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Optimal design of pumping stations of inland intensive fishfarms

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Abstract

An algorithm for selection of least cost or optimum pump combinations in water supply systems and to evaluate the system's energy cost of inland intensive fishfarms is presented. The model is based on solving a non-linear programming problem. Optimum design refers to the selection of pump type, capacity, and number of units that results in minimum design and operating costs for a given water demand curve. The optimization process consists of three main steps: (1) determination of fishfarm daily water requirements; (2) determination of all sets of pumping stations that satisfy the maximum requirements of flow and energy head of the fishfarm water distribution network; and (3) selection of the least-cost set among the feasible sets of pumping stations. The model was established based on data from an actual eel fishfarm in southern Spain. Application of the model shows that the optimal solution with the pump operation scheme at a constant rate (maximum requirements of flow) saved 70% of the actual total annual cost of the pumping station. The optimal solution with a variable pumping rate (pumped flow adjustment to match demand) saved 92% of the actual total annual cost with all fixed speed pump groups. Savings about 95% were obtained when one variable speed pump group was included in the optimal solution.

Keywords: Energy savings; Pump efficiency; Pump scheduling; Yield costs; Eel

1. Introduction

The energy cost is one of the most important cost components in inland intensive fishfarms. Since large amounts of electricity are required to pump, transport and apply water, the profitability of some farms is heavily dependent upon energy costs. Such as described by Kerr (1981), in an installation requiring a pump delivery head (energy head) of 20 m, the costs of the energy required for pumping might represent some 15% of the farm costs of production.

The rapid increase in energy prices that has occurred during the last decades has created the need for increased emphasis on energy conservation. Due to energy costs for pumping, methodologies that can maximize cost savings while satisfying system performance criteria are sought for the management of fishfarms. One of these methods can be to improve the design or selection of pumping stations. As the diameter, speed of rotation, and type of impeller affect the pump performance, it is appropriate to match the required maximum flow rate to a high pump efficiency. However, the pumping system efficiency falls at lower

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flow rates which, for constant speed pumps, can only be achieved by either dumping the excess flow or throttling the excess pressure. It is therefore sensible to consider that the maximum flow is provided by two, three or more pumps.

In this paper, a methodology is presented for the optimal design of pumping stations in water supply systems and to evaluate the system's energy cost. Optimal design of pumping stations refers to the selection of pump type, capacity, and number of units that results in minimum design and operating costs for a given annual water demand curve. This is a large-scale non-linear programming problem, because of the size of the problem in terms of the number and the nonlinearly of the decision variables and constraints.

Optimization of water supply system operation in municipal water districts have received wide coverage in the literature, e.g., Tarquin and Dowdy (1989), Zessler and Shamir (1989), Brion and Mays (1991), Jowitt and Germanopoulos (1992), Ulanicki et al. (1993), Nitivattananon et al. (1996), Cembrano et al. (2000), León et al. (2000), and Biscos et al. (2003). The main goal of these models is to define the optimal scheduling of the pumping station over a 24-h period. For every hour, the solution must identify the pump, or pump combination, which should be working in order to satisfy the water demand at minimum cost. Nearly all of these works are limited to the operation phase of a given or defined water supply system. In irrigation water supply systems, Buchleiter and Heermann (1986, 1990), Moradi-Jalal et al. (2003) and Planells et al. (2005) have developed methods to optimize the type and number of pumps as well as scheduling the operation of irrigation pumps, considering both the initial investment and the cost of consumed energy. Applications of these models show considerable savings, about 20–25% in annual total cost of the pumping station. In the case of the inland intensive fishfarms, in spite of the high energy costs required for pumping, it is surprising to find few studies in the literature based on the optimum design and management of the water supply systems (Kerr, 1981).

A 24-h water demand pattern is assumed in the most of the aforementioned investigations. In this paper, a daily demand histogram during the annual operation period is considered. The full demand during the annual operation period must be satisfied through the designed pumping station. The annual water demand curve allows to select pump combinations which result in the lowest annual total cost (annual depreciation cost and annual operation cost), and that the energy cost evaluation of the delivery system is determined in a more approximate form in comparison with the 'traditional' methods that consider only the point of maximum necessity operation (Stetson et al., 1975; Lansey and Mays, 1989; Jowitt and Germanopoulos, 1992; Breytenbach et al., 1996).

