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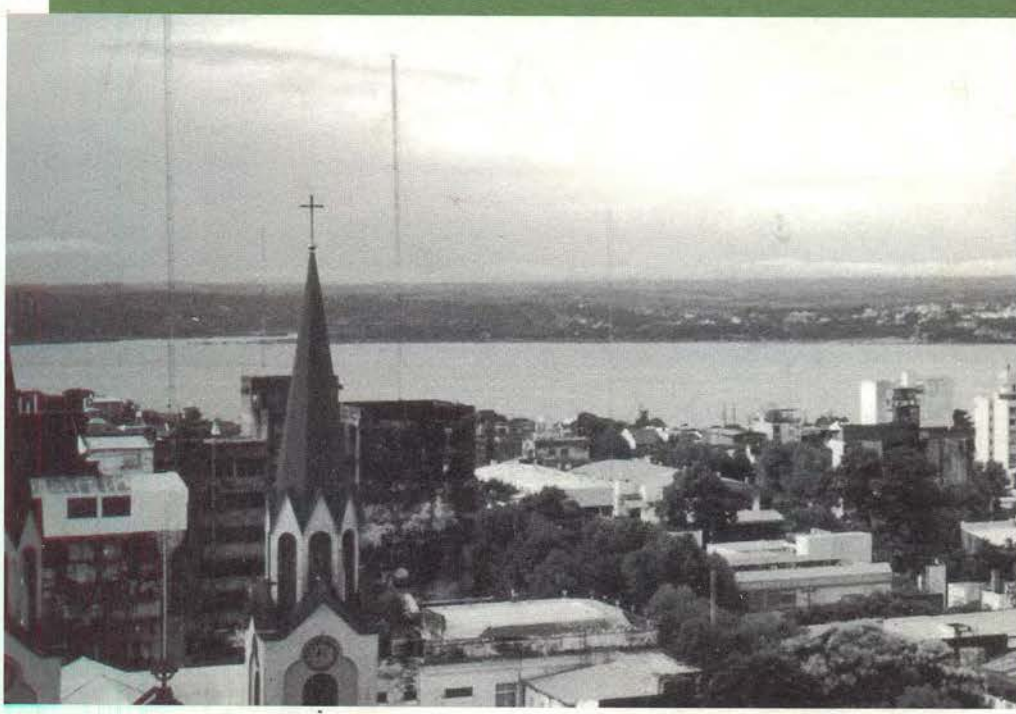
International Environmental Technology Centre (IETC)

THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA BASIN

Proceedings

9-17 March 2001, City of Posadas, Argentina



PROCEEDINGS

of the

THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN:

"Informed Decision Processes for Sustainable Development of Reservoirs"

and

SHORT TRAINING COURSES ON LAKE AND RESERVOIR WATER QUALITY MONITORING AND ECOLOGICAL MODELLING

March 9 to 17, 2001
City of Posadas, Province of Misiones, Argentina

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FOREWORD

The La Plata River Basin is the second largest in South America covering area of about 3.1 million square km with very dense and rich drainage flowing through five countries being Argentina, Bolivia, Brazil Paraguay and Uruguay. Its importance in terms of development, environment and economy for the region is enormous and particularly in terms of energy production from hydroelectric systems. Along the basin a number of multi purpose dams and reservoirs have already been built producing electricity while still there are more under construction or in the drawing board. In view of the negative potential damage that dams may have on the environment and the basin itself many conservationist and the society in general are calling for a revision of the government's plans.

Based on the findings and recommendations of the World Commission on Dams and the experience of the La Plata River Basin the need to review the plans to build and manage new dams and reservoirs in the basin appears to be quite timely. It is expected that through this process appropriate strategies and procedures will be identified so that their construction and use will pose the least environmental risks while at the same time providing the largest possible benefits to the riparian countries. This effort requires not only the political will and the institutional support but also a network of environmental research and management to ensure that the appropriate decisions are taken.

The III International Workshop on Regional Approaches to Reservoir Development and Management in the La Plata River Basin was convened in the City of Posadas, Provincia de Misiones in Argentina to serve as the arena for an open and multisectorial debate on sustainable development of reservoirs and host the foundation of the La Plata River Basin Environmental Research and Management Network (RIGA). The latter was one as one of the most important recommendations of the previous II International Workshop on the subject held in 1994 calling for the creation of a regional network to develop further the communication, interaction and cooperation among organizations within the basin devoted to water resources and environment management.

UNEP-DTIE-IETC as well as ILEC decided to support from the beginning the process towards the sustainable planning and management of dams and reservoirs in the La Plata River Basin as well as the establishment of RIGA. Furthermore, as part of the III International Workshop two training courses were provided related to Water Quality Monitoring and Eutrophication Management. On the latter a Training Package entitled PAMOLARE 2L consisting of a set of simple numerical models able to forecast eutrophication in lakes and reservoirs was developed and used for the course. This package in its Pilot Version (1.0) is included in the present Report with the hope of assisting decision making in forecasting the appearance of eutrophication.

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THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN:
"Informed Decision Processes for Sustainable Development of Reservoirs"

March 9 to 17, 2001 - City of Posadas, Province of Misiones, Argentina

Organized by

United Nations Environment Programme-Division of Technology, Industry and Economics -International Environmental Technology Centre (UNEP-DTIE-IETC)

International Lake Environment Committee Foundation (ILEC)

Argentine Water Resources Institute (IARH)

La Plata River Basin Environmental Research and Management Network (RIGA)

Secretary of State General and Cabinet Coordination, Province of Misiones, Argentina

National Water Institute (INA), Argentina

Co-organized by

Japanese Ministry of Environment

Faculty of Exact, Chemical and Natural Sciences, National University of Misiones, Argentina.

Japan Fund for Global Environment/Japan Environment Cooperation

Undersecretary of Water Resources, Ministry of Infrastructure and Housing, Argentina.

Joint Argentinean Paraguayan Commission of the Paraná River

With the adhesion of

Centre of Applied Ecology for the Litoral (CECOAL), Argentina

Institute of Limnology "Dr. Raúl A. Ringuelet" (ILPLA-CONICET), Argentina

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FOREWORD

Last March 2001, along 9 days of very intense activity, over 140 representatives of many organizations from the various countries of the La Plata River Basin, and abroad, gathered in Posadas City, Province of Misiones, Argentina, to openly discuss about sustainable development and management of reservoirs. Understanding functions of lakes/reservoirs through monitoring, prediction of reservoir responses through modeling and institutional arrangements for participated decision processes, were subject to debate by the participants in the context of their own personal and country experiences and lessons learned in the region.

Short training activities on Water Quality Monitoring and Ecological Modeling of Lakes and Reservoirs, provided scientific and technological input for discussions. Thirty four (34) papers of general and specific interest, ten (10) lectures and keynote speeches by distinguished specialists and over twenty short background papers with recommendations on the Workshop topics, from various stakeholders sectors, were submitted to the meeting and most of them presented orally by their authors. All these materials were subject to critical analysis and evaluation by the participants in working group sessions, which yielded the Final Conclusions and Recommendations concerning scientific, technological and institutional aspects of sustainable reservoir development and management.

The III International Workshop also hosted the foundation of the La Plata River Basin Environmental Research and Management Network (RIGA), providing a remarkable framework for such a regional cooperative effort towards sustainable and integrated management of water resources.

Alberto T. Calcagno

On behalf of the Local Organizing Committee

ACKNOWLEDGEMENTS

The III International Workshop could be carried out thanks to the support of the International Environmental Technology Centre (UNEP-DTIE-IETC), the International Lake Environment Committee Foundation (ILEC) and the National Water Institute (INA). Also the Japanese Ministry of Environment and the Japan Fund for Global Environment/Japan Environment Cooperation contributed with their funding to the development of the pre Workshop training activities.

Organization of the Workshop was mainly driven by the Argentine Water Resources Institute (IARH), and succeeded thanks to the cooperation of the Faculty of Exact, Chemical and Natural Sciences of the National University of Misiones, the Secretary of State General and Cabinet Coordination of the Province of Misiones and the Joint Argentinean Paraguayan Commission of the Paraná River (COMIP).

Many persons within said organizations contributed to the success of the meeting. On the names of just a small number of them like Carlos Angelaccio, Carlos Brieva, José I. Enriquez, Cristina Foulon, Carlos Galian, Carolina Illañez, Ana Mugetti, Vicente Santiago Fandiño and Yosuke Yamashiki, let us express our deep gratitude and appreciation for the collaboration of them all.

Alberto T. Calcagno

On behalf of the Local Organizing Committee

LIST OF ACRONYMS

ACRONYM	DESCRIPTION[1]
AA	Aguas Argentinas S.A., Argentina
AAM	Asociación Misionera de Mediación, Argentina
AAPURE	Asociación Argentina para el Uso Racional de la Energia, Argentina
ABRH	AsSociaçao Brasileira de Recursos Hídricos, Brasil
APA-Chaco	Administración provincial del Agua, Provincia del Chaco, Argentina
APMA	Associação de Proteção do Meio Ambiente de Limeira, Brasil
BID	Banco Interamereicano de Desarrollo (IDB - Inter American Development Bank)
CAP	Comité Argentino de Presas, Argentina
CECOAL	Centro de Ecología Aplicada del Litoral, Corrientes, Argentina
CEHPAR	Centro de Estudios Hidráulicos "Professor Parigot de Souza", Paraná, Brasil
CESP	Companhia Electrica de São Paulo, São Paulo, Brasil
CICTT	Centro de Investigaciones Científicas y de Transferencia de Tecnología a la Producción, Entre Ríos, Argentina
CIRSA	Centro de Investigaciones de la Región Semiárida, INA, Argentina
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brasil
COMIP	Comisión Mixta Argentino Paraguaya del Río Paraná, Argentina-Paraguay
COPEL	Companhia Paranaense de Energía, Paraná, Brasil
COREBE	Comisión Regional del Río Bermejo, Argentina
CPN	Centro Nacional Patagónico, Pto. Madryn, Chubut, Argentina
CTMSG	Comisión Mixta Técnica de Salto Grande, Argentina-Uruguay
DH-ER	Dirección de Hidráulica, Subsecretaría de Recursos Hídricos, Entre Ríos, Argentina

[1] Most names and geographical references are given in their native language

ACRONYM	DESCRIPTION[1]
DIPAS	Dirección Provincial de Agua y Saneamiento, Provincia de Córdoba, Argentina
DNH	Dirección Nacional de Hidrografia, Uruguay
DEE-GSE-KU	Department of Environmental Engineering, Graduate School of Engineering, Kyoto University, Japan
DSEES-GSES-KU	Department of Socio Environmental Energy Science, Graduate School of Energy Science, Kyoto University, Japan
DTIE	Division of Technology, Industry and Economics
EBY	Entidad Binacional Yacyretá, Argentina-Paraguay
EMSA	Electricidad de Misiones S.A., Misiones, Argentina
FCA-UN Comahue	Facultad de Ciencias Agrarias, Universidad Nacional de Comahue, Neuquén, Argentina
FCEFyN-UNC	Facultad de Ciencias Exactas, Físicas y Naturales, Univesidad Nacional de Córdoba, Argentina
FCEM	Federación de Cooperativas Eléctricas de Misiones, Misiones, Argentina
FCE-UNAM	Facultad de Ciencias Económicas, UNAM, Argentina
FHySC-UNAM	Facultad de Humanidades y Ciencias Sociales de la Universidad Nacional de Misiones, Argentina
FI – UNLP	Facultad de Ingeniería, Universidad Nacional de La Plata, Argentina
FI- URU	Facultad de Ingeniería, Universidad de la República del Uruguay, Uruguay
FICH-UNL	Facultad de Ciencias Hídricas, Universidad Nacional del Litoral, Santa Fe, Argentina.
FI-UNAM	Facultad de Ingeniería, UNAM, Misiones, Argentina
GEMS	Global Environment Monitoring System
GIEU	Grupo Interdisciplinario de Ecología Urbana, Entre Ríos, Argentina
HE	Hidroconsult Engenharia S/C Ltda.. Florianópolis, SC, Brasil
IB	Itaipú Binational Entity, Brazil-Paraguay
ICA	Instituto Correntino del Agua, Corrientes, Argentina
IC-NCST	Institute of Chemistry – National Council of Science and Technology (NCST), Vietnam

ACRONYM	DESCRIPTION[1]
IDTIQ	Instituto de Desarrollo Tecnológico para la Industria Química. Instituto Nacional de Tecnología, Santa Fe, Argentina
IETC	United Nations Environment Programme – Division of Technology, Industry and Economics - International Environmental Technology Centre (UNEP-DTIE-IETC)
IFAI	Instituto de Fomento Agropecuario e Industrial, Provincia de Misiones, Argentina
IHP V-UNESCO	International Hydrological Programme IHP V, Project 2.3/2.4 on EcoHydrology, UNESCO
IIE	Instituto Internacional de Ecología, São Carlos, SP, Brasil
ILINOA	Instituto de Limnología del Noroeste Argentino, Tucumán, Argentina
IMAS	Instituto Misionero de Agua y Saneamiento, Misiones, Argentina
IMFIA	Instituto de Mecánica de Fluidos e Ingeniería Ambiental, Universidad de la República del Uruguay, Uruguay
INA	Instituto Nacional del Agua, SSRH-MIV, Argentina
IPH	Instituto de Pesquisas Hidráulicas, Universidad Federal de Río Grande do Sul, Porto Alegre, Rio Grande Do Sul, Brasil
MEyRNR	Ministerio de Ecología y Recursos Naturales Renovables, Misiones, Argentina
MRECIC	Ministerio de Relaciones Exteriores, Comercio Internacional y Culto, Argentina
PAMOLARE	Planning and Management of Lakes and Reservoirs focusing on Eutrophication
RCEQC	Research Center for Environmental Quality Control, Graduate School of Engineering, Kyoto University, Japan
SABESP	Companhia de Saneamiento Básico do Estado de São Paulo, São Paulo, Brazil
SCyT-UBA	Secretaría de Ciencia y Técnica, Universidad de Buenos Aires, Argentina
SEMA-MS	Secretaría de Meio Ambiente, Estado de Matto Grosso do Sul, Brasil
SSRC	Subsecretaría de Relaciones con la Comunidad. Provincia de Misiones, Argentina

ACRONYM	DESCRIPTION[1]
SSRH- MIV	Subsecretaría de Recursos Hídricos de la Nación. Ministerio de Infraestructura, Argentina
SSRNyE	Subsecretaría de Recursos Naturales y Ecología, Formosa, Argentina
SUPCE – ER	Sub Unidad Provincial de Coordinación de Emergencias, Provincia de Entre Ríos, Argentina
UERJ	Universidade do Estado de Río de Janeiro, Brasil
UM	Universidad de Morón, Provincia de Buenos Aires, Argentina
UNAM	Universidad Nacional de Misiones, Argentina
UNCRD	United Nations Centre for Regional Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Education and Science Organization
UNSJ	Universidad Nacional de San Juan, San Juan, Argentina.
USP	Universidade de São Paulo, São Paulo, Brasil
WCD	World Commission on Dams
WRRC-DPRI	Water Resources Research Center, Disaster Prevention Research Institute, Kyoto University (WRRC-DPRI-Kyoto University)

THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN

1. Introduction

The Third International Workshop on Regional Approaches to Reservoir Management and Development in La Plata River Basin, was held from March 9 to 17, 2001, in the city of Posadas, Province of Misiones, Argentina. Over 130 participants from the countries of the Basin and abroad, attended the various activities which included two short training courses on Water Quality Monitoring and Ecological Modeling of Lakes and Reservoirs, the III International Workshop and the Foundation Session of the La Plata River Basin Environmental Research and Management Network (RIGA)

The meeting was meant for experts from the five countries of the La Plata River Basin, willing to exchange country experiences, to analyze emerging policy issues in reservoir development and management and to identify and agree upon strategies and guidelines that should be incorporated to the planning, design, construction and operation stages to ensure that a participated and informed decision process leads to sustainable development and management of reservoirs.

These Proceedings present a summary of the background, objectives, focus, activities, conclusions and recommendations of the Workshop developed along nine days of intense dedication by the participants, lecturers and organizers. The list of participants, keynote speeches, papers and recommendations, as well the most relevant papers presented to the Workshop are included as Annexes.

2. Background and Objectives

This III International Workshop on Regional Approaches to Reservoir Development and Management in the La Plata River Basin is meant to (i) set the arena for an open and multisectorial debate on sustainable development of reservoirs; (ii) host foundation activities of the La Plata River Basin Environmental Research and Management Network (RIGA), which is one of the most relevant activities stemming from the recommendations of the previous I and II International Workshops, and in doing so, (iii) provide continuity and follow up to the previous regional meetings successfully held in 1991 and 1994.

The First Workshop-Training Course entitled "International Workshop on Regional Approaches to Reservoir Development and Management in the La Plata River Basin: Focus on Environmental aspects", was held at Sao Carlos (USP) and Itaipú (IB), Brazil, and Yacyretá (EBY - Ituzaingó), Argentina in August 1991. The Second, with focus on management aspects, was held at. Salto Grande (CTMSG - Concordia) and Buenos Aires (BID/INTAL), Argentina, in 1994[2]. A distinctive output of this last meeting was a strong recommendation towards the creation of a regional network to develop further the

[2] Both meetings were organized by the International Lake Environment Committee Foundation (ILEC), United Nations Environmental Programme (UNEP), United Nations Centre for Regional Development (UNCRD) together with regional and local organizations.

communication, interaction and cooperation among organizations within the basin devoted to water resources and environment management.

As a consequence, and with the support of national and international organizations like the National Council for Research and Technology Development (CNPq) of Brazil, the Argentine Water Resources Institute and the Inter American Development Bank, among many others, the grounds for the implementation of the **La Plata River Basin Environmental Research and Management Network (RIGA)**, integrated by organizations from all five countries of the basin, have been set.

La Plata River Basin, the second largest in South America spans its area of about 3,1 million sq.km and very dense and rich drainage network over the territory of five countries in the southern end of the continent. A large number of multipurpose reservoir systems have been built and many others are being planned, constituting a key feature for the development of the region. Reservoirs have been beneficial for the community in the region by satisfying energy demands, making water available for various uses and providing useful services. But they have also produced, due to their large scale interventions in land and water ecosystems, some unsuccessful experiences resulting in deleterious social and ecological effects.

