（基底岩與沉積岩）。四個目標國家——肯亞、烏干達、坦尚尼亞和南蘇丹——均共享東非裂谷系統的構造背景：前寒武紀結晶基底岩（風化 / 破裂含水層）、玄武岩火山岩序列，以及局部沖積沉積物。烏干達 30% 低傳導率的數據，在未進行 VES 勘測的情況下，可保守適用於四個目標國家的基底岩地區。肯亞（基底岩地帶）、坦尚尼亞（基底岩地帶）及南蘇丹（西南部前寒武紀基底岩）均存在相近的低傳導率挑戰。

English

Three Problem Categories

Hydrogeological [Most Fundamental]	19% of boreholes are sited in aquifers below the minimum transmissivity threshold; 38% have pump cylinders less than 10m below the water table; 23% have water columns under 20m. Complex nonlinear relationships between water level, transmissivity and screen position mean no single indicator can reliably predict functionality status.
Equipment & Materials [Most Pervasive]	53% of GI rising main pipes corroded; 82% of uPVC rising main pipes damaged. In Uganda, 98% of GI pipes fail galvanising standards due to corrosive groundwater. In Malawi, 81% of uPVC pipes are damaged and 98% of Afridev pump rods are below standard diameter — both directly attributable to the maintenance practice of cutting and re-joining pipe sections rather than full replacement. Problem documented since the 1980s with no systemic supply chain improvement to date.
Construction Design [Preventable]	Casing and screen configuration is a statistically significant risk factor for unreliable borehole classification (multinomial regression, p<0.01). Standard designs applied without reference to local hydrogeology. Construction supervision widely absent.

中文

三個問題層次

水文地質問題 [最根本]	19% 的水井位於傳導率低於最低需求的地層；38% 泵筒距水面不足 10m，乾季高強度使用時容易抽乾；23% 水柱長度不足 20m。水位、傳導率與篩管位置之間存在複雜非線性關係，單一指標無法可靠預測功能狀態。
設備材料問題 [最普遍]	53% 的 GI 上升主管腐蝕、82% 的 uPVC 上升主管損壞。烏干達 98% 的 GI 管因腐蝕性地下水導致鍍鋅厚度不足；馬拉威 81% 的 uPVC 管損壞、98% 的 Afridev 活塞桿直徑低於標準——兩者均直接源於切管重接而非整段更換的維修習慣。此問題自 1980 年代即有記錄，至今供應鏈未有系統性改善。
施工設計問題 [可預防]	套管與篩管配置是「不可靠」分類的統計顯著風險因素（多項式迴歸，p<0.01）。標準設計未因地制宜。施工現場監督普遍缺失。

KEY TERMS — CHAPTER 1 / 第一章

Abbr.	Term	English Definition	中文說明
EARS	East African Rift System / 東非裂谷系統	Tectonic rift formed by divergence of the Nubian and Somalian plates. Produces the crystalline basement and volcanic geology shared by all four target countries.	由努比亞板塊與索馬利亞板塊分離形成的構造裂谷，產生四個目標國家共有的結晶基底岩與火山岩地質特徵。
GI	Galvanised Iron / 鍍鋅鐵	Steel coated with zinc to resist corrosion. Standard in India Mark pumps. In Uganda, 98% fail galvanising thickness standards.	鍍鋅鋼鐵，India Mark 手壓井的標準材料。烏干達 98% 的 GI 管鍍鋅厚度不足。
uPVC	Unplasticised Polyvinyl Chloride / 硬質聚氯乙烯	Rigid PVC pipe. Preferred rising main for all four target countries. Corrosion-resistant; damage rate in Uganda only 1% vs GI pipe 37%.	硬質 PVC 管，四個目標國家優先採用的上升主管材料，烏干達損壞率僅 1% (GI 管為 37%)。
HPB	Handpump Borehole / 手壓井鑽孔	A drilled borehole fitted with a mechanical handpump for manual water extraction.	安裝機械式手壓泵的鑽孔水井，是東非最主要的農村供水技術。
Transmissivity	地下水傳導率 (T)	Rate of groundwater flow through an aquifer (m^2/day). Minimum for handpump sustainability: $>1.4 m^2/day$. Uganda: 30% of sites below threshold.	地下水穿過含水層的流動速率 ($m^2/天$)，手壓井最低門檻 $>1.4 m^2/天$ ，烏干達約 30% 地點低於此門檻。
Aquifer	含水層	Underground layer of permeable rock or sediment that holds and transmits groundwater.	能儲存並傳導地下水的地下透水岩石或沉積物層。

Material Specifications: Rising Mains

管件材料規範：上升主管

CHAPTER SUMMARY · 章節摘要

uPVC rising mains are the preferred material for all four target countries. GI pipes are prohibited in Uganda and strongly discouraged elsewhere. Key procurement standard: wall thickness $\geq 5.1\text{mm}$ verified by ultrasonic gauge. Prohibited practices: cutting and re-joining, re-threading, and mixing stainless steel with galvanised steel.

uPVC 上升主管為四個目標國家優先選用材料，GI 管在烏干達禁用。採購關鍵標準：管壁厚度 $\geq 5.1\text{mm}$ ，超音波驗收。禁止切管重接、重新套螺紋及混用不鏽鋼與鍍鋅鋼。

Applicable to all four target countries. Uganda-specific corrosive groundwater conditions make GI pipe prohibition especially critical there, but sub-standard galvanising is a widespread supply chain problem across East Africa. / 適用於全部四個目標國家。烏干達地下水腐蝕性強，GI 管禁用尤為關鍵，但鍍鋅厚度不足是整個東非供應鏈的普遍問題。

English

GI Pipe vs uPVC Pipe

Indicator	GI Pipe (Galvanised Iron)	uPVC Pipe
Damage rate (Uganda)	37%	1%
Corrosion risk	Very high — especially in corrosive groundwater	Negligible
Galvanising compliance (Uganda)	Only 2% meet standard	N/A
Primary failure cause	Corrosion perforation; galvanising worn at threaded joints	Improper cutting and re-joining during maintenance
East Africa recommendation	Prohibited in Uganda; strongly discouraged elsewhere	Preferred material for all four target countries

uPVC Pipe Procurement Specifications

Minimum wall thickness	$\geq 5.1\text{ mm}$
Standard section length	3 m
Acceptance inspection tool	Ultrasonic thickness gauge — 5 MHz probe (e.g. Elcometer MTG4)
Standard reference	RWSN Afridev Specification Rev.5-2007

Prohibited practices (all four countries): (1) Standard GI rising main pipes — prohibited in Uganda; strongly discouraged in Kenya, Tanzania and South Sudan. (2) Cutting and re-gluing uPVC pipe sections during maintenance — prohibited; full section replacement required. (3) Re-threading shortened GI pipes — prohibited. (4) Mixing stainless steel and galvanised steel components in the same string — prohibited due to galvanic corrosion risk.

中文

GI 管 vs uPVC 管對比

指標	GI 管 (鍍鋅鐵管)	uPVC 管
損壞率 (烏干達)	37%	1%
腐蝕風險	極高——腐蝕性地下水環境尤甚	幾乎無
鍍鋅達標率 (烏干達)	僅 2% 符合標準	不適用
主要失效原因	腐蝕穿孔；螺紋接頭處鍍鋅層最先磨損	維修時切管重接操作不當
東非地區建議	烏干達禁用；其他目標國家強烈不建議	四個目標國家均優先採用

uPVC 管採購驗收規格

最低管壁厚度	$\geq 5.1\text{ mm}$
標準節長	3 m
驗收工具	超音波測厚儀——5 MHz 探頭 (如 Elcometer MTG4)
規範依據	RWSN Afridev Specification Rev.5-2007

四個目標國家禁止操作： (1) 標準 GI 上升主管——烏干達禁用；肯亞、坦尚尼亞、南蘇丹強烈不建議使用。 (2) 維修時切管重接 uPVC 管——禁止；必須整段更換。 (3) 截短 GI 管後重新套螺紋——禁止。 (4) 不鏽鋼與鍍鋅鋼管件混用於同一管柱——禁止，存在電化學腐蝕風險。

KEY TERMS — CHAPTER 2 / 第二章

Abbr.	Term	English Definition	中文說明
Rising Main	上升主管	Pipe string from pump cylinder to surface. Most commonly damaged component in all three research countries.	從泵筒延伸至地面的管柱，是研究三國中最常損壞的部件。
RWSN	Rural Water Supply Network / 農村供水網絡	International standards body. Publishes Afridev and India Mark handpump specifications referenced throughout this document.	制定農村手壓井標準的國際機構，本文件引用的 Afridev 及 India Mark 規範均由此機構發布。
Afridev	Afridev Handpump	VLOM-classified handpump using uPVC rising mains. Designed for community-level maintenance. Max depth: 45m. Standard: RWSN Rev.5-2007.	採用 uPVC 上升主管的 VLOM 型手壓井，為社區自行維護設計，最大深度 45m。
VLOM	Village Level Operation & Maintenance / 村級操作與維護	Handpump design standard allowing trained community members to repair without specialist tools.	允許受訓社區成員無需專業工具即可完成維修的手壓井設計標準。
Galvanic Corrosion	電化學腐蝕	Accelerated corrosion when two dissimilar metals contact in groundwater (e.g. stainless steel + GI). Reason why material mixing is prohibited.	兩種不同金屬（如不鏽鋼與 GI）在地下水中接觸時發生的加速腐蝕，這是禁止混用材料的根本原因。

Material Specifications: Pump Rods

管件材料規範：活塞桿

CHAPTER SUMMARY • 章節摘要

Pump rod sub-standard diameter is a supply chain-wide problem: 70% in Uganda, 98% in Malawi fall below standard. Stainless steel rods reduce corrosion from 69% to 3.5% in Uganda. Minimum acceptable diameter at procurement: ≥11mm. No mixing of stainless steel and GI rods in the same string.

活塞桿直徑不足是供應鏈普遍問題：烏干達 70%、馬拉威 98% 不達標。不鏽鋼桿將腐蝕率從 69% 降至 3.5%。採購最低桿徑 ≥11mm，禁止不鏽鋼與 GI 桿混用。

Pump rod sub-standard diameter is a widespread supply chain problem across East Africa, not limited to the research countries. Stainless steel rods outperform GI rods across all corrosion conditions and are recommended for all four target countries. / 活塞桿直徑不符規範是整個東非供應鏈的普遍問題，不限於研究所涉國家。不鏽鋼桿在所有腐蝕條件下均優於 GI 桿，建議在四個目標國家全面採用。

English

Region / Material	Damage Rate	Corrosion Rate
Uganda — GI rods	14%	69%
Uganda — Stainless steel rods	2%	3.5%
Ethiopia — GI rods	52%	55%
Malawi — Afridev GI rods	56%	43%
Standard rod diameter (India Mark II)	12 mm	
Minimum acceptable diameter at procurement	≥ 11 mm	
Uganda rods below standard diameter	70% of sample	
Malawi (Afridev) rods below standard diameter	98% of sample	
Recommended material — all four target countries	Stainless steel rods	

Prohibited: (1) Mixing stainless steel and GI rods in the same string — galvanic corrosion risk. (2) Accepting rods with diameter below 11 mm. (3) Single-rod replacement without verifying full-string material consistency.

