NATURAL FLOWS DETERMINATION IN GAUGED HYDROLOGICAL BASINS.
PART I: ALTERNATIVE METHOD FOR IRRIGATION RETURN FLOWS ESTIMATION

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INTRODUCTION

It is of vital importance to quantify the natural flows (natural availability) and to define control mechanisms that would permit the sustainable use of surface water resources. The determination of natural flows through gauged historical flows consists of removing the effects of the human activity that used water, including extractions, return flows and storage effects (Wurbs, 2005). All the sectors that use water can generate a volume that returns into the natural drainage system of a basin. Irrigation activity is the main water use sector in most basins, but in very few occasions is it possible to have measurements of the water volume that returns to surface flow after its use. When this happens, it is a common practice to use typical values reported in literature: 20% to 50% of the volume used in irrigation (Yoshitani & Tianqi, 2007; Jothiprakash, 2003). This procedure introduces a high uncertainty into the estimation of natural flows.

OBJECTIVE

To propose an alternative method for the estimation of the irrigation return flows in hydrological basins.

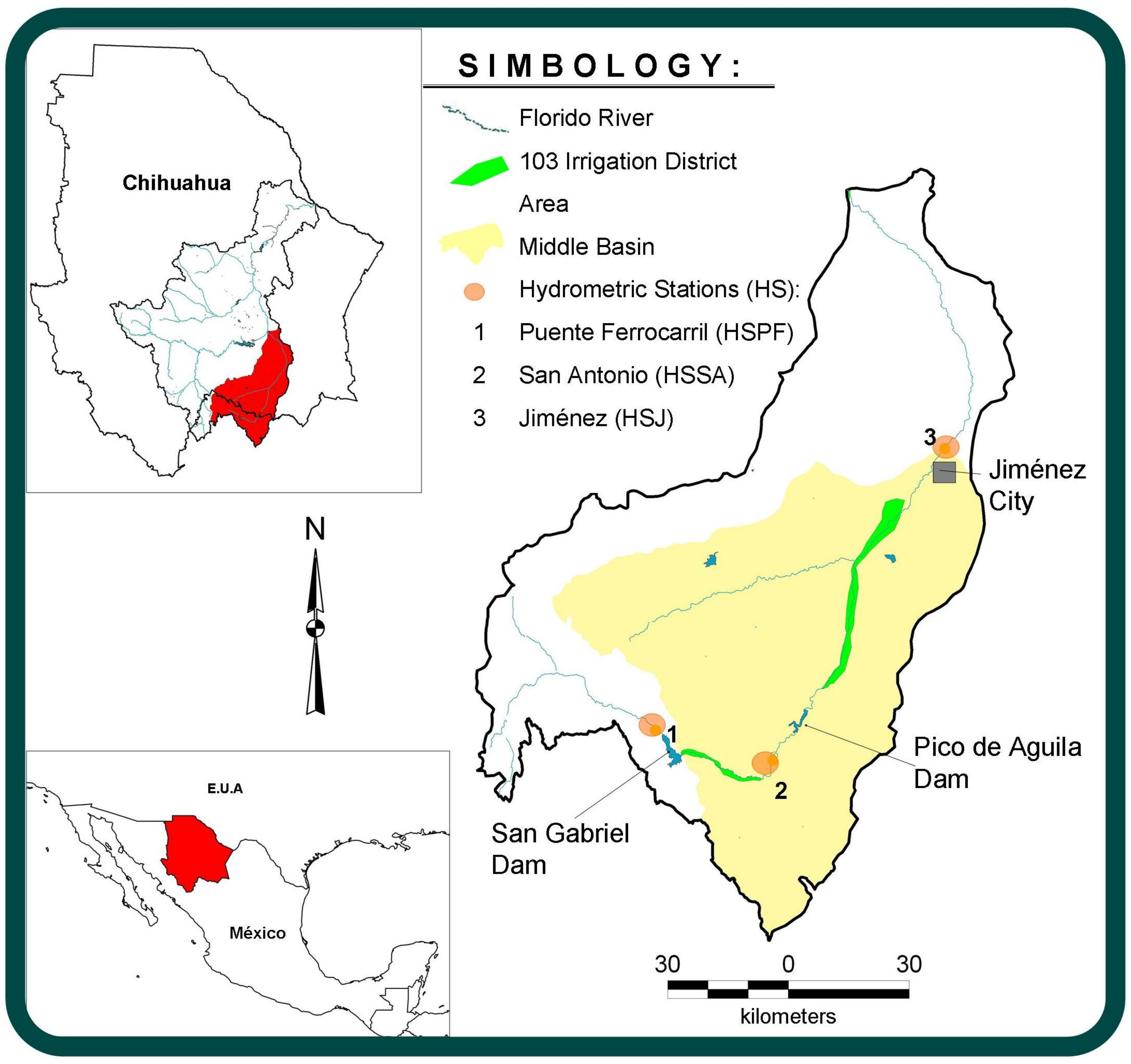

Figure 1. Location of the study area.

METHODOLOGY

The study zone (6,245 km²) spans from the San Gabriel dam to the hydrometric station near Jiménez City; it is located in the southern portion of the state of Chihuahua, México (Figure 1). From 1982 to 2000 (period of analysis), an annual mean water use of 108.6 Mm³ (million cubic meters) was estimated (CNA-OCRB, 2006), and there were no water exports or imports to neighboring basins. No return flows from public urban use are considered because of the size of communities and their water demand, but Irrigation District 103 does generate irrigation return flows (CNA, 1997).

