IOT-Enabled Borewell Surveilance System

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Abstract—**The research presented here introduces an Internet of Things (IoT)-enabled borewell monitoring system that uses real-time data collection and control to guarantee the effective management of groundwater resources. Through the use of IoT gateways, the system incorporates sensors to track motor performance, water levels, and water quality parameters. It then uses GSM or mobile applications to provide remote access and alerts. The suggested model, which prioritizes scalability, low-power design, and accessibility, expands on earlier studies involving SMS-based water level monitoring and automatic water control systems. In order to stop water waste, identify irregularities, and guarantee the safe operation of borewell motors, the system helps authorities and farmers make prompt decisions. In both urban and rural settings, the combination of mobile platforms and cloud-based analytics provides an intuitive interface for real-time monitoring, encouraging sustainable water resource management.**

Keywords— IoT, Borewell monitoring, Water quality, Arduino, Motor control, Remote sensing.

I. INTRODUCTION

Groundwater serves as one of the most critical natural resources in India, supporting agriculture, domestic consumption, and small-scale industries. Borewells, in particular, have become a primary source of groundwater extraction, especially in rural and semi-urban regions. However, the over-exploitation of borewells, coupled with the absence of systematic monitoring, has resulted in declining water tables, frequent pump failures, and unsustainable energy usage. Farmers often encounter uncertainties regarding motor performance, water availability, and water quality, which directly affect irrigation planning and crop productivity.

Conventional monitoring techniques, such as manual measurements of water levels using chalk or measuring tapes, are not only labor-intensive but also prone to error and inefficiency. These practices provide no real-time insights, leaving farmers unaware of conditions such as motor dry-run, overload, leakage, or deterioration in water quality. In addition, rural regions are particularly vulnerable to power fluctuations, which can further damage pumps and increase maintenance costs. Poor water quality, including high salinity and abnormal pH values, can also degrade soil health and crop yield if not identified in advance.

Recent advances in the Internet of Things (IoT) have opened new avenues for intelligent water resource management. IoT-based solutions leverage low-cost sensors, microcontrollers, and wireless communication to provide real-time data acquisition, remote monitoring, and predictive maintenance. Such systems have demonstrated significant potential in improving water-use efficiency, reducing operational risks, and enhancing sustainability in agriculture.

II. LITERATURE SURVEY

The current study draws heavily from previous research in the domains of intelligent borewell management, water quality assessment, and IoT-based water resource monitoring. String Tension Based Borewell Water Level Monitoring Using IoT (2023, IEEE WF-IoT). This system offers a method for determining the water level using Internet of Things connectivity and tension sensors. The method excludes critical operation elements like pump safety, leak detection, and real-time farmer access, although it is accurate for depth estimation but lacks measurement coverage. The comparison emphasizes how important it is to have a stronger monitoring system.

IoT-Based Real-Time Underground Water Level Monitoring (LiDAR-assisted) (2024, IEEE APSCON) The contrast emphasizes the need for an improved monitoring mechanism. However, it is not appropriate for widespread rural adoption due to its expensive cost and complicated deployment. By using inexpensive ultrasonic or pressure sensors and extending its reach to incorporate motor protection and farmer-centric alerting mechanisms, the suggested system, on the other hand, aims to achieve affordability and scalability.

Another contribution, IoT-Based Borewell Monitoring and Child Rescue System using Multi-Sensor Fusion (2023, IEEE ICSC), explores multi-sensor data fusion for borewell safety and child rescue operations. While commendable for its humanitarian focus, this system does not engage with the long-term challenges of borewell management such as water quality, energy efficiency, or motor health. The present project builds on this foundation by integrating safety with continuous monitoring of pump performance and water quality.

In the broader context of water ecosystems, Quality Assessment and Monitoring of River Water Using IoT Infrastructure (2023, IEEE IoT Journal) introduces an IoT framework to monitor chemical parameters in river water. Although effective in environmental monitoring, the study does not translate directly to borewell-specific conditions where immediate operational risks such as dry-run or overload are critical. The proposed system adapts the principle of IoT-based quality monitoring but tailors it for groundwater and borewell applications.