中文

地區 / 材料	損壞率	腐蝕率
烏干達—GI 桿	14%	69%
烏干達—不鏽鋼桿	2%	3.5%
衣索比亞—GI 桿	52%	55%
馬拉威—Afridev GI 桿	56%	43%
標準桿徑 (India Mark II)	12 mm	
採購最低接受桿徑	≥ 11 mm	
烏干達桿徑低於標準比例	樣本中 70%	
馬拉威 (Afridev) 桿徑低於標準比例	樣本中 98%	
四個目標國家建議材料	不鏽鋼桿	

禁止操作： (1) 不鏽鋼桿與 GI 桿混用於同一管柱——存在電化學腐蝕風險。(2) 接受桿徑低於 11 mm 的桿件。(3) 單節更換時未確認全管柱材料一致性。

KEY TERMS — CHAPTER 3 / 第三章

Abbr.	Term	English Definition	中文說明
India Mark II/III	India Mark Handpump	Heavy-duty lever handpump using GI components. Not VL0M. Max depth: 50m (Mk II). Standard: RWSN Rev.2-2007.	採用 GI 配件的重型槓桿式手壓井，非 VL0M 型，最大深度 50m (Mark II)。
Pump Rod	活塞桿	Rod connecting the handle mechanism above ground to the pump cylinder below ground. Second most commonly damaged component.	連接地面泵柄機構與地下泵筒的桿件，是第二常見的損壞部件。
SS Rod	Stainless Steel Rod / 不鏽鋼活塞桿	Corrosion-resistant pump rod. Uganda corrosion rate: 3.5% vs GI rod 69%. Recommended for all four target countries.	耐腐蝕活塞桿，烏干達腐蝕率 3.5% (對比 GI 桿 69%)，建議在四個目標國家全面採用。

Criteria for New Borehole Drilling

決定鑽新井的條件

CHAPTER SUMMARY • 章節摘要

Mandatory VES geophysical survey before any drilling. Transmissivity must exceed 1.4 m²/day — the single most important gate condition. Without survey, failure rate is ~60%; with proper siting, below 10%. Applies across all four target countries, with 15–30% of basement rock sites typically below threshold.

鑽井前強制 VES 地球物理勘測，傳導率必須 >1.4 m²/天——最關鍵的單一閘門條件。未勘測失敗率約 60%，科學選址後降至 10% 以下。四個目標國家基底岩地區通常有 15–30% 的地點低於門檻。

English

Mandatory Technical Thresholds

Minimum groundwater transmissivity	> 1.4 m ² /day
Dry-season water level — Afridev	≤ 45 m below surface
Dry-season water level — India Mark II	≤ 50 m below surface
Minimum screen / open-hole length	≥ 10 m
Minimum pump cylinder depth below water table	> 10 m

All Conditions Required to Proceed

<input checked="" type="checkbox"/>	VES geophysical survey completed; transmissivity confirmed >1.4 m ² /day
<input checked="" type="checkbox"/>	Dry-season water level within pump design depth (measured in early morning during dry season — this represents the annual maximum depth)
<input checked="" type="checkbox"/>	Existing water sources insufficient to meet community needs during drought / dry season
<input checked="" type="checkbox"/>	Community governance capacity meets minimum standard per project scoring mechanism

East Africa Warning: In Uganda approximately 30% of sites have transmissivity below the minimum threshold — sites that produce low yield from day one. Comparable proportions can be expected in Kenya (basement aquifer zones), Tanzania (basement areas) and South Sudan (basement-dominated geology) without prior survey. Drilling without a VES survey results in an estimated 60% failure rate; with proper siting this drops below 10%. Survey cost is far less than the total cost of a failed borehole.

中文

強制技術門檻

地下水傳導率最低門檻	> 1.4 m ² /天
乾季地下水位——Afridev	≤ 地表以下 45 m
乾季地下水位——India Mark II	≤ 地表以下 50 m
最低篩管 / 裸眼段長度	≥ 10 m
泵筒距水面最小距離	> 10 m

啟動鑽井的完整條件（全部符合才啟動）

<input checked="" type="checkbox"/>	VES 地球物理探測完成，傳導率確認 >1.4 m ² /天
<input checked="" type="checkbox"/>	乾季地下水位在目標手壓井型號的設計抽水深度以內（應於乾季早晨測量——此為年度最深值）
<input checked="" type="checkbox"/>	現有水源在旱季 / 乾季無法滿足社區基本用水需求
<input checked="" type="checkbox"/>	社區治理能力評分達到專案機制最低標準

東非地區警告：烏干達約 30% 的地點傳導率低於最低門檻，啟用第一天即為低產井。在未進行 VES 勘測的情況下，肯亞（基底岩含水層地區）、坦尚尼亞（基底岩地區）及南蘇丹（以基底岩地質為主）可預期有相近比例。未經勘測直接鑽井失敗率估計達 60%，勘測後可降至 10% 以下。勘測費用遠低於一口失敗井的總成本。

KEY TERMS — CHAPTER 4 / 第四章

Abbr.	Term	English Definition	中文說明
VES	Vertical Electrical Sounding / 垂直電阻率探測	Geophysical survey measuring subsurface electrical resistivity to estimate aquifer transmissivity. Mandatory before any drilling under this programme.	量測地下電阻率以估算含水層傳導率的地球物理勘測方法，本計畫任何新鑽作業前為強制要求。
Crystalline Basement	結晶基底岩	Ancient Precambrian rock (granite, gneiss). Groundwater only in weathered zones and fractures — typically low transmissivity. Dominant geology in Uganda, Kenya and South Sudan.	古老前寒武紀岩石（花崗岩、片麻岩），地下水僅在風化層與裂縫中存在，傳導率偏低，是烏干達、肯亞及南蘇丹的主要地質。
Screen	篩管	Slotted casing section in the aquifer zone allowing water entry while excluding sand. Minimum 10m. Position verified by CCTV.	含水層位置的開槽套管，允許水進入同時阻擋泥沙，最低 10m，位置由 CCTV 確認。
Casing	套管	Solid pipe above the aquifer preventing borehole wall collapse and surface contamination.	含水層以上防止井壁坍塌與地表污染的實心管襯。
Gravel Pack	礫石填充	Layer of graded gravel between borehole wall and screen. Stabilises formation and improves water flow.	鑽孔壁與篩管之間的分級礫石層，穩定地層並改善水流入效果。
Pumping Test	抽水測試	2.5-hour constant-rate pump test to determine aquifer transmissivity and recovery rate. Mandatory at P4.	2.5 小時定流量抽水測試，用以測定含水層傳導率與恢復率，P4 階段為強制要求。
Recovery Rate	恢復率	Percentage of water level recovery after pumping stops. Minimum $\geq 90\%$ required before borehole acceptance.	抽水停止後水位恢復的百分比，驗收最低標準為 $\geq 90\%$ 。

Criteria for Rehabilitation

決定維修的條件

CHAPTER SUMMARY • 章節摘要

Prioritise rehabilitation when transmissivity and water level remain within design parameters and failure is equipment-related. Abandon when screen position is uncorrectable, water level permanently exceeds design depth, or effective screen length is <1m. Every repair must restore original cylinder depth — shortening pipes gradually raises the cylinder and accelerates failure.

傳導率與水位在設計範圍內且故障屬設備問題時優先維修。篩管位置無法修正、水位永久超出設計深度或有效篩管長度 <1m 時放棄維修。每次維修必須恢復原始泵筒深度。

English

Prioritise Rehabilitation — all three must apply	Abandon Rehabilitation — any one is sufficient
<ul style="list-style-type: none"> <input checked="" type="checkbox"/> Transmissivity still >1.4 m²/day on test <input checked="" type="checkbox"/> Water level within pump design depth <input checked="" type="checkbox"/> Failure cause is equipment-related 	<ul style="list-style-type: none"> <input checked="" type="checkbox"/> Casing/screen severely mispositioned; not correctable from surface <input checked="" type="checkbox"/> Water level permanently below pump design depth <input checked="" type="checkbox"/> Effective screen length <1m (silting or collapse)

Common Repairable Failures (by frequency)

Rising main corrosion / damage	Most common failure in Uganda and corrosive groundwater zones. Replace with uPVC (full sections). Do not substitute GI pipe. Do not cut and re-join.
Pump rod wear / sub-standard diameter	Replace full string with stainless steel rods. Verify diameter ≥11mm. Do not mix materials.
Seals and valves — worn or missing	Annual routine replacement. Do not wait for complete failure.
Cylinder position gradually raised	Each pipe shortening raises the cylinder. Measure and restore original cylinder depth during every repair. If cylinder cannot be restored to >10m below water table, assess for new borehole.

中文

優先維修——三項均須符合	放棄維修——任一條件即足夠
<ul style="list-style-type: none"> <input checked="" type="checkbox"/> 測試傳導率仍 >1.4 m²/天 <input checked="" type="checkbox"/> 水位在設計抽水深度以內 <input checked="" type="checkbox"/> 故障原因屬設備問題 	<ul style="list-style-type: none"> <input checked="" type="checkbox"/> 套管 / 篩管位置嚴重不當，無法從地面修正 <input checked="" type="checkbox"/> 水位永久低於泵設計深度 <input checked="" type="checkbox"/> 有效篩管長度 <1m (淤積或塌陷)

常見可修復故障 (依發生頻率排列)

上升主管腐蝕 / 損壞	烏干達及腐蝕性地下水地區最常見故障。須以 uPVC 管整段更換，不可以 GI 管替代，禁止切管重接。
活塞桿磨損 / 直徑不足	整套更換為不鏽鋼桿，確認桿徑 ≥11mm，禁止混用材料。
密封圈與閥門磨損或遺失	年度例行更換，不應等到完全失效才處理。
泵筒位置逐漸上移	每次截短管件都會使泵筒升高。每次維修均須量測並恢復原始泵筒深度。若泵筒無法恢復至水面以下 >10m，應評估鑽新井。

KEY TERMS — CHAPTER 5 / 第五章

Abbr.	Term	English Definition	中文說明
Pump Cylinder	泵筒	Below-ground component with pistons and valves creating suction. Must stay >10m below water table to prevent dry-season failure.	位於地下、內含活塞與閥門產生吸力的部件，必須保持在水面以下 >10m 以防乾季抽空。
Rehabilitation	復修	Repair or restoration of an existing borehole to restore functionality. Typically 70–85% cheaper than drilling new.	對現有水井進行維修或修復以恢復功能，通常比鑽新井節省 70–85% 的費用。
Open-hole	裸眼段	Borehole section without casing relying on rock integrity. Common in Uganda basement aquifers.	不安裝套管的鑽孔段，依賴岩石本身穩定性，常見於烏干達基底岩含水層。

Six-Category Functionality Classification

六類功能分類操作定義

CHAPTER SUMMARY · 章節摘要

Six categories replace the binary working/not-working classification. Low Yield (LY) is the most operationally critical to detect early — community has water but below design standard, accelerating wear. Assess annually in the dry season using the bucket test (10 litres in 60 seconds = 10 l/min). Based on Bonsor et al. (2018).

