**Software Modelling of Experimentally Measured Parshall Flumes for Evaluating Aeration Performance**

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**ABSTRACT**

A Parshall flume is a stationary hydraulic structure used to measure liquid flow in a channel or flume. It comprises a segment that gets smaller before coming to an expanding outlet and a foundation that is level. The "throat" is the narrowest portion and includes areas with upward-sloping sides and a downward floor. The Parshall flume's main function is to accurately calculate flow rates, and its secondary use is to aid in boosting the amount of oxygen in a channel. The Parshall flume's narrowing section experiences increased flow speed. Dissolved oxygen is a crucial factor in ensuring the sustainability of aquatic habitats. The installation of Parshall flumes is one method for increasing the amount of oxygen in rivers. There is a lot of information that is readily accessible as a result of the communication and interaction between flow-measuring equipment and sensors. The main goal of artificial intelligence research is to use data and technology to improve the accuracy and efficiency of flow-measuring equipment. A type of artificial intelligence known as "machine learning" enables software applications to improve their capacity for outcome forecasting without explicit, direct programming. These algorithms take into account experimental and past data as input and predict new output values for improved utilization and comprehension.

**KEYWORDS:** - Parshall flume, Machine learning (ML), Artificial intelligence (AI), Aeration

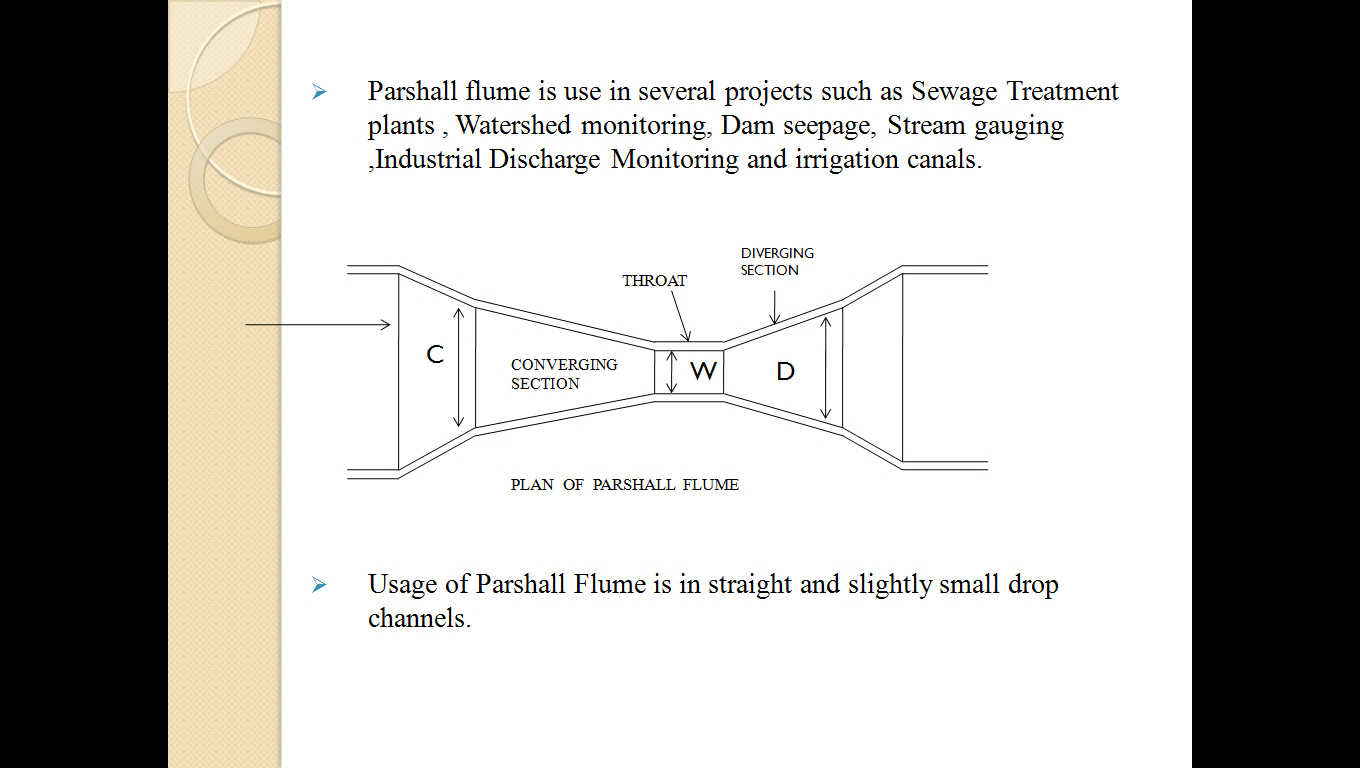
**I INTRODUCTION**

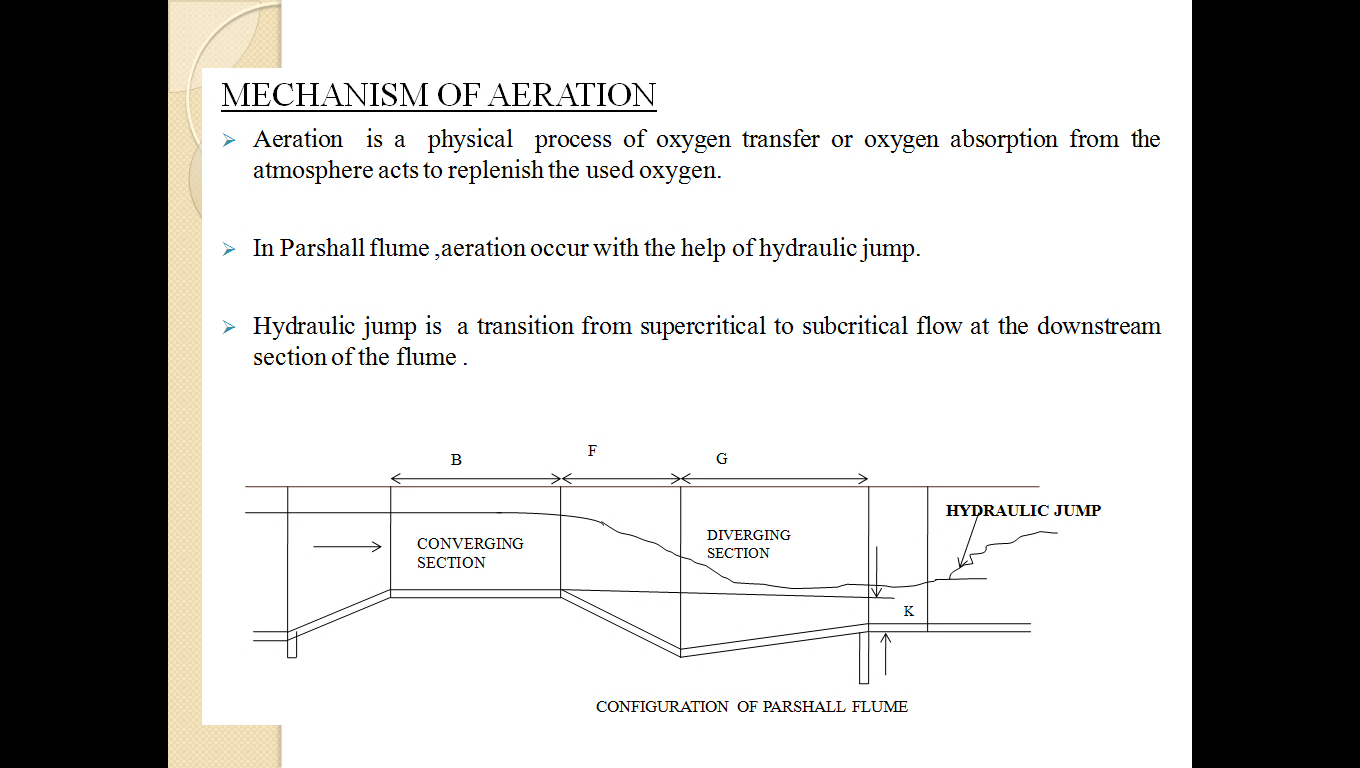
A major indicator for determining the health of rivers and artificial canal systems, which are essential for both human usage and aquatic life, is the level of oxygen present in both surface and subsurface layers. Due to the lack of water turbulence in large reservoirs created by dams, oxygen concentrations are frequently low. This problem develops in irrigation channels as well, endangering aquatic life. Different hydraulic structures, such as stepped spillways, nozzle orifices, and free overflow designs, provide efficient responses to these issues. Stepped spillways and free overfall spillways are successful at improving aeration in river environments.Straight canals, on the other hand, may not be suitable for these alternatives, which leads to a preference for drop structures like baffled blocks, chutes, weirs, and cascades. Small Parshall flumes are an effective solution for straight channels with little slope. These hydraulic systems function by creating turbulence, which causes tiny air bubbles to mix with the flowing mass. Through the physical aeration process, which is also known as re-aeration, used oxygen is replaced.