The determination of the optimal design of pumping stations for a given annual water demand curve by means an optimization method is the main purpose of this paper. Once the optimization process and the method of solution were identified, a program for a personal computer was written to find the optimal design of the pumping station. This program was named ACUIGES v.1.0 and was written in Microsoft Visual Basic® programming language. The mathematical model development in this paper forms the basis of ACUIGES v.1.0 software. The model was verified by applying the developed software to an intensive eel fishfarm located in southern Spain.

2. Material and methods

The design of a pumping station includes the selection of type, size and number of pump units for specified water demand characteristics. The optimization process to determine the optimal design of pumping stations in water supply systems of intensive inland fishfarms consists of three main steps: (1) determination of fishfarm daily water requirements (Section 2.1); (2) determination of all sets of pumping stations that satisfy the maximum requirements of flow and energy head of the fishfarm water distribution network; and (3) selection of the least-cost set among the feasible sets of pumping stations. To implement the steps (2 and 3) in the optimization process, a pump selection algorithm was developed for finding the least cost or optimum pump combinations (Sections 2.2 and 2.3).

2.1. Water requirements of the fishfarm

The determination of the water requirements can be expressed according to Eq. (1) (Kerr, 1981):

$$\mathrm{Demand}(t) = \frac{\mathrm{SOC} \cdot \mathrm{Bio}(t)}{C_{\mathrm{in}} - C_{\mathrm{out}}} \tag{1}$$

where Demand(t) represents water requirements at time period t in l/min per cubic meter of rearing volume; SOC is the specific oxygen consumption of the fish in mg O_2/kg min; Bio(t) is the biomass at time period t expressed as fish density in kg/m^3; C_{in} represents the inlet water's oxygen concentration in mg O_2/l; and C_{out} is the outlet water's oxygen concentration in mg O_2/l.

2.2. Pump selection algorithm: mathematical model development

The main purpose of the optimization model described in this paper is to minimize the total annual costs of pumping stations, which are composed of both annual depreciation cost and annual operation cost. The objective function may be formulated as:

$$\mathrm{Min}(\mathrm{ATC})_k = \left[\sum_{t=1}^{m}\sum_{j=1}^{n}\frac{\gamma Q_j(t)\mathrm{TDH}_j(t)}{\eta_j(t)}C_{\mathrm{E}}(t)\Delta t\right] + \left[\sum_{j=1}^{n}\frac{r(1+r)^{\mathrm{T}}}{(1+r)^{\mathrm{T}}-1}C_{I,j}\right] \quad (2)$$

in which $(\mathrm{ATC})_k$ is the annual total cost of pumping station k; m the number of time steps of the optimization procedure; n the number of groups or machines of pumping station k; γ the specific gravity of the water; $Q_j(t)$ the discharge from pump j at time period t; $\mathrm{TDH}_j(t)$ the pumping head or total dynamic head of pump j at time step t; $\eta_j(t)$ the efficiency of pump j at time step t; $C_{\mathrm{E}}(t)$ the unit energy cost at time step t, in €/kWh; Δt the length of time that pumping station k operates during period t; r the rate of interest; T the project 's useful life; and $C_{I,j}$ is the cost of the jth machine. The objective function Eq. (2) is constrained by:

- Limitations on pump discharge $Q_j(t)$ and discharge energy head $\mathrm{TDH}_j(t)$ that are function of the hydraulic characteristics of the pumps:

$$Q_j(t) \le Q\mathrm{max}_j \quad \text{and} \quad \mathrm{TDHmin}_j \le \mathrm{TDH}_j(t) \le \mathrm{TDHmax}_j \quad \forall t \quad (3)$$

where $Q\mathrm{max}_j$ is the maximum discharge of pump j and TDHmin_j and TDHmax_j are the minimum and maximum pumping heads of pump j, respectively.

- Mass balance, that is to say, the total discharge from pumping station must be equal to the total water demand of the fishfarm (Demand) at time step t:

$$\sum_{j=1}^{n} Q_j(t) = \mathrm{Demand}(t) \quad \forall t \quad (4)$$

There are two difficulties in formulating this model. First, the cost function tends to be non-linear in terms of pump discharge and discharge energy head. Second, a computational time problem occurs when a large number of time steps for a planning period is considered in the model. These difficulties are due to the fact that Eqs. (2)–(4) are directly dependent on the type, size, and number of pumping units, as well as the water demand curves and number of time increments used in the discretization scheme of the demand curves. As a result, an iterative solution of the optimization problem is generally required (Section 2.3). Further simplification can be achieved by selecting equal time increments Δt for the discretization of the demand curves. In this study, daily increments were considered because typically the operating plan of water distribution systems is prepared for a period of 24 h in advance (Shvartser et al., 1993; Pulido-Calvo et al., 2003b).

