ADVANCES IN THE TRAINING ON WATER RESOURCES AT THE UNIVERSITY OF CARABOBO

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ABSTRACT: This article deals with advances in the training on water resources at the University of Carabobo (UC), Venezuela, carried out by a research unit belonging to the UC Engineering Faculty renamed as Center of Hydrological and Environmental Research (CIHAM UC, in Spanish) from 2007 to the present. CIHAM-UC operated as Center of Hydraulic Research (CIH-UC, in Spanish) since 1971. CIHAM-UC is focused on six research lines: 1) Integrated Management of Watersheds: Monitoring and Environmental Management. 2) Modeling of hydrological and environmental variables. 3) Environmental Risk Assessment: Vulnerability and Adaptability. 4) Environment, 5) Extreme Hydrological Process Modeling: Droughts and Floods. 6) Climate change. The main CIHAM-UC's scientific products have consisted of academic projects, theses, scientific articles and books to support undergraduate and graduate programs at UC, to enhance the impact of the UC Engineering Faculty in the economic and social environment of the region and the country.
KEYWORDS: CIHAM-UC; Center of Hydrological and Environmental Research; Water Resource Studies.

AVANÇOS NO TREINAMENTO SOBRE RECURSOS HÍDRICOS NA UNIVERSIDADE DE CARABOBO

RESUMO: Este artigo trata dos avanços na formação sobre recursos hídricos na Universidade de Carabobo (UC), Venezuela, realizada por uma unidade de pesquisa pertencente à Faculdade de Engenharia da UC rebatizada como Centro de Pesquisa Hidrológica e Ambiental (CIHAM UC, em espanhol) de 2007 até o presente. O CIHAM-UC operava como Centro de Pesquisa Hidráulica (CIH-UC, em espanhol) desde 1971. O CIHAM-UC está focado em seis linhas de pesquisa: 1) Gestão Integrada de Bacias Hidrográficas: Monitoramento e Gestão Ambiental. 2) Modelagem de variáveis hidrológicas e ambientais. 3) Avaliação de Risco Ambiental: Vulnerabilidade e Adaptabilidade. 4) Meio Ambiente, 5) Modelagem de Processos Hidrológicos Extremos: Secas e Inundações. 6) Mudança climática. Os principais produtos científicos do

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CIHAM-UC consistiram em projetos acadêmicos, teses, artigos científicos e livros de apoio aos programas de graduação e pós-graduação da UC, para aumentar o impacto da Faculdade de Engenharia da UC no ambiente econômico e social da região e do país.
PALAVRAS-CHAVE: CIHAM-UC; Centro de Pesquisa Hidrológica e Ambiental; Estudos de Recursos Hídricos.

AVANCES EN LA FORMACIÓN SOBRE RECURSOS HÍDRICOS EN LA UNIVERSIDAD DE CARABOBO

RESUMEN: Este artículo aborda los avances en la formación sobre recursos hídricos en la Universidad de Carabobo (UC), Venezuela, llevados a cabo por una unidad de investigación perteneciente a la Facultad de Ingeniería de la UC, rebautizada como Centro de Investigaciones Hidrológicas y Ambientales (CIHAM UC), desde 2007 hasta la actualidad. El CIHAM-UC funcionaba como Centro de Investigaciones Hidráulicas (CIH-UC) desde 1971. CIHAM-UC se centra en seis líneas de investigación: 1) Gestión Integrada de Cuencas Hidrográficas: Monitoreo y Gestión Ambiental. 2) Modelización de variables hidrológicas y ambientales. 3) Evaluación de Riesgos Ambientales: Vulnerabilidad y Adaptabilidad. 4) Medio Ambiente, 5) Modelización de Procesos Hidrológicos Extremos: Sequías e Inundaciones. 6) Cambio Climático. Los principales productos científicos del CIHAM-UC han consistido en proyectos académicos, tesis, artículos científicos y libros de apoyo a los programas de pregrado y postgrado de la UC, para potenciar el impacto de la Facultad de Ingeniería UC en el entorno económico y social de la región y el país.
PALABRAS CLAVES: CIHAM-UC; Centro de Investigaciones Hidrológicas y Ambientales; Estudios de Recursos Hídricos.