六類分類取代二元功能判斷。低產 (LY) 是最需要早期偵測的類別——社區有水但低於標準，加速磨損。每年乾季桶測 (60 秒裝滿 10 公升 = 10 l/min)。依據 Bonsor et al. (2018)。

English

Category	Field Assessment Criteria	Required Action
Fully Functional (FF)	Yield \geq 10 l/min; downtime < 30 days in past year	Annual monitoring
Unreliable (UR)	Yield meets standard; downtime \geq 30 days in past year	Investigate downtime cause; repair
Low Yield (LY)	Yield < 10 l/min; downtime < 30 days Δ Most overlooked category — community has water but long-term component wear is accelerated	Pumping test; assess rehabilitation or new borehole
Unreliable & Low Yield (UR-LY)	Yield < 10 l/min; downtime \geq 30 days	Priority intervention
Non-functional (NF)	No water on day of assessment; delivered water at some point in the past year	Immediate repair assessment
Abandoned (AB)	No water for more than one year	Full assessment; likely new borehole

Field Measurement Method

Yield measurement	Bucket test — 10-litre bucket; target: fill within 60 seconds = 10 l/min
Downtime record	Interview community water committee; confirm cumulative days out of service in past 12 months
Assessment timing	Annually during dry season — represents worst-case conditions. Wet-season results are not representative and should not be used as the primary classification basis.

Classification is a snapshot in time, not a permanent status. A non-functional (NF) borehole may be repaired within days; a fully functional (FF) borehole may become low yield (LY) in the dry season. Low yield (LY) is the most operationally critical category to detect early: the community still has water, but yield below design standard accelerates equipment wear and increases failure risk.

中文

分類	現場判斷條件	必要行動
完全功能 (FF)	出水量 \geq 10 l/min; 過去一年停機 < 30 天	年度追蹤
不可靠 (UR)	出水量達標; 過去一年停機 \geq 30 天	調查停機原因; 維修
低產 (LY)	出水量 < 10 l/min; 停機 < 30 天 Δ 最容易被忽視的類別——社區仍有水，但設備磨損加速	抽水測試; 評估維修或鑽新井
不可靠且低產 (UR-LY)	出水量 < 10 l/min; 停機 \geq 30 天	優先介入
非功能 (NF)	評估當日無法出水; 過去一年曾出水	立即維修評估
棄置 (AB)	超過一年未出水	完整評估; 可能需鑽新井

現場量測方法

出水量量測	桶測法——10 公升桶; 目標: 60 秒內裝滿 = 10 l/min
停機記錄	訪談社區水委員會; 確認過去 12 個月累計停機天數
評估時機	每年乾季執行——代表最嚴苛條件。雨季結果不具代表性，不應作為主要分類依據。

分類是現場快照，不代表永久狀態。非功能 (NF) 井可能數天內修復；完全功能 (FF) 井乾季可能降為低產 (LY)。低產 (LY) 是最需要早期偵測的類別：社區仍有水，但出水量低於設計標準，加速設備磨損並增加故障風險。

KEY TERMS — CHAPTER 6 / 第六章

Abbr.	Term	English Definition	中文說明
FF	Fully Functional / 完全功能	Yield ≥ 10 l/min; downtime <30 days/year. Performing to design standard.	出水量 ≥ 10 l/min；年停機 <30 天，達到設計標準。
UR	Unreliable / 不可靠	Yield meets standard; downtime ≥ 30 days/year.	出水量達標但年停機 ≥ 30 天，社區斷水時間過長。
LY	Low Yield / 低產	Yield <10 l/min; downtime <30 days. Community has water but below design standard — most overlooked.	出水量 <10 l/min，社區有水但低於標準，最容易被忽視。
UR-LY	Unreliable & Low Yield / 不可靠且低產	Both yield below standard AND downtime ≥ 30 days/year. Priority intervention.	出水量低於標準且年停機 ≥ 30 天，需優先介入。
NF	Non-functional / 非功能	No water on day of assessment; delivered water in the past year.	評估當日無法出水，但過去一年曾出水。
AB	Abandoned / 棄置	No water for more than one year.	超過一年未出水。
l/min	Litres per Minute / 每分鐘公升數	Unit of water flow rate. Handpump design yield: ≥ 10 l/min = 10-litre bucket filled every 60 seconds.	水流量單位，手壓井設計出水量 ≥ 10 l/min，即每 60 秒裝滿一個 10 公升水桶。

Cost Structure Reference Framework

成本結構參考框架

CHAPTER SUMMARY • 章節摘要

Cost structure for three scenarios: new borehole, rehabilitation, and P6 annual monitoring. All figures to be completed with local quotes. Rehabilitation typically saves 70–85% versus new construction. Once figures are filled in, the actual savings ratio can be reported directly to donors.

三種情境的成本結構：新鑽孔、維修及 P6 年度監測，所有數字待填入當地報價。維修通常比新鑽節省 70–85%，填入數字後可直接向捐款人報告實際節省比例。

Cost figures to be completed with local quotes from Kenya, Uganda, Tanzania and South Sudan respectively. Unit costs vary significantly by country and access conditions. / 成本數字需分別填入肯亞、烏干達、坦尚尼亞及南蘇丹的當地報價。各國及不同地點的成本差異顯著。

English

New Borehole — Full Cost per Borehole

Item	Description	Amount (USD)
Hydrogeological survey (VES)	Geophysical survey, transmissivity assessment, site selection report	_____
Drilling works	Drilling, casing installation, gravel pack, cement grouting	_____
Pumping test	2.5-hour constant-rate test; transmissivity report	_____
CCTV inspection	Screen and casing position verification	_____
Handpump and components	Afridev or India Mark II; corrosion-resistant materials (uPVC rising mains, stainless steel rods)	_____
Apron and drainage works	Concrete apron, drainage gradient, livestock fencing	_____
Initial water quality testing	pH, turbidity, E. coli, TDS, iron, fluoride	_____
Community training	Operation, basic maintenance, water committee setup	_____
Total — new borehole		_____

Rehabilitation — Cost per Intervention

Item	Description	Amount (USD)
Field diagnostic assessment	Water level measurement, pumping test, functionality classification	_____
Rising main replacement	uPVC full-section replacement including labour	_____
Pump rod replacement	Full stainless steel rod string including labour	_____
Seals and valves	Annual routine replacement	_____
Post-repair water quality retest	Confirm water safety after intervention	_____
Total — rehabilitation		_____

P6 Annual Monitoring — Cost per Borehole per Year

Item	Description	Amount (USD)
Functionality assessment visit	Bucket test, downtime interview, classification record	_____
Seasonal water quality monitoring	Dry season + wet season (two tests per year)	_____
Preventive component replacement	Seals and valves annual replacement	_____
Annual total		_____

Cost-effectiveness note: The main white paper states rehabilitation saves 70–85% compared to new construction. Once figures above are completed, the actual savings ratio for this programme can be calculated and reported directly to donors.

中文

鑽新井完整成本（每口）

項目	說明	金額 (USD)
水文地質勘測 (VES)	地球物理探測、傳導率評估、選址報告	_____

項目	說明	金額 (USD)
鑽井工程	鑽探、套管安裝、礫石填充、水泥封填	=====
抽水測試	2.5 小時定流量測試；傳導率報告	=====
CCTV 驗收	篩管與套管位置確認	=====
手壓井及配件	Afridev 或 India Mark II；耐腐蝕材料 (uPVC 上升主管、不鏽鋼活塞桿)	=====
井台與排水工程	混凝土井台、排水坡度、牲畜圍欄	=====
水質初始檢測	pH、濁度、大腸桿菌、TDS、鐵、氟化物	=====
社區培訓	操作、基本維護、水委員會建立	=====
新井合計		=====

維修成本 (每次介入)

項目	說明	金額 (USD)
現場診斷評估	水位測量、抽水測試、功能分類	=====
上升主管更換	uPVC 管整段更換，含人工	=====
活塞桿更換	不鏽鋼桿整套更換，含人工	=====
密封圈與閥門	年度例行更換	=====
維修後水質複測	確認介入後水質安全	=====
維修合計		=====

P6 年度追蹤成本 (每口井 / 每年)

項目	說明	金額 (USD)
功能評估訪視	桶測、停機訪談、分類記錄	=====
季節性水質監測	乾季 + 雨季各一次 (每年兩次)	=====
預防性零件更換	密封圈與閥門年度更換	=====
年度合計		=====

KEY TERMS – CHAPTER 7 / 第七章

Abbr.	Term	English Definition	中文說明
USD	US Dollar	United States Dollar. All cost estimates in this document are expressed in USD.	美元：本文件所有費用估算均以美元表示。
VES	Vertical Electrical Sounding	Geophysical survey required before drilling. See Chapter 4.	垂直電阻率探測：鑽井前必須進行的地球物理勘測，詳見第四章。
CCTV	Closed-Circuit Television Survey	Camera lowered into the completed borehole to visually verify screen position, casing condition, and construction quality.	閉路電視檢測：將攝影機放入完工鑽孔，視覺確認篩管位置、套管狀況及施工品質。
TDS	Total Dissolved Solids	Water quality parameter measuring the total concentration of dissolved minerals. High TDS can indicate corrosive or contaminated water.	總溶解固體：水質參數，量測溶解礦物質總濃度。TDS 偏高可能表示水質具腐蝕性或受污染。
E. coli	Escherichia coli	Faecal indicator bacteria. Presence in water indicates contamination by human or animal waste. Must not be detected in drinking water.	大腸桿菌：糞便指示菌，在水中出現代表受人類或動物糞便污染。飲用水中必須未檢出。
NTU	Nephelometric Turbidity Units	Unit measuring water cloudiness/turbidity. Higher values indicate suspended particles.	濁度單位：量測水體混濁程度，數值越高代表懸浮顆粒越多。
pH	Power of Hydrogen	Scale (0–14) measuring acidity or alkalinity of water. Neutral = 7. Low pH (acidic) water is more corrosive to metal components.	酸鹼值：0–14 的量測尺度，中性為 7。低 pH (酸性) 水對金屬管件腐蝕性更強。

KEY TERMS — CHAPTER 7 / 第七章

Abbr.	Term	English Definition	中文說明
USD	US Dollar / 美元	Currency used for all cost estimates in this document.	本文件所有費用估算採用的貨幣單位。
CCTV	Closed-Circuit TV Survey / 閉路電視勘察	Camera lowered into borehole to verify screen position and construction quality. Required before P5.	放入鑽孔的攝影機勘察，確認篩管位置與施工品質，P5 驗收前為必要程序。
TDS	Total Dissolved Solids / 總溶解固體	Total dissolved mineral concentration (mg/L). High TDS may indicate corrosive water affecting component lifespan.	溶解礦物質總濃度 (mg/L)，偏高可能表示水質具腐蝕性，影響管件壽命。
E. coli	Escherichia coli / 大腸桿菌	Faecal indicator bacteria. Must not be detected in drinking water.	糞便指示菌，飲用水中必須未檢出。
NTU	Nephelometric Turbidity Units / 濁度單位	Unit measuring water cloudiness. Higher values = more suspended particles.	量測水體混濁程度的單位，數值越高代表懸浮顆粒越多。
pH	Power of Hydrogen / 酸鹼值	Scale 0-14. Low pH (acidic) increases corrosion risk for metal components.	0-14 的酸鹼尺度，低 pH (酸性) 增加金屬管件的腐蝕風險。

P1–P6 Implementation Flowchart

P1–P6 執行流程圖

CHAPTER SUMMARY • 章節摘要

Six sequential phases with mandatory gate conditions at each transition. P2 (VES survey) and P4 (construction) are the highest-risk phases. Track 1 (hydrogeologist) is independent of Track 2 (contractor). The P6 five-year monitoring phase is where early deterioration must be caught using the Chapter 6 functionality classification.