2.3. Pump selection algorithm: solution of mathematical model

Pump performance is expressed by energy head discharge TDH–Q and power consumption discharge P–Q curves (characteristic curves or pump performance curves or manufacturers' curves). These curves may be approximated by quadratic equations (Sabet and Helweg, 1989; Yin et al., 1996; Mays, 2000; Moradi-Jalal et al., 2003; Pulido-Calvo et al., 2003a):

$$\mathrm{TDH} = AQ^2 + BQ + C \qquad P = DQ^2 + EQ + F \quad (5)$$

The A to F coefficients were obtained by means of least-squares regression techniques using the TDH–Q data pairs and P–Q data pairs obtained from digitalized manufactures' curves for each pump size and type (range of pump discharge: 1–5000 m^3/h and range of pump head: 1–180 m). The polynomial coefficients and the investment cost of each pump were stored in Microsoft EXCEL® data files. Therefore, the database structure for the pump data had seven columns (A to F coefficients + pump investment cost) and 437 rows (437 different pumps).

Generally, several pumps of similar sizes may operate in parallel to satisfy the different flow and head requirements at the pumping station. Second-order polynomial equations for TDH–Q and P–Q are calculated for each pump type and for all possible pump combinations using least-square regressions.

Given the characteristics of the distribution system and the water daily demands, the required energy head H_{p} at time period t in the pumping to the fishfarm (system head curve) is calculated applying the energy equation (Walski, 1984; Mays, 2000):

$$H_{\mathrm{p}}(t) = H_{\mathrm{ST}} + h_f(t) \quad (6)$$

where H_{ST} is the total static head that is defined to be equal to the vertical height between the low water level

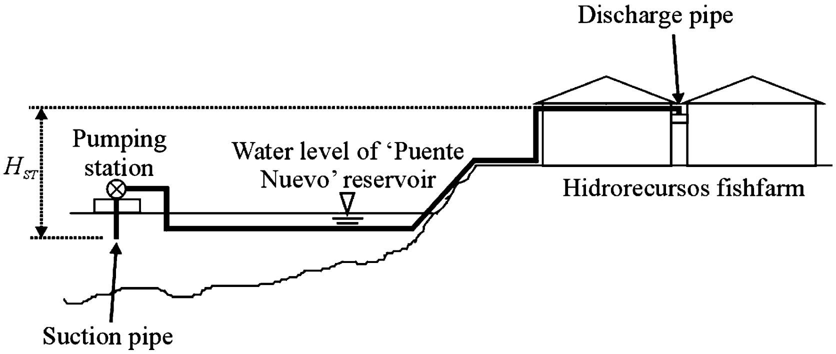


Fig. 1. Scheme of water supply system of Hidrorecursos fishfarm.

and the highest fishfarm delivery point and h_f is the total friction loss (Fig. 1).

The friction head losses h_f in Eq. (6) are calculated applying the Darcy–Weisbach equation and the friction factor f is estimated by means of the Colebrook–White equation (Eq. (8)):

$$H_{\mathrm{p}}(t) = H_{\mathrm{ST}} + 8f\frac{\mathrm{L}Q(t)^2}{2g\pi^2D^5} \tag{7}$$

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{k/D}{3.7} + \frac{2.51}{\Re\sqrt{f}}\right) \tag{8}$$

where L and D are the suction or discharge pipes length and diameter, respectively, $\Re$ is the Reynold's number, and k/D is the relative roughness that is function of pipe material type.

