NATURAL FLOWS DETERMINATION IN GAUGED HYDROLOGICAL BASINS. PART II: THE EFFECT OF TIME SCALE

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INTRODUCTION

Mankind's capacity to foresee, plan and administer natural resources, and water in particular, is being put to the test in many parts of the planet. However, in order to plan the use of water resources it is first necessary to quantify them spatially and temporally, and to determine the limit to which these resources can be used sustainably (Carabias et al., 2005). This can be achieved through the determination of natural (virgin) flows, which correspond to the natural availability of surface water resources in a hydrological basin (SEMARNAP, 2000). Natural flows represent or characterize the hydrological behavior of a basin, and can be determined from the adjustment of hydrometric records of rivers, through the application of rain-runoff hydrological models or through statistical methods (TNRCC, 1997).

OBJECTIVE

To analyze the effect of the annual and monthly time scales in the determination of natural flow in hydrological basins.

METHODOLOGY

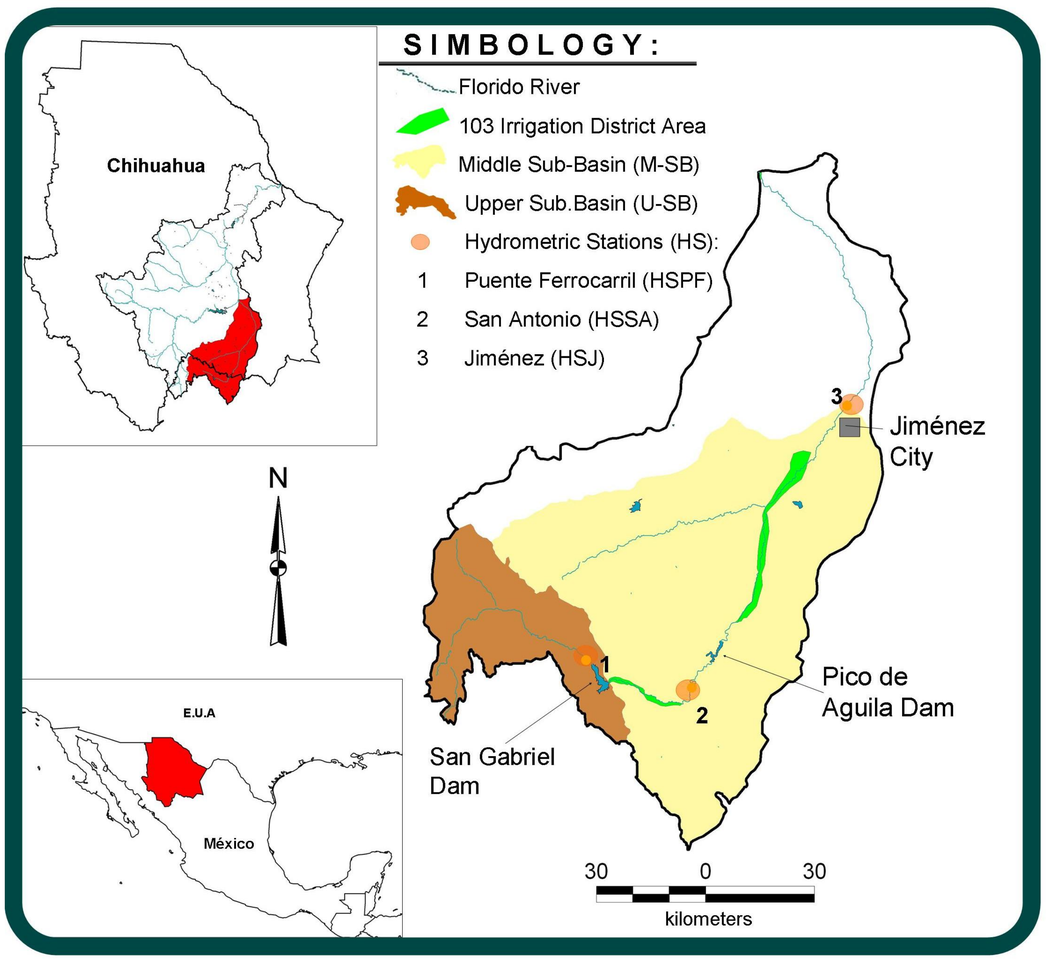

Figure 1. Location of the study area.