六個連續階段，每個過渡點設有強制關門條件。P2（勘測）與 P4（施工）是風險最高的階段。第一軌（水文地質專家）獨立於第二軌（承包商）。P6 五年追蹤是利用第六章功能分類偵測早期劣化的關鍵階段。

English

Phase gate conditions must be fully met before proceeding to the next phase. Any unmet gate condition halts the project at that phase pending resolution.

- P1

Project Application

專案申請

Responsible: Programme office review; community

Community submits water needs application. Initial public health and sanitation assessment. Added to project waitlist with priority scoring.

▶ Gate: Public health risk score meets threshold + preliminary geological feasibility confirmed
- P2

Hydrogeological Survey

水文地質勘測

Responsible: Licensed hydrogeologist (Track 1); programme supervision

VES geophysical survey. Transmissivity and dry-season water level assessment. Borehole siting confirmed. Survey report submitted.

↑ See Chapter 4: drilling criteria confirmed at this phase

▶ Gate: Transmissivity >1.4 m²/day AND water level within design depth — if not met, site rejected or alternative location assessed
- P3

Community Mobilisation

社區動員

Responsible: Programme coordinator; water committee

Water committee formed. Responsibilities and cost-sharing arrangements agreed. MOU signed by committee representatives. Maintenance fund mechanism confirmed.

▶ Gate: MOU signed + committee member list confirmed + maintenance fund mechanism in place
- P4

Borehole Construction

鑽井施工

Responsible: Licensed contractor (Track 2) — lead; programme site supervisor

Drilling, casing, gravel pack, cement grouting. Pumping test (2.5 hours). Handpump installation using corrosion-resistant materials. Initial water quality testing. GPS-tagged photographic evidence submitted daily.

↑ See Chapters 2 & 3: material specifications enforced at this phase

↑ See Chapter 7: construction costs incurred at this phase

▶ Gate: Recovery rate ≥90% + water quality pass + CCTV confirms screen position + complete evidence package submitted
- P5

Acceptance & Handover

驗收交付

Responsible: Programme acceptance officer; contractor support; community receives

10-item acceptance checklist completed. Community operation and basic maintenance training delivered. Formal handover ceremony. Registry system fully updated.

▶ Gate: All 10 acceptance items passed; registry record complete
- P6

Five-Year Monitoring & O&M

五年追蹤維運

Responsible: Programme monitoring team; community water committee daily management; contractor repair tickets

Year 1–2: quarterly visits. Year 3–4: bi-annual visits. Year 5: full evaluation. Annual functionality classification, seasonal water quality monitoring, repair ticket processing.

↑ See Chapter 6: six-category functionality classification applied at every visit

↑ See Chapter 7: annual monitoring costs incurred at this phase

Responsibility Summary

Licensed contractor (Track 2)	P4 lead, P5 support, P6 repair tickets
Licensed hydrogeologist (Track 1)	P2 lead

Programme office	P1-P6 oversight, review, registry
Community water committee	P3 formation, P5 receives, P6 daily management

中文

每個階段的關門條件必須完全符合才能進入下一階段。任何未達到的關門條件將使專案暫停於該階段，待問題解決後才能繼續。

- P1 Project Application / 專案申請**
 負責方：計畫辦公室審核；社區
 社區提交用水需求申請。初步公共衛生與環境衛生評估。依優先評分納入等待名單。
 ▶ 關門：公共衛生風險評分達標 + 初步地質可行性確認
- P2 Hydrogeological Survey / 水文地質勘測**
 負責方：持照水文地質專家（第一軌）；計畫監督
 VES 地球物理探測。傳導率與乾季水位評估。確認鑽井位置。提交勘測報告。
 ↑ 見第四章：鑽新井條件在此確認
 ▶ 關門：傳導率 >1.4 m²/天 且水位在設計深度以內——不符合則拒絕該地點或評估替代位置
- P3 Community Mobilisation / 社區動員**
 負責方：計畫協調員；水委員會
 成立水委員會。確認責任分工與費用分擔安排。委員會代表簽署 MOU。確認維護資金機制。
 ▶ 關門：MOU 簽署 + 委員會名單確認 + 維護資金機制到位
- P4 Borehole Construction / 鑽井施工**
 負責方：持照承包商（第二軌）主責；計畫現場監督
 鑽探、套管安裝、礫石填充、水泥封填。抽水測試（2.5 小時）。使用耐腐蝕材料安裝手壓井。水質初始檢測。每日提交 GPS 標記照片證據。
 ↑ 見第二、三章：材料規格在此執行
 ↑ 見第七章：建設成本在此發生
 ▶ 關門：恢復率 ≥90% + 水質達標 + CCTV 確認篩管位置 + 完整證據包提交
- P5 Acceptance & Handover / 驗收交付**
 負責方：計畫驗收人員；承包商協助；社區接收
 完成 10 項驗收清單。完成社區操作及基本維護培訓。舉行正式移交儀式。完整更新登錄系統。
 ▶ 關門：10 項驗收清單全部通過；登錄記錄完整
- P6 Five-Year Monitoring & O&M / 五年追蹤維護**
 負責方：計畫監測團隊；社區水委員會日常管理；承包商維修工單
 第 1-2 年：每季訪視。第 3-4 年：每半年訪視。第 5 年：完整評估。年度功能分類、季節性水質監測、維修工單處理。
 ↑ 見第六章：六類功能分類在每次訪視時執行
 ↑ 見第七章：年度監測成本在此發生

責任分工摘要

持照承包商（第二軌）	P4 主責，P5 協助，P6 維修工單
持照水文地質專家（第一軌）	P2 主責
計畫辦公室	P1-P6 全程監督、審核、登錄
社區水委員會	P3 建立，P5 接收，P6 日常管理

KEY TERMS — CHAPTER 8 / 第八章

Abbr.	Term	English Definition	中文說明
P1-P6	Project Phases / 專案執行階段	Six sequential phases: Application → Survey → Mobilisation → Construction → Acceptance → Monitoring.	六個連續執行階段：申請→勘測→動員→施工→驗收→監測。
Phase Gate	階段閘門	Mandatory checkpoint between phases. All conditions must be met before proceeding.	階段之間的強制性查核點，所有條件須全部符合才能推進。
Track 1	第一軌——水文地質專家	Licensed hydrogeologist for P2 survey. Independent of drilling contractor.	負責 P2 勘測的持照水文地質專家，獨立於鑽井承包商。
Track 2	第二軌——鑽井承包商	Licensed contractor for P4 construction, under programme supervision.	負責 P4 施工的持照承包商，於計畫監督下執行。
MOU	Memorandum of Understanding / 諒解備忘錄	Formal written agreement between programme and community water committee defining responsibilities and maintenance obligations.	計畫方與社區水委員會的正式書面協議，明確責任分工與維護義務。
O&M	Operation & Maintenance / 操作與維護	Ongoing activities: community daily operation, periodic inspection, planned component replacement.	持續性工作：社區日常操作、定期檢查與計劃性零件更換。

Contractor Qualification & Partnership Process

承包商資格標準與合作流程

CHAPTER SUMMARY · 章節摘要

Invitation-based qualification model — contractors who do not fully meet criteria are encouraged to apply and offered a training pathway. Two hard requirements: valid drilling licence and pumping test competency. All other criteria are trainable. Four-step process: expression of interest → technical assessment → training → trial project.

邀請型資格評估模式，不完全符合條件的承包商鼓勵申請並提供培訓路徑。兩項硬性要求：有效鑽井執照與抽水測試能力。四步流程：意願表單→技術評估→培訓→試行專案。

English

We use an invitation-based qualification model, not a hard-exclusion filter. Contractors who do not currently meet all recommended criteria are still encouraged to apply — we assess willingness and capacity to improve, and provide a training pathway to certification.

Approved Implementation Partner — Uganda / 烏干達核可執行夥伴：

Yeshua Living Water Company Limited

Uganda-registered borehole drilling contractor. Approved execution partner for Love Binti International borehole construction works (P4) in Uganda. / 烏干達註冊鑽井承包商，為愛女孩國際關懷協會烏干達鑽井施工（P4）的核可執行夥伴。

Qualification Item	Notes	Type
Valid drilling licence and national government registration	The only criterion that cannot be substituted by training	Hard requirement
Pumping test equipment and competency	Capable of conducting 2.5-hour constant-rate test with water level recording; recovery rate $\geq 90\%$	Hard requirement
RWSN handpump specifications and component handling protocols	Including: no cutting/re-gluing uPVC, no re-threading GI pipe, no material mixing	Trainable
GPS-tagged photo submission capability	Smartphone with EXIF coordinates; photos within 100m of application site coordinates	Trainable
Minimum 3 completed borehole references	Client contacts available for verification	Bonus

Four-Step Partnership Process

1	Expression of Interest Form — licence number, operating country/region, equipment list, reference projects
2	Technical Assessment Interview — programme officer confirms technical capacity; focus on component handling protocols and material knowledge
3	Training (if required) — material specifications, corrosion prevention, uPVC and stainless steel handling, GPS photo submission. Certification issued on completion.
4	Partnership Agreement + Trial Project — first project under enhanced supervision. Added to approved contractor register upon satisfactory completion.

中文

我們採用邀請型資格評估模式，而非硬性篩除。目前不完全符合建議條件的承包商仍鼓勵申請——我們評估其改進意願與能力，並提供培訓路徑至取得認證。

資格項目	說明	類型
有效鑽井執照及所在國政府登記	唯一不可由培訓替代的條件	硬性要求
抽水測試設備與操作能力	能執行 2.5 小時定流量測試並記錄水位；恢復率 $\geq 90\%$	硬性要求
RWSN 手壓井規範及管件操作規範	包含：禁止切管重接 uPVC、禁止重新套螺紋 GI 管、禁止混用材料	可培訓
GPS 標記照片提交能力	智慧型手機含 EXIF 座標；照片與申請地點座標距離 $< 100\text{m}$	可培訓
最少 3 個已完工鑽井案例	可提供客戶聯絡人供查證	加分項目

四步合作流程

1	填寫意願表單——執照號碼、所在國/地區、設備清單、過往案例
2	技術評估訪談——計畫人員確認技術能力；重點評估管件操作規範與材料認知
3	培訓（如需要）——材料規格、防腐蝕處理、uPVC 及不鏽鋼管件操作、GPS 照片提交。完成後取得合格認證。
4	簽署合作協議 + 試行專案——首個專案設加強監督。評估通過後納入正式承包商名冊。

KEY TERMS — CHAPTER 9 / 第九章

Abbr.	Term	English Definition	中文說明
GPS	Global Positioning System / 全球定位系統	Satellite positioning system. All construction photos must contain GPS/ EXIF data to verify site location.	衛星定位系統，所有施工照片必須含 GPS 資料以核實施工地點。
EXIF	Exchangeable Image File Format / 照片地理標記	Metadata in digital photos including GPS coordinates, date and time. Verifies photos were taken at the correct location.	數位照片的元數據，包含 GPS 座標、日期與時間，用於核實照片確實拍攝於正確地點。
SOP	Standard Operating Procedure / 標準作業程序	Written instructions for specific tasks. Maintenance SOPs prohibit pipe shortening and material mixing.	特定工作的書面說明，維修 SOP 明確禁止截短管件與混用材料。
RWSN	Rural Water Supply Network / 農村供水網絡	International standards body for handpumps. All approved contractors must follow RWSN specifications.	手壓井國際標準機構，所有核可的承包商必須遵循 RWSN 規範。

Technical Problems & Solutions

技術問題與對應解決方法

CHAPTER SUMMARY · 章節摘要

Four systemic problems with corresponding solutions: (1) unsited boreholes → mandatory VES; (2) GI pipe corrosion → prohibition and full-section uPVC replacement; (3) sub-standard rod diameter → stainless steel with procurement verification; (4) binary functionality → six-category classification with annual dry-season monitoring.

