Measuring, Monitoring & Documentation Systems

The **Sensors Layer** defines all devices and documentation systems used by AOFS controllers to ensure **safe operation, authoritative control, and auditable farm management**.

All AOFS-compliant deployments **must implement the sensors and documentation systems specified here**.

1. Sensor Layer Scope & Authority

AOFS sensors are classified by **operational authority**, not by technology type.

Sensor inputs fall into four functional roles:

- **Safety enforcement** (prevent damage or loss)
- **Authoritative control inputs** (drive irrigation decisions)
- **Documentation & audit**
- **Optimization & research**

AOFS controllers **must never depend on remote systems** to interpret or validate sensor data.

2. Critical Safety & Protection Sensors

Purpose: Prevent equipment damage, flooding, dry-run pumps, and unsafe operating states.

Mandatory Measurements:

- Tank levels: LOW and FULL float switches
- Flow meters on main and zoned pipelines
- Pressure sensors on pumps and main distribution lines
- Rainfall measurement for irrigation lockout

Safety Requirements:

- These sensors **must directly enforce Field Controller fail-safes**
- Operation must be fully local and offline
- Loss or invalid data from these sensors must trigger safe shutdown or degraded mode

3. Primary Agronomic Control Sensors

Soil Monitoring Sensors

Purpose: Provide authoritative inputs for irrigation scheduling.

Required Measurements:

- Soil moisture (volumetric water content) per irrigation zone

Optional but Recommended:

- Soil temperature
- Electrical conductivity (salinity)

Placement Guidelines:

- At least one sensor per irrigation zone
- Additional sensors for heterogeneous fields
- Placement at crop-appropriate root depth

Weather Monitoring Sensors

Purpose: Modify irrigation behavior and enforce environmental lockouts.

Required Measurements:

- Rainfall
- Ambient temperature
- Relative humidity

Optional Measurements:

- Wind speed
- Solar radiation / light intensity

Integration with AOFS:

- Rainfall triggers irrigation suspension
- Weather data refines thresholds and scheduling

Water Monitoring Sensors

Purpose: Track tank levels and authorize irrigation schedules.

Required Measurements:

- Tank LOW and FULL levels
- Flow rate in main and zoned pipelines

Optional Measurements:

- Tank temperature
- Salinity / water quality

Grid Water Availability & Predictive Tank Fill

Purpose: Optimize water sourcing from grid and local wells, based on availability probabilities.

Required Measurements (if grid water is available):

- Flow rate and pressure of grid water supply
- Availability signal (on/off)

Optional Measurements:

- Historical grid water supply patterns
- Probability of grid water availability in next hours or days

Integration & Control Logic:

- AOFS may delay pumping from well if there is a high probability of grid water availability
- Partial tank fill strategies: maintain mandatory minimum levels locally, avoid overfilling if grid water is likely
- Safety thresholds for tank levels must always be enforced, independent of probabilistic logic
- Logging of decisions, sensor readings, and probabilities is required for learning and optimization

4. Power / Energy Monitoring

Purpose: Protect electrical systems and support energy-aware operation.

Required Measurements:

- Pump power consumption
- Valve power consumption

Optional Measurements:

- Battery voltage and current
- Solar panel output

Integration:

- Low-voltage or overload conditions must trigger fail-safe behavior
- Energy data may inform event prioritization and anomaly detection

Grid Power Monitoring & Predictive Use

Purpose: Enable AOFS to safely use intermittent grid power and optimize energy costs.

Required Measurements (if grid is available):

- Grid voltage, current, and frequency
- Short-term fluctuations and harmonics
- Availability signal (on/off)

Optional Measurements:

- Historical grid availability patterns
- Probabilistic prediction of grid power for upcoming hours

Integration & Control Logic:

- AOFS must only allow grid power usage if parameters are within safe thresholds
- Automatic relays and actuators must cut off grid supply immediately on overvoltage, under-voltage, or unsafe frequency
- Predictive patterns can inform decisions, e.g., delaying high-load pump operations until grid is likely available
- All local safety thresholds remain authoritative and override probabilistic logic

5. Human Input / External Event Logging

Purpose: Capture critical farm activities not measurable by sensors.

AOFS treats human input as **first-class data**, equal to automated sensor measurements.

Examples of Loggable Events:

- Fertilizer application
- Manual irrigation or drainage
- Pest or disease treatment
- Planting, pruning, or harvest activities

Requirements:

- All events must be timestamped
- Events must be linked to a field or irrigation zone
- Operator identity must be recorded
- Full audit trail for edits or deletions is required

6. Optical / Camera Documentation Systems

Purpose: Provide visual documentation for review, auditing, and optional analysis.

AOFS Scope:

- Still images only
- No video streaming requirements

Use Cases:

- Crop development tracking
- Soil surface condition documentation
- Pest or disease observation

Requirements:

- Images must be timestamped
- Camera ID and zone reference required
- Images stored locally on the Field Controller
- Optional synchronization with Farm and HQ Controllers

AI-based image analysis is **explicitly optional** and must not interfere with core logging or manual review.

7. Data Logging & Synchronization Rules

- All sensor readings and human-input events **must be logged locally**
- Logs must include:
  - Timestamp
  - Source or sensor ID
  - Measured value or event data
  - Status or quality flags
- Synchronization follows AOFS federation rules
- Loss of connectivity must never result in data loss
- Grid power and water predictive measurements and decisions must be logged, including:
  1. Probability estimates for predictive logic
  2. Decisions made (pump on/off, fill levels)
  3. Outcome of the decisions for future optimization

8. Calibration & Maintenance

- All sensors must be calibrated according to manufacturer specifications
- AOFS deployments must log:
  - Calibration events
  - Maintenance actions
  - Sensor replacements
- Calibration and maintenance logs are auditable and synchronized

9. Compliance Requirements

Minimum mandatory implementation:

- Soil moisture sensors per irrigation zone
- Tank LOW and FULL level sensors
- Flow meters and pressure sensors on irrigation systems
- Power monitoring for pumps and valves
- Rainfall measurement for irrigation lockout

Optional sensors enhance optimization and research but **do not affect baseline compliance**.

10. References

- Field Controller Layer
- Farm Controller Layer (Local / Federated)
- Hydraulic & Water Systems
- Electrical & Control Interfaces