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):

$$Cp = V2 + Exb + Ev - V1 + Ex - Im - R + \Delta V$$

Where:

V1= gauged volume entering from the upstream basin
V2= 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.

Proposed method for return flows estimation:

The method consists of determining the annual hydrogram of monthly mean natural flow from the available hydrometric records and the mass conservation equation, with no initial consideration of agricultural return flows. If the annual hydrogram of mean monthly natural flow shows increments of flow during the dry season, they can only be attributed to return flows. This is an anomaly with respect to the theoretical hydrogram, and occurs during the dry months that have the greatest demand for irrigation water. The anomaly can be corrected by re-calculating the natural flows while introducing irrigation return values (as a percentage of the volume used for irrigation), until a value is found for which the deformation of the hydrogram disappears.

RESULTS AND DISCUSSION

Natural flow without considering irrigation returns (Ir).

The natural mean annual flow estimated initially was 77.44 Mm³ (Ir=0). The greatest demand occurs during the dry months, and part of this water volume used by agricultural activities returns to the river. This is manifested in the deformation of the annual hydrogram of mean monthly natural flow (Figure 2) that shows during the dry months as an increment in natural flows in the absence of rainfall. During these months, natural or base flows are minimal, conversely to the demand for irrigation; consequently, the presence of agricultural water excesses returning to the river is also more evident.