The pump selection algorithm developed in this paper is a direct procedure for finding the least cost or optimum pump combinations. Several pump combinations can satisfy the maximum requirements of flow and energy head of the water distribution system. The search procedure for selecting pump combinations divides the maximum flow 2, 3, ..., q times. In this way, for each value of the division d ($2 \leq d \leq q$; in this case, $q = 10$ is considered in this paper), the pumps are chosen that give the flow (Q/d) with energy head equal to or higher than the maximum requirements (H_{p}) of the water distribution network (Fig. 2: in this case, I_2 is impeller selected). If a pump combination can supply the flow but not at the required energy head, a penalty is added to discourage selection of this combination. For example, in Fig. 2 the impellers I_3, I_4 and I_5 are not selected because they cannot supply the required energy head (H_{p}). The pump combinations are also chosen with pump efficiency equal to or higher than 60% (large losses of power consumption are avoided).

With the requirements of flow and energy head of the water distribution network (system head curve) in each time step (daily step) of the annual operation period and with the selected pump combinations, the system's energy cost is evaluated. The power consumption discharge P–Q curves will determine the power consumption P for each time step t and hence the energy cost. The final step in the optimal design is to select the pumping station system with the minimum annual cost, which is a function of both energy cost and depreciation cost of the initial investment.

The steps in the development of the optimization model are summarized in Fig. 3 and can be explained as follows: (1) determination of all sets of pumping stations that satisfy the maximum requirements of flow and energy head of the fishfarm water distribution network; and (2) selection of the least-cost set among the feasible sets of pumping stations.

The pump efficiency (η) is the ratio of the energy imported to the water (pump output power or supplied power = $\gamma\cdot\mathrm{TDH}\cdot Q$) to the energy delivered to the pump shaft (pump input power or absorbed power or power consumption $P = \gamma\cdot\mathrm{TDH}\cdot Q/\eta$). The pump regulating efficiency (η_{reg}) is the ratio of the energy required at the water (required power = $\gamma\cdot H_{\mathrm{p}}\cdot Q$, with H_{p} the required

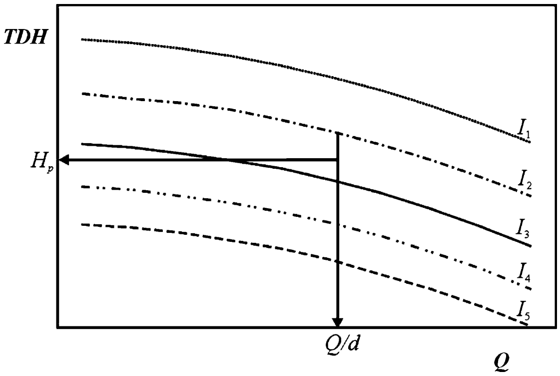


Fig. 2. I_1 to I_5 are the same pump type with different diameters of impellers. Selection of impeller type for requirements of energy head H_{p} and of flow Q/d (in this case, I_2 is impeller selected).