As a consequence the region depicts a long history of successes and failures in reservoir development and management. Failures, mainly in the ecological and social fields, have casted environmental concerns in the recent times over reservoir construction and operation in the region. Of course this concern is not unique to the La Plata River Basin. The conflict between development and environment has found in reservoir development and management appropriate grounds to nourish the confronting opinions of many experts and organizations either in the governmental or non governmental sector, at local, national and international level, all over the world. Therefore, the concept of sustainable development faces, in the field of dams and reservoirs, a major challenge which calls for the joint efforts of all sectors to overcome it successfully.

Last November 2000, the World Commission on Dams (WCD) issued its Final Report on "Dams and Development: A new Framework for Decision Making" [3], which develops a global review of the performance of dams, and presents "an integrated assessment of when, how and why dams succeed or fail in meeting development objectives" as well as criteria and guidelines for good practice, strategic priorities and recommendations for the assessment of options, planning and the project cycle for the development of water resources and energy.

In the context of said report, but with focus on the rich experiences in the La Plata River Basin, it appears the need to review, with a constructive approach, the management and decision making processes involved in the development of existing reservoirs and the planning of future ones, in order to identify appropriate strategies for environmentally sound development and management of reservoirs in the region. Complementary, it appears the need to rebuild confidence in that the improvements achieved in the physical and social sciences and technologies, may contribute to successfully develop said strategies. This Workshop intended to stimulate actions concerning both issues.

[3] Dams and Development: A New Framework for Decision Making. Report of the World Commission on Dams An Overview. November 2000

At global level, involvement of all stakeholders, increased cooperation in international water basins and massive increase in water investments are some of the most relevant key actions identified by the World Water Vision (II World Water Forum, Le Hague, The Netherlands, 2000) to achieve the main objectives of integrated water resources management. La Plata River Basin faces the challenge of effectively implementing the recommendations from said Forum. Steps have already been taken in said direction. Some GEF funded projects, like the Upper Paraguay and the Bermejo River Binational Basin Strategic Action Programmes or the Guarani Regional Aquifer constitute good examples, among others. Development and management of multiple purpose reservoirs should be incorporated into the basin wide and participatory approach promoted by these initiatives. Said perception is reinforced by the existence of a legal framework in the countries of La Plata River Basin, both either national or international, which calls for participation and involvement of stakeholders in the use and protection of natural resources.

Therefore, La Plata River Basin displays a rich experience, past and recent, and, consequently, lessons learned by researchers, planning and funding agencies, including the major international banks, consultants, construction firms, NGOs and community based organizations should provide a valuable input to discussions and elaborations in the meeting.

In this context this III Workshop provided a forum for an open, high level, constructive debate among stakeholders to discuss and identify specific scientific, technological, institutional, economic, social and environmental criteria and guidelines, tailored to the region, that should be incorporated into project decision process leading to sustainable design, construction and management of reservoirs.

3. Focus

This III Workshop focuses on the implementation of truly informed decision processes to steer the identification, design, construction, management and dismantling of dams and reservoirs into the pathways of sustainable development. Said processes rely mainly (i) on data availability and systematic evaluation of lake-watershed environmental status and trends; (ii) a sound understanding, and appropriate conceptual and numerical modeling approaches to the simulation and prediction, of reservoirs response to watershed inputs and interrelationships in order to preserve biodiversity, water uses and human health and (iii) viable institutional and organizational arrangements to facilitate and encourage the participation of the community in project development and management activities, in the context of a basin wide approach.

To address these issues the meeting comprised two main components. The first was devoted to training activities and comprised a workshop on Water Quality Monitoring and a short training course on Ecological Modeling, both referred to lakes and reservoirs. Both activities provided input for discussions into the III International Workshop, which was the second main component. Workshop activities, were designed to enlighten the following points:

1. The extent to which the incorporation of new monitoring, data acquisition and processing techniques in the region have contributed to and may further improve information availability and the ability to assess ecosystems behavior and trends for planning and management purposes.

2. The availability of simple and friendly modeling techniques, based on a sufficient understanding of the dynamic linkages between reservoirs and their watersheds (upstream, on-site and downstream influences), tested in the region, capable of comprehending, simulating and predicting ecosystems behavior within reasonable uncertainty limits for sound decision making. Furthermore, the viability of promoting a generalized adoption of said modeling as a tool for the integrated planning and management process leading to decision making.

3. The institutional and organizational arrangements needed to further facilitate and implement truly informed decision processes for reservoir planning, construction and operation duly accounting for stakeholder information, participation and involvement.

4. Pre -Workshop Activities

A Workshop on Water Quality Monitoring and a Short Training Course on Ecological Modeling for Eutrophication Prediction in Lakes and Reservoirs, as effective and reliable design and management tools were offered to scientists, managers and specialists from various fields actively involved in research, technology development and management of water resources, particularly reservoir development and operation, in La Plata River Basin.

4.1. Water Quality Monitoring Workshop (ILEC)[4]

This workshop aimed at transferring monitoring technology and skills appropriate for reservoirs in the La Plata River Basin. Professor José G. Tundisi (IIE- ILEC Scientific Committee member) was the course leader, and together with Prof. Chris Magadza (ILEC Scientific Committee member), Prof. Le Quoc Hung (Institute of Chemistry- NCST Vietnam) and Dr. Yosuke Yamashiki (ILEC) lectured the course presenting modern monitoring and assessing techniques and concepts in the context of integrated water resources management. Field continuous and point sampling demonstration activities were carried out along the Paraná river, downstream Posadas City. Mr. Le Quoc Hung presented an on line continuous monitoring and digital recording equipment, capable of providing longitudinal and transect subsurface profiles of various water quality parameters while Prof. Tundisi and Dr. Yosuke Yamashiki (ILEC) demonstrated techniques for sampling point vertical profiles using multiparameter sampling devices.

The Faculty of Exact, Chemical and Natural Sciences of the National University of Misiones provided the facilities for the course. The *Prefectura Naval Argentina* (Fluvial GuardCoast Navy Corps) supplied the boat for the navigation. About **30 participants** from the four countries of La Plata River Basin as well as international experts attended the course and field activities.

[4] The organization of the Water Quality Monitoring Workshop was led by ILEC with the support of the Japan Fund for Global Environment

4.2. Short Training Course on Ecological Modeling (UNEP-DTIE-IETC and ILEC) [5]

The course, focusing on eutrophication in lakes and reservoirs, aimed at assisting decision makers, planners and managers in understanding the eutrophication processes and how to foreseen them, introduced the PAMOLARE 2L training package which included a number of models por PCs specifically designed for the purpose. Application examples of the model on lakes / reservoirs in different regions, were presented to illustrate about the usefulness of this kind of tools in the planning and management process. Prof. Sven E. Jorgensen (Chairman ILEC Scientific Committee) and Dr. Yosuke Yamashiki (Course leader, UNEP-DTIE-IETC) lectured theoretical and practical aspects involving the Two-layer Ecological Model for lakes/reservoirs entitled PAMOLARE2L, which is being developed by a joint effort of ILEC, UNEP-DTIE-IETC, RCEQC-Kyoto University (Japan) and the Danish Royal School of Pharmacy.

About **40 participants**, from four countries of La Plata River Basin, as well as international invited experts, attended the course and practiced the use of the model benefiting from the computer facilities kindly provided by the Faculty of Human Sciences of the University of Misiones. Dr. Fabián López (CIHRSA-INA, Arg.) and Dr. Angelo Saggio (UFSC, Br.) presented model applications case studies of San Roque Reservoir (Arg.) and Barra Bonita Reservoir (Br.), respectively.

4.3. Seminar Sessions

Over 30 papers, based on the activities and experiences achieved within their organizations and addressing the themes proposed by the Workshop, were submitted by the participants of the Training Courses and III Workshop. Complementing the training course activities, three Seminar Sessions were held, which provide an opportunity for the authors of 16 selected papers to present their findings and discussed them with the audience.

5. Third International Workshop Activities and Program

Workshop participation was open to researchers, senior staff and managers of governmental, non governmental and private sector organizations dealing with water resources, in particular reservoirs, and environment, in the La Plata River Basin region. Consequently relevant organizations, representative of the various stakeholders groups from each country and abroad, were invited to participate in the Workshop and to collaborate in the preparation and coordination of the Plenary Sessions. Annex I presents the programme of activities developed during the III Workshops while the participants who attended the Workshop and/or training activities are listed in Annex II. Annex III presents the list of papers, lectures, reports and recommendations submitted to the Workshop.

[5] The organization of the Ecological Modeling Training Course was led by UNEP-DTIE-IETC and ILEC with the support of Japanese Ministry of Environment

5.1. Opening Session

The opening ceremony was chaired by the Governor of the Province of Misiores, Argentina, who welcomed the participants and formally declared the Workshop inaugurated. Welcome speeches on behalf of the Local Organizing Committee and the International Organizations, were also offered by Mr. Alberto T. Calcagno and Mr. Vicente Santiago Fandiño respectively.

A representative of the World Commission on Dams (WCD), Mr. James Workman, offered the opening keynote speech presenting the Final Report of the WCD "Dams and Development: A New Framework for Decision-Making"

5.2. Plenary Sessions

Six **Plenary Sessions** addressed the focus topics described in section C above, on the basis of proposals with recommendations reflecting the opinion and experience of representative stakeholders sectors involved in reservoir development and management. A major part of the elaborations submitted by representatives of various stakeholder sectors, namely, science and technology, non governmental, private, international organizations, international funding agencies and governmental organizations, were presented by their authors during these sessions, giving room to enlightening discussions. Furthermore, keynote speeches by representatives of international organizations (UNESCO-IHP, UNEP-DTIE-IETC and ILEC) and international funding agencies (World Bank) were given in Plenary Sessions 4 and 5 dedicated to those sectors. Over 140 participants from the various countries of La Plata River Basin, representing a large number of organization devoted to water resources management in the Basin, as well as international invited experts, attended the III Workshop activities.

5.3. Working Group Sessions

The findings resulting from Plenary Sessions provided input to the discussions in the three Working Groups addressing each of the main themes of the meeting focus.

Working Group I:	Data, information and understanding.
Working Group II:	Tools for prediction and assessment of impacts.
Working Group III:	Informed Decision Processes: Public participation.

The participants distributed among the various groups according to their preferences. The themes were discussed by each Group along a full day of intense activity and participation, moderated by a facilitator nominated by the Organization. The Conclusion and Recommendations of each Group, stemming from the discussions were edited by rapporteurs nominated by the participants.

5.4. Special sessions

Three **Special Sessions** were devoted to keynote speeches, special lectures and the presentation of papers selected among those submitted by the participants. Mr. Richard

Robarts (UNEP-WHO GEMS/WATER Programme, Canada) presented the GEMS/WATER Programme, in the context of the need to modernize water quality monitoring programmes in the region. Discussions following the presentations provided input for working group activities and contributed to the elaboration of the conclusions. See in Annex I the schedule of their presentation.

5.5. Final Plenary Session

The conclusions and recommendations elaborated by all three Working Groups were presented to the Plenary Final Session. They were adopted by the assembly together with the general conclusion of the Workshop. Said General Conclusion and Recommendations are presented below in Section 6 of this report.

5.6. RIGA Foundation Session

The III International Workshop also hosted the presentation and foundation of the **La Plata River Basin Environmental Research and Management Network (RIGA)**[6], a non governmental regional initiative which stems from the recommendations of the previous two International Workshops. RIGA is a cooperative effort by a number of organizations from Argentina, Brazil and Uruguay devoted to water resources and environmental research and management, to promote interaction, communication, technology transfer and coordination among governmental, non governmental and private organizations in the La Plata River Basin. Formal foundation of the RIGA was initiated during the **RIGA Session**, with the signature of the Statute and the minute of the session by founding organizations from the three countries attending the Session. The Declaration of Posadas, inviting other organizations in the Basin to join the initiative was issued at that time and is attached to this Proceedings as Annex IV.

6. Conclusions and Recommendations of the III Workshop

6.1. General Conclusion

The participants of the Third International Workshop on Regional Approaches to Reservoir Development and Management in the La Plata River Basin, as a result from the papers, recommendations and discussions held during the Plenary, Seminar and Special Sessions and in the Short Training Activities on Water Quality Monitoring and Ecological Modeling of Lakes and Reservoirs, agree on the need of renewing efforts towards the achievement of an integrated management and sustainable development of water resources at the watershed level, the present paradigms concerning water management.

They recognize the need to promote the sustainable development of the enormous potential offered by those resources all over the Basin, appropriately incorporating the technical, economical, social and environmental considerations which guarantee the acknowledgement of the economic, social and environmental value of water.

[6] Red de Investigación y Gestión Ambiental de la Cuenca del Río de la Plata (RIGA)

They agreed on that reservoirs, due to their capacity of addressing simultaneously various water uses, constitute a valid option[7], amongst other possible ones to be compared in equal conditions within the set of structural and non structural measures available to society, to achieve said sustainable development, in accordance with the legal arrangements existing in each jurisdiction. While recognizing that said projects, particularly those of larger dimensions, imply a significant intervention in the natural and socioeconomic system, comprising the whole basin.

Therefore, they consider a must to ensure that the decision making process of these kind of undertakings, should attend the criteria of participatory planning and adaptive management, in the context of an integrated management of water resources with an ecosystem approach at watershed level within each of the countries in the La Plata River Basin.

To this end the participants consider as appropriate to take in account the strategic priorities and guidelines recommended in the Final Report[8] of the World Commission on Dams, to which purpose said recommendations should be analyzed more in depth and be determined the best ways for their effective implementation in the reservoirs presently in operation or under planning.

Within said general framework, in order to make viable the implementation of informed and participated decision processes for reservoir development and management in the La Plata River basin, and in relation with the specific themes of this III Workshop, they recommend:

6.2. Specific Recommendations on the III International Workshop Focus Topics

6.2.1. Data, Information *and Understanding*

<u>Sustainability of Monitoring Networks</u>

Availability of data (hydro meteorological, physical-chemical and biological) in digital format, good quality and adequate quantity is essential for the realization of any study or project related to water resources use and management. This cannot be achieved without the commitment of the Governments of the countries to perform a continuous monitoring by means of the agencies involved in the collection, storage, processing and dissemination of information.

The functioning (implementation, operation and maintenance) of monitoring networks demand the availability of sufficient funding. Charging a price to water users (including discharge of effluents as a water use) has proved to be an effective tool. A recommended measure is to establish, through proper legal arrangements, that such economic resources should be allotted to the agencies in charge of water resources monitoring and management; part of it should be reinvested in the basin where they come from and the remainder be used

[7] The representatives of two NGOs, namely Ms Ana Petra Roge (Eco La Paz) and Mr Roberto A Ríos, (Asociación Ecologista "Yvy Marané'y") did not agree with this statement in what refers to dams as a valid option for development of water resources.

[8] Dams and Environment: A New Framework for Decision-Making, World Commission on Dams, November 2000.

in those regions where monitoring and management is needed but no funds are available for such purpose.

Given the leading role of biological communities in the metabolism of ecosystems, as descriptors which conspicuously reflect the environmental impacts of the interventions made, qualitative and quantitative aspects of biodiversity, community structure and bioindicators, among others, should be monitored.

Access to Information

Monitoring information of water and environmental variables collected and validated by public organizations should be accessible, free and of public domain (only reproduction costs should be charged); as regards organizations undergoing concession or privatization processes, necessary care should be taken to ensure that the information collected by organizations once said processes are completed, continues to be of public domain.

It is recommended that RIGA elaborates a Data Book of Reservoirs in the La Plata River Basin as a regional contribution to ILEC World Data Book

Network Auditing

It is a commendable practice to carry out audits of the existing networks, as a means to guarantee the quality of the data.

Standardization of sampling methodologies

It is fundamental to standardize methodologies for quantitative and qualitative monitoring. Elaboration or adaptation of common methodological guidelines at the regional level is an indispensable activity.

Monitoring networks and watershed management

Proper planning, implementation and operation of monitoring networks is imperative to achieve an adequate management of watersheds.

Small reservoirs

Extrapolation of data from monitoring networks of large extension to address problems in watershed of small dimensions less than 500 sq km, may lead to inadequate results. Establishment of monitoring plans (quantity and quality) in small watershed would contribute to cope with this situation. Users of said projects should collaborate according to their possibilities, as a means to minimize costs associated to monitoring activities.

Diffused loads

Due to the scarce monitoring of diffused loads contribution existing in the region, either urban or rural, it is recommended to increase the collection of this kind of information as a way to contribute to a representative evaluation and control of the various processes which take place within the watershed. To this end, the study of bed sediments in reservoirs may provide relevant information.

Final Considerations

It is recommended that a Working Group be created in the framework of RIGA, to develop an Action Plan to carry out the recommendations issued in this meeting.
It is urged that these recommendations be formally communicated to the Governments of the country members of the La Plata River Basin asking them to devote their best efforts to secure their accomplishment.

6.2.2. Technologies for Prediction and Assessment of Impacts

It is recommended the use of technological tools for the systematic assessment of environmental consequences, during the planning, construction and operation of reservoirs, in the context of the watershed, as a task prior to decision making, accompanying the process of evaluation of alternatives leading to execution and definition of operating practices.

The results obtained through the application of said tools should be made available to the public with the endorsement of the scientific community in order to provide objective analysis tools as an approximation to reality within the corresponding limitations arising from the database and assumptions adopted.

As a step previous to the implementation of technological tools it should be paid attention to the aspects of cooperation, training, transference and adoption of technology, equipment, capacity of interpreting results and funding of the technical organizations of the region which are in charge of developing the utilization of said tools.

It is proposed that within the institutional framework of the La Plata River Basin, the technical component be integrated in a more effective way with a view to develop an effective interchange of information about problems, experiences and solutions.

There exists in the region an adequate technological level for the development and implementation of prediction and management tools for the problems related to reservoir development. It is envisaged as highly useful the conformation of regional centers for the adaptation and validation of said tools making use of the existing institutions.

As a further step in technology development, efforts should be devoted to the development of management tools (holistic models) for decision making incorporating social and economic variables that take in account the new paradigms on integrated watershed management.

It is recommended the integration of the use of these technological tools, to elaborate diagnosis of reservoirs in operation and its use in the environmental assessment of new projects.

It is considered a need the definition and complementation of water quality and sediment guideline criteria at watershed level, in the light of acquired experiences and on the basis of the technical requirements of the developed assessment tools. Diagnostic situations leading to the planning of mitigation and/or remediation measures at the regional level in the medium term should be evaluated within said framework.