四個系統性問題與對應解決方法：(1) 未勘測鑽井→強制 VES；(2) GI 管腐蝕→禁用並以 uPVC 整段更換；(3) 桿徑不足→不鏽鋼桿採購量測；(4) 二元功能分類→六類分類加年度乾季監測。

English

Problem 1: Borehole siting without scientific basis — estimated 60% failure rate

In Uganda approximately 30% of sites have transmissivity below the minimum threshold, producing low yield from day one. Comparable proportions expected in Kenya, Tanzania and South Sudan without prior survey. Failure is structural — no amount of maintenance can compensate for an aquifer that cannot sustain a handpump.

Solution: Mandatory VES survey as P2 phase gate; sub-threshold sites do not proceed to P4

Failure rate reducible from an estimated 60% to below 10% through proper hydrogeological siting. Survey cost recoverable within the first avoided failure.

Problem 2: GI pipe corrosion — most common and most overlooked failure cause

98% of Uganda GI rising main pipes have sub-standard galvanising. Corrosive groundwater accelerates zinc layer depletion. Maintenance practice of shortening and re-threading pipes further destroys galvanising at joints. Problem documented since the 1980s with no systemic supply chain improvement.

Solution: Prohibit GI rising mains; replace uPVC in full sections only; annual seals and valves replacement

Procurement specifications prohibit GI rising mains. Maintenance SOP prohibits cutting, re-joining and re-threading. Seals and valves placed on annual preventive replacement schedule — do not wait for failure.

Problem 3: Pump rod diameters widely below design standard

70% of Uganda GI rods and 98% of Malawi Afridev rods are below standard diameter at procurement. Sub-standard diameter combined with corrosion accelerates fracture and gradually raises cylinder position, eventually causing dry-season pump failure.

Solution: Switch to stainless steel rods; verify diameter $\geq 11\text{mm}$ at procurement; no material mixing

Stainless steel rod corrosion rate: 3.5% vs GI rod: 69% in Uganda. Procurement must include physical diameter verification (callipers). Full string must be same material — no mixing.

Problem 4: Binary functionality classification misses early deterioration

Most programmes classify only "working / not working." Low yield (LY) status — where community has water but below design standard — is invisible. By the time the pump stops working, the deterioration window for low-cost repair has passed.

Solution: Six-category classification + annual dry-season bucket test + P6 five-year monitoring

Bonsor et al. (2018) six-category framework enables early detection. Annual dry-season bucket test and downtime interview take under 30 minutes per borehole. Early intervention in the LY or UR category averts progression to NF or AB — directly supporting the main white paper's five-year monitoring commitment.

中文

問題一：選址無科學依據——失敗率估計達 60%

烏干達約 30% 的地點傳導率低於最低門檻，啟用第一天即低產。在未進行 VES 勘測的情況下，肯亞、坦尚尼亞、南蘇丹可預期有相近比例。失敗屬結構性問題——無論如何維護，都無法彌補含水層本身無法支撐手壓井的問題。

對應：VES 勘測作為 P2 關門，傳導率不達標不進入 P4

透過科學選址，失敗率可從估計的 60% 降至 10% 以下。勘測費用可在第一口避免失敗的水井中回收。

問題二：GI 管腐蝕——最常見且最被忽視的失效原因

烏干達 98% 的 GI 上升主管鍍鋅厚度不足。腐蝕性地下水加速鋅層消耗。截短重新套螺紋的維修習慣進一步破壞接頭處鍍鋅層。此問題自 1980 年代有記錄，至今供應鏈未有系統性改善。

對應：禁用 GI 上升主管；uPVC 管整段更換；密封圈與閥門年度例行更換

採購規格禁用 GI 上升主管。維修 SOP 禁止切管、重接與重新套螺紋。密封圈與閥門列入年度預防性更換計畫——不應等到失效才處理。

問題三：活塞桿直徑普遍低於設計標準

烏干達 70% 的 GI 桿及馬拉威 98% 的 Afridev GI 桿在採購時桿徑即低於標準。直徑不足加上腐蝕加速斷裂，並逐漸使泵筒位置上移，最終導致乾季出水斷。

對應：改用不鏽鋼桿；採購時量測確認桿徑 $\geq 11\text{mm}$ ；禁止混用材料

烏干達不鏽鋼桿腐蝕率 3.5% vs GI 桿 69%。採購必須包含桿徑物理量測（游標卡尺）。整套管柱材料必須一致——禁止混用。

問題四：功能分類過於二元，早期劣化無法偵測

多數計畫只區分「有水 / 無水」。低產 (LY) 狀態——社區仍有水但低於設計標準——處於隱形狀態。等到泵完全停止出水，低成本介入的時機已過。

對應：六類功能分類 + 每年乾季桶測 + P6 五年追蹤

Bonsor et al. (2018) 六類框架使早期偵測成為可能。每口井年度乾季桶測與停機訪談不到 30 分鐘。在 LY 或 UR 類別早期介入，可防止惡化為 NF 或 AB——直接支持主白皮書的五年追蹤承諾。

Main White Paper / 主白皮書	Water Resources White Paper v2.0 • Love Binti International • 2025
Technical Reference / 技術文獻	MacAllister et al., Sci. Total Environ. 851 (2022) 158343
Functionality Standard / 功能分類標準	Bonsor et al., Hydrogeology Journal 26 (2018) 367–370
Material Standards / 材料規範	RWSN Afridev Spec. Rev.5-2007 • India Mark II Rev.2-2007

Solar-Powered Borehole Systems — Limitations, Evidence Gaps & Organisational Capacity

太陽能鑽孔供水系統——限制、證據缺口與組織能力聲明

CHAPTER SUMMARY · 章節摘要

Solar-powered borehole systems (SPWS) require 5× higher aquifer transmissivity (>9.5 m²/day) than handpumps. Key evidence gaps remain: no multi-country SPWS failure study for East African basement aquifers, unquantified over-abstraction risk, and no validated 3-year+ fee recovery model. Love Binti International has 11 completed SPWS installations supported by URE (Taiwan), Sunry and AllGrand.

太陽能鑽孔系統需要手壓井五倍的含水層傳導率 (>9.5 m²/天)。主要證據缺口：無東非基底岩 SPWS 多國失效研究、過度抽取風險未量化、三年以上費用回收模型未驗證。愛女孩國際關懷協會已完工 11 個 SPWS，由聯合再生能源（台灣）、三瑞及 AllGrand 提供技術支援。

English

This chapter addresses solar-powered borehole water systems (SPWS) as a technology distinct from handpump boreholes. It sets out the current limitations of the evidence base, the known gaps in East African implementation data, and Love Binti International's established technical capacity for SPWS deployment. A full technical standard for SPWS — equivalent in scope to Chapters 1–10 of this document — is under development and will be issued as a separate supplement once systematic field data from completed installations has been compiled and reviewed.

中文

本章討論太陽能鑽孔供水系統（SPWS）作為一種有別於手壓井的技術體系，說明現有實證基礎的限制、東非執行資料的已知缺口，以及愛女孩國際關懷協會在 SPWS 部署方面已具備的技術能力。完整的太陽能系統技術標準——範圍相當於本文件第一至十章——目前正在制定中，將在已完工案例的系統性實地資料整理與審查完成後另行發布為獨立補充文件。

Why SPWS is a fundamentally different technical system / 為何 SPWS 是根本不同的技術體系

Dimension / 維度	Handpump Borehole / 手壓井鑽孔	Solar Borehole System / 太陽能鑽孔系統
Transmissivity threshold / 傳導率門檻	>1.4 m ² /day	>9.5 m ² /day (5× higher / 高五倍)
Design yield / 設計出水量	10 l/min	60+ l/min
Primary failure mode / 主要失效模式	Mechanical wear, corrosion / 機械磨損、腐蝕	Electrical fault, over-abstraction, theft / 電氣故障、過度抽取、竊盜
Maintenance / 維護主體	Community VLOM / 社區自行維修	Licensed electrician required / 需持照電氣工程師
Service population / 服務人口	~300 per borehole / 每孔約 300 人	1,000–2,000 across 4–5 communities / 跨 4–5 個社區
East Africa evidence base / 東非實證基礎	Comprehensive (MacAllister et al., 2022)	Limited — no equivalent multi-country study

Source / 資料來源: Bianchi et al. (2020); MacAllister et al. (2022); Nature Communications Earth & Environment (2023)

Current evidence gaps / 目前的證據缺口

English

Gap / 缺口	Severity / 嚴重程度	Notes / 說明
No systematic multi-country SPWS failure study for East African basement aquifers	Critical / 關鍵	Handpump failure rates took decades to quantify. SPWS data far more fragmented.
Long-term over-abstraction data at community scale	Critical / 關鍵	Solar pumps extract 5–10× more than handpumps. Permanent aquifer drawdown risk unquantified.
Electrical component lifespan under East African field conditions	Significant / 顯著	Heat, humidity, dust and intermittent maintenance not reflected in manufacturer specifications.
Fee recovery sustainability beyond Year 3	Significant / 顯著	Capital costs USD 15,000–50,000 per system. Evidence on sustained community collection limited.
Solar irradiance and panel sizing methodology	Well covered / 充分	

Gap / 缺口	Severity / 嚴重程度	Notes / 說明
		GIZ/FAO SPIS tool mature and validated. East Africa solar resource data comprehensive.

中文

缺口摘要：目前不存在針對東非結晶基底岩環境下 SPWS 失效模式的系統性多國實地研究（對應手壓井的 MacAllister et al., 2022）。太陽能泵的抽取量是手壓井的 5-10 倍，在低儲量含水層中永久性水位下降風險真實存在但量化不足。電氣組件壽命與費用回收的長期可持續性均缺乏充分實證。唯一資料充分的領域是太陽輻射量與面板選型（GIZ/FAO SPIS 工具已成熟驗證）。

Known deployment limitations in East Africa / 東非部署的已知限制

English

Limitation 1 Aquifer constraints are binding	In East Africa, the limiting factor for SPWS performance is aquifer transmissivity, not solar irradiance. 57% of sites in Ethiopia and Malawi, and 80% in Uganda, fall below the 9.5 m ² /day threshold. SPWS deployment without rigorous prior VES survey will produce higher failure rates than handpump programmes.
Limitation 2 Community maintenance gap	VLOM design allows community members to repair handpumps. SPWS electrical faults require a licensed electrician — a skillset unavailable in most rural East African communities, adding cost and response time to every failure event.
Limitation 3 Panel theft and vandalism	Solar panel theft is one of the most commonly reported SPWS failure causes in East Africa. Security fencing, panel anchoring and community guardianship protocols are required infrastructure — not optional.
Limitation 4 No validated cost-recovery model	SPWS capital costs require sustained fee recovery to maintain electrical components over a 10–20 year lifespan. Evidence on successful mechanisms in low-income East African communities beyond 3-year project cycles is limited.

