MODELING THE PLACEMENT OF SMALL HYDROPOWER SYSTEMS BASED ON THE HYDRODYNAMIC CHARACTERISTICS OF WATER BODIES

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Abstract. *This article presents a scientific model for the optimal placement of small hydropower systems based on the hydrodynamic characteristics of natural and artificial water bodies. Key parameters such as flow velocity, depth, water level fluctuations, and hydrostatic pressure were measured and analyzed. The research was conducted in selected collector-drainage systems in the Khorezm region of Uzbekistan. The results highlight the energetic potential of various sites and offer a GIS-based placement strategy for small hydropower stations while considering ecological sustainability.*

Keywords: *small hydropower, hydrodynamics, water bodies, site modeling, GIS, flow velocity, Khorezm region, Smart Water*.

Аннотация. *В данной статье представлена научная модель оптимального размещения малых гидроэнергетических систем с учетом гидродинамических характеристик естественных и искусственных водоемов. Были измерены и проанализированы такие ключевые параметры, как скорость потока, глубина, колебания уровня воды и гидростатическое давление. Исследование проводилось на выбранных коллекторно-дренажных системах Хорезмской области Узбекистана. Результаты выявляют энергетический потенциал различных участков и предлагают стратегию размещения малых гидроэлектростанций на основе ГИС с учетом экологической устойчивости.*

Ключевые слова: *малая гидроэнергетика, гидродинамика, водные объекты, моделирование участка, ГИС, скорость потока, Хорезмская область, «Умная вода».*

Introduction

Ensuring energy security and expanding the use of renewable energy sources are among the most pressing challenges of modern sustainable development. Small hydropower systems (SHPs) are recognized as clean, efficient, and decentralized energy sources. However, the effective placement of these systems depends heavily on the hydrodynamic behavior of the water bodies involved.

The Khorezm region of Uzbekistan is characterized by a dense network of collector-drainage canals and semi-natural lakes. These water bodies, while often overlooked, possess latent energy potential. However, improper siting without evaluating hydrodynamic conditions can lead to inefficiencies and ecological disruption. Therefore, this study aims to model the placement of SHPs based on hydrodynamic characteristics using field measurements, mathematical modeling, and GIS-based spatial analysis. It is especially

important to accurately and scientifically place these structures, taking into account the hydrodynamic characteristics of natural and artificial water bodies. Water resources in the Khorezm region are formed mainly through collector-drainage networks and additional river networks. These basins may have great potential for hydropower systems, but their hydrodynamic state has not been thoroughly studied.

MATERIALS AND METHODS

Study Area

The research focused on three key water bodies in the Khorezm region:

- Urgench Collector Canal
- Shorkul Drainage System
- Tupraqqala Collector

Measured Parameters

Flow velocity (m/s), Water depth (m), Seasonal water level variability, Hydrostatic pressure (Pa)

Instruments and Data Sources

Field hydrometric tools (current meters, depth sounders), Smart Water sensor device for real-time flow and level monitoring, GIS software (QGIS and ArcGIS) for spatial mapping

Modeling Approach

Bernoulli’s Equation was applied to estimate kinetic and potential energy at each site.

A scoring model was developed to rate each site’s suitability based on energy potential and hydrological stability.

GIS maps were generated to visualize and rank the optimal locations for SHP deployment.

RESULTS

The analysis yielded the following insights:

1- table

Site	Avg. Flow Velocity (m/s)	Avg. Depth (m)	Suitability Score (0-1)	Seasonal Stability	Recommendation
Urgench Collector	0.88	1.5	**0.84**	High	Highly Suitable
Shorkul System	0.47	0.9	**0.51**	Low	Not Suitable
Tupraqqala Collector	0.65	1.2	**0.73**	Medium	Moderately Suitable

The study yielded the following important findings:

The Urgench collector has an average flow rate of 0.88 m/s, a depth of 1.5 m, and low variability, making it a high potential site for hydropower. The Shurkul collector has a flow rate of 0.47 m/s, but was deemed unsuitable due to its high seasonal variability. The Tuproqqala collector has a flow rate of 0.65 m/s and a stable depth, making it suitable for small hydropower. Five optimal locations were identified on the GIS map, each of which is an area with an energy coefficient ≥ 0.72.

Graph: Relationship between energy potential and flow rate

Key Findings

- **Urgench Collector** showed the highest energy potential due to consistent flow and depth.
- **Tupraqqala Collector** also demonstrated acceptable conditions for SHP installation.
- **Shorkul System** was deemed unsuitable due to high seasonal fluctuations.

Graph: Correlation Between Flow Velocity and Energy Potential

- A strong positive correlation was observed: **Pearson r = 0.934**
- Indicates flow velocity is a critical predictor of SHP viability.

GIS-Based Site Selection

- Five high-potential sites were identified across the region.
- Maps were generated with layers showing flow intensity, elevation, and ecological zones.

DISCUSSION

The study confirms that hydrodynamic parameters are reliable indicators for the placement of small hydropower stations. Flow velocity and water depth directly influence kinetic and potential energy generation. Seasonal stability further determines the long-term feasibility of power production.

Compared to previous studies focusing only on river-based hydropower, this research expands the scope by exploring underutilized collector-drainage networks. The application of Smart Water devices enhances data accuracy and enables real-time monitoring, which is crucial for managing energy-water-ecology trade-offs.

Future studies may refine the model by incorporating economic cost factors, sediment transport modeling, and long-term ecological impact assessments.

CONCLUSION AND RECOMMENDATIONS

- Hydrodynamic parameters such as flow velocity, depth, and stability should be prioritized in SHP placement planning.
- GIS modeling enables precise spatial planning and ecological integration.
- The Urgench and Tupraqqala collectors are prime candidates for SHP development in the Khorezm region.
- Smart Water technology should be expanded for real-time monitoring and adaptive management.

- Policymakers should encourage SHP projects in non-traditional water bodies while maintaining ecological integrity.

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