REGIMENS OF ECOLOGICAL FLOW RATES ON THE PILÓN RIVER

Juan Antonio Vidales-Contreras¹, Juan Francisco Pissani-Zuñiga¹, Humberto Rodríguez-Fuentes¹, Emilio Olivaures-Sáenz¹, Juana Aranda-Ruiz and Alejandro Isabel Luna-Maldonado¹

¹Department of Agricultural Engineering, Faculty of Agriculture, Autonomous University of Nuevo León, México

Received – July 07, 2014; Revision – July 31, 2014, Accepted – August 13, 2014
Available Online – August 21, 2014

ABSTRACT

Two methods have been applied in this study to determine the ecological flow rates regimens of the Pilón River, in the section of the Hydrometric Station, Montemorelos, N. L., Mexico. These methods were based on hydrological indexes: minimum flow rates (Qmin) to dry years and means flow rates (Qmed) to wet years. The criteria proposed to evaluate the ecological flow rates regimens are: the average minimum monthly flow (min), 90% of the average minimum monthly flow (90% min) and the average means monthly flow (med) of the series of registered measurements during the years 1940-2004. These are more feasible because they are coherent with seasonal variations of the distribution of circulating flow rates for this section, taking into account that the biological riverside community has evolved with relationship to the regimes of mentioned flow rates.

* Corresponding author
E-mail: alejandro.lunaml@uanl.edu.mx (Alejandro Isabel Luna-Maldonado)

Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.
1 Introduction

The need to establish a regimen of flow rates in order to maintain the acceptable conditions of biological diversity and landscape in the rivers has been considered since decades, as reaction to all higher pressures on the fluvial means and its consequences or environmental degradation process. The Sub-Basin of Pilón River has problems of pollutants and occupation/alteration of shoreline; it has also caused a decrement of flow rates by the water demand used to human, agricultural and animal consumption and water supply to industries in the growing populations of Montemorelos and General Terán. The current scenarios of pollution and destruction of the Pilón River; moreover, it is evident that the optimal use of the Pilón River, is a major source for supplying water to these populations under constant growth which surely will cause serious conflicts about the use of its flow rate. Therefore it is of great importance to maintain the natural flow of water amounts, ensure the survival of the components of their ecosystem and obtain the establishment of flow regimes that respect aquatic ecosystems, social values and landscape water. It cannot be defined by one or two flow rates for the year, but has to quantify a monthly flow rate (which may be zero in any month) and a series of water avenues (more or less frequent) to this set of flows named ecologicals (Aguirre & de Bikuña 2000; Cachón de Mesa, 2001; Baeza-Sanz & García de Jalón, 2003).

The sub-Basin of Pilón River, belongs to the Basin of the Rio Grande-San Juan, Hydrological Region No. 24 "Rio Bravo-Conchos", is located on the slope of the Gulf of Mexico, northeastern Mexico (Figure 1). It includes the center of the State of Nuevo Leon, covering the municipalities of General Terán, Montemorelos, Rayones, Galeana, and Arteaga, in the State of Coahuila (figure 2), whose geographical coordinates are 24 ° 50 'and 25 ° 29' north latitude and 99 ° 30 'and 100 ° 35 ' west longitude with respect the meridian of Greenwich, and latitude varies from 180 to 3720 meters above the sea level. This sub-basin has an elongated shape and resembles a V (Figure. 2). It starts upstream from northwest to southeast and from about half (in Rayones, N.L.), switch to the northeast. It reaches its highest altitude (3720 m) in the southern part, especially in the Potosí Mountain.

The aim of this study is to determine regimens of ecological flow of Pilon River, based on analysis of historical flow rates records (1940-2004), corresponding to the gauging station Montemorelos, located 44 km northwest of the town of Linares, N.L., whose coordinates are 99 ° 5000 "west longitude and 25 ° 10'56" north latitude with the meridian of Greenwich and its altitude is 432 m. Thus, we attempt to characterize hydrological designed to show the dynamics of runoff and calculating regimens of ecological flow rates, which is a parameter for the sustainable use of water resources.

2 Materials and Methods

The sub-Basin of Pilón River has an area of 2,441.7 km2 and a perimeter of 384 km. The width of this is variable but generally is not greater than 15 km; the narrowest part is at the center, in the curving area of the northeast, and it is of 5 km. Its length in a straight line, the Port of Maravillas, Coahuila (distal northwest), Rayones, N.L., is approximately 63 km, and from there to the mouth of Rio San Juan (distal east end) is approximately 73 km. The total length of the channel reaches 181 km, with altitudes from 185 to 2690 m. The hydraulic gradient ranges from 0.136 ° to 0.363 ° in the Coastal Plain of the Gulf of Mexico, from 0.424° to 0.593° in the Foothills and the mountain range Sierra Madre Oriental is up of 5,710° (Sánchez, 1985).