The integration at watershed level of basic information for the implementation and optimization of models addressing hidrosedimentological and contaminant transport aspects, is considered a must.

Mechanisms of international coordination to allow the development of contingency plans at watershed level available in the short term, should be established.

6.2.3. Informed Decision Processes – Public Participation

Organizations in charge of planning, building, managing and/or dismantling reservoirs should made available and disseminate the information to the public.

Organizations responsible for water resources management, in coordination with other competent sectors of the public administration, should implement participation processes including all involved stakeholders.

The countries of the region should adopt regulatory frameworks to promote and ensure the effective participation of all sectors.

The participation process should start with the initial project idea and accompany it along all its stages.

7. Final Considerations

This third edition of the International Workshop on Regional Approaches to Reservoir Development and Management in La Plata River Basin, succeeded in providing an arena for discussing conflictive issues concerning sustainable development of water resources, gathering together a large number of relevant specialists from the Basin and abroad, including representatives from different stakeholder sectors involved in water resources, environment and reservoir management. The objectives proposed were satisfactorily achieved and the topics submitted to debate provided a framework for the issuing of the General Conclusion and the Recommendations agreed by the participants.

The meeting also succeeded in hosting the foundation of the La Plata River Basin Environmental Research and Management Network (RIGA), which materializes the recommendations of the International Workshops I and II. Thus, this III Workshop, also meant as a follow up of the former meetings, highlights the importance of regional and international meetings and encourages their development as a way of effectively progressing in the pathway of sustainable development.

The Recommendations of the III Workshop call for further actions in the region and stronger cooperation among local, regional and international organizations. Some of these actions have been specifically endorsed to be incorporated into the Action Plan of RIGA, and, in fact, most of them fall within the objectives and programs of said regional initiative. Thus, not only the framework for action but the means to carry them out had been set in this III Workshop. It is to be hoped that the next IV Meeting will encounter the region and RIGA actively engaged in their realization.

THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES
TO RESERVOIR DEVELOPMENT AND MANAGEMENT
IN THE LA PLATA RIVER BASIN:
"Informed Decision Processes for Sustainable Development of Reservoirs"

March 9 to 17, 2001 - City of Posadas, Province of Misiones, Argentina

ANNEX I
PROGRAMME OF ACTIVITIES

III INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN

"Informed Decision Processes for Sustainable Development of Reservoirs"

SHORT TRAINING COURSES ON WATER QUALITY MONITORING AND ECOLOGICAL MODELING OF RESERVOIRS

March 9 to 17, 2001 - Posadas City, Province of Misiones, Argentina

DETAILED PROGRAMME OF ACTIVITIES

TRAINING WORKSHOP ON WATER QUALITY MONITORING OF LAKES AND RESERVOIRS

Time	Activity
	Friday March 9, 2001
8.30 – 9.30	**Registration of participants**
9.30 – 10.00	**Opening Ceremony of the Training Workshop on Water Quality Monitoring of Lakes and Reservoirs** Mr. Alberto T. Calcagno, on behalf of the Local Organizing Committee. Mr. Yosuke Yamashiki, on behalf of ILEC Mr. Horacio Schwieters, Dean of the Faculty of Exact, Chemical and Natural Sciences, National University of Misiones, Argentina.
10.00 - 12.30	**Workshop Session** Lecturer: Mr. José Galizia Tundisi (ILEC/IIE)
12.30 - 14.30	Lunch
14.30 - 18.00	**Workshop Session** Lecturers: Mr. José Galizia Tundisi (ILEC/IIE) Mr. Yosuke Yamashiki (UNEP-DTIE-IETC / ILEC) Mr. Le Quoc Hung (ICH-NCST)

TRAINING WORKSHOP ON WATER QUALITY MONITORING OF LAKES AND RESERVOIRS

Time	Activity
	Saturday March 10, 2001
8.00 – 12.30	Field trip along the Paraná River . Demonstration and practice of point and continuous in situ sampling activities Lecturers: Mr. José Galizia Tundisi (ILEC/IIE) Mr. Yosuke Yamashiki (UNEP-DTIE-IETC / ILEC) Mr. Le Quoc Hung (ICH-NCST)
15.30 – 17.30	**Workshop Session** Lecturers: Mr. José Galizia Tundisi (ILEC/IIE) Mr. Yosuke Yamashiki (UNEP-DTIE-IETC / ILEC) Mr. Le Quoc Hung (ICH-NCST)
17.30 - 18.00	**Conclusions** Mr. José Galizia Tundisi (ILEC/IIE)

TRAINING COURSE ON ECOLOGICAL MODELING OF LAKES AND RESERVOIRS

Time	Activity	Moderator / Rapporteur
	Sunday March 11, 2001	
8.30 – .30	**Registration of participants**	
9.30 – 10.00	**Opening Ceremony of the Short Training Course on Ecological Modeling of Lakes and Reservoirs** Mr. Alberto T. Calcagno, on behalf of the Local Organizing Committee. Mr. Yosuke Yamashiki, as Course Leader Mr. Vicente Santiago Fandiño, on behalf of UNEP-DTIE-IETC Mr. Carlos Galian, on behalf of the Faculty of Exact, Chemical and Natural Sciences, National University of Misiones, Argentina.	
10.00 - 12.30	**Training Course Session** Lecturer: Mr. Sven Jorgensen (ILEC)	
12.30 - 14.30	Lunch	
14.30 - 18.00 -	**Training Course Session** Lecturer: Mr. Yosuke Yamashiki (UNEP-DTIE-IETC /ILEC) Mr. Sven Jorgensen (ILEC)	
18.00 – 19.30	**Seminar Session 1** • Establishment of national environment water quality guidelines, Mr. Andres Carsen • Hydrological monitoring and reservoir operation management in the State of Paraná, Brazil, Ms. Arilde S. Gabriel de Camargo • Real time monitoring of water quality in water supply reservoirs in the Metropolitan Region of São Paulo (Brazil), Mr. Armando Pérez Flores • Water Quality and Sediment Monitoring in Los Molinos Reservoir, Córdoba, Argentina, Ms. Ana Cossavella	Mr. Carlos Galian (FCEQyN-UNAM) Mr. Alberto Calcagno (IARH/ILEC)

TRAINING COURSE ON ECOLOGICAL MODELING OF LAKES AND RESERVOIRS

Time	Activity	Moderator / Rapporteur
	Monday March 12, 2001	
9.00 - 12.30	**Training Course Session** Lecturer: Mr. Sven Jorgensen (ILEC)	
12.30 - 14.30	Lunch	
14.30 - 18.00	**Training Course Session** Lecturer: Mr. Yosuke Yamashiki (UNEP-DTIE-IETC /ILEC) Mr. Sven Jorgensen (ILEC)	
18.00 – 19.30	**Seminar Session 2** • Application of statistical techniques applied to optimization of sampling campaigns in a reservoir, Ms Alice. E. González • CEHPAR and its experience in the conservation and management of water resources, Ms. Regina Tiemy Kishi • Model for growth prediction of populations in limited environments, without predators, Mr. Eduardo Zamanillo • Integrated Management Plan of the Wetlands of River Parelheiros, Ms. Rosalice Mincherian • Environmental Management Programme for Casa de Piedra Reservoir, Colorado River. First Stage: monitoring and modeling, Mr. Sergio Stangaferro	Mr. Sven E. Jorgensen (ILEC) Mr. Angelo Saggio (USP)

TRAINING COURSE ON ECOLOGICAL MODELING OF LAKES AND RESERVOIRS

Time	Activity	Moderator / Rapporteur
	Tuesday March 13, 2001	
9.00 - 12.30	**Training Course Session** Lecturer: Mr. Sven Jorgensen (ILEC)	
12.30 - 14.30	Lunch	
14.30 - 18.00	**Training Course Session** Lecturers: Mr. Fabián López (CIHRSA-INA) – San Roque Reservopir Case Study Mr. Angelo Saggio (USP) – Barra Bonita Reservoir Case Study	
18.00 – 19.30	**Seminar Session 2** • Impact of environmental flows on drinking water supply in La Plata River Basin, Mr. Guillermo Nociari • Incidence of coastal raw sewage discharges in Setúbal shallow lake (Santa Fe), Mr. Alfredo Trento • Relocation of the City of Federación. Salto Grande Bi-national Hydropower Development (Argentina - Uruguay), Mr. Carlos Avogadro • Small hydropower plants in La Plata River Basin tributaries: A feasible alternatives for water power development, Ms. Nicole Ioanne Firta • Spatial and time variability of physical and chemical parameters in Ullum Reservoir, Ms. María Eugenia Paz	Mr. Yosuke Yamashiki (UNEP-DTIE-IETC / ILEC) Ms. Ana Mugetti (SSRH)

III INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN

"Informed Decision Processes for Sustainable Development of Reservoirs"

SHORT TRAINING COURSES ON WATER QUALITY MONITORING AND ECOLOGICAL MODELING OF RESERVOIRS

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III INTERNATIONAL WORKSHOP

Time	Activity	Moderator / Rapporteur
	Wednesday March 14, 2001	
8.30 – 12.30	**Registration of participants**	
9.30 – 10.30	**Opening Ceremony of the III International Workshop** Mr. Alberto T. Calcagno, on behalf of the Local Organizing Committee Mr. Vicente Santiago Fandiño on behalf of the International Organizations Mr. Carlos Rovira, Governor of the Province of Misiones	
10.30-11.30	**Presentation of the Final Report of the World Commission on Dams** Mr. James Workman. Senior Advisor, Media & Communications, WCD	
11.30-12.00	**Presentation of the Objectives, Activities and Expected Outputs from the Workshop** Mr. Alberto Calcagno, Organizing Committee	

III INTERNATIONAL WORKSHOP

Time	Activity	Moderator / Rapporteur
	Wednesday March 14, 2001	
15.00 – 16.30	**Plenary Session 1: Science and Technology Sector** Presentation of recommendations that reflect the opinion and experience of Universities and Institutions devoted to research and technology development. • Considerations about Sustainable Development and Projects of Hydraulic Infrastructure. Mr. Fabián López e Mr. Carlos Angelaccio – CIRHSA-INA (Arg.) • Hydraulic and Hydrology Centre "Professor Parigot de Souza", Ms. Ingrid Müller CEHPAR (Br.) • Problem Identification and Recommendations on reservoir monitoring, simulation and management. Mr. Carlos Tucci, IPH (Br.) • Sediment-nutrient-bacteria rol and its importance in water quality changing proceses in lakes and reservoirs. Ms. Claudia Orona, UNC (Arg.) Discussion	Mr. Alejandro Arcelus (DNH) Mr. Claudio Laboranti (SSRH)
	Coffee break	
16.45 – 18.15	**Plenary Session 2: Non Governmental Sector** Presentation of recommendations that reflect the opinion and experience of non governmental, users and civil society organizations, involved in natural resources management, environment protection and social development. • Does true participation exist?. Ms. Anna Petra Roge Amigos de la Tierra, (Arg.) • ABRH Vision: Water Resources Systems Management. Mr. Carlos Tucci ABRH, (Br.) • Informed Decision Processes for the Sustainable Development of Water Resources. Mr. Alberto T. Calcagno IARH, (Arg.) • Compromise with Sustainable Reservoirs Development and Management, Mr..Ernesto Ortega, CAP, (Arg.) Discussion	Mr. Marcelo Gaviño Novillo (UNLP) Ms. Alicia Fernández Cirelli (UBA)
	Coffee Break	

III INTERNATIONAL WORKSHOP

Time	Activity	Moderator / Rapporteur
	Wednesday March 14, 2001	
18.30 – 20.00	**Special Session 1** Key note lectures and presentations by the participants • The GEMS/WATER Programme and the Need to Modernize Water Quality Monitoring Programmes. Mr. Robart Richards, UNEP GEMS/Water Collaborating Centre, Environment Canada • Performance of fish facilities in Lower La Plata River Basin Reservoirs: Results and perspectives, Mr. Claudio Baigún (Arg.) • Quantification tools for the management of sedimentation in reservoirs, Mr. Pablo A. Tarela, INA, (Arg.) • Presentation of CYTED Programme – Ibero American Eutrophication Network. Ms. Alicia Fernández Cirelli, UBA (Arg.)	Mr. F. López (CIRHSA-INA) Mr. E. Nery Huerta (IB)

III INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN

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III INTERNATIONAL WORKSHOP

Time	Activity	Moderator / Rapporteur
	Thursday March 15, 2001	
9.00 – 10.30	**Plenary Session 3: Private Sector** Presentation of recommendations that reflect the opinion and experience of consulting, building and operating private organizations dealing with planning, design, construction, and operation of dams. • Environmental Challenges of an Energy Enterprise – Environmental Vision of COPEL. Ms. Arilde. S.G. de Camargo, COPEL (Br.) Discussion	Mr. Alberto Calcagno (IARH/ILEC) Mr. Daniel Perczyk (COMIP)
	Coffee break	
11.00 – 12.30	**Plenary Session 4: International Organizations** Presentation of experiences from international organizations dealing with natural resources and environment management • UNESCO- IHP V Programme "Ecohydrology": the use of ecosystem properties as management tools for integrated river basin management. Dr. Maciej Zalewsky Science Academy of Varzovia • Informed Decisión Proceses for Sustainable Development of Reservoirs: Technology as a part of the process. Dr. Vicente Santiago Fandiño. UNEP-DTIE-IETC • Activities of ILEC: Monitoring, modeling and databases. Dr. Yosuke Yamashiki . ILEC Discussion	Mr. Carlos Angelaccio (INA) Ms. Beatriz Tracanna de Albornoz (ILINOA)

III INTERNATIONAL WORKSHOP

Time	Activity	Moderator / Rapporteur
	Thursday March 15, 2001	
15.00 – 16.30	**Plenary Session 5: International Financing Organizations** Presentation of recommendations that reflect the opinion and experience of international funding organizations • Reservoir Sustainability, the RESCON project in the World Bank, Mr. Alessandro Palmieri, Senior Dam Specialist, World Bank Discussion	Mr. C. Tucci (ABRH, IPH) Ms. A. Mugetti (SSRH)
	Coffee break	
16.45 – 18.15	**Plenary Session 6: Governmental Sector** Presentation of recommendations that reflect the opinion and experience of governmental organizations dealing with natural resources and environmental management and, in particular, to dams and reservoir management • Considerations about Reservoir management by the National Board of Hydrography. Mr. Alejandro Arcelus, DNH (Ur.) • Environmental management of Itaipu Binational, Mr. Hélio Fontes, IB (Br.) • CESP experience in reservoir management. Mr. Uhlig, Alexandre (CESP) (Br.) • Operational Hydrologic System in Salto Grande Reservoir. Mr. Eduardo Zamanillo CTMSG (Arg.) • Water Institute of Corrientes. Mr. Mario Rujana (Arg.) • Warning on the Degradation of Water Quality and Lack of Integrated Water Resources Management in La Plata River Basin, Mr. Ramón Vargas APA (Arg.) Discussion	Mr. P. Bronstein Mr. I. Illich Müller (CEHPAR)
	Coffee break	

III INTERNATIONAL WORKSHOP

Time	Activity	Moderator / Rapporteur
	Thursday March 15, 2001	
18.30 – 20.00	**Special Session 2** Key note lectures and presentations by the participants • IWRM: Formulation of Multi Objective Optimization of Water Quantity and Quality in Storage Reservoirs. Mr. Paulo Chaves (Br.) • Environmental Guidelines for the Operation and Maintenance Management of the Yacyretá Hydroelectric System. Mr.. Alfredo Fortuny (Arg.) • Ayui reservoir: A joint venture for water management. Pablo Bronstein et al. • Optimal Strategy to Reduce Pollutant Emission. Ms. Matsumoto, Miyuki (Jp.) • An overview vision of the institutional situation of the water resources sector in Rio de Janeiro State, Brazil. Ms. Thereza C. de Rosso (Br.) • Incorporation of New Monitoring Techniques in La Plata River Basin Region, Ms. Nora L. Andreani (Arg.)	Mr. Carlos Galián (FCEFyN-UNAM) Mr. Oscar Duarte (DH-ER)

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III INTERNATIONAL WORKSHOP

Time	Activity	Moderator / Rapporteur
	Friday March 16, 2001	
	Working Group Session I:	
9.00 – 10.30	Group I: Data, Information and Understanding	Mr. Carlos Tucci Mr. Alejandro Arcelus
	Group II: Technologies for prediction and assessment of impacts	Mr. Carlos Angelaccio Ms. Daniela García
	Group III: Informed decision processes: Public participation	Ms. Ana Mugetti, Ms. Ana Roge
	Coffee break	
	Working Group Session II:	
11.00 – 12.30	Group I: Data, Information and Understanding	Mr. Carlos Tucci Mr. Alejandro Arcelus
	Group II: Technologies for prediction and assessment of impacts	Mr. Carlos Angelaccio Ms. Daniela García
	Group III: Informed decision processes: Public participation	Ms. Ana Mugetti, Ms. Ana Roge
15.00 – 16.30	**Working Group Session: Conclusions**	

III INTERNATIONAL WORKSHOP

Time	Activity	Moderator / Rapporteur
	Friday March 16, 2001	
	Group I: Data, Information and Understanding	Mr. Carlos Tucci Mr. Alejandro Arcelus
	Group II: Technologies for prediction and assessment of impacts	Mr. Carlos Angelaccio Ms. Daniela García
	Group III: Informed decision processes: Public participation	Ms. Ana Mugetti, Ms. Ana Roge
17.00 – 18.15	**Final Plenary Session:** Consideration of Workshop Conclusions and Recommendations	Mr. Alberto Calcagno Mr. Alejandro Arcelus Ms. Daniela García Ms. Ana Roge
	Coffee break	
18.30 – 20.00	**Special Session 3** Key note lectures and presentations by the participants • Analysis of the Report of the World Commision on Dams. Mr. Andrés Ortiz • Methodological proposal to be adopted by RIGA Network to address emergency situations. Mr. José E. Lobos (INA) • Evolution of Environmental Management in Yacyreta Reservoir. Mr. Enrique Gandolla (EBY) • Information, participation and commitment of involved stakeholders. Ms. Silvina Nosiglia de Cella • Institute of Fluid Mechanics and Environmental Engineering (IMFIA) of the Faculty of Engineering of the University of the Republic of Uruguay, Ms. Alice. E. González (IMFIA) • Regional Approaches to the Restauration and Preservation of Water Quality of reservoirs in watersheds of Tucuman. Ms. Beatriz Tracanna de Albornoz (ILINOA) • Populations of shads in Paraná Medio River. Ms. Elly Cordiviola de Yuan (INALI)	Mr. Luis Jacobo Ms. María J. Fioriti

III INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN

March 9 to 17, 2001 - Posadas City, Province of Misiones, Argentina

DETAILED PROGRAMME OF ACTIVITIES

III INTERNATIONAL WORKSHOP

Time	Activity	Moderator
	Saturday March 17, 2001	
9.00-10.00	**Presentation of Conclusions and Recommendations**	Mr. Alberto Calcagno
10.00-11.30	**Session of the La Plata River Basin Environment Research and Management Network (RIGA)** Presentation of the initiative: background, objectives, organization, plan of action, financial programme, statute. Mr. Alberto Calcagno, RIGA Technical Committee Coordinator Reading of RIGA Foundation Act and the Declaration of Posadas, Ms. Ana Mugetti Signature of Foundation Act by representatives of member organizations	Mr. Alberto Calcagno Ms. Ana Mugetti
12.00 – 12.30	**Closing Ceremony** Mr. Vicente Santiago Fandiño, on behalf of UNEP-DTIE-IETC Mr. Yosuke Yamashiki, on behalf of ILEC Mr.. Horacio Schwieters, on behalf of the Faculty of Exact, Chemical and Natural Sciences, National University of Misiones, Argentina Mr. Alberto T. Calcagno, on behalf of the Local Organizing Committee Mr. Luis Jacobo, on behalf of the Government of the Province of Misiones.	

THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN:
"Informed Decision Processes for Sustainable Development of Reservoirs"
March 9 to 17, 2001 - City of Posadas, Province of Misiones, Argentina

ANNEX II
LIST OF PARTICIPANTS

III INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN

"Informed Decision Processes for Sustainable Development of Reservoirs"

SHORT TRAINING COURSES ON WATER QUALITY MONITORING AND ECOLOGICAL MODELING OF RESERVOIRS

March 9 to 17, 2001 - Posadas City, Province of Misiones, Argentina

LIST OF PARTICIPANTS

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9	Arcelus, Alejandro	DNH	Rincón 575 piso 2	11000	Montevideo	Montevideo	Uruguay	(59 82) 9164666 int3328 (59 82) 9164667	dnh@uyweb.com.uy

LIST OF PARTICIPANTS

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"Informed Decision Processes for Sustainable Development of Reservoirs"
March 9 to 17, 2001 - City of Posadas, Province of Misiones, Argentina

ANNEX III

LIST OF PAPERS, LECTURES, KEYNOTE SPEECHES AND SHORT BACKGROUND PAPERS WITH RECOMMENDATIONS SUBMITTED TO THE WORKSHOP

THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN:
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LIST OF PAPERS, LECTURES, KEYNOTE SPEECHES AND SHORT BACKGROUND PAPERS WITH RECOMMENDATIONS SUBMITTED TO THE WORKSHOP BY CATEGORY AND TITLE

PAPERS

TITLE	AUTHOR/S
Aplicación de técnicas estadísticas a la optimización de campañas de muestreo en un embalses / Statistical Techniques Applied to Optimisation of Sampling Campaigns in a Reservoir	González, Alice. E. (IMFIA)
Calidad del agua del Embalse de Itaipu. Programa de estudios de la ITAIPU / Water Quality in Itaipú Reservoir. Program of Studies of ITAIPU Binational	Hermosa A., José Luis (IB)
CEHPAR e sua experiência en la conservação e gestão dos recursos hídricos / CEHPAR and its experience in the conservation and management of water resources	Kishi, Regina Tiemy et al.
Conflicts and management perspectives of reservoirs in the São Francisco River (Brazil) / Perspectivas de conflicto y gestión de embalses en la Cuenca del Río san Francisco (Brasil)	Gaal Vadas, Rolando (Br.)
El Embalse de Río Hondo (Stgo. del Estero-Tucumán, Argentina): Un Humedal Conflictivo / Rio Hondo Reservoir (Stgo. del Estero-Tucumán, Argentina): A conflicting wetland	Villagra de Gamundi, Alcira ILINOA (Arg.)
Embalse Ayui: un emprendimiento coparticipativo de gestión conjunta. / Ayui reservoir: A joint venture for water management.	Bronstein, Pablo et al.
Establecimiento de niveles guía nacionales de calidad de agua ambiente / Establishment of national environment water quality guidelines	Carsen, Andrés y Jakomin, Luz M. (SSRH-MIV)
Evolución de la Gestión Ambiental en el Proyecto Yacyretá / Evolution of Environmental Management in Yacyreta Reservoir.	Gandolla, Enrique (EBY)

PAPERS

TITLE	AUTHOR/S
Funcionamiento de los sistemas de transferencia para peces en represas de la baja Cuenca del Plata: Resultados y perspectivas. / Performance of fish facilities in Lower La Plata River Basin Reservoirs: Results and perspectives	Baigún, Claudio (CPN) & Oldani, Norberto (IDTIQ)
Gerenciamiento integrado de recursos hídricos- monitoramento e avaliação da qualidade da agua / Integrated water resources management- Water Quality Monitoring and Assessment.	Tundisi, José Galizia (IIE)
Herramientas de cuantificación para la gestión de la Sedimentación de Embalses / Quantification tools for the management of sedimentation in reservoirs	Tarela, Pablo A. (INA)
Hydrological monitoring and reservoir operation management in the State of Paraná, Brazil / Gestión del monitoreo hidrológico y de la operación de embalses en el Estado de Paraná, Brasil	Gabriel de Camargo, Arilde S. (COPEL)
Impacto de los flujos ambientales en la Cuenca del Plata sobre la producción de agua potable / Impact of environmental flows on drinking water supply in La Plata River Basin	Nociari, Guillermo y López, Walter. (AA)
Implementación del Procedimiento Cadena de Custodia de Muestras en Programas de Monitoreo Ambiental como Elemento de Aseguramiento de la Calidad / Implementation of Sampling Custody Chains Procedures in Environmental Monitoring Programs as a Quality Assurance Element.	Rodríguez Speroni, María A. (INA)
Incidencia de las descargas cloacales costeras en la Laguna Setúbal (Santa Fe) / Incidence of coastal raw sewage discharges in Setúbal shallow lake (Santa Fe)	Trento, Alfredo et al. (FICH-UNL)
IWRM: Formulation of Multi Objective Optimization of Water Quantity and Quality in Storage Reservoirs / GIRH: Formulación de una Optimización Multiobjetivo de Cantidad y Calidad del Agua en Embalses de Regulación	Chaves, Paulo (WRRC)
Limnoisperma Fortunei (Bivalvia: Mytilidae) en los circuitos de enfriamiento y otros sectores de la Central Hidoeléctrica de Yacyretá / *Limnoisperma Fortunei* (Bivalvia: Mytilidae) in the cooling systems and other sectors of Yacyretá Hydropower Plant	Di Persia, Danilo (GIEU) y D´Angelo, Raúl (CICTT)
Modelación matemática del transporte de sedimentos y la evolución del lecho de embalses / Mathematical modeling of sediment transport and reservoir bed evolution.	Tarela, Pablo & Menéndez, Angel (INA)

PAPERS

TITLE	AUTHOR/S
Modelo de predicción de crecimiento de poblaciones en ambientes acotados, sin predadores / Model for growth prediction of populations in limited environments, without predators	Irigoyen, Manuel et al. (CTMSG)
Monitoreamento em tempo real da qualidade da água dos manaciais da Região metropolitana de São Paulo (Brasil) / Real time monitoring of water quality in water supply reservoirs in the Metropolitan Region of São Paulo (Brazil)	Pérez Flores, Armando (SABESP)
Monitoreo de Calidad de Agua y Sedimentos del Embalse Los Molinos I, Córdoba, Argentina / Water Quality and Sediment Monitoring in Los Molinos Reservoir, Córdoba, Argentina	Cossavella, Ana et al. (FCEFyN-UNC -CIRSA-DIPAS)
Monitoreo de Lagunas del Area Metropolitana del Gran Resistencia / Monitoring of shallow lakes in the Metropolitan Area of Great Resistencia	Otaño, Silvia H. y Vera, Delia S. (APA-Chaco)
PAMOLARE Training Package Version 1.0 / Módulo de Capacitación de PAMOLARE Versión 1.0	UNEP-DTIE-IETC / ILEC
Plano de Gerenciamiento Integrado da Várzea do Parelheiros / Integrated Management Plan of the Wetlands of River Parelheiros	Mincherian, R y Kertzman, F. (SABESP)
Prediction of Colonization of macrophytes in the Yacyretá reservoir of the Paraná River (Argentina and Paraguay) / Predicción de la Colonización de Macrófitas en el Embalse de Yacyreta en el Río Paraná.	Neiff, Juan J. et al. (CECOAL)
Programa de Gestión Ambiental del Embalse Casa de Piedra, Río Colorado (Argentina). Primera Etapa: monitoreo y modelado / Environmental Management Programme for Casa de Piedra Reservoir, Colorado River. First Stage: monitoring and modeling	Horne, Federico et al. (FCA-UNC)
Programa de Monitoreo del Embalse San Roque (Córdoba, Argentina), Período 1999-2000 / Monitoring Programme of San Roque Reservoir (Córdoba , Argentina), Period 1999-2000	Bustamante, María et al. (CIRSA)
Propuesta metodológica para ser adoptada por los integrantes de la red RIGA frente a situaciones de emergencia / Methodological proposal to be adopted by RIGA Network to address emergency situations	Lobos, José E. CTUA-INA (Arg.)
Relocalización de la Ciudad de Federación: Aprovechamiento Hidroeléctrico Binacional Salto Grande (Argentina-Uruguay) / / Relocation of the City of Federación. Salto Grande Bi-national Hydropower Development (Argentina - Uruguay)	Avogadro, Carlos (UM.)

PAPERS

TITLE	AUTHOR/S
Small hydropower plants in La Plata River Basin tributaries: A feasible alternatives for water power development / Pequeñas centrales hidroeléctricas en tributarios de la Cuenca del Río de la Plata: Alternativas factibles para el desarrollo de energía hidroeléctrica	Firta, Ioana N. et al. (HE)
Strategy to Reduce Pollutant Emission: Nitrogen Balance in Forest and Integrated Watershed Management. Case Study of Lake Biwa, Japan / Estrategia para Reducir la Emisión de Contaminantes: Balance de Nitrógeno en un Bosque y Manejo Integrado de los Recursos Hídricos.	Matsumoto, Miyuki (DSEES-GSES-KU)
Uma visão panorámica da situação institucional do sector de recursos hídricos no estado do Rio de Janeiro, Brasil / An overall vision of the institutional situation of the water resources sector in Rio de Janeiro State, Brazil	Almeida RossoT. C. de e Saldanha Machado, C. (UERJ)
Variabilidad espacial y temporal de los parámetros físicos-químicos en el embalse de Ullum / Spatial and time variability of physical and chemical parameters in Ullum Reservoir	Paz, María Eugenia et al. (UNSJ)

LECTURES / KEYNOTE SPEECHES

TITLE	SPEAKER
Activities of ILEC: Monitoring, Modeling and Databases / Actividades de ILEC: Monitoreo, modelación y bases de datos.	Yamashiki, Yosuke. (ILEC)
Pautas Ambientales en la Gestión de la Operación y Mantenimiento del Complejo Hidroeléctrico Yacyreta. / Environmental Guidelines for the Operation and Maintenance Management of the Yacyretá Hydroelectric System.	Fortuny, Alfredo (EBY)
Presentación de los Objetivos, Actividades y Resultados Esperados del III Taller / Presentation of the Objectives, Activities and Expected Outputs from the III Workshop	Calcagno, Alberto T. IARH-ILEC
Presentación de RIGA: Red de Investigación y Gestión Ambiental de la Cuenca del Río de la Plata / Presentation of RIGA: La Plata River Basin Environmental Research and Management Network	Calcagno, Alberto T. (RIGA)

Presentación del Programa CYTED - Red Iberoamericana de Eutroficación / Presentation of CYTED Programme – Ibero American Eutrophication Network	Fernández Cirelli, Alicia (SCyT-UBA)
Presentation of the Final report of the World Comisión on Dams (WCD)/ Presentación del Informe de la Comisión Mundial de Represas	Workman, James. (WCD)
Procesos Informados de Decisión para el Desarrollo Sustentable de Embalses: La tecnología como parte del proceso / Informed Decisión Proceses for Sustainable Development of Reservoirs: Technology as a part of the process..	Santiago Fandiño, Vicente (UNEP-DTIE-IETC)
Reservoir Sustainability, the RESCON project in the World Bank / Sustentabilidad de Embalses, el Proyecto RESCON del Banco Mundial	Palmieri, Alessandro (World Bank)
The GEMS/WATER Programme and the Need to Modernize Water Quality Monitoring Programmes / El Programa GEMS/WATER y la Necesidad de Modernizar los Programas de Monitoreo de Calidad de Aguas	Robarts, Richard, (UNEP GEMS/Water)
UNESCO- IHP V Programme "Ecohydrology": The use of ecosystem properties as management tools for integrated river basin management / El Programa "Ecohidrología" UNESCO - PHI V: El uso de las propiedades del ecosistema como herramienta de manejo para la gestión integrada de cuencas.	Zalewsky, Maciej (UNESCO IHP V – Projects 2.3/2.4)

SHORT BACKGROUND PAPERS WITH RECOMMENDATIONS

TITLE	AUTHOR/S
A experiencia da CESP na gestão dos seus reservatórios. / CESP experience in reservoir management	Uhlig, Alexandre et al. (CESP)
A visão da ABRH: Gerenciamiento dos Sistema Hídricos / ABRH Vision: Water Resources Systems Management	Tucci, Carlos (ABRH)
Acuífero Guaraní en la Provincia de Corrientes / Guarani Aquifer in the Province of Corrientes	Angeleri, José
Alerta sobre el Deterioro de la calidad del Agua y la falta de gestión Integral de los Recursos Hídricos de la Cuenca del Plata / Warning on the Degradation of Water Quality and Lack of Integrated Water Resources Management in La Plata River Basin	Vargas, Ramón (APA)

SHORT BACKGROUND PAPERS WITH RECOMMENDATIONS

TITLE	AUTHOR/S
Algunas Acciones de la Subsecretaría de Recursos Hídricos de la república Argentina / Some Activities of the Argentine Undersecretariat of Water Resources	Fioriti, María J. (SSRH-MIV))
Calidad del Agua en el Embalse de Itaipú / Water Quality in Itaipú Reservoir	Hermosa, H. José L. (IB)
Centro de Hidráulica e Hidrología "Professor Parigot de Souza / Hydraulic and Hydrology Centre "Professor Parigot de Souza"	Müller, Ingrid Illich (CEHPAR)
Compromiso con el Desarrollo y Gestión de Embalses Sustentables / Compromise with Sustainable Reservoirs Development and Management	Ortega, Ernesto (CAP)
Consideraciones sobre el Desarrollo Sustentable y las Obras de Infraestructura Hidráulica / Considerations about Sustainable Development and Projects of Hydraulic Infrastructure.	López, Fabian (CIRSA) & Angelaccio, Carlos (INA)
Consideraciones sobre la gestión de embalses por parte de la Dirección Nacional de Hidrografía. / Considerations about Reservoir management by the National Board of Hydrography	Arcelus, Alejandro (DNH)
Desafíos Ambientais de uma Empresa de Energía- A Visão Ambiental da COPEL / Environmental Challenges of an Energy Enterprise – Environmental Vision of COPEL	Gabriel de Camargo, Arilde S. (COPEL)
El Conocimiento de los Recursos Hídricos / Water Resources Knowledge	Millón, Jorge E. et al. (FI-UNSJ)
El Sistema de Hidrología Operativo de la Represa de Salto Grande / Operational Hydrologic System in Salto Grande Reservoir	Irigoyen, M et al. (CTMSG)
Enfoques regionales de recuperación y preservación de la calidad de agua de embalses en cuencas de Tucumán / Regional Approaches to the Restauration and Preservation of Water Quality of Reservoirs in Watersheds of Tucuman.	Tracanna de Albornoz, Beatriz (ILINOA)
Eventual trasvase entre Lago Presa Yacyretá y Esteros del Iberá / Posible water transfer between Yacyretá Reservoir and Ibera Wetlands	Angeleri, José
Existe la verdadera participación? / Does true participation exist?.	Roge, Anna Petra (Eco La Paz)

SHORT BACKGROUND PAPERS WITH RECOMMENDATIONS

TITLE	AUTHOR/S
Explotación futura de minerales pesados aguas debajo de la Presa de Yacyretá / Future exploitation of heavy minerals downstream Yacyreta Dam	Angeleri, José (Arg.)
Gestión Ambiental de Itaipú Binacional / Environmental management of Itaipu Binational	Ing. H. José L. Hermosa (IB)
Identificación de problemas y recomendaciones sobre monitoreo, simulación y gestión de embalses / Problem identification and recommendations on reservoir monitoring, simulation and management.	Tucci, Carlos (IPH)
Información, participación y compromiso de los actores sociales involucrados / Information, participation and commitment of involved stakeholders	Nosiglia de Cella, Silvina (AAM) & Tapia, Gachi (FCD)
Instituto Correntino del Agua / Water Institute of Corrientes	Rujana, Mario (ICA)
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La Incorporación de Nuevas Técnicas de Monitoreo en la región de la Cuenca del Plata / Incorporation of New Monitoring Techniques in La Plata River Basin Region	Andreani, Nora L.
Las poblaciones de sábalo en el río Paraná Medio / Populations of shads in Paraná Medio River	Cordiviola de Yuan, Elly (INALI)
Procesos Informados de Decisión para el Desarroollo Sustentable de los recursos Hídricos / Informed Decisión Processes for the Sustainable Development of Water Resources	Calcagno, Alberto T. (IARH)
Programa de Apoio de las Organizaciones No Gubernamentales para el Desarrollo en la Areas de Embalses y Cuencas / Program for the Support of Non Governmental Organizations for Development of Reservoir Areas and Watersheds	Pareja C., J. Marco A. (APMA)
Rol de sedimentos-nutrientes-bacterias y su importancia en los procesos de variación de calidad del agua en lagos y embalses / Sediment-nutrient-bacteria rol and its importance in water quality changing processes in lakes and reservoirs	Orona, Claudia et al. (UNC-CIRSA-DIPAS)

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ANNEX IV
DECLARATION OF POSADAS

RIGA

Red de Investigación y Gestión Ambiental de la Cuenca del Plata

Red de Investigaçao y Gestão Ambiental da Bacia do Prata

DECLARATION OF POSADAS

On March 17, 2001, in the city of Posadas, Province of Misiones, Argentina, the representatives of the institutions of Argentina, Brazil and Uruguay which integrate the Foundation Group of **La Plata River Basin Environmental Research and Management Network (RIGA)**, who undersign this Declaration, gathered themselves within the framework of the Third International Workshop on Regional Approaches to Reservoir Development and Management in the La Plata River Basin, to initiate the Foundation Act of the Network, which will remain open until forthcoming November 15, 2001.