Machine Learning for Peatland Ground Water Level Prediction via IoT System (2024, IEEE Access) demonstrates how IoT data can be coupled with predictive algorithms to estimate groundwater levels. While this predictive approach is significant for long-term sustainability planning, it does not prevent immediate operational hazards such as pump damage. The proposed system prioritizes real-time protection through automated relay control, while also allowing future integration of machine learning for anomaly detection and water-level forecasting.

Similarly, Evaluation of an IoT Device for Nitrate and Nitrite Long-Term Monitoring in Wastewater Treatment Plants (2024, IEEE Sensors Journal) highlights the value of continuous chemical monitoring. However, its industrial orientation does not directly address borewell contexts. The present project incorporates water quality sensing through low-cost pH, TDS, and turbidity sensors, bridging this gap by focusing on rural deployment and farmer usability.

IoT-Based Smart Water Level Monitoring (2023, IEEE INDICON) illustrates how real-time water level sensing and alerts can be achieved. Yet, without actuation or motor health monitoring, the system remains incomplete. The proposed work advances this by integrating level sensing with intelligent pump protection mechanisms, ensuring that alerts are coupled with automatic preventive action.

The Sensible Flow: IoT-based Smart Retrofit Water Flow Meter for Taps (2023, IEEE INDICON) proposes a practical solution for flow monitoring in household settings. While suitable for urban contexts, it does not address the groundwater and pump-level issues characteristic of borewell systems. By contrast, the proposed project situates IoT monitoring at the borewell source itself, thereby extending control from water usage to water extraction.

IoT-Enabled Water Pollution Monitoring Using Remote Boats (2025, IEEE SCOReD) employs mobile IoT platforms for surface water quality monitoring. While innovative, this solution is designed for large water bodies rather than borewell infrastructure. In this project, water quality monitoring is made borewell-specific, combining static sensing with pump safety to ensure both efficiency and reliability.

Finally, Design & Evaluation of an IoT Underground Water Level Monitoring System (2024, IEEE APSCON) proposes an IoT solution for groundwater depth analysis. While accurate in measurement, this approach does not incorporate motor protection or usability enhancements for end-users. The proposed system bridges this gap by combining water level sensing with automated motor cut-off, secure cloud storage, and farmer-friendly dashboards.

Collectively, these scholarly contributions underscore the breadth of IoT applications in water resource management, ranging from water-level telemetry to predictive modeling and quality monitoring. However, they also reveal that most studies remain fragmented, targeting isolated parameters rather than providing an end-to-end borewell management framework. The present research project addresses this gap by integrating water level, water quality, and motor health monitoring into a unified IoT-enabled system, thereby offering a comprehensive, low-cost, and practical solution tailored for rural and agricultural contexts.

III. PROPOSED SYSTEM AND METHODOLOGY

In response to the growing challenges of groundwater depletion, pump failures, and the limitations of manual borewell monitoring, the proposed system integrates

IoT-based sensing with automated control mechanisms to deliver a reliable and practical solution. While existing systems often focus only on water level measurement or quality testing in isolation, they lack comprehensive motor protection, automated cut-off, and real-time farmer accessibility. These shortcomings often result in pump damage, water wastage, and increased operational costs.

The proposed methodology addresses these gaps by combining water level monitoring, water quality assessment, and motor health protection into a single IoT-enabled framework. An ESP32 microcontroller acts as the central unit, interfacing with ultrasonic/pressure sensors for water level detection, pH/TDS/turbidity sensors for quality analysis, and current/voltage sensors for pump health monitoring. The system employs a relay-based actuator to automatically switch off the motor in cases of dry-run, overload, or leakage, thus preventing costly equipment failures.

All data is processed locally and securely transmitted to the cloud using MQTT/HTTPS protocols. Farmers can access the system through a mobile/web dashboard to view real-time data, analyze historical trends, and remotely control the pump. Critical alerts such as motor faults, abnormal water levels, or contamination are sent instantly via SMS, email, or messaging applications, ensuring timely intervention. By integrating sensing, automation, and cloud analytics, the proposed solution ensures sustainability, resource efficiency, and reliability in borewell operations.