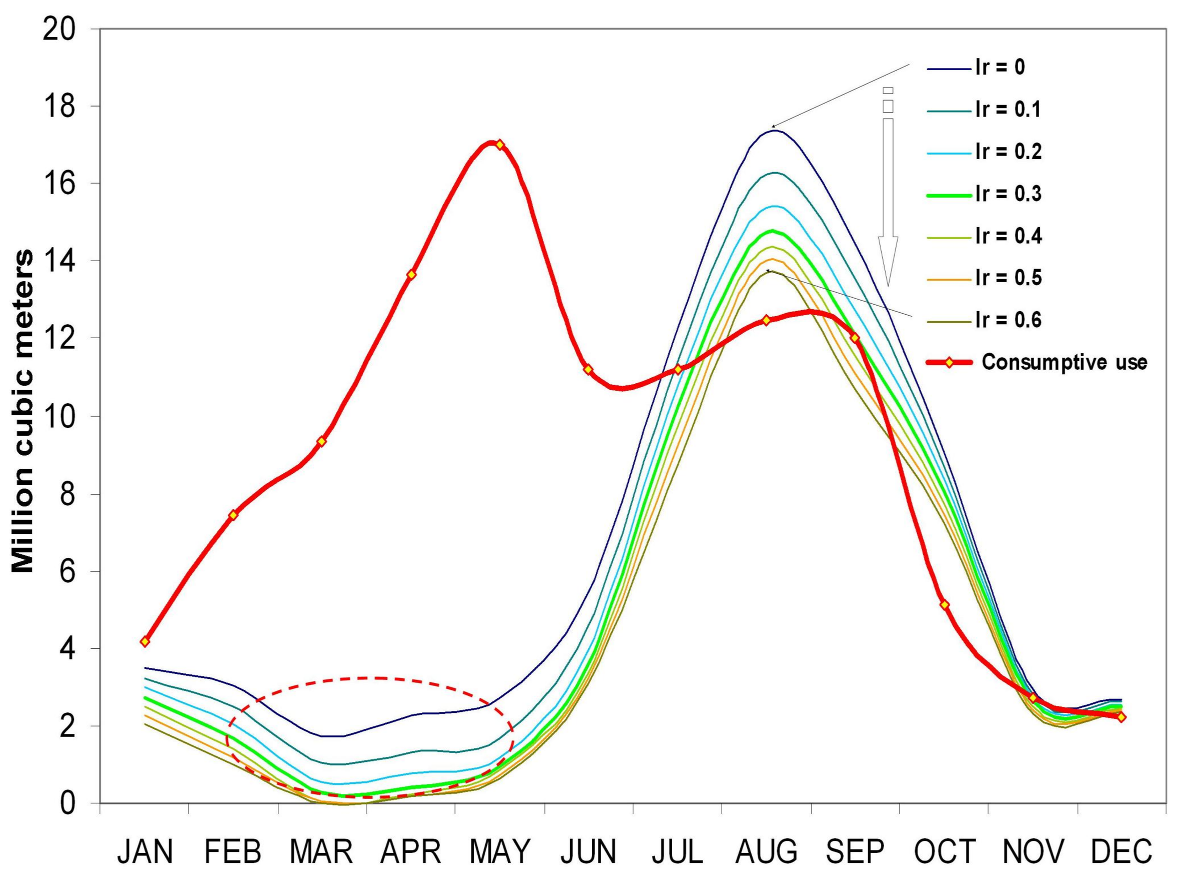

Figure 2. Natural flow (including irrigation return flows) and mean monthly consumptive use from 1982 to 2002.