RIGA is a regional non governmental non profit entity, which stems from the initiative of a representative group of qualified professionals belonging to organizations devoted to water and environment management, who have been meeting in said regional events since 1991. With the formal beginning of the Foundation Act, it comes to an end the pre-foundation process started in November 1999, in occasion of Buenos Aires Meeting when the participating founding organizations issued the Declaration of Buenos Aires, informing about the initiative and inviting to join it.

The involved institutions participating in said process thank the cooperation and financial support provided by ILEC, UNEP-DTIE-IETC, UNCRD, UNEP, IDB, CNPq (Brazil) and the Ministry of Foreign Affairs of Argentina

Fully aware of the importance of improving the conditions of sustainable use and development of the water resources as well as the integrated management of the environment in the La Plata River Basin and convinced that RIGA constitutes a communication, cooperation and interaction mechanism specifically created for such purpose, those undersigning this Declaration, **invite other governmental and non governmental organizations of Argentina, Bolivia, Brazil, Paraguay and Uruguay related with the management of water resources and the environment to integrate and actively participate in RIGA, expressing formally their adhesion to the initiative**[9].

[9] To this end, as well as to receive further information about RIGA, please address any of the representatives of the organizations that integrate the Transition Technical Committee: Coordinator: Ing. Alberto Calcagno (riga_iarh@iarh.org.ar; IARH (iarh@iarh.org.ar); SSRH-Arg (mfiori@miv.gov.ar); SSRH-ER (oduarte@dher@ciudad.com.ar); FICH-UNL (fich@fich.unl.edu.ar); COPEL (fred@copel.com); CESP (alexandre.uhlig@cec.cesp.com.br); CEHPAR (ingrid@lactec.org.br); IPH-UFRGS (tucci@if.ufrgs.br); DNH (dnh@uyweb.com.uy); IMFIA (lesy@fing.edu.uy).

ORGANIZATIONS AND THEIR REPRESENTATIVES WHO SIGNED THE DECLARATION OF POSADAS

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INALI Instituto Nacional de Limnología CONICET (Arg.)	Dra. Elly Cordiviola de Yuan
IPH-UFRGS Instituto de Pesquisas Hidráulicas (Br.) **ABRH** Associação Brasileira de Recursos Hídricos (Br.)	Dr. Carlos Tucci
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SSRH ER Subsecretaría de Recursos Hídricos de la Provincia de Entre Ríos (Arg.)	Ing. Oscar Duarte

THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES TO RESERVOIR DEVELOPMENT AND MANAGEMENT IN THE LA PLATA RIVER BASIN:
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ANNEX V
PAPER ABSTRACTS

Aplicación de Técnicas Estadísticas a la Optimización de Campañas de Muestreo en un Embalse

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Resumen

El trabajo que se presenta se refiere a la aplicación de técnicas estadísticas para la optimización del diseño de campañas de muestreo de calidad de aguas en un embalse. Se parte de un conjunto de datos de distintos parámetros recabados a partir de análisis de laboratorio sobre muestras extraídas en una serie de puntos geográficos del lago a distintas profundidades y en distintas épocas del año. A partir de la aplicación de herramientas estadísticas se llega a determinar el mínimo número de muestras que pueden tomarse sin perder información relevante, con lo que se consigue reducir considerablemente el número de puntos de extracción de muestras, y por ende los costos y tiempos de las campañas de extracción y de los análisis de laboratorio. Se considera una herramienta de gran interés para el diseño de monitoreos de largo plazo, donde se requiere una asignación inteligente de costos para maximizar resultados con recursos acotados.

Palabras clave: Muestreos; Calidad de aguas; Estadística aplicada; Lagos

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Statistical Techniques Applied to Optimisation of Sampling Campaigns in a Reservoir

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Abstract

This paper refers to the application of statistical techniques for the optimisation of the design of water quality sampling programs in a reservoir. The starting point is a group of different parameters' data obtained from laboratory analysis on samples extracted in some geographical points of the lake at different depths and in different times of the year. From the application of statistical tools, the minimum number of samples that can be taken without losing important information is obtained. That makes possible a considerably reduction in the number of sampling points, and as a consequence the cost and time of sample extraction campaigns and laboratory analyses become also reduced. This tool is of great interest for the design of long term sampling programs, where a careful assignment of costs is required to maximize results with reduced resources.

Keywords: Sampling; Water quality; Applied statistics; Lakes

Calidad del agua del Embalse de Itaipu. Programa de estudios de la ITAIPU Binacional

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Resumen

La evaluación de los resultados físico-químicos e hidrobiológicos en un periodo de 10 años permite concluir que los mismos no han sufrido un cambio definido, y que la composición general del plancton es similar a la observada en el antiguo rio Paraná. El Embalse se estratifica en la época cálida y puede ser clasificado como mesotrófico.

Palabras clave: Calidad de agua; Embalse; Itaipú.

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Water Quality in Itaipú Reservoir. Program of Studies of ITAIPU Binational

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Abstract

The evaluation of the main physical, chemical and hydrobiological results in the period of 10 years leads to conclude that they have not suffered a definite change, and that the general plankton composition is similar to the observed in the ancient Paraná river. The lake shows a stratification pattern in the warm period of the year and it can be classified as mesotrophic.

Keywords: Water quality; Reservoir; Itaipú

CEHPAR e sua experiência na conservação e gestão dos recursos hídricos

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Resumo

Este trabalho descreve alguns estudos do CEHPAR/LACTEC (Brasil) em corpos d'água e bacias de drenagem, salientando aqueles relacionados com a qualidade da água. Atuando desde 1959 com pesquisas e projetos, esta instituição tem acumulado e difundido experiências e conhecimentos, nos campos de hidráulica e hidrologia, subsidiando a construção de reservatórios para fins hidroenergéticos nas etapas de projeto, construção e operação. Dando ênfase aos estudos ambientais, o CEHPAR/LACTEC realiza ensaios físicos e químicos em águas e materiais diversos, desenvolve e aplica modelos matemáticos, assim como elabora estudos de diagnóstico ambiental de bacias hidrográficas, identificando usos dos solos e das águas e fontes potenciais de poluição. Estas ações vão ao encontro do desenvolvimento sustentável, que enfatiza a importância do equilíbrio entre as atividades humanas, o desenvolvimento tecnológico e o meio ambiente, bem como assegura o bom funcionamento e durabilidade das obras feitas pelo homem. O estudo de processos que ocorrem no meio ambiente e a busca de soluções eficientes e adequadas que minimizem impactos ambientais constituem metas prioritárias a serem atingidas pela Área de Recursos Ambientais do CEHPAR/ LACTEC.

Palavras-chaves: CEHPAR; LACTEC; Reservatório; Qualidade da água.

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CEHPAR and its experience in the conservation and management of water resources

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Abstract

This work summarizes some experiences of CEHPAR/LACTEC (Brasil) in studies of reservoirs and of drainage basins in the hydraulics hydrology and environment fields. Acting since 1959 with researches and projects, this institution has been accumulating and spread experiences and knowledge that help in the several phases of the reservoir, from the project and construction to the operation. Giving emphasis to the environmental studies, CEHPAR/LACTEC participates from analysis of the behavior of the physical-chemical and biological characteristics of water body, even studies of environmental diagnosis of basins, where the potential pollution sources are located, and mathematical modeling application and development. For a sustainable development, it is important of the equilibrium between the human activities and the environment, as well as the good operation and durability of the building constructed by the man. This objective it is only reached through the knowledge about processes that happen in the environment and the research of new ways that allow choose efficient measurements and methods with smaller impact to the environment.

Keywords: CEHPAR; LACTEC; Reservoir; Water quality.

Conflicts and Management Perspectives of Reservoirs in the Sao Francisco River (Brazil)

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Abstract

The Sao Francisco River is one of the most important rivers in Brazil, being known as the "River of National Unity". The 640.000 km^2 basin, which drains across the North East Brazil to the South West Atlantic Ocean, is well endowed with a rich variety of natural resources, including minerals, fish, wildlife, and lands suitable for agricultural development. The 3200 km river and its watershed has been subjected to intense economic development pressures.

The river has been historically operated exclusively for energy production and for water supply for irrigation projects. Modifications of the natural hydrological regime of the river which – while contributing to the production of "clean" energy for use by the people and industries of the basin and throughout Brazil – have proven especially destructive to organisms that depend, for reproduction and survival, on the quantity, quality, timing and rate of water flows (especially in the estuarine and coastal marine endpoints of the basin), and to groundwater sources that depend for recharge upon surface water flows.

The geomorphology of the river has been significantly modified by regulation (e.g., erosion of riverbanks, sedimentation, formation of islands in the delta, and erosion of the southern extreme of the delta). These modifications not only affect the estuary by altering flooding cycles, but also impact the nearshore marine environment by modifying the nutrient and sediment content of the river water, affecting marine fauna, and the sediment and turbidity dynamics of the estuary with observed, although unquantified, changes in the aquatic fauna, flora and geomorphology of the river mouth.

Some of the actions required to reduce impacts include (i) sound design engineering; (ii) quantification of water use (quantity and quality) and integrated operational criteria; (iii) multisectoral and public participation in the process of basin management; (iii) creation of basin committees and water user associations, representing different users and interests; (iv) application of modern water resources management principles such as tradable water rights, financial mechanisms (including polluter pays principle, water pricing, fines and taxes), monitoring systems, ecohydrology, Information Systems, and Decision Support Systems; (v) formulation of a watershed management program (including information sharing) and; (vi) strengthening of Federal, State and local institutions.

Keywords: Reservoir management; Watershed: Integrated inland coastal water resources management

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Perspectivas de Conflicto y Gestión de Embalses en el Río San Francisco (Brasil)

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Resumen

El Río Sao Francisco es uno de los ríos mas importantes en Brasil, llamado también como el "Río de Unidad Nacional". La cuenca de 640.000 km^2 , que drena en dirección nordeste para el Océano Atlántico, tiene una rica variedad de recursos naturales, que incluyen minerales, pescados, vida silvestre, y manchas de excelentes áreas agrícolas. Toda la extensión de los 3200 km del río y vares partes de la cuenca fueron expuestos a presiones intensas de desarrollo económico.

El río fue históricamente operado únicamente para la producción de energía eléctrica y para abastecimiento de agua para los proyectos de riego. Modificaciones del régimen hidrológico natural del río, por un lado contribuyeron para la producción de energía "limpia" para personas y industrias en la cuenca y en todo Brasil, pero por el otro lado, fueron muy destructivos para organismos que dependen, para reproducción y para sobrevivir, de demandas de agua en cantidad, cualidad, época y duración (especialmente en el estuario y costa marina) y también para las fuentes subterráneas que dependen de la recarga da aguas superficiales.

La geomorfología del río fue modificada significativamente por la regulación (erosión, deposito de sedimentos, formación de islas en el delta, y erosión del delta). Estos cambios no solo afectan el estuarios cambiando ciclos de llena, pero también el medio ambiente marino, cambiando el contenido de nutrientes y sedimentos en el agua, la fauna marina, la dinámica y cantidad de sedimentos, fauna acuática, flora, y la geomorfología del estuario.

Algunas de las acciones necesarias para reducir impactos incluyen (i) buenos proyectos de ingeniería; (ii) identificar y medir los diferentes de usos de agua (cantidad y cualidad) y criterios de operación; (iii) participación multisectorial y publica en el proceso de manejo de la cuenca; (iii) formación de comités de cuenca y asociaciones de usuarios de agua, representando diversos usuarios y interesados; (iv) aplicación de modernos principios de manejo de agua como mercados de agua, mecanismos financieros (incluyendo el principio del pagador contaminador, tarifas, multas y impuestos de agua), redes de monitoreo, ecohidrología, sistemas de informaciones y sistema de apoyo a la toma de decisiones; (v) elaboración de un programa de manejo de agua y transferencia de informaciones y; (vi) fortalecimiento de las instituciones Federales, Estatales y locales.

Palabras claves: Gestión de embalses; Cuenca Hidrográfica: Manejo integrado de aguas interiores y costeras

El Embalse de Río Hondo (Stgo. del Estero – Tucumán , Argentina): Un Humedal Conflictivo

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Resumen

El embalse de Río Hondo es un humedal que cumple un rol de gran importancia en la cuenca endorreica Salí – Dulce ya que ocupa una situación estratégica de recepción y redistribución del agua. Desde hace tres décadas se produce regularmente alta contaminación generada por sedimentos, residuos urbanos e industriales que son vertidos coincidentemente con la período de "aguas bajas". Hasta el presente se encararon estudios sobre aspectos físico – químicos y biológicos que permiten diagnosticar el alto grado de deterioro.

Los parámetros descriptores de contaminación (nutrientes, OD, DBO, clorofila a, entre otros) y las comunidades biológicas reflejaron en sus magnitudes, composición específica y abundancias, su sensible impacto de este ambiente "en tensión". Se aprecian diferencias significativas entre la zona limnética y la desembocadura de los tributarios ya que en la primera el volumen "amortiguó" en cierto modo su efecto. Se produce eutrofización con floraciones algales de cianofitas (*Microcystis aeruginosa*, *Anabaena flos- aquae*), abundantes euglenofitas, abundantes bacterias, ciliados y rotíferos bacteriófagos, todos elementos indicadores de alta saprobiedad, con predominancia de microcrustáceos macrofiltradores ciclo-poideos, disminución de la riqueza específica en niveles tróficos superiores (peces y aves) como resultado de una falta de políticas de conservación. Además se analizan las acciones de gestión tendientes a revertir dicha compleja situación y se proponen sugerencias.

Palabras claves: Embalses; Contaminación; Impacto ambiental; Argentina

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Rio Hondo Dam (Santiago del Estero – Tucumán, Argentina): A conflictive wetland

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Abstract

The strategic geographic location of the Río Hondo reservoir in terms of water reception and redistribution makes this dam play a significant functional role as a wetland within the endohreic basin of the Sali-Dulce river. For the past 30 years, this dam has been affected by an annual increase in contamination levels produced by the input of sediments (urban and industrial byproducts) that occurs mostly during low-water periods. To the present, a series of studies have focused on physical, chemical and biological aspects aiming at a diagnosis of the degree of alteration. Pollution-descriptive parameters (nutrients, DO, DBO, chlorophyll a, among others) and biological communities reflected in their specific composition and abundance, a sensible impact affecting this stressed environment.

Water volume differences determined significant differences between the impact observed in the limnetic zone and the tributaries' mouth. Eutrophication is reflected by cianophyte algae blooms (*Microcystis aeruginosa, Anabaena flosaquae*), abundant euglenophytes, abundant bacteria, ciliates, and bacteriophagous rotifers, all of them being indicators of high saprobiety, with dominance of macrofilter microcrustaceans ciclopoids, and decrease in the species richness at superior trophic levels (fishes and birds) as a result of a lack of a conservation policy. Management actions towards a reversion of this complex situation are analyzed and recommendations are made.

Keywords: Dam; Contamination; Environmental impact; Argentina

Embalse de Ayui: un emprendimiento coparticipativo de gestión conjunta

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Resumen

Se presentan el proyecto y los estudios ambientales de la *Presa de Embalse Ayuí*, desarrollados de acuerdo a los términos de la Ley Provincial N° 5067/96, y emprendidos en forma conjunta por un consorcio de establecimientos agropecuarios ribereños del arroyo Ayuí, en la zona de la ciudad de Mercedes, Corrientes, Argentina. Se lo compara con las alternativas implementadas hasta el momento en la región, consistentes en pequeños embalses en cabeceras de arroyos, manejados unilateralmente por los productores.

Se incluye una descripción del proyecto y una cuantificación de sus impactos ambientales negativos y positivos más significativos. También se describe la porción de ecosistema intervenida por el proyecto. Se efectúa un diagnóstico en cuanto a las tendencias de evolución observadas, tanto en el medio natural como en lo que hace a la intervención antrópica. También se describen las medidas de mitigación que fueron incorporadas desde el inicio del diseño de la obra, así como las recomendadas como complemento. Por último, se esboza el plan de gestión ambiental recomendado.

Palabras claves: Riego; Presa; Operación; Impacto; Gestión

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Ayui reservoir: A joint venture for water management

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Abstract

Design and environmental studies, in the framework of Provincial Law 5067/96, are carried out by a consortium of agricultural producers lying adjacent to Ayui River, close to the city of Mercedes, Corrientes Province, Argentina. The project is compared against the alternative operational mode presently used in the region, i.e., small dams in the upper zone of the tributaries managed by a single producer.
A description of the project and a quantification of the most significant negative and positive environmental impacts are included. The affected ecosystem is also described. A diagnosis about the evolutionary trends of environment, including the anthropic effects, is made. Mitigation measures taken into account from the very beginning of the design process and those recommended as a complement are described. Finally, the recommended environmental management plan is briefly introduced.

Keywords: Irrigation; Dam; Operation; Impact; Management

Establecimiento de niveles guía nacionales de calidad de agua Ambiente

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Resumen

Este trabajo expone los elementos metodológicos correspondientes a la elaboración de niveles guía nacionales para la Argentina, de parámetros prioritarios de calidad que tienen como objeto la salvaguarda de los componentes bióticos involucrados en los siguientes destinos del agua ambiente: a) fuente de provisión de agua para consumo humano, b) protección de la biota acuática, c) recreación humana, d) irrigación de cultivos y e) bebida de especies de producción animal. Esta elaboración está destinada a proveer el marco referencial primario para la especificación de objetivos y estándares de calidad específicos para los cuerpos de agua.

