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# Comparative evaluation of three distinct energy optimization tools applied to real water network (Monroe)

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ABSTRACT

Pump station is the biggest energy consumer in a water distribution system (WDS). A large amount of money is expended to provide energy for pumps. The environmental footprint associated with these excess energy demands is a source of concern. By implementing an optimum pump schedule that needs a minimum amount of energy to provide enough pressure and flow for water system, operational cost will be reduced and water system will be more environmentally friendly.

Researchers are trying to find practical tools and methods to optimize pump operation. In this research, Pollutant Emission Pump Station Optimization (PEPSO), Darwin Scheduler (DS) and another approach that uses Markov Decision Processes (MDP) have been used as three different tools for optimizing pump operation of WDS of Monroe, MI, USA. In all three methods pumping optimizations have been done based on reducing energy usage, at the end results of running these three tools have been compared. The comparison results show that pump operation that has been taken from MDP algorithm has the best result in terms of energy usage and the number of pump switches, while pump operation taken from DS can be more effective at volume stored in tanks. The simulations showed PEPSO to be considerably faster than the other two evaluated methods in arriving at the optimum solution.



## 1. Introduction

Water and energy are essential resources that our lives are depending on them, also these two resources are intricately intertwined. For instance, electricity generators, extract energy from water, and water is treated and transferred to consumers by electrical energy. Treating and transferring water to consumers need significant portion of energy. For example, approximately 35% of municipal energy usage is consumed in the water and wastewater facilities [1]; in addition, the most extensive part of the energy is used at pump stations [2]. In the United States 3% of all energy consumption is related to transferring portable water [3]. So optimizing pump operation can result in noticeable energy saving. Beside of energy usage in pump stations, the cost of energy is considerable issue. Over the lifetime of a typical pump, 3% of the total cost is for purchase and 74% is for providing energy [4]. Due to the significant financial implications, engineers, operators and policy makers are trying to find ways to improve the energy efficiency of pumping water in large water transmission systems [2]. Another hazard of over consuming energy is air pollution emission associated with generating and using energy. To consider a WDS as a sustainable system, assessing the amount of pollutant emissions associated with energy consumption is required [5]. Therefore, energy usage, energy cost and pollutant emission, are important factors that should be considered for optimizing a pump operation plan.

Traditionally engineers and experts define some scenarios that include required pressure and flow of WDS and based on available pumping capability and physical characteristics of the network, try to find an operational plan which can answer required pressure and flow of WDS and consume lowest possible amount of energy. But as the number of possible operational plans for a WDS is so large, it is not possible to investigate all possible pump schedules and find the optimum solution. So about four decades ago, researchers started to use some optimization techniques to find the optimum

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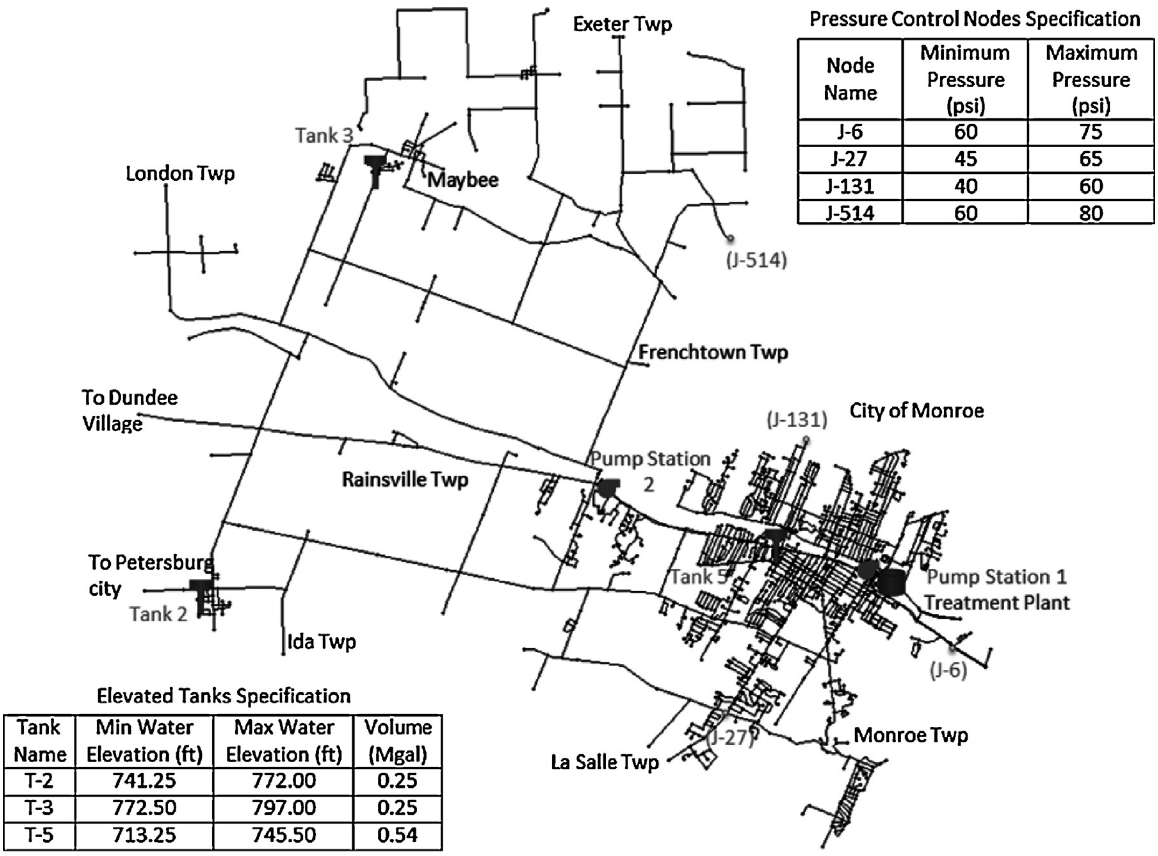