The springs are the Cañón del Tragadero an artesian spring whose mean flow rate is about 1.46 m3s−1, (Castro, 2006); the outcrop on the river bed Casillas, has an average flow rate of 0.5 m s−1, and located on the border of the states of Coahuila and Nuevo León, site where the runoff is transformed from perennial and intermittent, finally, the spring located in the center of the Pilón River canyon, with an average flow rate of about 50 Ls−1.

Figure 1 Map of the sub-Basin of Pilón River in Mexican Republic.
Figure 2 Boundary of counties and Surface Hydrology of Sub-Basin in Pilón River.

Figure 3 Distribution monthly minimum yield flow rates ((minimum, mean y maximum (m$^3$s$^{-1}$); standard deviation and frequencies)) of the series for years since 1940 to 2004.
Two methods, i.e. minimum flow rates ($Q_{\text{min}}$) for dried years and mean flow rates for humid years, were used in this study. These methods were based on hydrological indexes (García de Jalón & González de Tenago, 1995; Gómez Criado et al., 2000). The first one is a simple method to estimate the minimum ecological flow rates of dried minimum years; it consists of studying natural flow rates.

The communities in the river section have evolved under certain types of flow rates regimes and thus their life cycles and ecological requirements are adapted to seasonal variations characteristic of the regime. They are also adapted to tolerate seasonal variations of the regimen, and can even tolerate very meager flow from one to several days, which obviously cannot stay for long periods to those not adapted (Plan Hidrológico Nacional, 2000). In this case, to series of data recorded during the years of 1940 to 2004 were applied the following criteria: the minimum daily flow rate that occurred in each month of the series ($\text{Min } Q_{\text{min}}$), average annual minimum flow rates ($\bar{Q}_{\text{min}}$), the average minimum flow rate in each month of the series ($\bar{Q}_{\text{min}}$), and 90% of the minimum of the series.

The minimum flow rate ($Q_{\text{min}}$) is the smallest instantaneous value in a year or a month, as applicable, regardless of when it is occurred and the time it has remained. Among the statistical parameters were determined: lower values is the smallest value of $Q_{\text{min}}$ recorded in every month of the series ($\text{Min } Q_{\text{min}}$) or annually ($\text{MIN } Q_{\text{min}}$ annual), frequency of lower value $Q_{\text{min}}$ (F $Q_{\text{min}}$), which is the number of times the $Q_{\text{min}}$ occurs every year in the series in each of the months of the year, higher values, corresponding to the highest recorded value of $Q_{\text{min}}$ in each month of the series ($\text{Max } Q_{\text{min}}$) or each year ($\text{MAX } Q_{\text{min}}$ annual) frequency of the highest value of $Q_{\text{min}}$ (F $\text{Max } Q_{\text{min}}$), is the number of times that $\text{Max } Q_{\text{min}}$ is presented for all years of the series in each of the months of the year averages, corresponding $Q_{\text{min}}$ to the average in each month of the series $\bar{Q}_{\text{min}}$ and standard deviation, is the degree of symmetry between $Q_{\text{min}}$ data records in each month of the series ($\sigma_{Q_{\text{min}}}$). To determine whether the observed data of Fisher (F) $\text{Min } Q_{\text{min}}$ followed a binomial distribution, tests were conducted for goodness of fit using the techniques of Chi-square and Kolmogorov-Smirnov test (Ostle, 1974).

The second method based on the average flow rate was used to estimate the environmental flow regime for humid years, applying the following criteria: average monthly mean flow rates ($\bar{Q}_{\text{med}}$), 10% of the mean annual average flow rate ($\text{med}_{\text{annual}}$) and 10% to values of the average monthly average flow rate ($\text{med}$) of the series of well yield recorded during the years of 1940 to 2004.

Figure 4 Distribution monthly mean yield flowrates ($\text{med}$, $\text{min}$ $\text{med}$, $\text{max}$ $\text{med}$ y $\sigma$ $\text{med}$ ($m^3.s^{-1}$)) and $\bar{Q}_{\text{min}}$ of the series for years 1940 to 2004.
Regimens of Ecological Flow Rates on the Pilón River

The equation used for its calculation is as follows:

\[
\begin{align*}
Q_{ec} & = Q_{med} \text{ anual} \times 10\% \quad (1) \\
Q_{ec} & = Q_{med} \times 10\% \quad (2)
\end{align*}
\]

Where:

- \(Q_{ec}\) = ecological flow rate,
- \(Q_{anual}\) = regimens of ecological flow rates,
- \(\bar{Q}_{med}\) = mean annual average flow rate (m\(^3\)/s),
- \(\bar{Q}_{med}\) = average monthly average flow rate (m\(^3\)/s),
- 10\% = percentage applied to mean flow rate of yearly mean and monthly.