The Parshall flume is divided into three sections: a beginning section that narrows, a middle section with an upward-sloping throat, and a concluding section that widens. For high-velocity flow in bigger Parshall flumes, several researchers developed a brand-new rating equation [1]. Some researchers used a small 3-inch Parshall flume and a modified venturi flume in their trials, and they found that these structures significantly improve the flow's aeration efficiency [2].

The general geometrical dimensions of the Parshall flume as shown in Figure 1.

* W- Throat width of Parshall flume
* K- Sill Height of Parshall Flume.
* F- Length of throat section.
* C- Width at the entrance of the converging section.
* D-Width at the end of the diverging section.
* B-Length of converging section.
* G-Length of diverging section.

(A)



(B)

**Fig.1 Layout of Parshall flume (A) Plan view of Parshall Flume, (B) Front view of Parshall flume**

**II AERATION METHODS IN DIFFERENT HYDRAULIC CONSTRUCTIONS**

For increasing wastewater volumes within moving water bodies, hydraulic constructions like nozzle orifices, venturi aerators, and stepped spillway weirs provide the best options. These hydraulic structures use different aeration techniques depending on their size, form, place of manufacturing, and length of the structure.

The following list of strategies for adding air to water bodies (aeration techniques) includes:

(a) Jet-based aeration,

(b) Stepped flow patterns.

(c) Hydraulic jump-achieved aeration, which promotes energy dissipation

By ensuring that the concentration of dissolved gases in the water stays within acceptable bounds, these systems help to improve water quality.

**III AERATION OF JETS**

A complex process is involved in aeration when a free overflow jet is used [3]. Figure 2 shows the four fundamental ways that air is drawn, as identified by [4].

A. Mode 1 - Continuous and Solid Jet:

• The air supply surrounds the jet in the shape of a thin layer.

• The capacity for air entrainment within the flow is limited.

• The surface of the water in the storage pool remains relatively calm.

B. Mode 2 - Oscillating Jet:

• Aeration takes place through the presence of sizable air pockets trapped between the surface of the pool and the rippling jet.

• Air is drawn in through the creation of a surface wave and splashing.

C. Mode 3 - Jet with Rough and Solid Surface:

• The introduction of air is more pronounced due to the development of trapped air pockets.

