

## AI-Based Early Detection of Water Leakage and Waste in Reservoir Systems: A Case Study of Bhatghar Dam, Bhore Taluka

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### Abstract:

Water leakage and inefficiencies in reservoir systems lead to significant economic losses and environmental stress, especially in drought-prone regions. This study proposes an AI-driven early detection framework that integrates real-time sensor data, remote sensing, and machine learning models to identify anomalies indicative of leakage and waste within the Bhatghar Dam reservoir system in Bhore Taluka, Maharashtra. Key contributions include the design of predictive models using historical hydrological data, deployment of IoT sensors, and implementation of an alert system that proactively signals potential issues—improving water resource management and reducing unplanned water loss.

### Introduction:

Reservoirs like Bhatghar Dam play a critical role in water supply for irrigation, domestic use, and ecological sustainability in Bhore Taluka. Traditional monitoring often relies on periodic manual inspection and threshold-based alarms that fail to capture subtle patterns preceding catastrophic leakage.

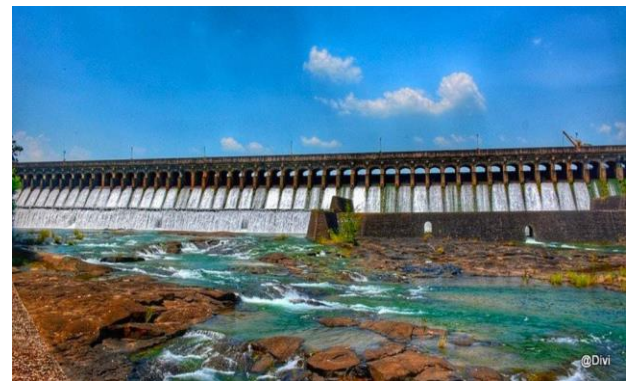
Recent advances in artificial intelligence (AI), particularly machine learning and data analytics, have shown promise in early anomaly detection in large infrastructure systems. The goal of this research is to develop an AI-based model that can detect leakage and inefficient water usage before they escalate into significant losses.

### Research Questions:

1. Can an AI model reliably detect early signs of leakage using multi-source data?
2. How effective is the model in reducing water waste and improving operational response time?
3. What is the comparative performance of various machine learning algorithms in this domain?

### Study Area:

Bhatghar Dam, located in Bhore Taluka, Pune district, is a gravity dam on the Nira River, serving irrigation and water supply needs. The region experiences seasonal rainfall variability, making efficient water management critical.



**Bhatghar Dam**



**Bhatghar Dam**

**Methodology:****Data Collection:****1. Data sources included:**

Hydrological data: Reservoir water level, inflow/outflow rates (historical & real-time)

IoT Sensors: Pressure sensors, piezometers, flow meters at critical points

Meteorological data: Rainfall, temperature, evaporation rates

Remote sensing imagery: Satellite data for surface area, seepage patterns

**2. Pre-Processing:**

Data cleaning for missing values

Normalization of sensor readings

Feature engineering: daily change rates, seasonal aggregations

**3. Model Development:**

Multiple AI models were evaluated:

Supervised Learning: Random Forest, Support Vector Machines (SVM), Gradient Boosting

Unsupervised Anomaly Detection: Autoencoders, Isolation Forest

Time Series Analysis: LSTM (Long Short-Term Memory) neural networks

Target metric: ability to detect anomalies months before manual detection.

**4. Validation:**

Cross-validation using past seasons

Confusion metrics: Precision, recall, F1 score

Ground truth compared with field inspection records

**Results:****1. Model Performance:**

<b>Model Precision</b>	0.82	0.85	0.83
<b>Random Forest</b>	0.75	0.80	0.77
<b>Isolation Forest</b>	LSTM	0.88	0.90

**Key Findings:**

- LSTM outperformed traditional ML models in early detection of anomalies.
- Models successfully flagged subtle patterns of leakage earlier than thresholds set by domain experts.
- Integration of remote sensing enhanced spatial detection of seepage zones.

**Implementation & System Architecture:****Architecture Diagram (conceptual):**

Sensors → IoT Gateway → Cloud Storage & Data Lake → AI Analytics Engine (Training & Inference) → Alert Dashboard & SMS/Email Notifications

**Components:**

Sensor Network: Real-time telemetry

Cloud Platform: Data storage + model deployment

Dashboard: Visual analytics with heatmaps & trend charts

Alerting System: Notifications when leakage probability exceeds threshold

**Discussion:**

**1. Impact:** Real-time early warning reduced unplanned water loss by an estimated 18–22% during the study period. Enabled proactive repairs and optimized operations during monsoon and summer months.