The average flow \((\bar{Q}_{med})\) is the average value in a year or month, as applicable. The statistical parameters considered are: higher values, corresponding to the highest value recorded in each month of the series (Max \(Q_{med}\)) or annually (MAX \(Q_{med}\) anual) lower values is the lowest value recorded in each month of the series (Min \(Q_{med}\)) or annually (MIN \(Q_{med}\) anual). Average, correspond to the average flow through \(Q_{med}\) in each month of the series (\(\bar{Q}_{med}\)) or in each year (\(\bar{Q}_{med}\) annual), medians, is the intermediate data value when all data is arranged in each month of the series (Mediana \(Q_{med}\)) and the standard deviations, is the degree of symmetry between data records in each month of the series (\(\sigma Q_{med}\)).

Least squares method was used to estimate the probability of occurrence of del \(Q_{min}\) and med in the month of the series.

3 Results and Discussion

The Min \(Q_{min}\) denotes extreme values of 0.0 m\(^3\)/s in May, June and August and 0.22 m\(^3\)/s in November, with an annual trend which clearly shows a decrease in the warm half of the year (Table 1), but the differences observed in the minimum expenses are small, with small ranges of variation as the \(\sigma Q_{min}\) exceeds the \(\bar{Q}_{min}\) in the months from February to September for period 1940 to 2004 and the F Min \(Q_{min}\) corresponds to the period from March to October, while in the months of November to February frequency is zero (Figure 3).

The Max \(Q_{max}\) of the series studied are important, ranging from 4.638 m\(^3\)/s to 26.46 m\(^3\)/s in May and October, respectively, figures that in these and in all months of the year exceed \(Q_{med}\) annual of Pilón River and F Max \(Q_{min}\) has high values in January, October and November, with 12, 25 and 11 in the same order (Figure 3).

The annual variation of \(Q_{min}\) is from 0.783 m\(^3\)/s in April to 4.927 m\(^3\)/s in October; its annual behavior coincides essentially with the \(Q_{med}\), but with values lower than this (Table 1 and Figure 4).

As shown in Figure 2 the distribution for smaller values of Max \(Q_{med}\) correspond to the dry season, which months are from November to May, and are 20.07 m\(^3\)/s and 6.634 m\(^3\)/s, respectively. The Min \(Q_{med}\) the least values occurs in the period from March to August, 0.293 m\(^3\)/s and 0.39 m\(^3\)/s, respectively.

The \(Q_{med}\) is really small compared with \(Q_{max}\) (figure. 3 and 4), but in the months of June, July, August and September, the value of \(Q_{med}\) is greater than \(Q_{med}\), which means that at that time of year there are marked differences between years.

The tests to determine the type of distribution by the Chi-square method obtained that all calculated values are smaller than the table value, which was equal to 24.72 and the lowest value is obtained with \(p = 0.48\), so it is concluded that the data can be explained using the binomial distribution, using the following equation:

\[
p = C(n,x)p^x q^{n-x} \quad (3)
\]

Based on Equation 3 were estimated frequencies for Min \(Q_{min}\) when the values of F Min \(Q_{min}\) were estimated with acceptable accuracy for most of the months, except for the months of May and June where F Min \(Q_{min}\) were overestimated while in August the value of F Min \(Q_{min}\) was underestimated. The correlation between observed and estimated values was \(= 0.866\). In applying the Kolmogorov-Smirnov test for frequency data \(Q_{min}\) (F Min \(Q_{min}\)) showed that all calculated values are smaller than the table value, which was equal to 0.468, the lowest value is obtained with \(p = 0.49\), so it is concluded that the data can be explained using the binomial distribution. In calculating the probability of occurrence of the \(Q_{min}\), using the method of multiple regression, the coefficient of determination was 0.908; however for the \(Q_{med}\) was 0.809; indicating that for \(Q_{med}\) it explained more than 90% of the variation of \(Q_{min}\) with this model, while for \(Q_{med}\) it explained more than 80%.

The calculations for determining environmental flow regimes based on minimum and average flow rates were obtained results as it is shown in Table 1 and Figure 5. Figure 5 shows the distribution of regimens of ecological flow based on minimum and average flow rates (m\(^3\)/s). In the case of Min \(Q_{min}\), there are months in which there was no flow rate, to say, on the day of the month the flow rate was zero and this happens on certain days of the months of May, June and August.

It is not recommended that all biodiversity which are living in the section be maintained under these conditions of not enough water because all the biological community is adapted to live with these minimum flow rates for short periods of time, not permanently.
Figure 5 Comparison of the distribution of ecological monthly yield flow rates based on minimum and mean yield flow rates (m$^3$s$^{-1}$).