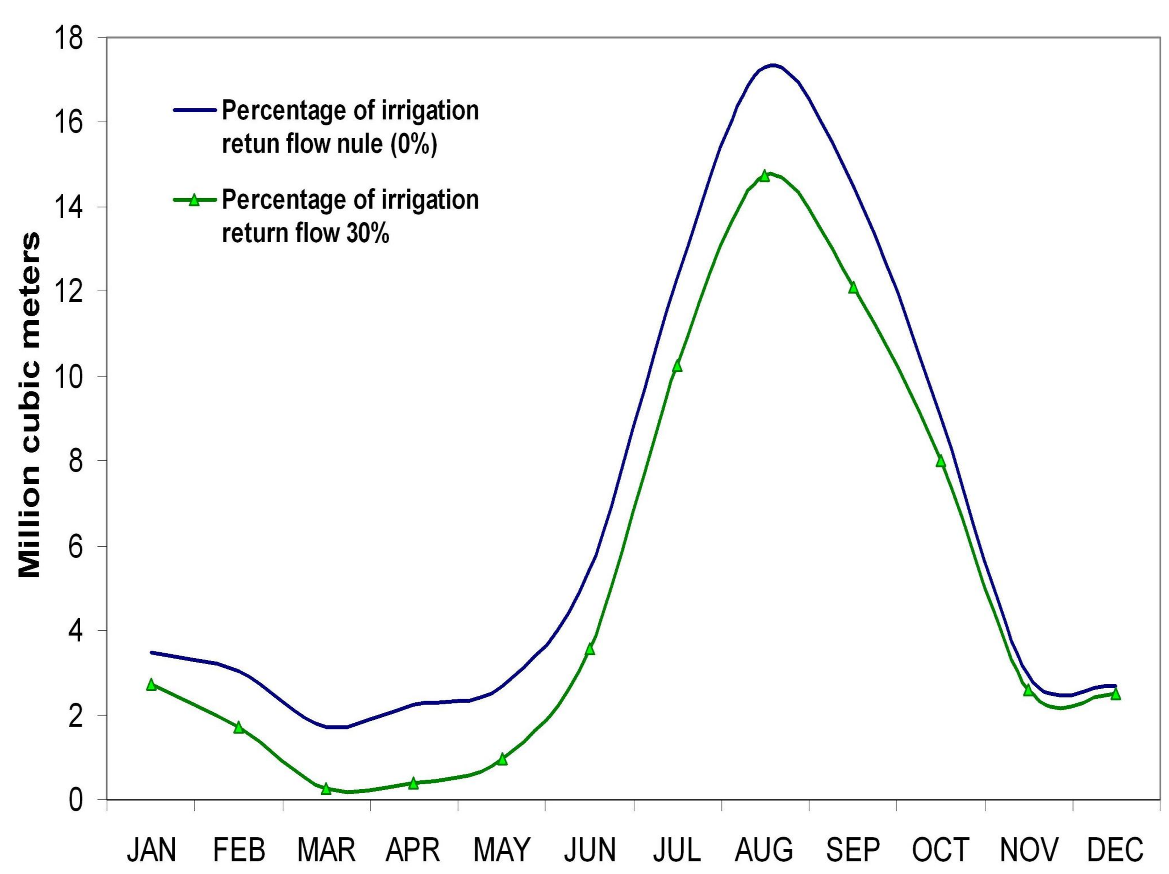

Figure 3. Natural flow and mean monthly consumptive use from 1982 to 2002 (considering 30% and 0% irrigation returns).

Natural flows using the "Alternative method".

The mean monthly natural flow was re-calculated for the period of analysis, considering irrigation return (Ir) percentages between 10% and 60% with increments of 10 percent points (Figure 2). Starting at a return corresponding to 30% of the volume used in agricultural activity, the natural flow hydrogram stops presenting the said deformation during the dry months.

The natural mean annual flow estimated including a return flow corresponding to 30% of the volume used in irrigation was 59.87 Mm³. This proposal to determine the percentage of irrigation water which returns to the river is valid as a mean value for the period of analysis. Figure 3 shows the initial annual hydrogram of mean monthly flow (without considering agricultural return flows) and the final hydrogram (considering an irrigation return flow of 30%). This figure shows how the anomaly generated by irrigation return flows was corrected, making it possible to quantify natural flows more precisely.

CONCLUSIONS

The results obtained for the Florido River basin show that the proposed method produces return flow percentages consistent with the values reported in literature, reducing the uncertainty of the estimation of return flows. The proposed method allows for a more precise determination of the natural flows in a hydrological basin.

REFERENCES:

Comisión Nacional del Agua (CNA), (1997), Programa Hidráulico de Gran Visión del Estado de Chihuahua, Contrato: SGC-GRN-CHIH-96-82A, México. D. F.

Comisión Nacional del Agua – Organismo de Cuenca Río Bravo (CNA-OCRB), (2006), Estudio de disponibilidad de agua superficial de la Cuenca del Río Bravo, Base de datos estadísticos de aprovechamiento de agua superficial en la Cuenca del Río Bravo, México, D.F.

Jothiprakash, V., (2003), Water Balance Model to Assess the Water Loss/Gain in a River System, IE(I)Journal-CV (84): http://www.ieindia.org/publish/cv/1103/nov03cv08.pdf. Cited 4 May 2007.

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), (2002), NOM-011-CNA-2000 Conservación del Recurso Agua - Que establece las especificaciones y el Método para determinar la disponibilidad media anual de las aguas nacionales, Diario Oficial de la Federación, miércoles 17 de abril, pp. 2-18 (Primera Sección), México D. F.

Wurbs, R. (2005), Texas Water Availability Modeling system, Journal of Water Resources Planning and Management, ASCE, 131(4): 270-279.

Yoshitani, J. and Tianqi, A., (2007), Development of natural flow hydrological database for PUB studies (Proceedings of the Kick-off meeting held in Brasilia 20-22 November 2002), IAHS Publi. 309, 2007: 201-207.