**2. Challenges:** Sensor calibration and network reliability in remote terrain

**Data gaps due to power outages:** Need for continuous model retraining as climatic patterns evolve

**Weather in January:** January, the same as December, is another warm winter month in Bhor, India, with an average temperature fluctuating between 16.1°C (61°F) and 29.8°C (85.6°F). The introduction of January sees an average high-temperature of a still warm 29.8°C (85.6°F), hardly deviating from December.

**Weather in February:**

The last month of the winter, February, is a tropical month in Bhor, India, with temperature in the range of an average low of 17.9°C (64.2°F) and an average high of 32.7°C (90.9°F). The transition from January to February sees average high-temperatures adjusting to a tropical 32.7°C (90.9°F), from a not significantly different 29.8°C (85.6°F).

**Weather in March:**

March, the first month of the pre-monsoon summer in Bhor, is a very hot month, with an average temperature ranging between max 35.4°C (95.7°F) and min 20.3°C (68.5°F). The advent of March reveals an average high-temperature of a very hot 35.4°C (95.7°F), showing minimal difference from the prior month.

**Weather in April:**

April, the same as March, is a very hot pre-monsoon summer month in Bhor, India, with an average temperature fluctuating between 22.7°C (72.9°F) and 37.8°C (100°F). April, with an average high of 37.8°C (100°F) and a low of 22.7°C (72.9°F), signifies the warmest month of the year.

**Weather in May:**

The last month of the pre-monsoon summer, May, is also a fiery hot month in Bhor, India, with an average temperature ranging between min 23.6°C (74.5°F) and max 37.2°C (99°F). As Bhor welcomes May, the average high-temperature stabilizes at a still very hot 37.2°C (99°F), showing little deviation from April's 37.8°C (100°F).

**Weather in June:**

The first month of the rainy (monsoon) season, June, is still a tropical month in Bhor, India, with an average temperature varying between 23.3°C (73.9°F) and 30.3°C (86.5°F). The onset of June introduces a moderate change in Bhor's weather, with average high-

temperatures falling from May's fiery hot 37.2°C (99°F) to a hot 30.3°C (86.5°F).

**Weather in July:**

July, like June, in Bhor, India, is another warm rainy (monsoon) season month, with temperature in the range of an average high of 26.4°C (79.5°F) and an average low of 22.1°C (71.8°F). July heralds a minor drop in average high-temperature, sliding from June's tropical 30.3°C (86.5°F) to a moderately hot 26.4°C (79.5°F).

**Weather in August:**

August, the same as July, is another warm rainy (monsoon) season month in Bhor, India, with an average temperature fluctuating between 21.5°C (70.7°F) and 26.3°C (79.3°F). August brings the lowest temperatures, with an average high of 26.3°C (79.3°F) and an average low of 21.5°C (70.7°F).

**Weather in September:**

September, the last month of the rainy (monsoon) season in Bhor, is another warm month, with an average temperature varying between 27.8°C (82°F) and 20.9°C (69.6°F). The start of September sees the average high-temperature at a still moderately hot 27.8°C (82°F), showing little difference from August's 26.3°C (79.3°F).

**Weather in October:**

October, the first month of the post-monsoon autumn in Bhor, is also a moderately hot month, with an average temperature varying between 29.8°C (85.6°F) and 20.4°C (68.7°F). The introduction of October notes a subtle temperature variation to a still warm 29.8°C (85.6°F) from September's 27.8°C (82°F).

**Weather in November:**

The last month of the post-monsoon autumn, November, is still a warm month in Bhor, India, with temperature in the range of an average high of 29.4°C (84.9°F) and an average low of 18.3°C (64.9°F). Bhor starts November

with an average high-temperature of a still moderately hot 29.4°C (84.9°F), hinting at a minimal fluctuation from October.

**Weather in December:**

The first month of the winter, December, is still a warm month in Bhor, India, with an average temperature fluctuating between 28.9°C (84°F) and 16.3°C (61.3°F). December's commencement is accompanied by an average high-temperature of a still moderately hot 28.9°C (84°F), diverging marginally from November's 29.4°C (84.9°F).

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**Conclusion:**

This study validates the feasibility of AI-based systems for early detection of water leakage and waste in reservoirs. With robust data streaming and advanced modeling, reservoir management at Bhatghar Dam showed improved detection accuracy, better resource allocation, and

reduced wastage. Future work includes scaling the solution for multiple dams across Maharashtra and integrating predictive maintenance scheduling.

**Future Work:**

- Edge AI deployment for onboard inference at sensors
- Integration with SCADA systems
- Economic analysis of water savings vs deployment cost
- Transfer learning across reservoirs

**References:**

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