中文

限制一 含水層約束是決定性限制	在東非，限制 SPWS 性能的關鍵因素是含水層傳導率，而非太陽輻射量。衣索比亞與馬拉威 57%、烏干達 80% 的地點傳導率低於 9.5 m ² /天門檻。未進行 VES 勘測即部署 SPWS 的失敗率將高於手壓井計畫。
限制二 社區維護能力缺口	VLOM 設計允許社區成員自行維修手壓井。SPWS 電氣故障需要持照電氣工程師——這一技能在東非大多數農村社區不存在，每次故障都會增加成本與回應時間。
限制三 面板竊盜與破壞	太陽能面板竊盜是東非最常見的 SPWS 失效原因之一。安全圍欄、面板固定系統與社區守護機制是必要基礎設施，而非可選配置。
限制四 費用回收模型尚未驗證	SPWS 資本成本需要持續的費用回收才能維持 10–20 年電氣組件的運作。東非農村低收入社區在三年專案週期後維持費用回收機制的成功案例實證有限。

Love Binti International's established SPWS capacity / 愛女孩國際關懷協會現有 SPWS 能力

Love Binti International has deployed 11 solar-powered borehole water systems in East Africa, establishing an operational supply chain and installation track record. The organisation is positioned to expand SPWS deployment as the evidence base matures. / 愛女孩國際關懷協會已在東非部署 11 套太陽能鑽孔供水系統，建立了完整的供應鏈與安裝紀錄，並將隨著實證基礎的成熟進一步擴大 SPWS 部署規模。

Capacity Item / 能力項目	Details / 說明
Completed installations / 已完工系統數	11 solar-powered borehole systems in East Africa / 11 套太陽能鑽孔系統，東非
Technology sponsor / 技術贊助單位	United Renewable Energy Co., Ltd. (URE / URECO) • 聯合再生能源股份有限公司 Hsinchu, Taiwan • Listed on Taiwan Stock Exchange • Formerly Neo Solar Power Corp. (merged 2018) • Reached 50% module market share in Taiwan 2018 • Products: solar cells, modules, energy storage systems • Certifications: IEC (Europe), UL (USA), MCS (UK), VPC (Taiwan) • One-stop services: module manufacturing, system construction, O&M, energy storage integration 台灣新竹。台灣上市公司。前身為新日光能源、昱晶能源與昇陽光電三合一合併（2018年）。2018年達台灣 50% 模組市佔率。產品：太陽能電池、模組、儲能系統。認證：IEC / UL / MCS / VPC。提供模組製造、系統施工、運維至儲能整合一站式服務
Local supply partners / 本地供應夥伴	1. 广东三瑞电源科技有限公司 • Guangdong Sunry Power U Limited Guangdong, China — solar storage systems and power supply technology operating in East Africa / 廣東，中國——在東非運營的太陽能儲能系統與電源科技供應商

Capacity Item / 能力項目	Details / 說明
	<p>2. AllGrand Power Source Development Limited Uganda-registered company • Associated with 山东奥冠新能源科技有限公司 (Shandong Aoguan New Energy Technology Co., Ltd.), China • Solar power source development and supply, East Africa operations / 烏干達註冊公司，關聯方為山東奧冠新能源科技有限公司（中國），太陽能電源開發與供應，東非業務</p> <p>Both suppliers provide: submersible pumps, mounting systems, inverters and field after-sales technical support / 兩家供應商均提供：潛水泵、安裝系統、逆變器及現場售後技術支援</p>
Implementation partner (drilling) / 執行夥伴 (施工)	<p>Yeshua Living Water Company Limited Uganda-registered borehole drilling contractor • Responsible for P4 borehole construction in Uganda • Approved under Love Binti International contractor qualification framework / 烏干達註冊鑽井承包商，負責烏干達 P4 鑽井施工，已通過愛女孩國際關懷協會承包商資格審核框架</p>
Phase gate framework / 閘門框架	<p>P1–P6 framework applied to all SPWS projects, including mandatory VES survey at P2 / P1–P6 閘門框架適用於所有 SPWS 專案，P2 強制執行 VES 勘測</p>

Scope of current capacity and what remains to be developed / 現有容量範圍與尚待完善之處

English

What Love Binti International can currently do: Deploy SPWS with vetted components from established supply partners • Conduct VES surveys before installation • Provide post-installation O&M support through local supplier networks • Apply URE panel quality certifications (IEC/UL/MCS) to ensure module standards • Apply P1–P6 phase gate framework to all SPWS projects.

What requires further development before a full SPWS technical standard can be issued: Validated transmissivity threshold specific to SPWS pump models in the field • Systematic failure mode data from the 11 completed installations • Tested fee recovery framework beyond Year 3 • Anti-theft and panel security protocols adapted to each target country • Electrical component lifespan data under East African field conditions.

中文

目前可執行：使用已審核供應夥伴的合格組件部署 SPWS • 安裝前執行 VES 勘測 • 透過本地供應商提供售後運維支援 • 利用 URE 面板國際認證 (IEC/UL/MCS) 確保模組品質 • 對所有 SPWS 專案應用 P1–P6 閘門框架。

發布完整 SPWS 技術標準前尚需完成：針對現場部署泵型號的傳導率門檻驗證 • 11 個已完工案例的系統性失效模式資料整理 • 超過三年的費用回收機制測試 • 各目標國家的防盜與面板安全規範 • 東非野外條件下電氣組件壽命資料。

Note to donors / 給捐款人的說明： The 11 completed SPWS installations represent a foundation of field experience. A full SPWS technical standard — with evidence-based thresholds equivalent to those in Chapters 1–10 of this document — will be issued once systematic data from these installations has been compiled and reviewed. Love Binti International will not scale SPWS deployment beyond proven site conditions until that standard is in place. / 已完工的 11 個 SPWS 案例構成現場經驗基礎。完整的 SPWS 技術標準——包含等同於本文件第一至十章的實證門檻——將在上述案例的系統性資料整理與審查完成後正式發布。在該標準確立之前，組織不會在未經驗證的地點條件下擴大 SPWS 部署規模。

KEY TERMS — CHAPTER 11 • 第十一章

Abbr.	Term	English Definition	中文說明
SPWS	Solar Piped Water System / 太陽能鑽孔供水系統	A borehole fitted with a solar-powered submersible pump, storage tank and piped distribution network serving multiple communities. Capital cost typically USD 15,000–50,000.	安裝太陽能潛水泵、儲水槽及管網配水系統的鑽孔，服務多個社區，資本成本通常為 15,000–50,000 美元。
URE / URECO	United Renewable Energy Co., Ltd. / 聯合再生能源股份有限公司	Taiwan-listed solar manufacturer (formerly Neo Solar Power Corp.). Technology sponsor for Love Binti International's SPWS programme. Certifications: IEC, UL, MCS, VPC.	台灣上市太陽能製造商（前身為新日光能源等三合一合併），愛女孩國際關懷協會 SPWS 計畫的技術贊助單位，持有 IEC、UL、MCS、VPC 等國際認證。
Submersible Pump	潛水泵	Electric pump installed below the water table inside the borehole. Powered by solar panels via an inverter. Requires electrician for maintenance — cannot be serviced by community members.	安裝於鑽孔內水面以下的電動泵，由太陽能面板透過逆變器供電，維修需電氣工程師，社區成員無法自行處理。
Inverter	逆變器	Electrical device converting DC power from solar panels to AC power for the pump. A common SPWS failure point requiring specialist repair.	將太陽能面板直流電轉換為泵所需交流電的電氣裝置，是 SPWS 常見故障點，需專業維修。
Over-abstraction	過度抽取	Pumping groundwater faster than the aquifer can recharge. Solar pumps extract 5–10× more than handpumps, raising risk of permanent water table decline in low-storage basement aquifers.	抽取地下水的速度超過含水層補給速率。太陽能泵抽取量是手壓井的 5–10 倍，在低儲量基底岩含水層中存在水位永久下降的風險。
9.5 m ² /day	SPWS Transmissivity Threshold / SPWS 傳導率門檻	Minimum aquifer transmissivity required to sustain 60 l/min yield for a solar pump. Compared to >1.4 m ² /day for a handpump. 57–80% of East African baseline aquifer sites fall below this threshold.	維持太陽能泵 60 l/min 出水量所需的最低含水層傳導率，相較手壓井的 >1.4 m ² /天高出約五倍，東非基底岩地區 57–80% 的地點低於此門檻。
kWp	Kilowatt-peak / 峰值千瓦	Unit of solar panel power output under standard test conditions. Typical SPWS requires 1.2–3.4 kWp depending on borehole depth and service population.	標準測試條件下太陽能面板的功率輸出單位，典型 SPWS 需 1.2–3.4 kWp，視鑽孔深度與服務人口而定。
IEC	International Electrotechnical Commission / 國際電工委員會	International standards body for electrical and electronic technology. IEC certification on solar panels is the primary European quality benchmark referenced in procurement.	電氣與電子技術國際標準機構，太陽能面板的 IEC 認證是採購時主要引用的歐洲品質基準。

Borehole Field Inspection Checklist

鑽孔現場檢查表

Applicable to: P2 Survey • P4 Construction • P5 Handover • P6 Annual Monitoring

適用於：P2 勘測 • P4 施工 • P5 交付 • P6 年度追蹤

Applicable Region / 適用地區: Kenya / 肯亞 • Uganda / 烏干達 • Tanzania / 坦尚尼亞 • South Sudan / 南蘇丹

Borehole ID / 鑽孔編號	Location — Country, County, Village / 地點——國家、縣、村
Inspection Date / 檢查日期	Inspection Type / 檢查類型 (circle / 圈選) P2 • P4 • P5 • P6
Contractor / 承包商	Inspector Name & Organisation / 檢查人員及機構

P2 — Hydrogeological Conditions / 水文地質條件確認

Transmissivity (T) / 地下水傳導率	_____ m ² /day (m ² /天)	Gate / 閘門: Must be >1.4 m ² /day 必須 >1.4 m ² /天
Dry-season static water level / 乾季靜水位	_____ m below surface (地表以下)	Afridev ≤45m / India MkII ≤50m
VES survey completed / VES 探測完成	<input type="checkbox"/> Yes 是 <input type="checkbox"/> No 否	
Site selection report submitted / 選址報告提交	<input type="checkbox"/> Yes 是 <input type="checkbox"/> No 否	

► P2 Gate / P2 閘門: All above met before proceeding to P3 / 以上全部符合才進入 P3

P4 — Construction Verification / 施工技術確認 (Contractor Lead / 承包商主責 • Programme Supervision / 計畫監督)

