Aqua-Guardian: Proposal for Continuous Water Quality Monitoring Buoy

25-26 Samsung Solve for Tomorrow Competition

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Section 1: The Rationale

Our student team at Atholton High School's Electronics Club is competing in the **2025-2026 Samsung Solve for Tomorrow** competition, aiming to address the environmental vulnerability of Columbia, Maryland's core water resources. The recent 1.3 million-gallon sewage overflow near Watchlight Court, and the recent health advisories due to Harmful Algal Blooms (HABs) in Lake Centennial and Triadelphia Reservoir have sparked the interest of students within Atholton HS to develop a tool that provides early warning of a crisis. Our goal is to augment existing monitoring efforts by providing continuous data and an automated flagging system to direct human attention to areas of heightened risk. Our project, the Aqua-Guardian, is a student-built, cellular-enabled IoT buoy designed to fill the existing data gap by providing real-time environmental intelligence that can be used to… target areas of elevated risk, draw attention to areas that need further testing, and provide citable evidence for research, which can especially be used to advocate for stronger environmental policy.

Competition Timeline: We are currently compiling technical details and data for our submission; this must be done before the *Application Entry Deadline.*

- **Application Entry Deadline -** 11/05/2025.
- **Pre-acquisition of components -** Design the buoy using CAD, and begin software development.
- **Advancement Notice -** 12/05/2025.
- **Build phase** - Bring the idea out of the concept phase.
- **Phase 2: 3 Minute Video Submission -** 01/21/2026.
- **Advancement Notice** - 02/11/2026
- **End of Social Media Voting Period** - 03/06/2026

Section 2: Aqua-Guardian: Low-Power, High-Efficiency Hardware

The single **Aqua-Guardian buoy** is engineered for maximum operational autonomy and precise data collection on one digital asset:

- **Computation & Power Management:** The system relies on the *Firebeetle ESP32 IOT Board* for its remarkable efficiency, achieving a deep sleep, which ensures months of operation via solar power. The board's pin-out is managed using the *DF Robot Gravity Sensor Expansion Board*.
- **Cellular Connectivity:** For guara*nteed off-shore data relay, we use the Crowtail CRT01260S Cellular + GPS Board*. This enables data transfer from remote locations and hard-to-reach areas within a water body.
- **Sensor Array:** The buoy integrates seven sensors to provide a complete picture of water chemistry: **pH**, **Dissolved Oxygen**, **Electrical Conductivity**, **Turbidity**, **Temperature**, **Oxidation-Reduction Potential**, and an internal **Water Leak Sensor**.
    - This sensor array uses industrial-grade components mainly from DF Robot to prevent anti-fouling and provide consistent, accurate readings.

Section 3: Environmental Intelligence for Targeted Action

The core innovation is our AI-enhanced platform, which converts raw sensor readings into clear diagnostic indicators, automatically flagging users when follow-up monitoring is needed:

- **Nutrient Enrichment Indicator:** This indicator tracks simultaneous spikes in EC and drops in ORP/DO after heavy rain/runoff. Sustained low ORP and DO also signify decomposing Organic Pollution (like sewage).
- **Algal Bloom Risk Score:** An aggregated score correlating rising Temperature, increasing Turbidity, rising pH, and the severe DO fluctuations (photosynthesis/respiration) characteristic of HABs. This score provides a priority flag for further and more precise testing.
- **Chemical/Industrial Pollution:** Anomalous readings in extreme pH, high EC, and abnormal ORP are flagged.
- Our system will integrate the use of AI to help with deriving a water body's condition and to filter out invalid readings caused by natural weather patterns, ensuring users are alerted only by scientifically significant deviations.

Section 5: Challenges

Building a robust, long-term environmental monitoring system, even on a small scale, presents complex engineering and scientific hurdles. Addressing these challenges effectively requires expert input to ensure the credibility and utility of our single deployment.

- **Sensor Calibration:** Electrochemical sensors like pH and ORP probes naturally suffer from sensor drift over time and require recalibration to maintain data accuracy. The use of industrial probes is meant to counter this, but the timeframe of deployment is still unknown..
- **Data Integrity and Preventing False Positives:** To prevent false flags from natural variables like heavy sediment flow or seasonal lake turnover, our system first establishes a dynamic baseline of the water body's normal rhythm, allowing our algorithm to intelligently distinguish true anomalies from these predictable fluctuations.
- **Biofouling:** Preventing **biofouling** (algae/bacteria growth) on sensor heads corrupts readings, particularly for optical sensors like turbidity.
- **Determining Sample Rate:** As aforementioned, tides and the presence of daylight can affect what the norm for sensor readouts should be. Not only that, but sampling at various times of the day can indicate other things like algae growth. Sampling rate will be customizable based on application, but for testing, we will need to know what to look out for.