Palabras clave: Agua ambiente; Parámetros de calidad; Niveles guía

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Establishment of national environment water quality guidelines

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Abstract

This paper presents the methodological elements related to the development of Argentine national water quality guidelines for quality priority parameters concerning the protection of the biotic components involved in the following uses of ambient water: a) raw water for drinking supply, b) protection of aquatic biota, c) human recreation, d) irrigation, e) livestock watering are exposed. This development pursues the accomplishment of the basis for the derivation of ambient water quality objectives and standards.

Key words: Ambient water; Quality parameters; Guidelines

Evolución de la Gestión Ambiental en el Proyecto Yacyretá

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Resumen

El trabajo contiene una apretada síntesis de los antecedentes de la actual gestión ambiental en la Entidad Binacional Yacyretá. En el mismo se podrá evaluar cómo la EBY fue incorporando progresivamente las cuestiones ambientales a su propia gestión, ausentes en las demandas sociales de principios de la década de los años 70 y consecuentemente en el proyecto original gestado en aquellos años, pero de insoslayable y creciente importancia en los últimos años.

La Entidad Binacional Yacyretá cuenta hoy con un conjunto de decisiones que fueron construyendo paulatinamente un importante andamiaje que sirve de soporte para la gestión ambiental: un Plan de Manejo de Medio Ambiente que contiene los programas, proyectos y acciones definidos con el necesario rigor técnico-científico; actualizado mediante un valioso proceso de consulta y participación con la sociedad local; un equipo de profesionales propio, formado y capacitado en las especialidades requeridas; relaciones con instituciones académicas y científicas que garantizan alto nivel y calidad de los trabajos; un sistema de evaluación externo e independiente de la ejecución de los programas ambientales; y normas propias que garantizan el financiamiento de los programas ambientales por toda la vida útil de la misma, incorporándolos a los costos de operación y mantenimiento de la central.

Palabras Claves: Gestión ambiental; Embalses; Yacyretá

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Evolution of Environmental Management in Yacyreta Reservoir

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Abstract

The paper comprises a short briefing of the antecedents of current environmental management in the Yacyreta Binational Entity (EBY). It allows to assess how EBY has been progressively incorporating environmental issues into its own management, which were absent in the social demands of the early 70's , and consequently, in the original design elaborated at that time, but which have become of unavoidable and increasing importance in the recent years.

The Yacyreta Binational Entity has available nowadays a set of decisions which progressively developed a very important framework to support the environmental management: an Environmental Management Plan comprising programs, projects and actions defined with proper technical and scientific rigorousness; updated by means of a valuable process of consultation and participation of local society; its own team of professionals, educated and trained in the necessary fields; relationships with academic and scientific institutions which guarantee a high level and quality of the undertakings; an external and independent system of evaluation in the execution of the environmental programs; and specific regulations which guarantee the financing of the environmental programmes along its lifetime, by including them into the operation and maintenance costs of the powerplant.

Keywords: Environmental management; Reservoirs; Yacyreta

Funcionamiento de los Sistemas de Transferencia para Peces en Represas de la Baja Cuenca del Plata: Resultados y Perspectivas

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Resumen

Las especies migradoras constituyen un rasgo característico de los grandes ríos de Sudamérica. Estas especies difieren en varios aspectos ecológicos importantes de las del hemisferio norte, para los cuales se han diseñado y construido la mayoría de los sistemas de transferencia de peces del mundo. En la baja cuenca del Plata, la represa de Salto Grande posee un sistema de esclusas Borland, mientras que en la represa de Yacyreta se ha construido dos elevadores para peces. Los resultados observados muestran que los sistemas de la baja cuenca, no han favorecido el pasaje de especies que migradoras importantes y que constituyen la base de las pesquerías regionales.

Por el contrario, han privilegiado la transferencia de especies de pequeño porte, distribución ubicua y escaso interés pesquero. La baja eficiencia para las especies migradoras obedece a problemas estructurales y funcionales de diseño. En Yacyreta, ello genera un elevado costo de transferencia para cada pez migrador. La piscicultura de repoblamiento para recuperar los stocks de peces migratorios en la alta cuenca (Brasil), no ha dado los resultados esperados por lo que resulta indispensable asegurar la construcción de sistemas mas eficientes. Los futuros pasos para peces en la cuenca, deberán diseñarse a partir de información bioecológica específica obtenida de manera apropiada, e integrada con criterios ingenieriles e información ambiental.

Palabras clave: Transferencia de Peces; Presas; Cuenca del Plata

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Performance of Fish Facilities in Lower La Plata River Basin Reservoirs: Results and Perspectives

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Abstract

Migratory fish species constitute a main feature in large rivers of South America. These species present different ecological characteristics from their counterparts in the North Hemisphere, for which most of the fishway systems in the world have been developed. In the lower De la Plata River basin, Salto Grande dam has two Borland locks and two fish elevators were installed in Yacyreta dam.

Results showed that such systems had limited success for transferring large amount of important migratory species, which are the basis of the regional fisheries. In turn, these systems primarily passed small non-migratory species, with ubiquitous distribution and without fishery importance. Low efficiency of fish passage facilities for migratory species can be attributed to functional and structural design limitations. In Yacyreta, low performance of fish elevators implies high costs for transferring migratory fishes. Stocking policies developed in the upper basin (Brazil) failed to restore migratory stocks, implying that sound fishway designs are required. Future fishways in the basin should be developed based on an integrated approach, that includes specific bioecological information obtained in an appropriate way, engineering criteria and suitable environmental information.

Key words: Fish facilities; Dams; La Plata River Basin

Integrated Water Resources Management- Water Quality Monitoring and Assessment

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Abstract

In this paper the author discusses some basic concepts in the organization of monitoring procedures. Monitoring is considered as an essential component of integrated water resources management. The number of variables, the choice of best methodology, the sampling statistics and accuracy are discussed. The new tendencies for adequate monitoring of a complex and variable system as a continental water body are presented, namely the authomatic sampling in real time, the biological monitoring and the need to develop early warning procedures and protocols to anticipate events.

Keywords: Water Quality; Monitoring; Assessment; Integrated water resources management

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Gerenciamento integrado de recursos hídricos – monitoramento e avaliação da qualidade da água.

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Resumo

Neste trabalho o autor discute alguns conceitos básicos do monitoramento. Este é considerado como um componente essencial do gerenciamento de recursos hídricos. O número de variáveis, a escolha de melhor metodologia, as estatísticas da amostragem e a acuracidade são discutidos. As novas tendências do monitoramento tais como o monitoramento em tempo real, o monitoramento biológico, e a necessidade de desenvolver sistemas de alerta para antecipar eventos são também discutidos.

Palavras-chaves: Qualidade da água; Monitoramento; Avaliação; Gerenciamento integrado de recursos hídricos

Herramientas de Cuantificación para la Gestión de la Sedimentación en Embalses

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Resumen

Se presenta una visión general del proceso de sedimentación en reservorios y sus efectos ambientales. El objetivo del trabajo es describir brevemente las herramientas de cálculo disponibles para determinar el impacto del proceso de sedimentación. Se presentan los métodos empíricos tradicionales y algunas experiencias de campo y laboratorio. Luego se describe un conjunto de modelos matemáticos 1D, 2D y 3D. Se explican sus ventajas y desventajas. Se concluye que el estado del conocimiento actual permite abordar esta problemática mediante la simulación numérica, preferentemente a través de modelos 1D o 2D. La aplicación de modelos 3D es todavía computacionalmente costosa, a la vez que requiere una gran base de datos. Los métodos empíricos deberían utilizarse para una evaluación preliminar.

Palabras clave: Sedimentación en embalses; Modelos matemáticos; Métodos empíricos; Estudios de campo.

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Quantification Tools for Reservoir Sedimentation Management

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Abstract

A general view of the reservoir sedimentation processes and their environmental effects is presented. The objective of the paper is to briefly describe the available calculation tools to assess the sedimentation impact. The traditional empirical methods and some laboratory and field experiences are presented. Then, a set of 1D, 2D and 3D mathematical models are described. Their advantages and disadvantages are explained. As a conclusion, the state of the art allows to approach the problem through numerical simulation, preferably using 1D or 2D models. The application of 3D models is still computationally expensive, and a large amount of data is required. The empirical methods should be used only as a preliminary evaluation.

Keywords: Reservoir sedimentation; Mathematical modeling; Empirical methods; Field studies.

Hydrological monitoring and reservoirs operation management in the State of Paraná, Brazil

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Abstract

In order to get a most efficient hydraulic and energetic operation in a Generation Company reservoir's system, it is important that the information and the necessary steps for a decision making are available at all the areas involved in a fast, secure and synchronized way. Regarding that COPEL (State of Paraná Energy Company) has been working on computer systems, models and tools since the 70'. Recently in 1997, the Hydrology of Operation Department proposed the development of a storage, processing, data consulting and decision support system – The HMS System –, integrating several data and software used in reservoirs monitoring.

The system development and installation were gradual, started with the Caxias' reservoir. In December of 1999 all the reservoirs operated by COPEL were already being monitored by the HMS System.

Among the benefits that the project brought to the company, stand out: a) convergence of information for an homogeneous database; b) automation of procedures: collecting of data, calculations and supporting process for decision making (automated operative rule); c) fast results; d) improvement of the quality of information; e) system integration; f) technological evolution.

Keywords: Hydrological monitoring, Reservoir operation; Decision suport system.

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Gestión del monitoreo hidrológico y de la operación de embalses en el Estado de Paraná, Brasil

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Resumen

Para alcanzar una operación hidráulica y energética más eficaz de un sistema de embalses de una Compañía de Generación, es importante que la información y los pasos necesarios en la toma de decisión estén absolutamente disponibles en las áreas implicadas de una manera rápida, segura y sincronizada. Con respecto a esto, COPEL (Brasil) ha estado trabajando en sistemas informáticos, modelos y herramientas desde los años 70. Recientemente en 1997, la Sección de Hidrología de la Operación propuso el desarrollo de un sistema (Sistema HMS) de consulta, procesamiento, almacenamiento y suporte a toma de decisión de datos integrando varios datos y software usados en la vigilancia de los embalses.

El desarrollo e instalación del sistema eran graduales, empezado con el embalse de Caxias. En diciembre de 1999 todos los embalses operados por COPEL eran supervisando ya por el Sistema HMS.

Entre las ventajas que el proyecto trajo a la compañía, destaque: a) convergencia de la información para un banco de datos homogéneo; b) automatización de procedimientos: el recoger de datos, cálculos y proceso de apoyo para la tomada de decisión (regla operativa automatizada); c) resultados rápidos; d) mejora de la calidad de información; e) integración del sistema; f) evolución tecnológica.

Palabras claves: Monitoreo hidrológico; Operación de Embalses; Sistemas Soporte de Decisión

Impacto de los flujos ambientales en la Cuenca del Plata sobre la producción de agua potable

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Resumen

En este trabajo se presenta el desarrollo de un procedimiento racional de gestión y control implementado en el año 2000 en Aguas argentinas S.A. Dos sistemas fueron analizados: el proceso de producción y la calidad del afluente. Del estudio del proceso de producción se obtuvieron los parámetros de agua cruda determinantes de la dosis de clarificación. El análisis del afluente permitió obtener la metodología de predicción de tendencias de dichas variables determinantes. Ambos estudios constituyen una herramienta fundamental para la elaboración del plan anual de gestión de insumos químicos en la producción de agua.

Palabras claves: Gestión racional; Red de información; Río Bermejo; Agua cruda; Presupuesto

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Impact of environmental flows on drinking water supply in La Plata River Basin

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Abstract

In this work it is shown the development of a rational procedure for management and control that was implemented in Aguas Argentinas, during year 2000.
Two systems were analyzed: the production process and influent´s quality. The first analysis let obtain the main variables to determine the dose of chemical reagents. The second one let obtain the procedure to predict trends in the mentioned variables. Both of the studies allowed to make the annual plan for the management of chemicals in water production.

Keywords: Rational management; Information network; Bermejo River; Raw water; Budget

Implementación del procedimiento cadena de custodia de muestras en programas de monitoreo ambiental como elemento de aseguramiento de la calidad

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Resumen

A partir de la intervención del Instituto Nacional del Agua en el derrame de hidrocarburos ocurrido en Enero de 1999, en las proximidades de la Costa de Magdalena, se incorpora a la metodología de trabajo habitual del Instituto una serie de controles tendientes al aseguramiento de la calidad en todas las etapas del proyecto. Dicho sistema incluye la utilización de planillas de registro de campo y de cadena de custodia a los efectos de garantizar el control de la muestra desde su colecta hasta el reporte de los resultados analíticos del laboratorio, así como la aplicación de un sistema de Control de Calidad en campo y laboratorio.

En el presente trabajo se desarrolla uno de los aspectos más importantes del programa de Control de Calidad vinculado a la obtención de la muestra, llamado *Cadena de Custodia*, cuya finalidad es la de asegurar la trazabilidad en el acarreo y posesión de todas las muestras.

Si bien el procedimiento de custodia de la muestra adquiere relevancia cuando la información obtenida debe ser presentada ante una instancia legal, se propone su implementación rutinaria debido a que la información generada es de mayor confiabilidad y permite además establecer una uniformidad de criterios en los diferentes programas de monitoreo de calidad ambiental.

Palabras Claves: Custodia de Muestras; Aseguramiento Calidad; Trazabilidad; Muestreo.

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Implementation of Sampling Custody Chains Procedures in Environmental Monitoring Programs as a Quality Assurance Element

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Abstract

Starting with the intervention of the National Institute of the Water in the oil spill happened in January of 1999, in the Magdalena coast- Bs. As. Province, it was incorporated to the routine methodology of sampling in the Institute, a series of quality controls applied in all the stages of the project. This system includes the use of field registration forms and custody chain, to guarantee the control of the sample from its collection until the report of the analytical results by the laboratory, as well as the application of a Control Quality system in field and laboratory.

This work shows one of the most important aspects of the Quality Control program related to the sampling program called "Chain of Custody", whose purpose is assure the tracking of Quality in the transport and possession of all the samples.

Although the custody procedure of the sample acquires relevance when the obtained information should be presented for legal purposes, its routine implementation during all the studies performed by the institutions will improve a better quality of date and an increase in the confidence of the monitoring environmental programs.

Key Words: Sample Custody; Quality Assurance; Tracking; Sampling

Incidencia de las descargas cloacales costeras en la Laguna Setubal (Provincia de Santa Fe, Argentina)

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Resumen

Se analizaron las concentraciones de *Escherichia coli*, coliformes termotolerantes y coliformes totales en muestras tomadas en aguas de la laguna Setúbal (Santa Fe, Argentina) y en conductos pluviales que descargan sobre sus playas en margen derecha. El objetivo del trabajo consistió en determinar la distribución espacial de bacterias hacia el interior del cuerpo de agua, receptor de las descargas. Se determinó que las aguas cuyas concentraciones superan los 200 NMP/100 ml de *Escherichia coli* y coliformes termotolerantes, ocupan una franja costera de 30 a 40 metros de ancho medidos desde la margen derecha. La toma de agua de la ciudad no es alcanzada por las descargas poluídas de los conductos, al menos para las condiciones hidrométricas de aguas medias en tiempo seco, para las cuales se realizaron los muestreos. La importancia del estudio se justifica en el aprovechamiento de sus aguas para recreación en la temporada estival, deportes náuticos y abastecimiento a la ciudad de Santa Fe.

Palabras claves: *Escherichia coli*; Coliformes; Aguas recreacionales; Toma de agua; Conductos pluviales; Distribución espacial

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Spatial distribution of coliform bacteria in the Setúbal lake (Santa Fe Province, Argentina)

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Abstract

Escherichia coli, thermotolerant coliform and total coliform concentrations were analysed in water samples collected from the Setúbal lake and pluvial drainages which discharge into its right bank. The aim of this work was to determine the bacteria spatial distribution towards the inner part of the water body where discharges take place. Waters with *Escherichia coli* and thermotolerant coliform concentrations higher than 200 NMP/ml were found to occupy a 30 - 40 m border edge, measured from the right bank. The city water intake is not affected by the polluted pluvial drainages, at least under the hydrometric conditions of mean level waters and dry weather when the sampling were carried out. The importance of this study lies in the use of the lake both for recreational purposes such as swimming and nautical sports, and as a source of water supply to Santa Fe town.

Keywords: *Escherichia coli*; Coliform; Recreational waters; Water intake; Pluvial drainages; Spatial distribution.

Integrated Water Resources Management: Formulation of Multi-objective Optimization on Water Quantity and Quality of Storage Reservoir

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Abstract

Short and long-term operation of a storage reservoir, focusing on quantity & quality assessment, is formulated in this paper. The objective is to improve benefits of a storage reservoir for all stakeholders involved with the water issues. Future scenarios under changing situations will be analyzed as this research progresses. Fuzzy dynamic programming (Fuzzy DP) is considered to be the most suitable tool to handle the posed problem. A case study is presented for the Barra Bonita Reservoir in the state of São Paulo, Brazil.

Keywords: Multi-objective Optimization; Dynamic Programming; Fuzzy Theory; Water Quality Model; Barra Bonita.

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Gestión Integrada de los Recursos Hídricos: Formulación de una Optimización Multiobjetivo de Cantidad y Calidad del Agua en Embalses de Regulación

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Resumen

En este trabajo se formula la operación de corto y largo plazo de un embalse de regulación, con énfasis en la evaluación de la cantidad y la calidad. El objetivo es incrementar los beneficios del embalse para todos los actores con intereses en los cuestiones de agua. Se analizarán escenarios futuros ba,o situaciones cambiantes a medida que la investigación progrese. Se considera que la Programación Dinámica Difusa (Fuzzy DP) es la herramienta mas apropiada para resolver el problema planteado. Se presenta un estudio de caso para el Embalse de Barra Bonita, Estado de San Pablo, Brasil.

Palabras clave: Optimización multiobjetivo; Programación dinámica; Teoría difusa; Modelo de Calidad de Agua; Barra Bonita

Limnoperna Fortunei (Bivalvia: Mytilidae) en los Circuitos de Enfriamiento y otros Sectores de la Central Hidroelectrica de Yacyretá

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Resumen

Limnoperna fortunei es un pequeño bivalvo de agua dulce que, introducido accidentalmente o por negligencia en el Río de la Plata, ha tenido una rápida dispersión en éste y en los ríos Paraná y Paraguay y sus tributarios. En el presente trabajo se hace referencia al desarrollo de densas poblaciones de este mitílido en distintos sectores de la central hidroeléctrica, donde se han encontrado larvas en los circuitos de conducción de agua para enfriamiento de las turbinas. Se hace referencia al potencial reproductivo de la especie y las posibles consecuencias de no mediar acciones eficientes de control.