The upper - middle basin of the Florido river, in the northern Mexican State of Chihuahua, constitutes the study area (Figure 1). It has an extension of 7,395 km^2 irrigated with surface water from the San Gabriel and Pico de Águila dams (CNA,1997). The basin was divided into the upper sub-basin (U-SB), with no infrastructure for water use; and the middle sub-basin (M-SB), where the 8,238 hectares and complete infrastructure of Irrigation District 103 (ID-103) are located. From 1982 to 2000 (period of analysis), an annual mean use of 2.28 Mm^3 (million cubic meters) and 108.6 Mm^3 were estimated for U-SB and M-SB, respectively (CNA-OCRB, 2006), and there are no water exports to or imports from neighboring basins. Because of the size of communities and their water demand, no return flows from public urban use are considered. The irrigation return flows were estimated as a 30% of the total volume used for this activity during the period of analysis, as detailed in a work developed by Silva-Hidalgo et al. (2008).

Determination of natural flows

Natural flow (Cp) in gauged basins is determined through the following expression derived from the general mass conservation equation (SEMARNAT, 2002):

$$Cp = V_2 + Exb + Ev - V_1 + Ex - Im - R + \Delta V$$

Where:
V_1= gauged volume entering from the upstream basin
V_2= gauged volume exiting to the downstream basin
Exb= volume of surface water extracted or diverted in the basin
Ev= evaporation
Ex= exported volume
Im= imported volume
R= volume of return flows
ΔV= change in storage volume.

The mean annual natural flow of both sub-basins was estimated using the annual and monthly time scales, for the period spanning from 1982 to 2002.

RESULTS AND DISCUSSION

Annual mean natural flow in U-SB and M-SB

The estimated natural flow was 116.8 Mm^3 for the U-SB at the annual scale, and 119.9 Mm^3 at the monthly scale. These results differ in only 2.65%, which shows that the time scale had very low impact. The mean annual natural flow in M-SB, calculated using a return flow of 30% as determined before, was 59.87 Mm^3 at the monthly scale and of 49.6 Mm^3 at the annual scale. These results are inconsistent and differ from each other by 20.7%, which suggests that the time scale is indeed very important in basins where water is used for irrigation. The inconsistency of the results obtained at different time scales can be explained if it is observed that, during the calculations for both sub-basins, negative natural flows were obtained during several years for some of the dry months, between February and June. The lower limit of the natural flow is reached when there is no flow, so a negative value of natural flow has no physical meaning, but can be related to water losses along the river, or to water extractions larger than reported.

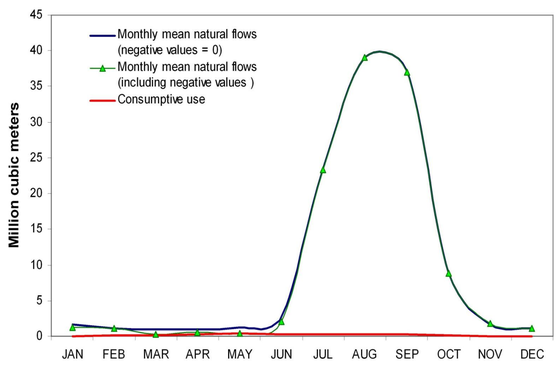

Figure 2. Natural flow and monthly consumptive use from 1982 to 2002 in U-SB.

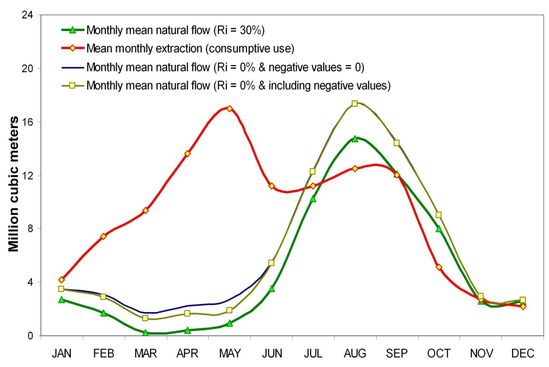

Figure 3. Natural flow and monthly consumptive use from 1982 to 2002 in M-SB.