INTRODUCTION

This article deals with the advances in the training on water resources at the University of Carabobo (UC), Venezuela, carried out by a research unit belonging to the Faculty of UC Engineering recognized as the Center for Hydrological and Environmental Research (CIHAM-UC, in Spanish) from 2007 to the present. CIHAM-UC has operated as a Hydraulic Research Center (CIH-UC, in Spanish) since 1971. CIHAM UC focuses on six lines of research: 1) Integrated Management of Watersheds: Environmental Monitoring and Management. 2) Modeling of hydrological and environmental variables. 3) Assessment of environmental risks: vulnerability and adaptability. 4) Environment (Transport and Transformation of Pollutants; Environmental Impact Assessment; Education and Environmental Ethics) 5) Modeling of Extreme Hydrological Processes: Droughts and Floods and 6) Climate Change. Until now, CIHAM-UC's main scientific products have consisted of academic projects, theses, scientific articles, and books to support the UC undergraduate and graduate programs, to enhance the impact of the Faculty of UC Engineering in the economic and social environment of the region and the country. Likewise, to stimulate in this way the growth of the research and innovation

capacity at UC. This article presents a summary of the results of the scientific production achieved by a research unit recognized by the University Council of the University of Carabobo as the Center for Hydrological and Environmental Research (CIHAM-UC) from 2006 to the present in resource studies hydric as well its future perspectives.

METHOD

CIHAM-UC has carried out water resources studies on a field and laboratory scale. On a field scale, studies have been carried out in five basins of Venezuela (Urama (Yaracuy and Carabobo States), Pao (Carabobo and Cojedes States), Tucutunemo (Aragua State), Unare (Guárico and Anzoátegui States)) located in the northern region of the country (Figure 1). On a laboratory scale, the studies have been carried out at the Elías Sánchez Díaz Hydraulic Laboratory and the Environmental Quality Laboratory, both attached to the School of UC Civil Engineering. Likewise, CIHAM-UC has carried out teamwork to support doctoral theses with other national universities (Ezequiel Zamora Experimental National University (UNELLEZ, in Spanish), Lisandro Alvarado Western-Central University (UCLA, in Spanish)) and international universities (University of Pamplona, Colombia).

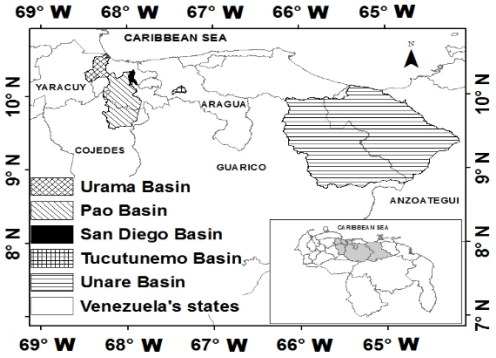
RESULTS

Integrated Management of Watersheds: Environmental Monitoring and Management

Results of the "Comprehensive Watershed Management with a Participatory approach. Cases: Pao and Unare Rivers", FONACIT-UC Project No. 2007001596

CIHAM-UC developed an experience derived from the FONACIT-UC Project N ° 2007001596 since 2006. The management of the basin was focused on the use and protection of water. The project was developed with the following objectives: 1) Hydrometeorological characterization of the Pao and Unare basins. 2) Modeling of the rain-runoff process of the Pao and Unare basins. 3) Implementation of the management proposal for the Pao and Unare basins with a participatory approach.

Figure 1. CIHAM-UC's study basins at Venezuela



The hydrometeorological characterization of the Pao and Unare basins implied the creation of a hydrometeorological monitoring network. This was installed in the Unare and Pao basins (Márquez, et al. 2011a, b, c), consisting of three Davis Instrument rain gauges and two Seba Hydrometrie Puls 20 water level gauges for the Unare basin as well as two rain gauges for the Pao basin. Meter type automatically observed, recorded and transmitted. These hydrometeorological networks operated from 2011 to 2018. For the Unare basin, three rain gauges were located in two states. The rain gauge No. 1 in the State of Guárico (09 ° 10'44.82 "N and 65 ° 35'14.79" W), the rain gauge No. 2 in the State of Anzoátegui (09 ° 25'07 "N and 64 ° 48'5.03 "W) and rain gauge N ° 3 in Anzoátegui state (09 ° 26'00.05 N and 65 ° 13'4.09" W). The two water level gauges were located in the middle and lower areas of the Unare basin. For the Pao basin, two rain gauges were located at the Dr. Alejo Zuloaga Water Treatment Plant (10 ° 08'19.6 "N and 68 ° 07'4.8" W) and the Pao Cachinche Reservoir (09 ° 52'16 " N and 68 ° 03'32.2 "W). Two workshops were held based on the FONACIT-UC Project No. 2007001596.