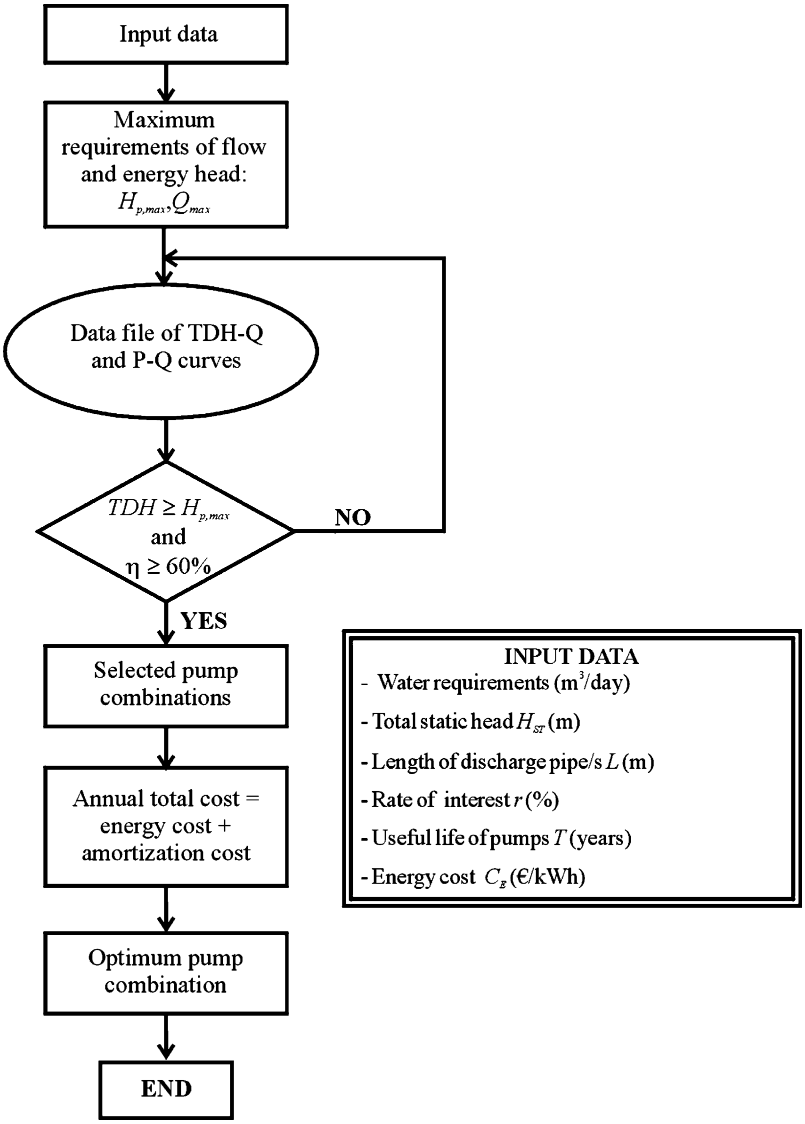


Fig. 3. Optimization model development.

energy head in the water supply system) to the energy imported to the water (pump output power), that is to say:

$$\eta_{\mathrm{reg}} = \frac{\gamma H_{\mathrm{p}} Q}{\gamma \mathrm{TDH}\, Q} = \frac{H_{\mathrm{p}}}{\mathrm{TDH}} \tag{9}$$

The pump regulating efficiency (η_{reg}) is used to evaluate the energy profitability of pumping systems. The difference among the required and absorbed powers will be smaller as the pump regulating efficiency is higher. The least energy cost pump combination will be the alternative that has the highest regulating efficiencies during all the annual operation period, that is to say, the pump combination that operates more closely adapted to system head curve.

Also, the speed variation analysis of one group of the least cost pumping station selected (the best alternative) was carried out. The pump affinity laws or homologous laws must be used to determine the pump performance curve at reduced speeds:

$$\begin{aligned} \mathrm{TDH} &= AQ^2 + B\alpha Q + C\alpha^2 \\ P &= DQ^2 + E\alpha Q + F\alpha^2 \end{aligned} \tag{10}$$

where α is the ratio between the reduced rotational speed and the maximum rotational speed. The possibility of using pumping stations with one variable speed pump implies pump regulating efficiencies equal to 100% during all the annual performance period.

3. Model application

The optimization model is applied to the main pumping station of Hidrorecursos S.A., an intensive eel fishfarm located in the province of Córdoba (southern Spain). The purpose of this application is to simulate the costs that would have been incurred if the pumping station were designed according to model developed in this paper, and to compare these costs with the actual costs.

3.1. Actual pumping system and water demand

In this fishfarm, the water is pumped from the Puente Nuevo reservoir. The main pumping station has a pump combination with two groups in parallel. Each pump group has an electric motor that operates at 1480 revolutions per minute (rpm) and the motor power is 300 horsepower (220.8 kW). In general, the pump operation scheme is at a constant rate and the excess flow is dumped when the water demand is lower. The pumping main or pipeline in which the flow is maintained by pumping is made of polyethylene ($k = 0.007$ mm; Mays, 2000) with a diameter D and length L of 300 mm and 100 m, respectively. The total static head H_{ST} is 39 m (Fig. 1).

Weekly biomass data [Bio(t)] were available from January of 1999 to January of 2001. The mean specific oxygen consumption (SOC) of the eel for the rearing density in the fishfarm was 4.83 mg O_2/kg min. On the other hand, the mean difference between the inlet and outlet water's oxygen concentrations ($C_{in} - C_{out}$) was 2 mg O_2/l. The maximum capacity and the maximum rearing density of the fishfarm were 2086 m^3 and 100 kg/m^3, respectively. With these data and taking as approach a constant biomass during every day of the week, the daily water requirements were calculated (Eq. (1); Fig. 4).

3.2. Optimal design of pumping system with operation scheme at constant rate

Table 1 shows the 34 pump combinations (of the 4370 possible) that satisfy the maximum requirements of flow (913 m^3/h) and energy head (42 m) of the water distribution network of the fishfarm, with a minimum pump efficiency η of 60%. Input data for the model include a pumping station useful life (T) of 20 years and an interest rate (r) of 5%.