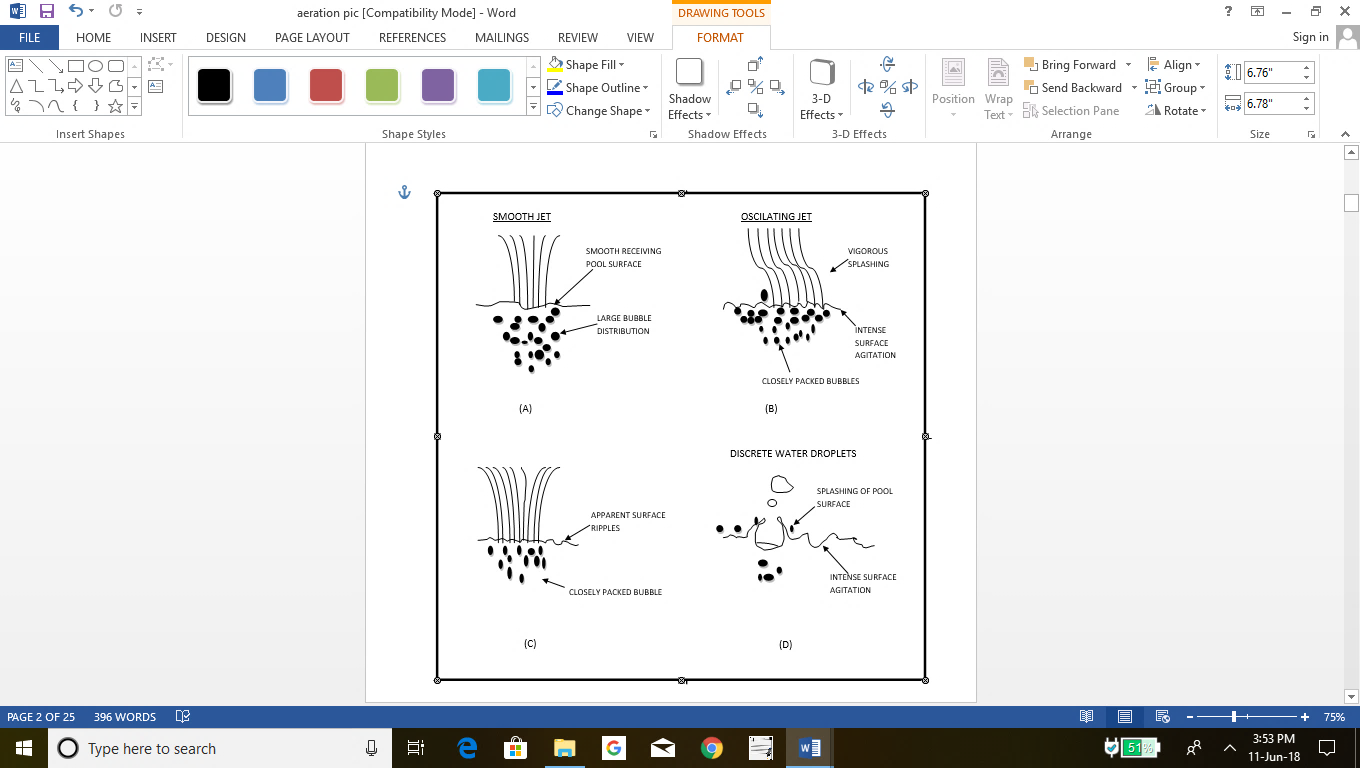
• This is influenced by the roughness of the jet's surface and the water level in the receiving pool.

• The process shares similarities with the smooth and solid jet.

D. Mode 4 - Fragmented Jet:

• The surface of the receiving pool experiences vigorous disturbance.

• Aeration happens as surface waves and pockets of air engulfing take effect.



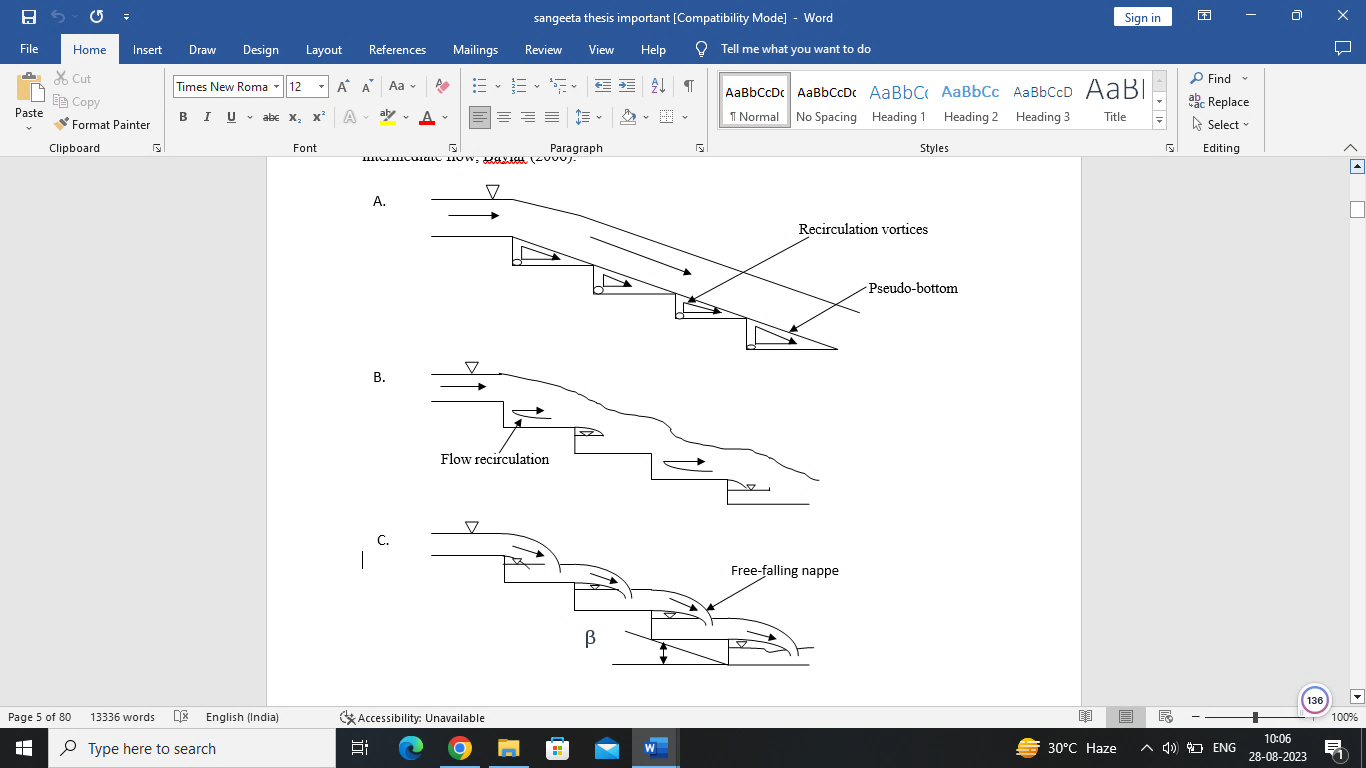
**Fig.2 Process of bubble creation through overfall jets exhibiting different levels of turbulence.**