The first workshop was held at the headquarters of the Ministry of the Environment in Barcelona, Anzoátegui State on November 11, 2011. This workshop was aimed at staff of the Ministry of Environment and Civil Protection, as well as the community councils. In it, results were presented on the installation of the hydrometeorological network and training in data acquisition for the civil protection personnel of the municipalities of Zaraza (Guárico State) and Manuel Bruzual (Anzoátegui State) in the Unare basin. The environmental management scheme involved: 1) Acquisition of data by civil protection personnel, 2) Data processing by civil protection personnel, universities, hydrological companies and the Ministry of the Environment. 3) Decision-making by Community Councils, Regional and National Planning Bodies. A second workshop was held at the headquarters of the Ministry of the Environment in

Barcelona, Anzoátegui State on August 23, 2012. This workshop was aimed at staff from the Ministry of Environment and Civil Protection, as well as the community councils focused on in the modeling of the rainfall-runoff process to estimate the water supply and zoning of the floodplains of the Unare basin.

Three rainfall-runoff models based on physical processes were validated and used to generate maps of the flood zones. Autoregressive statistical models fitted well to the observations of 63% of the rain sensors (R^2> 0.5). The observed rainfall intensities were properly fitted to previously calibrated IDF curve models. The maximum flood levels for Tr 2/100 years were of the order of 0.42 / 1.06 m. for the Guanape river; 1.25 / 2.29 for the Guaribe River, 0.19 / 0.25 m. for the Guere river, 0.29 / 0.5 m. for the Ipire River and 0.8 / 1.21 m. for the Tamanaco River (Márquez et al., 2012; Márquez & Farías; 2015). The water production of the Pao basin varied between 100 and 200 mm month^{-1} during the rainy season (Márquez & Pérez, 2019). From the dry to the rainy season, the monthly water production of the Pao sub-basins varies as follows: Chirgua Basin 15 to 40 mm month^{-1} (Márquez & Franceschi, 2019), Pira Pira 30 to 88 mm month^{-1} (Márquez & Solórzano, 2010), Paya 19 to 57 mm month^{-1} (Márquez & Barreto, 2010) and San Pedro 45 to 137 mm month^{-1} (Márquez & Cabrera, 2010). Regarding the Unare basin, most of the northern area near the Caribbean Sea (medium to low) produced a negative water balance while these results were positive for the southern region of the basin, varying between 0 and 100 mm month^{-1}. (Márquez et al. 2016a).

Results of the Design of Hydraulic Works for the Protection of Floods Destined to Reinforce Uncontrolled Settlements Near Large Rivers and Reservoirs in Carabobo and Anzoátegui States". FONACIT-UC Project No. 2013001499

In this research, seven water reservoirs were included to perform bathymetric measurements. The reservoirs included were Pao-Cachinche (Pao basin) and six reservoirs in the Unare basin (Tamanaco, El Cigarrón, El Pueblito, La Becerra, Vista Alegre and La Estancia). The bathymetry was carried out using as equipment a 30-pound winch and global positioning equipment. The results of updating the Area-Level-Capacity curves of the reservoirs of the Unare and Pao basins indicated that there is significant sedimentation (Márquez et al., 2015a), exceeding the design capacity for the storage of sediments in a reservoir from the Pao basin (Pao-Cachinche) and two from the Unare basin (Tamanaco and Vista Alegre). There is significant erosion of the bottom of four of the reservoirs of the Unare basin (El Cigarrón, El Pueblito, La Becerra and La Estancia)

(Márquez et al., 2015b). The Francis generator is proposed as a unit to convert hydraulic energy into electrical energy within the design of the micro-plants of hydroelectric generation for the water reservoirs in the Unare basin (El Pueblito reservoir) and Pao basin (Pao-Cachinche and Pao-La Balsa). (Márquez et al., 2016b, c, d).

Results of the Design of a Management Model for the Urama Wetland, Venezuela

CIHAM-UC is supporting a doctoral project entitled "Design of a management model for the Urama wetland, Venezuela." The model will be based on the components and criteria established in the Convention on Wetlands of International Importance, (RAMSAR Convention). As an advance, (López et al., 2020) proposed a method that improves precision in determining the dynamics of change of uses and land cover in tropical wetlands.