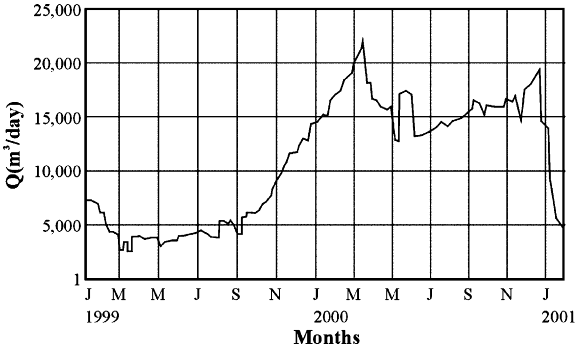


Fig. 4. Daily water requirements of Hidrorecursos fishfarm from January of 1999 to January of 2001.

The pump combination number 28 had the least annual operation cost (21,768 €/year) as well as the least annual total cost (22,047 €/year), with the traditional method which considers only the point of maximum requirements (pump operation scheme at constant rate) and with an average cost of electrical energy of 0.043 €/kWh. This solution represents a 70% annual total cost saving compared to the actual situation (average total annual cost of Hidrorecursos pumping station of 1999 and 2000 years = 72,100 €/year) with the pump operation scheme at a constant rate (maximum requirements of flow).

3.3. Optimal design of pumping system with operation scheme at non-constant rate

If the full daily demand during the annual operating period is satisfied (supply and demand are matched by the process of throttling the pump discharge), the pump combination number 19 had the least annual total cost (5400 €/year) with the simulation of the water demand developed in this study (Fig. 4). With this performance scheme the pump combination number 28 (optimal pump combination at constant rate) had an annual total cost 15% (6210 €/year) higher than the alternative 19.

The pump combination number 19 is the optimum alternative with nine groups in parallel. Each pump group has an electric motor that operates at 2900 rpm and the motor power is 40 horsepower (29.4 kW). The operator will have to turn on and off the pumps during the annual operation period in accordance with the water requirements. It is clear, by using this optimization model, a decrease of about 92% is obtained in annual operation cost and annual depreciation cost of the initial investment compared to actual situation.

Given that the water requirements of the fishfarm are different over the course of an annual operation period,

Table 1
Pump combinations that satisfy maximum requirements of flow and energy head of fishfarm water distribution network

Pump combination	rpm	Impeller diameter (mm)	Motor power (horsepower/pump)	Number of pumps in parallel	TDH–$H_{p,max}$ (m)	η (%)	η_{reg} (%)	Total cost (€/year)	Depreciation cost (€/year)	Energy cost (€/year)
1	1450	380	40	10	0.47	65	98	35,805	117	35,688
2	1450	382	75	7	1.7	73	96	46,608	190	46,418
3	1450	362	75	10	0.32	71	99	66,583	190	66,393
4	1450	408	100	3	1.23	76	97	26,582	245	26,337
5	1450	362	100	8	0.39	77	99	70,885	245	70,640
6	1450	362	100	9	0.74	73	98	79,746	245	79,501
7	1450	362	100	10	0.97	69	97	88,606	245	88,361
8	1450	408	125	2	0.34	72	99	22,131	300	21,831
9	1450	382	125	3	2.29	82	94	33,196	300	32,896
10	1450	362	125	4	0.54	84	98	44,261	300	43,961
11	1450	362	125	5	1.8	78	95	55,236	300	54,936
12	1450	362	125	6	2.16	71	95	66,392	300	66,092
13	1450	362	125	7	2.19	64	95	77,457	300	77,157
14	1450	360	180	2	0.34	77	99	31,932	449	31,483
15	1450	390	270	1	1.97	92	95	23,856	625	23,231
16	1450	360	270	2	1.87	67	95	47,712	625	47,087
17	1450	380	430	1	2.98	78	93	37,733	860	36,873
18	2900	212	40	7	0.34	72	99	24,697	89	24,608
19	2900	200	40	9	2.73	83	93	31,754	89	31,665
20	2900	212	60	5	2.33	74	94	26,529	141	26,388
21	2900	190	60	9	1.47	84	96	47,752	141	47,611
22	2900	190	60	10	2.64	82	94	53,058	141	52,917
23	2900	195	50	8	0.84	68	98	35,277	112	35,165
24	2900	195	50	9	1.72	64	96	39,687	112	39,575
25	2900	190	100	6	0.26	73	99	52,920	223	52,697
26	2900	190	100	7	2.1	68	95	61,740	223	61,517
27	2900	236	125	3	1.7	68	96	32,971	261	32,710
28	**2900**	**250**	**125**	**2**	**1.4**	**63**	**96**	**22,047**	**279**	**21,768**
29	2900	210	125	4	1.24	75	97	44,050	273	43,777
30	2900	200	125	6	2.71	65	93	66,058	271	65,787
31	1480	360	270	3	2.24	74	94	71,348	587	70,761
32	1480	350	270	4	0.72	66	98	95,119	586	94,533
33	1475	375	150	4	2.4	70	94	53,013	347	52,666
34	1480	360	220	3	0.39	69	99	58,181	486	57,695