**IV AERATION THROUGH STEPPED FLOW**

The graded spillway flow is what causes the significant self-aeration [5]. In Figure 3, a classification of the stepped flow phenomenon is shown.

1. Surface Skimming Flow
2. The Flow of Transition
3. Sheet Flow Up the Stairs

A recirculation region develops when there is a high discharge because water slides across the stairs. A sheet-like flow, known as nappe flow, is formed when the discharge is low and the steps are wide, on the other hand. At intermediate flow rates, the transitional flow regime begins to develop[5].



**Fig.3 Regimes of Flow :( A) Skimming flow, (B) Transition flow, (C) Nappe flow**

**V CURRENT UNDERSTANDING OF THE PARSHALL FLUME**

Currently, one of the most frequently used instruments for determining surface flow around the world is the Parshall flume. Many academics have been working on various aspects of the flume's design and operation for a long time in an effort to improve, streamline, and perfect them. The Parshall flume was created as a result of the intensive experimental studies that they culminated in.For those who may not be familiar with the Parshall flume's historical development, a brief summary of that development is given. In 1917, Cone was the first to suggest the idea of a flume with a short neck part in the middle, a diverging section, and a converging section in between. Throughout its whole length, Cone's "venturi flume" had a flat bottom. Cone thought it possible that the flume's specifications might need to be changed. Over a period of several decades, Dr. Parshall conducted substantial and thorough study. Parshall created the modern flume and expanded its applications, particularly in the field of agriculture, first working with Rowher in collaboration in 1921 and then on his own in 1928. His interpretation of the Parshall flume features an upstream converging part, a downstream diverging exit section, and an intermediate flat throat section that maintains a specified width along with a downward-sloping floor and an upward-sloping segment. Weirs of various shapes and Venturi flumes were used to measure flow at this time, but these instruments had a number of limitations and problems.

Dr. Parshall submitted an application for a patent for his original "Parshall flume" design six years after he started working on the creation of the "modified Venturi flume." Following that, similar flumes were erected in several irrigation facilities all around the United States [6]. The "Venturi Flume" was dubbed the "Parshall Measuring Flume" by the American Society of Civil Engineers' (ASCE) Irrigation Hydraulics Committee in 1929.

**VI MACHINE LEARNING TECHNIQUES**

Machine learning is a method of data analysis that gives computers the capacity to learn things the way people and other animals learn things naturally. This involves the use of computational methods by machine learning algorithms to extract insights directly from data, without the need for a pre-established equation to act as a model. The algorithm modifies itself to improve its efficacy as the number of examples available for learning increases. On the other hand, deep learning is a unique form of machine learning.

An overview of the numerous techniques used to evaluate the Parshall flume's performance using machine-based methodologies.