Modeling of hydrological and environmental variables

Results of Applying the U.S. Models. Army Engineer Hydrologic Engineering Center (HEC) for the Analysis of Hydrological-Environmental Variables. Case study of Floodplain Zoning in the Urama River Basin - Carabobo State - Venezuela

The results of the application of the models of the Hydrological Engineering Center of US Army Engineers (HEC) for the analysis of hydrological-environmental variables are presented. The case study of floodplain zoning in the Urama basin - Carabobo State-Venezuela (Guevara & Márquez, 2006), indicated that for a flood with a return periods of 10, 50 and 100 years, the affected residential areas would be those that are below 35 meters above sea level.

Results of the Modeling of Water Erosion and Sediment Transport in a Basin of the Pao-Cachinche Reservoir. FONACIT-UC Project No. 2006063596

In the project FONACIT-UC Project No. 2006063596 associated with a CIHAM-UC doctoral thesis (Guevara & Márquez, 2011), the measurements were carried out in an agricultural settlement of 1000 hectares, in agricultural plots whose main crops are potato tuber in the dry season and maize during the rainy season during the period 2007-2010. Models of erosion and sediment transport in furrows of agricultural fields were formulated and parameterized for different slopes of the land, which varied from 0.8 to 13% (Márquez & Guevara, 2009,2010,2011a, b, c, Linares et al., 2009). The proposed

models were modifications of equations contained in existing models for erosion prediction (for example, WEPP, DWEPP, EUROSEM, SHE) and sediment transport models (Duboys, 1879; Meyer-Peter & Müller, 1948; Bagnold, 1966; Kilimc & Richardson, 1973; Simons et al, 1981; Govers, 1990). For the different slopes, the classic models and their modifications were calibrated, validated and tested, to estimate the component of particle detachment capacity or net detachment and the sediment transport capacity. The results obtained through simulations carried out with different models indicated that: (a) the particle detachment capacity was better estimated through the linear model of excess shear stress, (b) the transport capacity limits the sedimentation process, and (c) the detachment and transport capacity.

Infiltration modeling

Regarding the infiltration models (Guevara & Márquez, 2012; Guevara & Márquez, 2009, Márquez & Pérez, 2011d), the parameters of infiltration models were estimated and compared with nine models, four of physical base, two semi-empirical and three empirical ones, supported by the results of 107 infiltration field tests carried out on agricultural soil in the Chirgua river basin, Carabobo, Venezuela. The results of the regression analysis showed that the parameters of the Mishra-Singh, Kostiakov and Horton models explained up to 70% of the variability (minimum R2 = 0.70).

Modeling of water quality in lakes and reservoirs

Multivariate linear models were proposed to estimate the physicochemical and biological parameters of the Pao-Cachinche reservoir (Márquez et al., 2019a, Márquez & Esta, 2019) and Valencia Lake (Márquez & Lara, 2019) using the reflectance of the surface of the images of Landsat satellite. Eight parameters were included (total phosphorus, total nitrogen, plankton, BOD, COD, total coliforms, electrical conductivity and pH). The results indicated that the adjustment between the water quality characteristics and the surface reflectance extracted from the Landsat satellite images was successful because the R^2 statistic indicates that the adjusted models explain between 70.18 and 75.18% in the physical-chemical variability and biological parameters.

Groundwater modeling

A spatio-temporal geostatistical modeling study of hydrogeochemical parameters was developed in the San Diego aquifer, Carabobo State, Venezuela during the period

2015-2017 (Márquez et al., 2018a). The modeling of all hydrogeochemical parameters was represented by the J-Bessel function. A spatio-temporal forecast model of water balance variables in the San Diego-Venezuela aquifer was proposed (Márquez et al., 2018b) combining GIS tools as a geostatistical analysis tool to make predictions of variables using statistical models of spatial prediction based in the Ordinary Krigging method followed by the application of forecasting models. In the calibration stage, the selected statistical spatial prediction model has been J-Bessel and the selected prediction model has been Brown's quadratic exponential smoothing with constant alpha. In the validation stage, the correlation coefficient has taken values higher than 0.98 and the determination coefficient higher than 0.96, confirming that the method used to generate the spatio-temporal forecast model achieves adequate predictions for the water balance variables.