Palabras Claves: *Limnoperna fortunei;* Especie invasora; Bivalbo asiático dulceacuícola; Embalse de Yacyretá: Colonización.

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Limnoisperma Fortunei (Bivalvia: Mytilidae) in the cooling systems and other sectors of Yacyretá Hydropower Plant

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Abstract

Limnoperna fortunei is a small bivalbe of fresh water; which was introduced accidentally or by negligence in the Río de la Plata river, it has got a quick dispersion in that river as well as in the Paraná and Paraguay rivers, and its tributaries. This present work deals about development of dense populations of this mytilid in different sections of the Yaciretá hydroelectric central; where it has been found larvae in the circuit of water conduction to cool the turbines. It does reference to the reproductive success of this species and the possible consequences if efficient actions of control are not taken place.

Keywords: *Limnoperna fortunei*; Invasive species; Freshwater asiatic bivalve; Yacyretá dam; Colonization.

Modelación matemática del transporte de sedimentos y la evolución del lecho de embalses

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Resumen

Se presenta un modelo matemático para predecir el proceso de sedimentación en un reservorio y simular el crecimiento del delta. El modelo está basado en una forma parabolizada y lateralmente integrada de las ecuaciones de movimiento. Para la resolución numérica se utiliza el método de los elementos finitos. La formulación del modelo y el esquema numérico de resolución se explican brevemente. El modelo es validado mediante comparaciones con datos de campo del lago Mead (EE.UU.). Se estudian la evolución longitudinal del perfil del lecho como así también la estratificación de la composición del suelo. Se explican tanto la formación como el crecimiento de las formas del fondo. Se muestra que la evolución del fondo del reservorio depende fuertemente de diversos parámetros: la geometría del reservorio, el ciclo hidrológico, el nivel de embalse, la carga de sedimentos y el tamaño de las partículas.

Palabras clave: Sedimentación en embalses; Modelación matemática; Simulación numérica; Crecimiento del delta; Evolución morfológica.

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Mathematical modeling of sediment transport and reservoir bed evolution

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Abstract

A mathematical model to predict the sedimentation process in a reservoir and to simulate the delta growth is presented. It is based on a parabolized and laterally integrated form of the governing equations. For the numerical resolution the finite element method is used. Model formulation and numerical scheme are both briefly explained. The model is validated through comparisons with field data from lake Mead (USA) surveys. The evolution of the longitudinal bottom profile as well as the resulting deposit stratification are studied. The formation and growth of bottom forms are explained. It is concluded that the reservoir bottom evolution depends strongly on several parameters: the geometry of the reservoir, the hydrological cycle, the lake level, the sediment load and the sediment size.

Keywords: Reservoir sedimentation; Mathematical modeling; Numerical simulation; Delta growth; Bottom evolution.

Modelo de predicción de crecimiento de poblaciones en ambientes acotados, sin predadores

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Resumen

En el presente trabajo se presenta un modelo determinístico de predicción de crecimiento de población en ambientes acotados y sin predadores, planteado en ecuaciones diferenciales para vincular los valores de población con sus variaciones. El modelo, además de proponer una curva de crecimiento en "S" como la logística, contempla el caso de oscilación amortiguada de crecimiento de poblaciones o de variaciones del medio o de población.

Palabras claves: Modelo; Crecimiento; Poblaciones; Ecuaciones diferenciales.

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Model for growth prediction of populations in limited environments, without predators

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Abstract

A deterministic model to predict the population growth in limited environments without predators is presented. The model, uses a differential equation to represent the relationships between the population size and its growth rates. The model proposes a "S" type growth curve, as the logistic, and can predicts a damped oscillation of population growing or changes of the environment or populations.

Keywords: Model; Growth; Populations; Differential equations

Monitoramento em tempo real da qualidade da água dos mananciais da Região Metropolitana de São Paulo (Brazil)

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Resumo

Este trabalho apresenta, o projeto implantado pela Companhia de Saneamento Básico do Estado de São Paulo – SABESP, para Monitoramento em Tempo Real da Qualidade da Água dos Mananciais da Região Metropolitana de São Paulo (Brazil).

Palavras-chaves: Monitoramento em Tempo Real; Reservatório; Qualidade da água; SABESP.

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Real time monitoring of water quality in water supply reservoirs in the Metropolitan Region of São Paulo (Brazil)

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Abstract

This work presents, the project implanted by São Paulo Basic Sanitation Company - SABESP, for in Real Time Monitoring of the Water Quality in the Water Source of São Paulo Metropolitan Area (Brasil).

Keywords: Real time monitoring; Reservoir; Water Quality; SABESP

Monitoreo de calidad de agua y sedimentos del embalse Los Molinos I, Córdoba, Argentina

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Resumen

El Embalse Los Molinos I está ubicado en la Provincia de Córdoba (Argentina), a 65 Km al sur de la Ciudad Capital. En la actualidad, a través de un sistema de canalización se utiliza para complementar el suministro de agua potable a la Ciudad de Córdoba, por lo que merece especial atención su preservación y adecuado manejo.

En los últimos años este reservorio ha presentado claros signos de problemas derivados del estado de eutrofia, tales como escasa transparencia, presencia de anoxia hipolimnética y frecuentes eventos de floraciones algales, con el consiguiente deterioro del recurso.

Con el objetivo de lograr un estudio integral y sistemático de la calidad del agua y los sedimentos abordado en forma interinstitucional e interdisciplinario y generar una base de datos para la aplicación futura de modelos de Eutrofización que contribuyan a la adecuada gestión, se iniciaron en el año 1.999 una serie de campañas de monitoreo de agua y sedimento del embalse y sus cuatro tributarios principales.

El objetivo del presente trabajo es presentar los avances y los resultados preliminares de los parámetros físico-químicos y biológicos de calidad correspondientes al embalse, conjuntamente con la utilización del programa PROFILE para el análisis y resumen de datos.

Palabras claves: Eutrofización; Embalse; Monitoreo; Nutrientes; *Ceratium sp.*

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Water Quality and Sediment Monitoring in Los Molinos Reservoir, Córdoba, Argentina

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Abstract

The reservoir Los Molinos I is located in the Province of Córdoba, Argentina, at 65 km at the south from the capital, Córdoba City. The preservation and appropriate use of this reservoir deserve special attention because it is connected to the city through a canal and is used to complement the drinking water supply.

In the last years, Los Molinos I has shown clear signs of problems related to eutrophication, such as low transparency, very low concentration of oxygen in the hypolimnion, and frequent algal blooms.

Since 1999, various field campaigns to monitor water, sediment and four main tributaries were started in order to achieve a comprehensive and systematic understanding of the status of water and sediment. This interdisciplinary and inter-institutional study also intends to generate data bases that allow to apply eutrophication models, aiming an appropriate management of the resource.

The aim of this work is to present the advances and preliminaries results obtained so far. Physicochemical and biologic parameters related to water and sediment quality are shown by using the program PROFILE to analyze and summarize the data.

Keywords: Eutrophication; Reservoir; Monitoring; Nutrients; *Ceratium Sp.*

Monitoreo de Lagunas del Area Metropolitana del Gran Resistencia

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Resumen

La conformación natural, social y tecnológica de los asentamientos humanos en el Área Metropolitana del Gran Resistencia (AMGR), dieron lugar a una dinámica de desarrollo urbano caracterizada por la expansión y apropiación de los ecosistemas lénticos que generaron procesos de contaminación y degradación. Entre las causas de estos procesos se encuentran la conexión clandestina de efluentes cloacales a la red plucvial, el establecimiento de personas en el borde de las lagunaas, la ocupación de áreas de riesgo hídrico, el relleno de lagunas, la proliferación de microbasurales espontáneos y la falta de conectividad de las lagunas con el río Negro.

El objetivo rector de estos monitoreos fue realizar una evaluación del estado de deterioro ambiental de las lagunas del AMGR e implementar medidas mitigadoras a corto plazo evaluando el comportamiento de los cuerpos de agua, así como realizar el seguimiento de las lagunas donde el Municipio emprendió tareas de recuperación. Este trabajo se circunscribe al monitoreo realizado en las lagunas del AMGR, especialmente aquellas que no sólo actúan como cuerpos receptores de lso drenajes urbanos sino que son utilizadas para el control de crecidas por medio de sistemas de bombeo hacia el Río Negro.

Del análisis de los datos de base relevados en los cuerpos de agua se concluyó que todos los ecosistemas estudiados presentan alto grado de eutrofización. Se propuso como medidas de mitigación el dragado en algunos casos y la recolección de macrófitas y limpieza de bordes en otros. Este trabajo se realizó en el marco del Plan de Monitoreo Ambiental de lagunas del AMGR., Programa de Protección contra Inundaciones (PPI), Programa Ambiental de Protección y Manejo de Humedales, Subunidad Central de Coordinación para la Emergencia (SUCCE), Sub Unidad provincial de Coordinación para la Emergencia (SUPCE).

Palabras clave: Eutrofización; Lagunas urbanas; Monitoreo; Calidad del Agua

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Monitoring of shallow lakes in the Metropolitan Area of Great Resistencia

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Abstract

The natural, social and technological conformation of the human settlements in the Metropolitan Area of the Great Resistencia (AMGR), gave place to a dynamics of the urban development characterized by the expansion and appropriation of the lentic ecosystems, which generated processes of contamination and degradation. The causes of these processess are the illegal sewage connections into the pluvial network, the settlement of people in lake shores, the occupation of water risk prone areas, the filling of the shallow lakes, the proliferation of spontaneous solid waste dumpings and the lack of connection of the lagoons with the Negro river.

The main objective of the monitoring was to carry out an evaluation of the state of environmental deterioration of the shallow lakes in the AMGR and to implement short term mitigation measures by assessing the behaviour of the water bodies, as well as to carry out the follow up of the lakes where the Municipality undertook recovery actions. This work refers to the monitoring carried out in the shallow lakes of the AMGR, especially those that not only act as receiving bodies of urban drainages but, rather, they are used for the control of floods by means of systems pumping into the Negro river.

From the analysis of the data collected in the water bodies, it is concluded that all the studied ecosystems present a high degree of eutrophycation. Dredging in some cases, and removal of vegetation and cleaning of the shorelines in others, have been proposed as mitigation measures. This work was carried out within the framework of the AMRG Shallow Lakes Environmental Monitoring Plan, Programme of Flooding Protection (PPI), Environmental Programme for Protection and Management of Wetlands, Central Coordination Sub Unit for the Emergency (SUCCE), Provincial Coordination Sub Unit for the Emergency (SUPCE).

Keywords: Eutrophication; Urban shallow lakes; Monitoring; Water quality

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Abstract

The PAMOLARE acronym is derived from Planning And Management Of Lakes And Reservoirs focusing on Eutrophication. Version 1.0 of the PAMOLARE training software package was developed for use by decision makers and all those professionals dealing with the planning and management of freshwater resources, engaged in lake and reservoir management in developing countries and countries with economies in transition. This package allows for a better understanding of eutrophication processes in lakes and reservoirs. The following three models are available in the PAMOLARE training package: 1) the Vollenweider plot, 2) 4st-model (a 1-layer lake model with 4 state variables plus several additional parameters, and 3) 2L-Model (a medium complex 2-layer model).

Users can select the most appropriate model on the basis of their purpose and the amount of data available. Target users of this package are decision makers and professionals who have a very limited background in lake modeling and wish to learn the basics of modeling; engineers and professionals with a background in lake modeling, and wish to better understand eutrophication processes in lake and decision makers and engineers engaged in lake and reservoir management who wish to predict the long-term status of lake and reservoir.

Keywords: Modeling; Eutrophication; Lakes; Reservoirs

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Conjunto para Capacitación PAMOLARE.Versión 1.0

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Resumen

El acrónimo PAMOLARE se deriva de "Planning And Management Of Lakes And Reservoirs focusing on Eutrophication" (Planeamiento y Gestión de Lagos y Embalses con foco en la Eutrofización). La Versión 1.0 del Conjunto de Programas Computacionales para Capacitación PAMOLARE ha sido desarrollado para ser usado por tomadores de decisión y todos aquellos profesionales dedicados al planeamiento y la gestión de recursos hídricos continentales, involucrados en la gestión de lagos y embalses en países en desarrollo y economías en transición. Este conjunto posibilita una mejor comprensión de los procesos de eutrofización en lagos y embalses. El conjunto de capacitación PAMOLARE tiene disponibles los tres modelos siguientes: 1) El diagrama de Vollenweider, 2) el 4st-model (modelo de lago de 1 capa con cuatro variables de estado mas varios parámetros adicionales), y 3) el 2L-Model (un modelo medianamente complejo de dos capas).

Los usuarios podrán seleccionar el modelo mas apropiado sobre la base de su objetivo y de la cantidad de información disponible. Los usuarios a los cuales está orientado este conjunto de programas son los tomadores de decisión y profesionales que tienen una experiencia limitada en modelación de lagos y desean aprender los fundamentos de la modelación, ingenieros e investigadores con experiencia en modelación de lagos que desean lograr una mejor comprensión de los procesos de eutrofización en lagos, y tomadores de decisión e ingenieros involucrados en la gestión de lagos y embalses que desean predecir su estado en el largo plazo

Palabras clave: Modelación; Eutrofización; Lagos; Embalses.

Plano de Gerenciamento Integrado da Várzea do Parelheiros

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Resumo

O presente trabalho trata do Plano de Gerenciamento Integrado para o Sistema Produtor Taquacetuba – Guarapiranga (Brazil), com ênfase no Plano de Manejo da Várzea do Parelheiros, contratado pela Sabesp e elaborado pela Empresa Geotec Geologia e Engenharia, contendo as alternativas e as intervenções propostas com o objetivo de possibilitar a transferência de água da Represa Billings para a Represa Guarapiranga, melhorando a qualidade das águas aduzidas de forma a garantir a qualidade do manancial representado pela Represa Guarapiranga.

Palavras chave: Gerenciamento; Várzea; Manejo; Wetlands

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Integrated Management Plan of the Wetlands of River Parelheiros

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Abstract

This paper is about the Integrated Management Plan of the Water Supply System Taquacetuba-Guarapiranga (Brazil), with focus on the proposed Plan for Management of the floodplain of the Parelheiros River. The study was commissioned by SABESP and completed by the"Geotec Geologia e Engenharia Co.". The Plan includes also the description of alternatives as well as of works proposed for the transfer of water from Billings Reservoir to Guarapiranga Reservoir. The purpose is to improve the quality of input water and thereby also ensure good water quality at the source, which is the Guarapiranga Reservoir.

Keywords: Management; Wetlands; Works

Prediction of colonization by macrophytes in the Yaciretá reservoir of the Paraná river (Argentina and Paraguay)

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Abstract

The potential colonization by anchored plants (PCAP) and the potential areas for initial colonization of free floating plants were estimated during the early filling phase for the Yaciretá reservoir (Argentina and Paraguay). In order to obtain the PCAP, the observed maximum depth of colonization of the anchored macrophytes before impoundment and the hypsographic curves were used. The species inhabiting the pre-impoundment area were classified according to the different bioforms before the inclusion in the analysis. The areal extent of PCAP (from depths between 0-4m) could reach 275 km^2 at 76m above sea level (current water level), whereas at 82 m above sea level (final filling level) the littoral zone will be increased by about 21.5%.

The potential area for geophytes was estimated to be 99 km^2; 131 km^2 for root-floating leaved plants and 120 km^2 for submerged plants, at 76 m above sea level. At 82 m above sea level, the geophytes could reach 271 km^2. The data for wind frequency, velocity and fetch, together with depth were used to calculate shallow and sheltered areas in which free floating plants could find favourable conditions to initial colonization. Physical and chemical features recorded at eight stations during the early filling phase are discussed in relation to potential plant development.

Keywords: Tropical rivers; Impounding reservoirs; South America; Potential macrophytes; Colonization; Reservoirs.

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Predicción de la Colonización de Macrófitas en el Embalse de Yacyreta en el Río Paraná.

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Resumen

Durante la primera fase temprana de llenado del embalse de Yacyretá (Argentina y Paraguay) se estimaron el potencial de colonización de plantas arraigadas (PCPA) y las áreas potenciales para la colonización de plantas flotantes libres. A los fines de obtener el PCPA, se usaron las máximas profundidades de colonización observadas de macrófitas arraigadas y las curvas hipsográficas. Las especies que habitaban el área antes de la inundación fueron clasificadas de acuerdo a sus diferentes bioformas antes de su inclusión en el análisis. La extensión areal del PCPA (profundidades entre 0 – 4m) podía llegar a 275 km^2 a 76 m sobre el nivel del mar (nivel actual del agua), mientras que a 82 m sobre el nivel del mar (nivel final de llenado) la zona litoral se incrementaría en casi 21,5%.

El área potencial para las geofitas se estimó en 99 km^2, 131 km^2 para plantas foliadas de raíces flotantes y 120 km^2 para plantas sumergidas, a 76 m s.n.m. A 82 m s.n.m., las geofitas pueden alcanzar 271 km^2. Se usaron los datos de frecuencia, velocidad y "fetch" de viento, junto con la profundidad para calcular las áreas someras y protegidas en donde las plantas flotantes libres pudieran encontrar condiciones favorables para una colonización inicial. Se analizan las características físicas y químicas registradas en ocho estaciones durante la fase temprana de llenado en relación con el potential de desarrollo de la vegetación.

Palabras Clave: Ríos Tropicales; Embalses; Sud America; Macrófitas potenciales; Colonización.

Programa de gestión ambiental del embalse Casa de Piedra, río Colorado. (Argentina) Primera etapa: monitoreo y modelado.

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Resumen

El presente trabajo es una síntesis de la propuesta realizada por la Universidad Nacional del Comahue para realizar el Programa de Gestión Ambiental del embalse Casa de Piedra ubicado sobre el Río Colorado (Argentina). La metodología consiste en recopilación de información existente referida a estudios de calidad física, química y biológica, relevamientos en terreno de parámetros y modelamiento matemático para poder planificar los usos de los recursos en el área del embalse. Se indican algunos avances realizados y los resultados que esperan obtenerse con la realización del estudio.