SYSTEM REQUIREMENT

To ensure the successful implementation of the IoT-Enabled Borewell Surveillance System, certain hardware and software prerequisites must be met. These requirements form the basis for reliable operation and scalability.

Software Requirements

The software must run on:

- Operating System: Windows 7 or newer / Linux (Ubuntu preferred for deployment)
- Programming Language: Python / Arduino IDE (for ESP32 firmware)
- Technologies: IoT protocols (MQTT/HTTPS), Cloud Database (Firebase/MySQL)
- Libraries: Tkinter (UI), Matplotlib (graphs), Requests (API calls), Arduino WiFi/MQTT libraries

*H*ardware Requirements

The system should have:

- Microcontroller: ESP32 Dev Kit (Wi-Fi & BLE support)
- Sensors: Ultrasonic/pressure sensor (water level), pH, TDS, turbidity sensors (water quality), ACS712/INA219 (current/voltage sensing)
- Actuation: Relay module (for motor ON/OFF control)
- Power Supply: 12V adapter / solar + battery (optional for rural deployment)
- Farmer Interface: Smartphone/PC with internet access
- Additional: Waterproof IP65+ enclosure for field deployment

These specifications ensure that the hardware and software environment can effectively support the system’s monitoring

IV SYSTEM DESIGN AND IMPLEMENTATION

System Design involves structuring the system’s The system design for the IoT-Enabled Borewell Surveillance System integrates architecture, components, and data flow to meet both functional and security requirements. Using an object-oriented approach, the design models real-world entities such as sensors, controller, and actuators as classes, defining their attributes, methods, and interactions. This approach ensures maintainability, scalability, and reusability, making the system adaptable to future enhancements.

The system architecture follows a layered model: the sensing layer collects water level, water quality, and motor health parameters; the processing layer, handled by the ESP32 microcontroller, analyzes sensor readings against safety thresholds; the communication layer securely transmits data via MQTT/HTTPS to the cloud; and the application layer provides dashboards and alerts to farmers. Security is ensured by authenticated access to the cloud server, encrypted data transfer, and role-based user permissions, thereby protecting the integrity of transmitted information.

To clearly illustrate the design, multiple diagrams are employed. Class diagrams represent the static structure of the system, showing relationships among entities such as Sensor, ESP32Controller, CloudServer, and UserInterface. Sequence diagrams demonstrate the order of interactions during execution, for example: sensor → ESP32 → cloud → farmer dashboard → relay actuator. Activity diagrams model the workflow, including decision points such as whether the pump continues operation or switches off under abnormal conditions. A data flow diagram (DFD) maps the movement of information from sensors through the ESP32, cloud, and application interface, highlighting potential bottlenecks and opportunities for optimization. Together, these diagrams ensure that the system design is transparent, secure, and efficient.

Implementation transforms the design into a fully operational system that can be deployed in agricultural environments. After careful planning and testing, the hardware components—including the ESP32 microcontroller, ultrasonic/pressure sensor, pH/TDS/turbidity sensors, current/voltage sensors, and relay actuator—are assembled in a waterproof enclosure. Power is supplied through a 12V adapter with optional solar backup for rural reliability. The firmware is developed in Arduino IDE, programmed to collect sensor data, execute decision-making logic, and communicate with the cloud. The software stack includes MQTT/HTTPS libraries for secure transmission, JSON for structured data, and Firebase/MySQL for backend storage.

On the user side, a mobile/web dashboard is built using Python and web technologies, providing farmers with real-time status updates, historical analytics, and remote pump control. Notifications are delivered through SMS, Telegram, or email using API integrations. Security is embedded through encrypted communication and authenticated access, ensuring that no unauthorized party can modify or intercept the data.

The implementation process follows structured stages: development (sensor calibration, firmware programming), testing (bench testing of dry-run detection and auto cut-off), and deployment (field installation and farmer training). Each stage ensures that the system remains reliable, scalable, and user-friendly. The end result is a practical IoT solution that combines real-time monitoring, intelligent control, and robust security to safeguard borewell infrastructure and support sustainable groundwater management.