Another study was presented as a remediation proposal for soils and groundwater in an aquifer in Venezuela through geostatistical modeling of hydrocarbon transport (Márquez & Rodríguez, 2018; Márquez et al., 2019c). The state of the confined aquifer due to the alternation of layers of low plasticity clay with well-graded sand has prevented the hydrocarbons in the soil from reaching a concentration that exceeds environmental regulations. For groundwater, the concentration of hydrocarbons such as TPH, TPH-GRO, Lead, Benzene, Toluene, Ethylbenzene, m.Xylene, O. Xylene and MTBE was higher than the environmental regulations. In most cases, the spatial prediction of hydrocarbons is explained by local polynomial interpolation of orders between 2 and 3.

Assessment of environmental risks: vulnerability and adaptability

Results of the estimation of flood risk in a tropical basin

Within the framework of the doctoral thesis project entitled "Plan for the sustainable management of flood risk in the Pao river basin, Carabobo State from a community perspective" supported by CIHAM-UC. (Farías et al., 2020) proposed a method to estimate the risk of flooding in tropical basins. The method followed six stages: 1) estimation of the effective precipitation map, 2) generation of the effective precipitation classification map, 3) estimation of the effective precipitation exceedance probability map, 4) estimation of the hydrological risk map and 5) method validation. According to the results obtained by (Farías et al. 2020), the flood risk method was sensitive to detect areas of moderate to low risk to those of urban use. In these, hydraulic

works are carried out for the use and control of water, as is the case of the three reservoirs built in the Pao basin.

Results to Estimate the Hydrogeological Vulnerability of an Aquifer

The DRASTIC method was developed by (Aller, 1985). The vulnerability to the risk of contamination of the San Diego aquifer was medium to high in the urban area (Márquez & Carrillo, 2015), specifically in those areas that combine high recharge dynamics, an unsaturated area made up of gravel and sand, high water level with respect to ground elevation. Similar results were found for the Guacara aquifer (Márquez & Peraza, 2018).

Environment

Transport and Transformation of Pollutants

Results of the transport modeling of organochlorine pesticides in the tucutueno river, zaomora municipality, aragua state

The doctoral thesis project "Organochlorine pesticide transport modeling in the Tucutunemo River, Zaomora Municipality, Aragua State" was developed on a field scale. The study area was located in the Tucutunemo river basin, Aragua state, central region of Venezuela. The basin is delimited by the following coordinates (Cárdenas et al. 2018, 2019, in press): 67 ° 19'00 "W, 67 ° 29'00" W, 10 ° 02'00 "N, 10 ° 08'30 "N. Three water and sediment monitoring stations (MS) were located in the upper (MS1), middle (MS2) and lower (MS3) areas of the basin. Water and sediment samples were collected every six months, in the dry (April) and rainy (October) seasons, from 2013 to 2016. To process the water and sediment samples, the laboratory facilities of the Ministry of the Environment in the State of Aragua were used. Eight organochlorine pesticides (p.p'-DDT, o.p'-DDT, p.p'-DDE, o.p'-DDE, p.p'-DDD, Aldrin, Endrin and Dieldrin) were determined. The biochemical transport and transformation model is proposed in two directions, along the river ($(\partial OCP)/\partial x$), and a thickness layer parallel to the z direction, ($(\partial OCP)/\partial z$). This study provides kinetic parameters linked to the Monod equation assuming a steady state condition for soluble and particulate OCPs. In the z direction, the semi-saturation coefficient / maximum utilization rate of the substrate, (Ks/km) ranged between 10^{-1}-10^{-3}, being associated with the exponential growth phase by microorganisms (Cárdenas et al., in press).