Pressure Control Nodes Specification

| Node Name | Minimum Pressure (psi) | Maximum Pressure (psi) |
|---|---|---|
| J-6 | 60 | 75 |
| J-27 | 45 | 65 |
| J-131 | 40 | 60 |
| J-514 | 60 | 80 |

Elevated Tanks Specification

| Tank Name | Min Water Elevation (ft) | Max Water Elevation (ft) | Volume (Mgal) |
|---|---|---|---|
| T-2 | 741.25 | 772.00 | 0.25 |
| T-3 | 772.50 | 797.00 | 0.25 |
| T-5 | 713.25 | 745.50 | 0.54 |

**Fig. 1.** Monroe water distribution system.

or near optimum solutions [6,7]. It starts with using some deterministic methods but as this type of problem are nonlinear and non-convex, those methods were not so efficient. So about two decades ago, implementing the meta-heuristic and evolutionary methods for operational optimization of WDS gets popular. One of the most famous methods among evolutionary algorithms is the Genetic Algorithm (GA). In mid-nineties, Murphy, Dandy et al. suggested to use the GA in this field and even now it is a popular and effective method for solving these types of problems [8]. GA is one of the most accepted methods to optimize pump operation of WDS [9]. At this time, even most of the commercial WDS optimizers are using this method [10,11]. Although the evolutionary algorithms and specifically GA provided acceptable result but we can find some other research efforts that are focusing on other alternative methods that some aspect of their solution can be better than the near optimum result of other methods like GA. For instance MDP is one of them that Fracasso, Barnes et al. used that for optimizing pump operation of WDS [12].

In this research, three different tools and methods that can optimize pump operation based on reducing energy consumption have been compared. These optimizing approaches include Darwin Scheduler (DS), Pollutant Emission Pump Station Optimization (PEPSO), and Markov Decision Process (MDP). The DS is an optimization tool of a comprehensive commercial water distribution modeling software package (WaterGEMS) that has been developed and distributed in the market by the Haestad Methods. PEPSO is an optimization software that has been developed by a team of engineers and researchers at Wayne State University. These two methods, can optimize pump operation with using genetic algorithm (GA), while in the third method, the MDP was used to optimize pump schedule.

Pump stations of Monroe WDS in Michigan State have been chosen as a case study and used for comparing three optimizing approaches. In addition, for hydraulic simulating of the water system, WaterGEMS software was used in all three methods. This paper is organized in 5 sections, in the second section water system and in the third section three methods have been explained. The fourth section describes the experiment and reports the results, and finally the last section summarizes our conclusion.

## 2. Water system characteristics

The city of Monroe is located 25 miles south of Detroit in southeastern part of Michigan State, along west coast of Lake Erie. The system serves a population of about 40,000 people with total demand of approximately 9.63 million gallons per day (MGD). Its service area covers 117 square miles, including the City of Monroe, City of Petersburg, all of Monroe Charter Township, Raisinville Township and Village of Dundee and Maybee. Also portions of LaSalle, Exeter, London, and Ida Townships are served by Monroe WDS. Total water demand for this system was calculated based on the daily discharge flows from the high lift pumps and water storage tanks. Diurnal patterns of water use were developed from operating logs provided by the utility. General characteristics of Hydraulic model are presented in Table 1.

A model schematic of the Monroe system is illustrated in Fig. 1. For running the water network in allowable pressure range, pressure of several critical nodes has been constrained. The minimum and maximum pressures for these junctions are shown in the upper right corner of Fig. 1. In addition, the minimum and maximum water levels and storage capacities for all three tanks within the system are presented in lower left corner of Fig. 1.