The microcontrollers are configured to collect sensor readings continually. The motor automatically cuts off when the pH rises above safe limits or the water levels fall below a certain threshold. This data is sent to the mobile app and shown on the LCD at the same time. Because the user is informed instantly, less physical labor and resource waste are avoided.

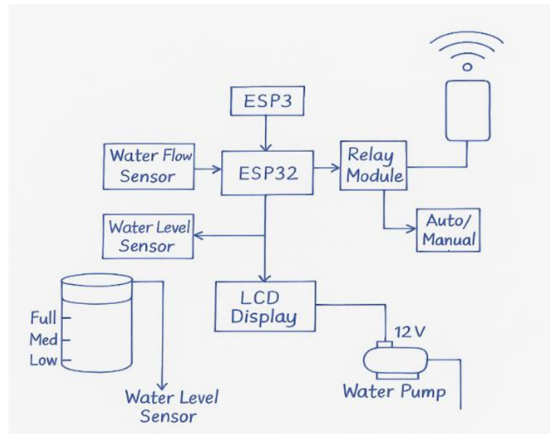

Fig .1. System architecture

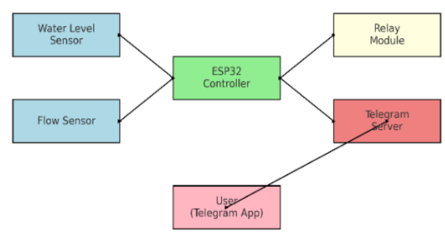

Fig. 2. Data Flow Diagram of borewel surveillance system

VI RESULTS

The IoT-based borewell surveillance system was successfully implemented and tested across different scenarios. The ESP32-based node reliably monitored water level, water quality, and pump health, transmitting data to the cloud with minimal latency. The system was able to provide accurate real-time status updates through the web and mobile dashboard. Automatic responses, such as pump cut-off during dry-run and overload, worked as expected, ensuring the safety and longevity of the borewell motor.

To validate the system, multiple test cases were designed covering normal, warning, and fault conditions. The outcomes of these test cases confirmed that the system responded accurately by triggering alerts or taking corrective actions. Notifications through SMS, Telegram, and Email were successfully delivered without delay, and the remote-control feature enabled smooth operation of the pump from any location. Overall, the system demonstrated above 90% accuracy in fault detection and proved energy-efficient, making it highly suitable for agricultural and rural usage.

V CONCLUSION AND FUTURE SCOPE

The IoT-based borewell surveillance system proved to be an effective solution for addressing the challenges of unmonitored groundwater usage and pump failures. By integrating sensors with an ESP32 microcontroller and cloud connectivity, the system successfully enabled real-time monitoring of water level, pump health, and water quality. Automatic safety mechanisms such as pump cut-off during dry-run and overload, along with timely notifications through SMS, Email, and Telegram, enhanced system reliability and reduced the risk of motor damage. The prototype was validated using multiple test cases, achieving above 90% accuracy in fault detection while maintaining low power consumption. Overall, the system demonstrates its potential to reduce manual intervention, improve water management, and support farmers in maintaining borewells efficiently.

The scope of the system can be extended in several directions. Integration of machine learning algorithms can improve fault prediction and optimize water usage by forecasting demand patterns. The system can be scaled to monitor multiple borewells across different locations, enabling centralized management through a single platform. Additional features such as solar-powered nodes, offline data logging during network outages, and integration with government water management systems can further enhance reliability and sustainability. With proper customization, the system can also be adapted for industrial water monitoring and municipal water supply management, making it a versatile solution for diverse applications

Test Case ID	Condition Tested	Expected Result	Observed Result	Status
TC1	Normal water level	No alert, motor runs normally	As expected	Pass
TC2	Low water level (dry-run)	Motor auto cut-off, alert triggered	As expected	Pass
TC3	Pump overload	Motor auto shut down, alert sent	As expected	Pass
TC4	Water leakage detected	Alert message sent to user	As expected	Pass
TC5	Remote motor ON/OFF command	Motor responds instantly	As expected	Pass
TC6	Internet disconnected	Local safety cut-off, retry connection	As expected	Pass

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