The cost evaluation was carried considering the pump operation scheme at constant rate.The pump combination number 28 (bold values) had the least annual total cost.

the optimum pump combination is the alternative that operates more closely adapted to system head curve, that is to say, the pump combination with the highest regulating efficiencies during all the annual operation period. Fig. 5 shows the comparison of regulating efficiencies of pump combinations of: (1) actual situation; (2) alternative 28; (3) alternative 19.

In the alternative 19, the possibility of including one variable speed group showed higher savings that with all pump groups at fixed rotating speed. The results showed savings about 95% in total annual cost of the pumping station, with pump rotating speeds of 2175–2900 rpm during all the annual operation period (range of α: 0.75–1).

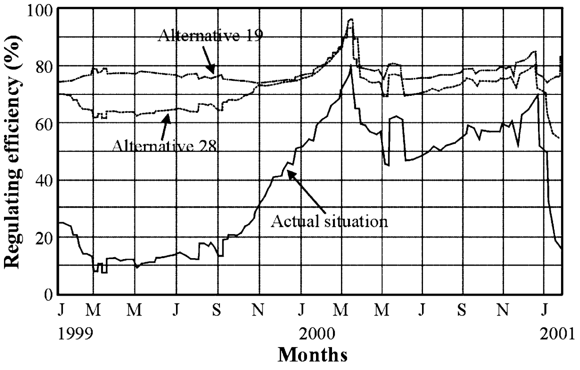
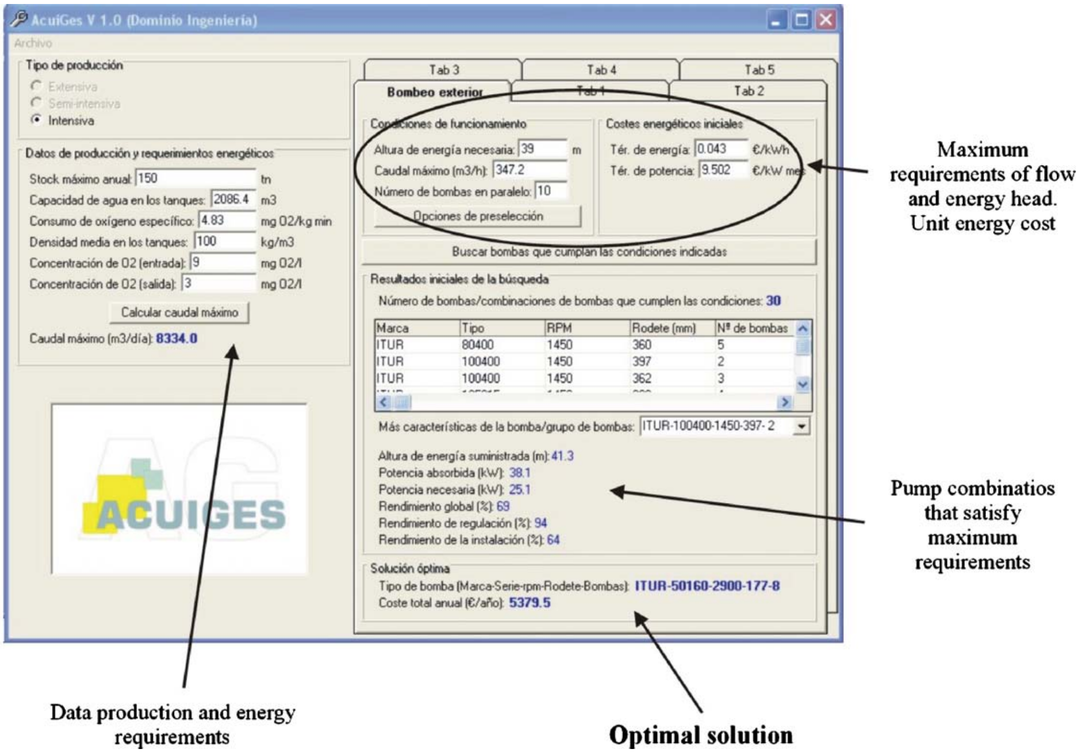