Total borehole depth / 鑽井總深度	_____ m	
Screen / open-hole length / 篩管長度	_____ m	Must be ≥10m / 必須 ≥10m
Cylinder installation depth / 泵筒安裝深度	_____ m	
Cylinder depth below water table / 泵筒距水面	_____ m	Must be >10m / 必須 >10m
Pumping test duration / 抽水測試時長	_____ hours (小時)	Must be ≥2.5 hrs / 必須 ≥2.5 小時
Pumping test recovery rate / 抽水測試恢復率	_____ %	Must be ≥90% / 必須 ≥90%
GPS coordinates (construction site) / GPS 座標	_____	Within 100m of application / 距申請座標 ≤100m

Rising Main Material Verification / 上升主管材料確認

uPVC or corrosion-resistant material (not GI pipe) / uPVC 或耐腐蝕材料 (非 GI 管) — GI pipe prohibited in Uganda, strongly discouraged elsewhere / 烏干達禁用，其他地區強烈不建議

Wall thickness verified ≥5.1mm (ultrasonic gauge) / 管壁厚度超音波抽驗 ≥5.1mm

Measured / 實測值: _____ mm

Full sections installed — no cutting and re-joining / 整段安裝，無截短重接痕跡

Section length meets standard 3m / 節長符合標準 3m

Pump Rod Material Verification / 活桿材料確認

Stainless steel rods (not GI rods) — recommended for all four target countries / 不鏽鋼桿 (非 GI 桿) — 四個目標國家均建議採用

Rod diameter verified ≥11mm (callipers) / 桿徑量測 ≥11mm (游標卡尺)

Measured / 實測值: _____ mm

Full string same material — no stainless steel / GI mixing / 整套同材料，無不鏽鋼與 GI 混用

Initial Water Quality Testing / 水質初始檢測

pH	_____	
Turbidity / 濁度 (NTU)	_____	
E. coli / 大腸桿菌	<input type="checkbox"/> Not detected 未檢出 <input type="checkbox"/> Detected 檢出	Gate / 閘門: Must not be detected 必須未檢出
TDS (mg/L)	_____	

Initial Water Quality Testing / 水質初始檢測		
Iron / 鐵 (mg/L)	_____	
Fluoride / 氟化物 (mg/L)	_____	

Evidence Package / 證據清單 — all required / 缺一不可		
<input type="checkbox"/> Daily drilling log — depth, strata, yield / 每日鑽井日誌——深度、地層、出水紀錄		
<input type="checkbox"/> Full pumping test report with water level curves / 抽水測試完整報告，含水位變化曲線		
<input type="checkbox"/> GPS-tagged photos with EXIF coordinates and watermark / GPS 標記照片，含 EXIF 座標與浮水印		
<input type="checkbox"/> CCTV screen position confirmation report / CCTV 篩管位置確認報告		
<input type="checkbox"/> Water quality test certificate / 水質檢測報告		
<input type="checkbox"/> Material inspection record — wall thickness and rod diameter measured values / 材料驗收記錄——管壁厚度與桿徑實測值		

▶ P4 Gate / P4 關門: All data compliant + evidence package complete before P5 / 以上所有數據達標 + 證據清單完整，才進入 P5

P5 — Pre-handover Final Verification / 交付前最終確認 (Programme Acceptance / 計畫驗收)

<input type="checkbox"/> Handpump delivers ≥ 10 l/min / 手壓井正常出水 ≥ 10 l/min		
<input type="checkbox"/> Concrete apron complete; drainage gradient correct / 混凝土井台完工；排水坡度正確		
<input type="checkbox"/> Livestock fencing installed / 牲畜圍欄安裝完成		
<input type="checkbox"/> Water committee completed operation training / 水委員會完成操作培訓		
<input type="checkbox"/> Basic maintenance training completed — seals and valves replacement / 基本維修培訓完成——密封圈與閘門更換		
<input type="checkbox"/> MOU formally signed; responsible parties confirmed / MOU 正式簽署；責任主體確認		
<input type="checkbox"/> Registry system fully updated / 登錄系統資料完整更新		
<input type="checkbox"/> Donor report photos complete — with GPS watermark / 捐款人報告照片齊全——含 GPS 浮水印		

▶ P5 Complete / P5 完成: All items checked → formal handover; proceed to P6 / 以上全部勾選 → 正式移交，進入 P6

P6 — Annual Monitoring / 年度追蹤 (Dry season annually / 每年乾季執行)

Yield — bucket test / 出水量 (桶測法)	_____ l/min	Target: 10L in 60 sec / 目標：60 秒裝滿 10 公升
Downtime past 12 months / 過去 12 個月停機天數	_____ days (天)	
Functionality category / 功能分類	<input type="checkbox"/> FF <input type="checkbox"/> UR <input type="checkbox"/> LY <input type="checkbox"/> UR-LY <input type="checkbox"/> NF <input type="checkbox"/> AB	

Equipment Condition / 設備狀況		
<input type="checkbox"/> Rising main — no corrosion or damage / 上升主管無腐蝕或破損	<input type="checkbox"/> Seals and valves — annual replacement done / 密封圈與閘門已年度更換	
<input type="checkbox"/> Pump rods — no bending or corrosion / 活塞桿無彎曲或腐蝕	<input type="checkbox"/> Cylinder position — not raised vs. installation record / 泵筒位置未上移 (與安裝記錄比對)	
<input type="checkbox"/> Apron drainage — normal / 井台排水正常	<input type="checkbox"/> Fencing — intact / 圍欄完整	

Seasonal Water Quality / 季節性水質監測		
Monitoring timing / 監測時機	<input type="checkbox"/> Dry season 乾季 <input type="checkbox"/> Wet season 雨季	
pH	_____	
E. coli / 大腸桿菌	<input type="checkbox"/> Not detected 未檢出 <input type="checkbox"/> Detected 檢出	Detected → suspend immediately 檢出→立即停用
Iron / 鐵 (mg/L)	_____	

Monitoring Notes / 追蹤備註		

Inspection Summary / 本次檢查總結		
Gate result / 關門結果	<input type="checkbox"/> Pass — proceed to next phase / 通過，進入下一階段 <input type="checkbox"/> Fail — hold / 未通過，暫停	
Follow-up required / 需要跟進事項	_____	

Next monitoring date / 下次追蹤日期

Contractor Signature / 承包商簽名

Programme Supervisor / 計畫監督人員

Water Committee Representative / 水委員會
代表

Date / 日期: _____

Date / 日期: _____

Date / 日期: _____

Master Glossary of Terms & Abbreviations

專有名詞與縮寫完整術語表

All technical terms and abbreviations used in this document, arranged alphabetically. Intended for donors, community representatives and programme staff unfamiliar with hydrogeology or water engineering terminology.

本文件所有技術術語與縮寫按字母順序排列，供不熟悉水文地質或水利工程術語的捐款人、社區代表及計畫人員參考。

Abbr. / 縮寫	Term / 術語	English Definition	中文說明
AB	Abandoned / 棄置	Functionality category: borehole not functional for over one year.	功能分類：超過一年未出水的棄置水井。
AFNE1/7	Transboundary Aquifer	IWMI reference codes for shared groundwater bodies across national borders in East Africa.	東非跨境含水層的 IWMI 編號，指跨越國界的共享地下水體。
Afridev	Afridev Handpump	VLOM-classified public domain handpump using uPVC rising mains. Max depth 45m. RWSN Spec. Rev. 5-2007.	採用 uPVC 上升主管的 VLOM 型公共領域手壓井，最大深度 45m。
Aquifer	含水層	Underground layer of permeable rock or sediment that stores and transmits groundwater.	能儲存並傳導地下水的地下透水岩石或沉積物層。
Basement Rock	結晶基底岩	Ancient Precambrian crystalline rock (granite, gneiss) underlying much of East Africa. Groundwater in weathered/fractured zones only.	東非大部分地區的古老前寒武紀結晶岩石，地下水僅存在於風化層與裂縫中。
Casing	套管	Solid pipe lining in the borehole above the aquifer, preventing wall collapse and surface contamination.	安裝於含水層以上的實心管襯，防止井壁坍塌與地表污染。
CCTV	Closed-Circuit TV Survey / 閉路電視勘察	Camera lowered into completed borehole to visually verify screen/casing position and construction quality. Required before P5 acceptance.	將攝影機放入完工鑽孔，視覺確認篩管與套管位置及施工品質，P5 驗收前為必要程序。
Crystalline Basement	結晶基底岩	See Basement Rock. Dominant geology in Uganda, much of Kenya and South Sudan. Typically low transmissivity.	見「結晶基底岩」，為烏干達、大部分肯亞及南蘇丹的主要地質，傳導率通常偏低。
EARS	East African Rift System / 東非裂谷系統	Tectonic rift formed by divergence of Nubian and Somalian plates. Creates the characteristic geology (basement + volcanic) shared by all four target countries.	由努比亞板塊與索馬利亞板塊分離形成的構造裂谷，產生四個目標國家共有的結晶基底岩與火山岩地質特徵。
E. coli	Escherichia coli / 大腸桿菌	Faecal indicator bacterium. Must not be detected in drinking water. Presence indicates contamination by human or animal waste.	糞便指示菌，飲用水中必須未檢出，其存在表示受到人類或動物糞便污染。
EXIF	Exchangeable Image File Format / 照片地理標記	Metadata in digital photos including GPS coordinates, date and time. Required in all construction photos to verify site authenticity.	數位照片的元數據，包含 GPS 座標、日期與時間，所有施工照片必須包含此資訊以核實地點真實性。
FF	Fully Functional / 完全功能	Yield ≥ 10 l/min; downtime <30 days/year. Performing to design standard.	出水量 ≥ 10 l/min；年停機 <30 天，達到設計標準。
Galvanic Corrosion	電化學腐蝕	Accelerated corrosion when two dissimilar metals (e.g. stainless steel + GI) contact in the presence of an electrolyte such as groundwater. Reason why material mixing is prohibited.	兩種不同金屬（如不鏽鋼與鍍鋅鋼）在地下水等電解質中接觸時發生的加速腐蝕，這是禁止混用材料的原因。