Results of the dynamic modeling of the processes of removal of organic matter and nitrogen from the effluents of the tanneries by means of a sequential batch reactor

The doctoral thesis project "dynamic modeling of the processes of removal of organic matter and nitrogen from the effluents of tanneries by means of a sequential batch reactor" was developed as a team between CIHAM-UC and the Agroindustrial Engineering Program, Lisandro Alvarado Central-Western University, Lara-Venezuela State (UCLA, in Spanish). The applied method involved seven stages (Freytez et al., 2019a, b): 1) Construction of the sequential batch reactor (SBR), 2) Selection of the substrate, 3) Acclimatization of the biomass to the substrate, 4) Experimental design, 5) SBR performance evaluation, 6) Mathematical modeling, 7) Comparison of results. The modified ASM1 models have been tested under conditions of high COD concentration as input substrate and input ammonium concentration of wastewater obtained from a tanning industry. The modification of the ASM 1 model to adapt it to the operational performance of a sequential discontinuous reactor in the oxic-anoxic phases has resulted in mathematical equations that allow estimating the concentration of the removed nitrogenous forms such as ammonium and nitrate in the aeration and anoxic phases of SBR and it was found that the coefficient of determination (R^2) resulted in a statistical adjustment rated from good to excellent.

Results for the "design models of upflow anaerobic filters separated in two phases and three phases”

The doctoral thesis project "Design models of upflow anaerobic filters separated in two phases and three phases” was developed as a team between CIHAM-UC and the Environmental Research Group: Water, Air and Soil of the University of Pamplona, Colombia. The experimental stage was carried out on a laboratory scale, using the resources of the University of Pamplona, while CIHAM-UC contributed to the mathematical modeling. The applied method involved five stages (Márquez et al., 2020; Maldonado et al., 2018a, b, 2020): 1) Characterization of the leachate, 2) Design and construction of reactors UAF-2SS and UAF-3SS, 3) Adaptation and acclimatization of the UAF-2SS and UAF-3SS reactors, 4) Start-up and operation of the UAF-2SS and UAF-3SS reactors, 5) Development of mathematical models for the UAF-2SS and UAF-3SS reactors. Two scenarios were proposed (Márquez et al., 2020). Scenario 1 consisted of models for the biochemical transformation of substrates. Scenario 2 was based on

coupled models for transport and biochemical transformation processes. In Scenario N ° 2, the coupled model allows estimating the molecular diffusion of substrates along the length of the filter and the thickness of the biofilm. The coupled model represents a more suitable mathematical structure to design the physical characteristics of the UAF-2SS and UAF-3SS reactors based on the remaining fraction of organic compounds according to the number of phases within the upflow anaerobic filter.

Environment: Environmental Impact Assessment

Results of the constitutional requirements for environmental evaluation systems in engineering works

According to (Márquez & Orlandi, 2019), the constitutional requirement to request an environmental impact assessment for all those activities that may cause damage to ecosystems does not imply excluding the use of other environmental assessment systems. It is necessary to classify those engineering works that are potentially harmful to the functional structure of ecosystems.

Environment: Ethics and Education

Results of the reactivation of three test benches of high, medium and low power electric generators (hmlp-egbs) for the conversion of hydraulic energy, elías sánchez díaz hydraulic laboratory. fonacit-uc project no. 2014000418

The main support for the electromechanical maintenance of the Kaplan, Francis and Pelton generators on a pilot scale was received from the personnel of the national public company COPORACIÓN ELÉCTRICA (CORPOELEC). The project activities were carried out in three stages, which were as follows (Márquez & Salazar, 2015): 1) Rehabilitation of the electric power supply system for the HMLP-EGBs (Márquez & Salazar, 2015). 2) Rehabilitation of the water supply system of the HMLP-EGBs (Márquez & Salazar, 2015; Márquez et al., 2015a, Márquez et al., 2016a, b, Márquez & Canchica, 2016; Márquez et al., 2016) . 3) Rehabilitation of the HMLP-EGBs (Márquez & Salazar, 2015; Márquez et al., 2015a, Márquez et al., 2016a, b, c; Márquez & Canchica, 2016)**.**

1)Performance curves for HMLP-EGBs (Kaplan generator)

A 9x9x6 factorial experimental design (486 tests) was applied. Nine levels of distributor blade angle (1 to 2 in.). Nine levels of impeller blade angle (-5-35 °). Six levels were established for the rotation speed of the Kaplan turbine shaft (200 to 1200 RPM),

piezometric head of one foot; finding that the operating efficiency increased from 50 to 95% as the flow rate increased, the angle of the distributor blades and the rotation speed of the turbine shaft. The implementation of a data acquisition system in a digital platform was designed to control and regulate the data acquisition process, making the appropriate representation of the values measured in the process (Márquez et al., 2015a, Márquez et al., 2016a, b, c).