Fig. 5. Regulating efficiencies of pump combinations of actual situation, alternative 28 and alternative 19.



Tipo de producción
○ Extensiva
○ Semi-intensiva
● Intensiva

Datos de producción y requerimientos energéticos
Stock máximo anual: 150 tn
Capacidad de agua en los tanques: 2086.4 m3
Consumo de oxígeno específico: 4.83 mg O2/kg min
Densidad media en los tanques: 100 kg/m3
Concentración de O2 (entrada): 9 mg O2/l
Concentración de O2 (salida): 3 mg O2/l
Caudal máximo (m3/día): 8334.0

Condiciones de funcionamiento
Altura de energía necesaria: 39 m
Caudal máximo (m3/h): 347.2
Número de bombas en paralelo: 10

Costes energéticos iniciales
Tér. de energía: 0.043 €/kWh
Tér. de potencia: 9.502 €/kW mes

Resultados iniciales de la búsqueda
Número de bombas/combinaciones de bombas que cumplen las condiciones: 30

Marca	Tipo	RPM	Rodete (mm)	Nº de bombas
ITUR	80400	1450	360	5
ITUR	100400	1450	397	2
ITUR	100400	1450	362	3

Más características de la bomba/grupo de bombas: ITUR-100400-1450-397- 2
Altura de energía suministrada (m): 41.3
Potencia absorbida (kW): 38.1
Potencia necesaria (kW): 25.1
Rendimiento global (%): 69
Rendimiento de regulación (%): 94
Rendimiento de la instalación (%): 64

Solución óptima
Tipo de bomba (Marca-Serie-rpm-Rodete-Bombas): ITUR-50160-2900-177-8
Coste total anual (€/año): 5379.5

Fig. 6. Main window of ACUIGES v.1.0 computer program (spanish version).

The results showed in Sections 3.2 and 3.3 were achieved through the use of the aforementioned inputs as well as the optimization equations implemented in ACUIGES computer program (Fig. 6).

4. Conclusions

The energy required for operating pumping stations in inland intensive fishfarms may be significant. Thus, an optimization model has been developed to identify the pump, or pump combination, which should be working in order to satisfy the water demand at minimum annual total cost (annual operation cost plus annual depreciation cost of the initial investment). The difficulty of the discrete pump discharges and the possibility of using one variable speed pump in the pumping station have been considered in this model.

To support operational decisions, a computer software package for the model was also coded and applied successfully to a real fishfarm. It was found that the proposed model may significantly reduce the total annual cost, which may have a high influence on the final price/quality of the biomass produced in the fishfarm. The price and quality determine the fishfarm profitability and its capacity to compete in the market, since are the difference factors with the product of the others fishfarms.

A major portion of energy cost savings, without change the yields of the fishfarm, may results through employing a better operation scheme of pumping stations. This could be obtained shifting pumping away from times of high energy tariffs, with a regulating reservoir between the water supply source and the delivery system that buffers the system from fluctuating demands.

The model was developed so that it should be applicable for other fishfarm water supply system by introducing a similar set of data. It will be very effective if the water daily demand simulation is accurate. This approach of water daily requirements is highly related with the available information/data of the fishfarm facilities. This way, in those fishfarms with a high control level of their operation schemes, a great amount of information about physico-chemical parameters (ammonium concentration, oxygen requirements, etc.) and yield factors (biomass stocked, growth and mortality rates, etc.), will allow to carry out a more easy and accurate estimation of water daily demands. If this estimation is not possible, the model developed in this study is useful for the selection least cost pump combinations versus to a selection without economic and hydraulic constrains that satisfy the water maximum requirements.

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