Abbr. / 縮寫	Term / 術語	English Definition	中文說明
GI	Galvanised Iron Pipe/ Rod / 鍍鋅鐵管／桿	Steel component with zinc coating. Standard in India Mark pumps. 98% fail galvanising standard in Uganda. Prohibited as rising main in Uganda; strongly discouraged elsewhere.	外層鍍鋅的鋼管或鋼桿，India Mark 手壓井的標準配件。烏干達 98% 鍍鋅厚度不足；烏干達禁用，其他地區強烈不建議。
GPS	Global Positioning System / 全球定位系統	Satellite-based system providing location coordinates. All construction photos must contain GPS/EXIF data for site verification.	衛星定位系統，提供位置座標。所有施工照片必須含 GPS 資料以核實施工地點。
Gravel Pack	礫石填充	Layer of graded gravel placed between the borehole wall and screen to stabilise the formation and improve water flow into the borehole.	置於鑽孔壁與篩管之間的分級礫石層，穩定地層並改善水流入鑽孔的效果。
HPB	Handpump Borehole / 手壓井鑽孔	A drilled borehole fitted with a mechanical handpump. The primary rural water supply technology in East Africa.	安裝機械式手壓泵的鑽孔水井，是東非最主要的農村供水技術。
India Mark II/ III	India Mark Handpump	Heavy-duty lever handpump using GI components. Not VLOM. Max depth 50m (Mk II) or 80m (Extra Deep). RWSN Spec. Rev.2-2007.	採用 GI 配件的重型槓桿式手壓井，非 VLOM 型，最大深度 50m (Mark II)。
l/min	Litres per Minute / 每分鐘公升數	Unit of flow rate. Handpump design yield: ≥ 10 l/min = 10-litre bucket filled every 60 seconds.	流量單位。手壓井設計出水量 ≥ 10 l/min，即每 60 秒裝滿一個 10 公升水桶。
LY	Low Yield / 低產	Functionality category: yield < 10 l/min, downtime < 30 days/year. Most overlooked — community has water but below standard; accelerates component wear.	功能分類：出水量 < 10 l/min，年停機 < 30 天。最常被忽視——社區有水但低於標準，加速設備磨損。
m ² /day	Transmissivity Unit / 傳導率單位	Unit of aquifer transmissivity. Minimum threshold for handpump sustainability: > 1.4 m ² /day.	含水層傳導率單位，手壓井可持續運作的最低門檻為 > 1.4 m ² /天。
MOU	Memorandum of Understanding / 諒解備忘錄	Formal written agreement between programme and community water committee defining responsibilities, cost-sharing and maintenance obligations. Required before P4.	計畫方與社區水委員會的正式書面協議，明確責任、費用分擔及維護義務，P4 前為必要文件。
NF	Non-functional / 非功能	Functionality category: no water on day of assessment; delivered water at some point in the past year.	功能分類：評估當日無法出水，但過去一年曾出水。
NTU	Nephelometric Turbidity Units / 濁度單位	Unit measuring water cloudiness. Higher values indicate more suspended particles. Relevant to drinking water safety assessment.	量測水體混濁程度的單位，數值越高代表懸浮顆粒越多，與飲用水安全評估直接相關。
O&M	Operation & Maintenance / 操作與維護	Ongoing activities to keep a borehole functional: community daily operation, periodic inspection, planned component replacement.	保持水井正常運作所需的持續性工作，包括社區日常操作、定期檢查與計劃性零件更換。
Open-hole	裸眼段	Borehole section without casing, relying on rock integrity. Common in Uganda crystalline basement. Uncased length tracked by CCTV inspection.	不安裝套管的鑽孔段，依賴岩石本身的結構穩定性，常見於烏干達結晶基底岩，由 CCTV 檢測追蹤。
P1-P6	Project Phases / 專案執行階段	Six sequential phases: Application → Survey → Mobilisation → Construction → Acceptance → Monitoring. Each has a mandatory gate condition.	六個連續執行階段：申請→勘測→動員→施工→驗收→監測，每階段設有強制性關門條件。

Abbr. / 縮寫	Term / 術語	English Definition	中文說明
Phase Gate	階段閘門	Mandatory checkpoint between phases. All conditions must be met before proceeding. Protects programme quality by preventing sub-standard work from advancing.	階段之間的強制性查核點，所有條件須全部符合才能推進，防止不達標的工作進入下一階段。
pH	Power of Hydrogen / 酸鹼值	Scale 0–14 measuring water acidity/alkalinity. Neutral = 7. Low pH (acidic) increases corrosion risk for metal pump components.	0–14 的酸鹼量測尺度，中性為 7。低 pH（酸性）增加金屬泵件的腐蝕風險。
Pump Cylinder	泵筒	Below-ground component with pistons and valves creating suction. Must remain >10m below water table to prevent dry-season failure.	位於地下的泵體，內含活塞與閘門產生吸力，必須保持在水面以下 >10m 以防乾季抽空。
Recovery Rate	抽水測試恢復率	Percentage of water level recovered after pumping test cessation. Indicates aquifer recharge capacity. Minimum: ≥90% before borehole acceptance.	抽水測試停止後水位恢復的百分比，反映含水層補給能力，驗收最低標準為 ≥90%。
Rehabilitation	復修 / 維修	Repair or restoration of an existing borehole to restore functionality. Typically 70–85% cheaper than drilling a new borehole.	對現有水井進行維修或修復以恢復功能，通常比鑽新井節省 70–85% 的費用。
Rising Main	上升主管	Pipe string from pump cylinder to surface. Most commonly damaged component. Must be uPVC (full sections, no cutting) in all four target countries.	從泵筒到地面的管柱，是最常損壞的部件，四個目標國家均須採用 uPVC 管段安裝，禁止截短。
RWSN	Rural Water Supply Network / 農村供水網絡	International standards body for rural handpumps. Publishes Afridev and India Mark specifications. Based in St Gallen, Switzerland." "制定農村手壓井標準的國際機構，發布 Afridev 及 India Mark 規範，總部位於瑞士聖加侖。	
Screen	篩管	Slotted casing in the aquifer zone allowing water entry while excluding sediment. Minimum length: 10m. Position verified by CCTV.	含水層位置的開槽套管，允許水進入同時阻擋泥沙，最低長度 10m，位置由 CCTV 確認。
SOP	Standard Operating Procedure / 標準作業程序	Written step-by-step instructions for a task. Maintenance SOPs in this programme prohibit pipe shortening, re-threading and material mixing.	特定工作的書面逐步說明，本計畫維修 SOP 明確禁止截短管件、重新套螺紋及混用材料。
TDS	Total Dissolved Solids / 總溶解固體	Water quality parameter: total concentration of dissolved minerals (mg/L). High TDS may indicate corrosive or mineralised water affecting component lifespan.	水質參數：溶解礦物質總濃度 (mg/L)。TDS 偏高可能表示水質具腐蝕性或礦化度高，影響管件壽命。
Track 1	第一軌——水文地質專家	Licensed hydrogeologist responsible for P2 survey. Independent of drilling contractor to avoid conflict of interest." "負責 P2 勘測的持照水文地質專家，獨立於鑽井承包商以避免利益衝突。	
Track 2	第二軌——鑽井承包商	Licensed drilling contractor responsible for P4 construction, under programme supervision." "負責 P4 施工的持照鑽井承包商，於計畫監督下執行。	

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Transmissivity	地下水傳導率 (T)	Rate of groundwater flow through an aquifer (m ² /day). Minimum for handpump: >1.4 m ² /day. Uganda: 30% of sites below threshold.", "地下水穿過含水層的流動速率 (m ² /天)。手壓井最低門檻 >1.4 m ² /天，烏干達約 30% 地點低於門檻。	
UR	Unreliable / 不可靠	Functionality category: yield meets standard but downtime ≥30 days/year.", "功能分類：出水量達標但年停機 ≥30 天。	
UR-LY	Unreliable & Low Yield / 不可靠且低產	Functionality category: both yield below standard AND downtime ≥30 days/year. Priority for intervention.", "功能分類：出水量低於標準且年停機 ≥30 天，需優先介入。	
USD	US Dollar / 美元	United States Dollar. Currency used for all cost estimates in this document.", "美元，本文件所有費用估算採用的貨幣單位。	
uPVC	Unplasticised Polyvinyl Chloride / 硬質聚氯乙烯	Rigid PVC pipe. Preferred rising main material for all four target countries. Must be replaced in full 3m sections — no cutting. Wall thickness ≥5.1mm.", "硬質 PVC 管，四個目標國家優先採用的上升主管材料，必須以 3m 整節更換，禁止截短，管壁厚度 ≥5.1mm。	
VES	Vertical Electrical Sounding / 垂直電阻率探測	Geophysical method measuring subsurface electrical resistivity to estimate transmissivity and identify suitable borehole sites. Mandatory before drilling.", "地球物理勘測方法，透過量測地下電阻率估算傳導率並確認鑽井位置，鑽井前為強制要求。	
VLOM	Village Level Operation & Maintenance	Handpump design standard (e.g. Afridev, India Mark III) enabling repair by trained community members without specialist tools or equipment.", "村級操作與維護：手壓井設計標準（如 Afridev、India Mark III），使受訓社區成員無需專業工具即可完成維修。	
Water Committee	社區水委員會	Community-elected group responsible for borehole management, fee collection, maintenance coordination, and liaison with the programme.", "由社區選出的管理小組，負責水井管理、費用收取、維護協調及與計畫方的聯絡。	
IEC	International Electrotechnical Commission / 國際電工委員會	International standards body for electrical/electronic technology. IEC certification is the primary European quality benchmark for solar panels.	電氣與電子技術國際標準機構，太陽能面板的 IEC 認證是採購時主要引用的歐洲品質基準。
Inverter	逆變器	Converts DC power from solar panels to AC power for the pump. A common SPWS failure point requiring specialist repair.	將太陽能面板直流電轉換為泵所需交流電的裝置，是 SPWS 常見故障點，需專業維修。
kWp		Unit of solar panel power output under standard test conditions.	

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	Kilowatt-peak / 峰值千瓦	Typical SPWS: 1.2–3.4 kWp depending on depth and population.	標準測試條件下太陽能面板的功率輸出單位，典型 SPWS 需 1.2–3.4 kWp。
Over-abstraction	過度抽取	Pumping groundwater faster than the aquifer recharges. Solar pumps extract 5–10× more than handpumps — risk of permanent water table decline in low-storage aquifers.	抽取地下水的速度超過含水層補給速率，太陽能泵抽取量是手壓井的 5–10 倍，在低儲量含水層中存在水位永久下降的風險。
SPWS	Solar Piped Water System / 太陽能鑽孔供水系統	Borehole with solar-powered submersible pump, storage tank and piped distribution serving multiple communities. Capital cost typically USD 15,000–50,000.	安裝太陽能潛水泵、儲水槽及管網的鑽孔供水系統，服務多個社區，資本成本通常為 15,000–50,000 美元。
Submersible Pump	潛水泵	Electric pump installed below the water table inside the borehole. Powered by solar panels via inverter. Requires licensed electrician for maintenance.	安裝於鑽孔內水面以下的電動泵，由太陽能板透過逆變器供電，維修需持照電氣工程師。
URE / URECO	United Renewable Energy / 聯合再生能源	Taiwan-listed solar manufacturer (formerly Neo Solar Power Corp., merged 2018). Technology sponsor for Love Binti International SPWS programme. Certifications: IEC, UL, MCS, VPC.	台灣上市太陽能製造商（前身為新日光源等三合一合併，2018年），愛女孩國際關懷協會 SPWS 計畫技術贊助單位，持有 IEC、UL、MCS、VPC 認證。
Sunry / 三瑞	Guangdong Sunry Power U Limited / 广东三瑞电源科技有限公司	China-origin solar storage and power supply technology company operating in East Africa. Local supply partner for Love Binti International SPWS programme.	廣東中國太陽能儲能與電源科技公司，在東非運營，為愛女孩國際關懷協會 SPWS 計畫的本地供應夥伴。
Yeshua LW	Yeshua Living Water Company Limited	Uganda-registered borehole drilling contractor. Approved implementation partner for Love Binti International P4 borehole construction works in Uganda.	烏干達註冊鑽井承包商，為愛女孩國際關懷協會烏干達 P4 鑽井施工核可執行夥伴。
AllGrand	AllGrand Power Source Development Limited 山东奥冠新能源科技有限公司	Uganda-registered solar company associated with Shandong Aoguan New Energy Technology Co., Ltd. (China). Local supply partner for Love Binti International SPWS programme in East Africa.	烏干達註冊太陽能公司，關聯方為山東奧冠新能源科技有限公司（中國），為愛女孩國際關懷協會 SPWS 計畫的東非本地供應夥伴。