Figures 2 and 3 show the annual hydrograms of monthly mean natural flow: a) including the negative values initially obtained for some years, and b) correcting the negative values by assigning a value of zero.

CONCLUSIONS

It is concluded that for basins with irrigation infrastructure, the monthly time scale should be used for natural flow determinations. The use of an annual scale is only advised for preliminary evaluations.

Time series of natural flows estimated at the monthly scale.

The U-SB contains the origin of the Florido River, so it receives no more flow contributions than those that originate in its own surface. The extraction performed in U-SB has practically no effect on the natural flow pattern, so the historical gauged flows are very similar to the estimated natural flows (Figure 4).

M-SB is located downstream from U-SB, so it receives the flows that leave the latter. The flows from U-SB have a great influence over the gauged volumes at the exit of M-SB. Until before 1994, the gauged flow in HSJ was very similar to the sum of the natural flow generated in M-SB and the flow coming from U-SB (Figure 5). Since 1994, when the Pico de Águila Dam started operating, the gauged flows in HSJ incorporate the effect of storage and regulation of the dam; thus, at least during the analyzed period the flows from U-SB have ceased to have influence over the flows observed at HSJ.

It can be observed that there is a sensible decrease in natural flows from 1992 to 2002 (with the exception of 1993 and 1996). This follows the decrease in precipitations during a period of drought (Núñez-López *et al*., 2007).

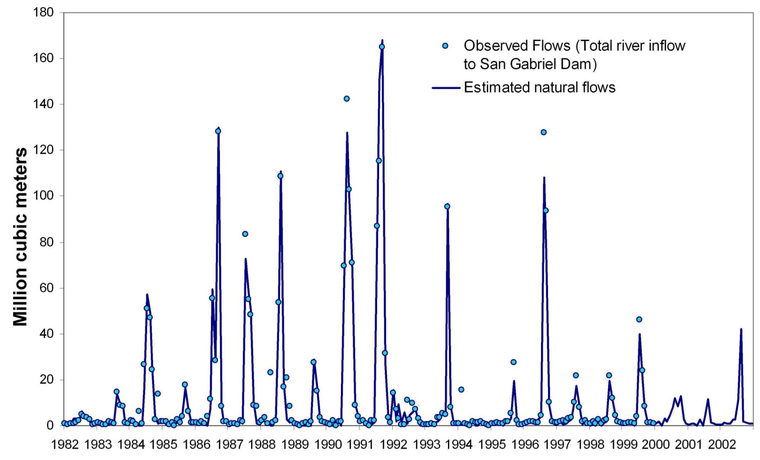

Figure 4. Natural flow estimated from 1982 to 2002 at the exit of U-SB, and total river inflow to San Grabriel Dam of the NSWDB (IMTA and CNA, 2000).

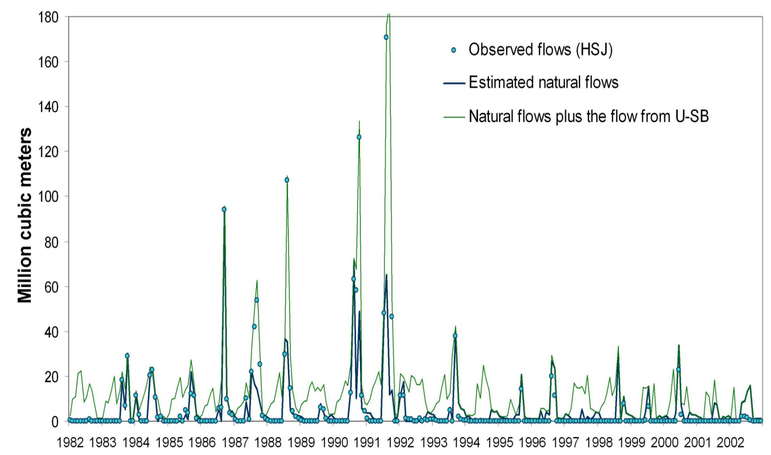

Figure 5. Monthly natural flow estimated from 1982 to 2002 at the exit of M-SB, historical flow gauged at HSJ, and natural flow plus the flow from U-SB.

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