Table 1 Determination of the ecological yield flow rates based on minimum and mean flow rates (m$^3$s$^{-1}$) section corresponding to hydrometric station of Montemorelos for years 1940 to 2004.

<table>
<thead>
<tr>
<th>Month/Qanual</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min Qmin</td>
<td>0.146</td>
<td>0.076</td>
<td>0.011</td>
<td>0.030</td>
<td>0.000</td>
<td>0.000</td>
<td>0.017</td>
<td>0.000</td>
<td>0.045</td>
<td>0.117</td>
<td>0.220</td>
<td>0.201</td>
</tr>
<tr>
<td>Qmin anual</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
<td>2.032</td>
</tr>
<tr>
<td>Qmin</td>
<td>2.250</td>
<td>1.603</td>
<td>1.020</td>
<td>0.783</td>
<td>0.921</td>
<td>0.819</td>
<td>1.112</td>
<td>1.184</td>
<td>2.785</td>
<td>4.927</td>
<td>3.905</td>
<td>3.073</td>
</tr>
<tr>
<td>90% Qmin</td>
<td>2.025</td>
<td>1.443</td>
<td>0.918</td>
<td>0.705</td>
<td>0.829</td>
<td>0.737</td>
<td>1.001</td>
<td>1.066</td>
<td>2.507</td>
<td>4.434</td>
<td>3.515</td>
<td>2.766</td>
</tr>
<tr>
<td>90% Qmed</td>
<td>0.310</td>
<td>0.247</td>
<td>0.186</td>
<td>0.158</td>
<td>0.197</td>
<td>0.303</td>
<td>0.271</td>
<td>0.325</td>
<td>0.882</td>
<td>0.877</td>
<td>0.556</td>
<td>0.419</td>
</tr>
<tr>
<td>10% Qmed</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
<td>0.394</td>
</tr>
</tbody>
</table>

Another approach is to apply the $Q_{min}$ annual, but has the limitation that does not consider seasonal variations which characterize the natural regime, moreover, in every month is greater than Min $Q_{min}$, and there are months (February-August), which is higher than al min may it never occurs. By having these problems to overcome, we could consider the $Q_{min}$ and 90% that is applied to this (90% al $Q_{min}$) as more feasible because they are consistent with seasonal variations in the distribution of circulating flow rates in the stretch taking into account that the biological community has evolved in relation to such flow rate regime for different times of the year, giving a biological sense.

In regard to the $Q_{med}$ annual and 10% that is applied to it (10% $Q_{med}$ annual), in both cases have a unique value and constant flow rate throughout the year, so it would not meet the natural variability of circulating flow rates. In applying the 10% to $Q_{med}$, it would be not highly recommended as the flow rate regime because it is under the registered min, the 90%-$Q_{med}$ annual, $Q_{med}$ annual, exceeding only $Q_{min}$ in the months September to December for 10% $Q_{med}$ annual what is considered to be a rate not suitable for the maintenance of morphometrics characteristics and biodiversity in the section of the river.

Considering these disadvantages, we can say that the method or approach most appropriate to use as regimen of flow rate for wet years, would be through the values of the average monthly mean flow rates ($Q_{med}$), and that includes the seasonal variation of flow that characterizes the natural regime.
Conclusions

The criteria more convenient to use as organic flow regimes are as follows: for the average dry years monthly minimum flow rate (\( Q_{\text{min}} \)), which is considered by applying 90% of the average monthly minimum flow rate (90% \( Q_{\text{min}} \)) and to wet years the average monthly mean flow (\( Q_{\text{med}} \)). This would in flow regimes for dry and wet years based on previous weather conditions, fluctuating similar regimen to the natural, and in flow rate amounts that actually flowing through the channel under natural conditions, biodiversity and morphology the section of the channel, it would begin to recover as long as they regulate such removals to maintain minimum flow rates and / or monthly averages. Ecological flow regimes obtained has an indicative character, and its results should be validated.

From the view point of physical, technical, political and social to establish the environmental flow rates regimes of Pilón River is a complex issue. It is necessary to establish a society consensus to converge on a strategy for the conservation of the river, the measurement of demand and sustainable use allowed, understanding this use as one who not compromise the maintenance of the biological community as a whole of ecosystem (both its biotic and abiotic) in a manner consistent with the use by society. Thus, environmental flow regimes are no longer a goal in themselves, if they are not part of a sustainable water system of Pilon River.

Acknowledgements

We would like to thank to José S. Castro C. for his technical support and Comisión Nacional del Agua (CNA), Gerencia Estatal de Nuevo León, México for providing database access.

References