2) Performance curves for BPGE-MP (Francis Generator)

A 10x2 factorial experimental design (20 tests) was applied. Ten levels of inlet flow rates (50 to 275 GPM) and two levels of distributor opening (50 and 100%) were set; finding that under a completely open condition of the distributor, the electrical power increased from 0 to 180 W as the flow rate increased from 0 to 300 GPM (Márquez & Canchica, 2016; Márquez et al., 2016 a, b).

3) Performance curves for BPGE-AP (Pelton Generator)

A 4x5x9 factorial experimental design (180 tests) was applied. Four levels of inlet flow rates (50 to 200 GPM). Five guide vane opening levels were set (1/5 to 1 in.) Nine turbine shaft rotation speeds (400 to 1200 RPM); finding that the power to the brake increased from 0 to 3 kW as the turning speed and the opening of the guide blade were reduced from 1000 to 400 RPM and from ¾ to ½ inch, respectively (Márquez & Canchica, 2016; Márquez et al., 2016 a, b).

Modeling of extreme hydrological processes: droughts and floods

Results of drought modeling

Between UNELLEZ-VIPI; Research Group on Watersheds and Hydraulic Resources of the Academic Program on Engineering, Architecture and Technology, San Carlos-Cojedes. Venezuela and CIHAM-UC, a method was developed, calibrated and validated that combines probabilistic networks, intelligent systems and macroclimatic teleconnections (Paredes & Guevara, 2010). Sites with frequent droughts had a higher chance of success. The most favorable regions for the implementation of this method were the Central and Western Plains, the Coriano System and the eastern slopes of the Cordillera de Perija.

Forecast results of flood risk in a tropical country.

A method was proposed to forecast the flood risk for a tropical country called CIHAM-UC-FFR (Márquez et al., 2020). The method is based on the rain-runoff process. The CIHAM-UC-FFR method consisted of three stages: 1) calibration and validation of the effective precipitation model, called the CIHAM-UC-EP model, 2) calibration of forecast models for components of the CIHAM-UC-EP model, 3) proposed model for flood risk forecasting, called CIHAM-UC-FR. The results on the method to forecast flood risk found by (Márquez et al., 2020) were that the CIHAM-UC-EP model has a mathematical structure derived from a conceptual model obtained by applying the principle of mass conservation combined with the principle adapted from Fick's law. The CIHAM-UC-FR model is a stochastic equation based on the probability of exceedance of the predicted effective precipitation. Various scenarios are shown for a future time where the risk of flooding progressively decreases as the useful life parameter of the hydraulic work increases.

CONCLUSIONS

In the short term, CIHAM UC has developed studies in partnership with public and private institutions, national and international universities, producing results that contribute to the sustainable use of water and the contribution of the University of Carabobo with its socioeconomic environment**.**

Figura 2 Rehabilitación de generador Kaplan a escala de laboratorio. Laboratorio UC-Hidráulico. A) Inicio de rehabilitación con fecha 23/10/2013, b) Rehabilitación final con fecha 07-10-2015.

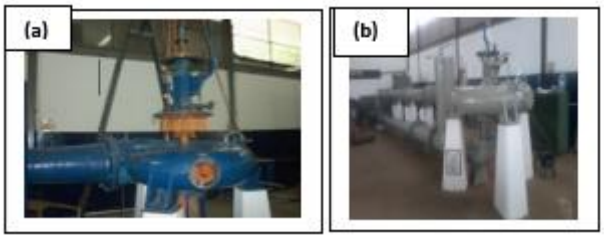
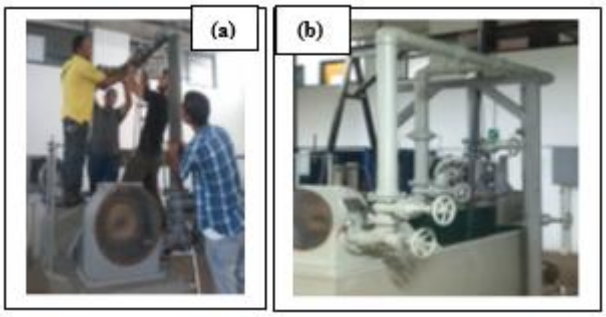


Figure 3 Rehabilitation of high (Pelton), medium (Francis) power electric generators test benches to laboratory scale. UC-Hydraulic Laboratory. A) Replacing the water supply system from PVC to galvanized iron dated 09-01-2016, b) Final rehabilitation dated 10-10-2016.



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