1. GAUSSIAN PROCESSES (GP)

The Bayseria framework for Gaussian Processes (GP) regression is one non-parametric model that has received attention in the field of machine learning. The GP regression method is non-parametric and probabilistic in character. According to [7] and [8], who proved the probabilistic mean technique of GP regression with regard to input data, it is useful in a variety of hydraulic engineering conundrums. A functional space-spanning pathway is represented by Gaussian Processes (GP). Any finite set of values in a GP manifests a multivariate joint Gaussian distribution [9]. A GP is a collection of random variables.

b) M5P TREE MODEL

Numerous experimental studies have highlighted the importance of the M5P model in the management of water resources. The GP and regression approaches have both shown themselves to be superior to the neural network approach in this situation. On their dataset, they used the M5P model tree-based regression technique to get good results [10]. This technique entails creating a linear regression model for each of the compact subspaces created by partitioning the parameter space into subspaces. The Model Tree, which keeps fixed values at its terminal nodes and makes it comparable to a linear function, extends and generalizes the idea of regression trees.

The main and most obvious benefit of using model trees over regression trees is the better compactness of the model trees as compared to the generated regression trees. Model trees' regression function uses fewer variables and allows for more precise decision-making. The M5 algorithm is used for the ongoing study. The M5P seeks to create a model that establishes a relationship between the input variables and the fixed target value of the training dataset. Based on how well these models predict values for hypothetical instances, their predictive ability can be evaluated.

c) ARTIFICIAL NEURAL NETWORK (ANN)

The idea of ANN is inspired from the biological nervous system, however it leaves out some of the finer biological details. ANNs are large-scale systems that mimic the organization of the human brain by utilizing several parallel processing units linked together. The multilayer backpropagation network (MLP), among the different ANN paradigms, is the most appropriate architecture.

Multiple parallel processing units known as neurons make up ANN networks. The connectivity strengths (S) or weights (W) of each layer within the ANN connect it to the layer below it. Throughout training, initial weight estimates are continuously modified. In this procedure, all errors are propagated backwards by comparing the anticipated output to the actual data. To increase training speed and get around problems like local minima, adaptive learning rates are used.Trial-and-error techniques are used to determine the number of neurons in buried layers. Significant research attention has recently been focused on the field of ANN. Numerous fields, including speech recognition [11] and picture recognition [12], are where they are used. There have been numerous efforts made to determine the ideal ANN parameter values. The choice of these ideal values frequently depends on statistical indicators like the correlation coefficient and root mean square error (RMSE).

d) ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM (ANFIS)

A platform that is flexible and extends its capabilities beyond numerical analysis into multi-domain simulations is offered by MATLAB, a program designed primarily for numerical computing. ANFIS, a computational system based on computer software, works by using different training and testing datasets as inputs to produce useful output results. Gradient descent and the least squares approach are two learning approaches that can be effectively combined to create the hybrid learning approach known as ANFIS. The gradient descent, as an addition to the least squares approach, facilitates the progressive change in the underlying nature of the membership function, which is the key component driving quick training.

As a result, ANFIS frequently produces positive results soon after training begins, especially after the first application of the least square approach. The output is created by joining all of the inputs at the interface layer. The literature has developed a variety of categorization approaches, some of which are based on fuzzy logic. The fuzzy logic approach's key strength is its capacity to handle uncertainty in context. Researchers work to create models that are effective at turning what people see as significant categories into concrete results. Three inputs were used for two different ANFIS models in the software modeling technique used by [13] to determine the air entrainment rate of a weir.

**VII FUNDAMENTAL APPROACH EMPLOYED IN THE ASSESSMENT OF THE PERFORMANCE OF PARSHALL FLUME**

**Fig.4 Methodology used in software technique**

**VIII CONCLUSION**

The understanding of complex patterns among numerous function variables is substantially improved by the use of machine learning techniques, a type of software-driven analysis. This method helps in the development of intricate and ideal equations suited to desired results. A deeper understanding of underlying phenomena is being achieved thanks in large part to the steadily increasing application of machine learning. Different approaches produce different associations, so it is important to carefully choose the best one. For instance, the M5P method outperforms ANFIS when used in the context of Parshall flume analysis.Similar to this, it has been discovered that when dealing with hydraulic systems, the Person VII Universal Kernel (PUK) Gaussian Process (GP) provides somewhat improved results when compared to the Gaussian Process (GP) using the Radial Basis Function (RBF) Kernel in the situation of small Parshall Flume [13]. Utilizing machine learning for the analysis of various hydraulic structures is a focus of many researchers.

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