Palabras claves: Río Colorado; Monitoreo; Calidad de agua; Algas; Gestión

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Environmental management program for Casa de Piedra reservoir, Colorado river (Argentina). First stage: monitoring and modelling

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Abstract

This work is a synthesis of the proposal, made by Comahue National University, of an Environmental Management Program for Casa de Piedra Reservoir, which is located on Colorado river (Argentina). The methodology consists in the collection of existing information about studies of physical, chemical and biological properties, survey of land parameters and mathematical modeling in order to make planning of resources utilization in the reservoir area possible. Some advances already made are reported here together with the expected results of the study.

Keywords: Río Colorado; Monitoring; Water quality; Algae; Management

Programa de Monitoreo del Embalse San Roque (Córdoba, Argentina), periodo 1999-2000

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Resumen

Desde hace ya varios años el embalse San Roque muestra signos evidentes de eutrofización. Esto se manifiesta mediante altos contenidos de P en el agua y de elevadas concentraciones de clorofila-a como consecuencia del aumento de nutrientes, provenientes tanto de fuentes externas como internas. Surge la necesidad entonces de conocer y mejorar la calidad del recurso que abastece a la mayoría de la población de la Ciudad de Córdoba (70%). Para tales fines se desarrolló un programa de monitoreo sistemático sobre el embalse San Roque de parámetros de calidad de agua y ambientales con la finalidad de realizar el seguimiento de la evolución del fitoplancton. El presente trabajo tiene el objetivo no solo de mostrar el diseño y la metodología de trabajo de se llevó a cabo entre Septiembre de 1999 y Enero 2001 sino también los principales resultados obtenidos hasta el presente.

Palabras clave: Embalse San Roque; Monitoreo; Calidad del Agua; Fitoplancton

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Monitoring Programme of San Roque Reservoir (Córdoba , Argentina), Period 1999-2000

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Abstract

In the last years the San Roque Reservoir is showing evident signs of eutrophication. This is a consequence of high contents of phosphorous and chlorophyll "a" in water characterized by an increase of internal and external sources of nutrients. As a result of this, the need to know and evaluate the principal water resource which provides drinking water to 70% of the people of Cordoba City comes up. A systematic monitoring program was developed in order to achieve environmental and water quality information to evaluate the phytoplankton evolution. The program includes campaigns in the water body between September 1999 and January 2001. The objective of this paper is to show not only the work planning and methodology but also some results.

Keywords: San Roque Reservoir; Monitoring; Water Quality; Phytoplankton

Propuesta metodológica para ser adoptada por los integrantes de la red Riga frente a situaciones de emergencia

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Resumen

La ocurrencia de accidentes ambientales que ponen en peligro la calidad de las aguas de los grandes ríos de la Cuenca del Plata y los numerosos embalses en la misma, se vuelve cada día más evidente. La necesidad de proteger la salud de la población y el medio ambiente es una responsabilidad prioritaria. Se propone la adopción por parte de las instituciones integrantes de la RIGA, de una metodología común para accionar ante eventos de emergencia. Esta metodología sería distribuida y actualizada por RIGA.

Palabras claves: Metodología; Muestreo; Emergencia; Derrames; Red

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Methodological proposal to be adopted by RIGA Network to address emergency situations

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Abstract

The occurrance of environmental spills that may cause serious hazard to water quality of La Plata Basin rivers and its numerous dams, becomes more evident from day to day. The need to protect the health of the population and the environment is a priority. It is proposed that the institutions belonging to RIGA, adopt a common action methodology to be used in case of emergency events. RIGA would distribute and update this methodology

Keywords: Methodology; Monitoring; Emergency; Spills; Network

Relocalización de la Ciudad de Federación. Aprovechamiento Hidroeléctrico Binacional Salto Grande (Argentina - Uruguay)

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Resumen

El presente trabajo trata sobre la relocalización de la ciudad de Federación, ubicada en la Provincia de Entre Ríos (Argentina), motivada por la construcción del Aprovechamiento Hidroeléctrico de Salto grande (Binacional Argentina-Uruguay). La obra data de la década de 1970. El desarrollo del trabajo comprende una breve descripción del aprovechamiento hidroeléctrico y del marco de referencia que incluye: la ubicación geográfica de la ciudad, ilustrada con croquis de la antigua y nueva ciudad de Federación con su vinculación terrestre; características de la zona y crecimiento de la población obtenida de censos para diferentes años, comprendiendo el período 1970-1999, es decir, anterior y posterior a la relocalización, en el cual se observa un interesante incremento poblacional.

Posteriormente se incluye una breve reseña histórica de la ciudad y de las diferentes leyes nacionales de incumbencia con las expropiaciones. Con mayor amplitud se trata el tema de los impactos sociales y sus consecuencias, ocasionados por la relocalización, y las conclusiones y recomendaciones surgidas de un análisis que abarca la observación a 20 años de su fundación oficial (25 de marzo de 1979). Se observa a través de este ejemplo la necesidad de contar con una activa participación de los actores sociales involucrados, enmarcada en una destacada planificación regional.

Palabras clave: Embalse de Salto Grande; Relocalización: Impactos sociales; Participación social

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Relocation of the City of Federación. Salto Grande Bi-national. Hydropower Development (Argentina - Uruguay)

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Abstract

This paper is about the relocation of the City of Federación, located in the Province of Entre Ríos (Argentina), as a result of the construction of the Hydropower Development of Salto Grande (Binational Argentina-Uruguay). The development was made in the 1970 decade. The paper presents a short description of the Hydroelectric Development and a reference framework which includes the geographical location of the city illustrated with drawings of the old and new city of Federación with its terrestrial links, characteristics of the region and growing of the population obtained through census of different years, during the period 1970-1999, that is to say before and after the relocation, in which an interesting population growth took place..

Afterwards, a historical summary of the city and differente national laws referring to the expropriations, are presented. The social impacts, and its consequences, produced by the relocation as well as the conclusions and recommendations coming out from an analysis which encompasses a period of 20 years from its official foundation (May 25, 1979), is developed in detail. Through this example, it becomes evident the need of obtaining an active participation of the people within the framework of a regional planning.

Keywords: Salto Grande Reservoir; Resettlement; Social impacts; Social participation.

Small Hydropower Plants in La Plata River Basin Tributaries: A Feasible Alternative for Water Power Development

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Abstract

The new regulatory scenario for small hydropower projects in Brazil resulted in a large number of new projects with this characteristic, after new rules were established by the Brazilian Electric Power Agency, redefining the required characteristics of a hydropower plant in order to be considered as a small hydropower plant, for which the concession for exploitation is granted by the Agency without bidding process. Many of the projects under study are in the tributaries of the main rivers in the La Plata River Basin. Some of these projects are already under construction.

Small hydropower plants differ from the large hydropower projects not only for their power production capacity: their impacts on the surrounding environment are deeply different, what makes them to be an attractive alternative to increase the electric power offer for the energy-hungry Brazilian market. As the number of projects increases, the knowledge on their environmental impacts is better developed. The current status of the development of small hydropower projects and their most frequent impacts are analyzed in this paper.

Keywords: Hydropower plant; reservoir; environment.

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Pequenas centrais hidrelétricas nos tributários da Bacia do Rio da Prata: Alternativas factibles para o desenvolvimento da energía hidrelétrica

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Resumo

As novas regras definidas para as pequenas centrais hidrelétricas no Brasil tem resultado num grande número de projetos com esta característica, após o estabelecimento de nova regulamentação pela Agência Nacional de Energia Elétrica, redefinindo as características necessárias para uma hidrelétrica ser classificada como pequena central hidrelétrica, com dispensa de processo licitatório para a concessão do direito de exploração. Vários dos projetos em estudo estão localizados nos tributários dos rios principais da Bacia Hidrográfica do Rio da Prata. Alguns destes projetos encontram-se já em construção.

As pequenas centrais hidrelétricas diferem dos projetos de grande porte não apenas pela sua capacidade instalada: seus impactos sobre o meio ambiente são profundamente diferentes, o que as torna atrativas para o aumento da oferta de energia para o mercado brasileiro. Com o aumento no número de projetos, o conhecimento sobre seus impactos ambientais também vem se desenvolvendo. O estágio atual do desenvolvimento de pequenas centrais hidrelétricas no Brasil e seus impactos mais freqüentes são analisados neste trabalho.

Palavras-chave: Centrais hidrelétricas; Reservatórios: Meio Ambiente

Strategy to Reduce Pollutant Emission: Nitrogen Balance in Forest and Integrated Watershed Management. Case Study of Lake Biwa, Japan

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Abstract

It is very important to estimate nutrient inflow from non-point sources, like forests, into lakes to prevent eutrophication. In this paper, the quantity of total nitrogen reduced by the forest around Lake Biwa, Japan is estimated. Nitrogen comes in the runoff after rainfall, and runs off through the soil. In this analysis, it was found that the amount of total nitrogen by forests around the lake was large. Artificial nitrogen removal is a very expensive process. Despite this, forests play an important role in water quality. Forests are gradually being devastated, and it is difficult to earn one's living from forestry around Lake Biwa. But it is time to reconsider forestry, not just as a wood producer, but also as a natural protector for the environment.

Key words: Lakes; Eutrophication; Nutrients; Nitrogen removal; Forests.

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Estrategia para Reducir la Emisión de Contaminantes: Balance de Nitrógeno en un Bosque y Manejo Integrado de los Recursos Hídricos

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Resumen

Es muy importante estimar el ingreso de los nutrientes provenientes de fuentes no puntuales, como bosques, en los lagos para evitar la eutrofización. En este trabajo se estima la cantidad total de nitrógeno reducido por los bosques que rodean el Lago Biwa, en Japón. El nitrógeno ingresa junto con la escorrentía luego de las lluvias y escurre a través del suelo. En este análisis se encontró que la cantidad de nitrógeno total removido por los bosques marginales es grande. La remoción artificial del nitrógeno es un proceso muy costoso. Sin embargo los bosques juegan un rol muy importante en la calidad del agua. Ellos están siendo gradualmente desvastados y resulta my difícil ganar el sustento a partir de ese recurso alrededor del Lago Biwa. Es tiempo de reconsiderar el recurso forestal, no sólo como un productor de madera, sino también como un protector natural del medio ambiente.

Palabras clave: Lagos; Eutrofización; Nutrientes; Remoción de nitrógeno; Bosques.

Uma visão panorâmica da situação institucional do setor de recursos hídricos no estado do Rio de Janeiro, Brasil

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Resumo

O objetivo deste trabalho é propiciar uma visão de conjunto da situação institucional do setor de recursos hídricos do Estado do Rio de Janeiro (Brazil) face à nova Lei federal 9.433/97. Para tanto, serão descritos a geografia, as unidades hidrográficas e o quadro atual da organização administrativa do território fluminense. Alguns aspectos relacionados ao saneamento ambiental e gerenciamento costeiros também serão considerados.

Palavras-chave: Gestão de Recursos Hídricos; Saneamento; Políticas Públicas; Rio de Janeiro; Brasil.

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An overall vision of the institutional situation of the water resources sector in Rio de Janeiro State, Brazil

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Abstract

The purpose of this paper is to furnish a vision of the State of Rio de Janeiro (Brazil) water resources under the institutional situation due to the new Federal Water Act 9.433/97. It shows the geography, hydrologic units and the State of Rio de Janeiro administrative organization. Some aspects related to environmental sanitary and coastal management are also considered.

Keywords: Water Resources Management; Basic Sanitation; Public Police; Brazil; Rio de Janeiro.

Variabilidad espacial y temporal de los parámetros físicos - químicos en el embalse de Ullum.

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Resumen

Se da cuenta de investigaciones efectuadas relativas al estudio de la evolución temporal y espacial de los parámetros físicos y químicos de calidad de agua que caracterizan el sistema lacustre Embalse de Ullum, Provincia de San Juan, proponiendo una metodología para medir las variables aconsejadas por organismos internacionales (EPA, ADEQ), aplicando las técnicas de monitoreo actualizadas desarrolladas por estos organismos y por otros centros de investigación, que norman estudios del medio ambiente con métodos de Laboratorio.

Palabras Clave: Embalses; Calidad de Agua; Parámetros Físicos; Parámetros Químicos

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Spatial and time variability of physical and chemical parameters in Ullum Reservoir

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Abstract

This paper deals with investigations carried out relative to the study of the temporary and spatial evolution of the physical and chemical parameters of water quality that characterize the lacustrine system in Ullum Reservoir, Province of San Juan. A methodology to measure the variables advised by International Organizations (EPA, ADEQ) is proposed and updated techniques of monitoring developed by said organizations and other research centers, which standardize environmental studies with laboratory methods, are applied.

Keywords: Reservoirs; Water Quality; Physical parameters; Chemical parameters

THIRD INTERNATIONAL WORKSHOP ON REGIONAL APPROACHES
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IN THE LA PLATA RIVER BASIN:
"Informed Decision Processes for Sustainable Development of Reservoirs"

March 9 to 17, 2001 - City of Posadas, Province of Misiones, Argentina

ANNEX VI
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Statistical Techniques Applied to Optimisation of Sampling Campaigns in a Reservoir

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Abstract

This paper refers to the application of statistical techniques for the optimisation of the design of water quality sampling programs in a reservoir. The starting point is a group of different parameters' data obtained from laboratory analysis on samples extracted in some geographical points of the lake at different depths and in different times of the year. From the application of statistical tools, the minimum number of samples that can be taken without losing important information is obtained. That makes possible a considerably reduction in the number of sampling points, and as a consequence the cost and time of sample extraction campaigns and laboratory analyses become also reduced. This tool is of great interest for the design of long term sampling programs, where a careful assignment of costs is required to maximize results with reduced resources.

Keywords: Sampling; Water quality; Applied statistics; Lakes

Resumen

El trabajo que se presenta se refiere a la aplicación de técnicas estadísticas para la optimización del diseño de campañas de muestreo de calidad de aguas en un embalse. Se parte de un conjunto de datos de distintos parámetros recabados a partir de análisis de laboratorio sobre muestras extraídas en una serie de puntos geográficos del lago a distintas profundidades y en distintas épocas del año. A partir de la aplicación de herramientas estadísticas se llega a determinar el mínimo número de muestras que pueden tomarse sin perder información relevante, con lo que se consigue reducir considerablemente el número de puntos de extracción de muestras, y por ende los costos y tiempos de las campañas de extracción y de los análisis de laboratorio. Se considera una herramienta de gran interés para el diseño de monitoreos de largo plazo, donde se requiere una asignación inteligente de costos para maximizar resultados con recursos acotados.

Palabras clave: Muestreos; Calidad de aguas; Estadística aplicada; Lagos

A. Introduction

Enclosed resources are often an important limitation to water bodies studies. Sometimes it is necessary to continue the studies with this restriction. There are only few studies that can be reliable without good field information. In many cases, data collection has very large incidence on the costs, but the lack of this information can limit conclusion validity.

This paper shows a way to use simple statistical techniques for the design and optimisation of water quality sampling in a lentic water body. Few field data is necessary to begin. The application of statistical techniques to this initial data allows improving resources assignment, and collecting only the relevant information. This is specially interesting when data collection will go on for a long time, as the first intensive campaigns provides basic information for the design of sampling and analysis routines.

B. Why Use Statistical Techniques?

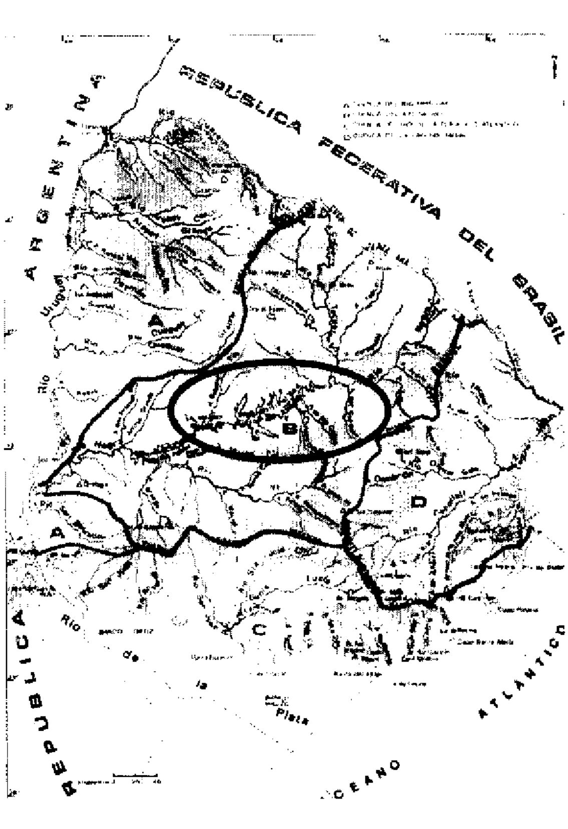
Statistical techniques offer objective criteria to make decisions. In water quality monitoring, decisions associated with the right selection of sampling points can bring important benefits.

When -as usual- there are little resources to use, it is necessary to maximize the relevancy of field information. The right selection of sampling points, sampling frequency, even of the parameters to analyse, helps to assign resources in the best way. The existing resources (people, materials, number of laboratory analysis allowed, time) can be assigned in order to collect samples only in points that are proved to be different. In the same way, frequency of samples can be diminished during homogeneous periods; or the analysed parameters can be reduced when they can be reliably inferred one from the others.

Statistics provides tools that make easier the objective interpretation of data, but it can not substitute the interpretation itself. In other words, statistical tools are useful when the physical meaning of the analysed information is not forgotten. Besides, statistical techniques should not become the object of the study. Fulfilling the conditions of a statistical test can be a result of the study, but it can not become the essence of it.

C. Case of Study: Water Quality Monitoring in Rincón del Bonete Reservoir

The selected case shows an application of this work proposal.



During 1993 and 1994 the Environmental Engineering Department of IMFIA (Universidad de la República) was working in accordance with UTE (the power distribution service of Uruguay) in a project called "Cooperation in UTE's Environmental Management Plan Definition". At that time, UTE's Environmental Management Office was new, and the collection of relevant environmental information was the first step of the project. Water quality of the Negro River reservoirs was studied. The selected case is about sampling works done in Rincón del Bonete reservoir.

Rincón del Bonete is the artificial reservoir of Gabriel Terra Hydroelectric Dam, the largest and oldest of the three hydroelectric dams on Negro River. The dam is located about 15 km upstream Paso de los Toros city. Reservoir surface is 1140 km^2 at level 80 m and 1500 km^2 at level 83 m. Useful volume rises to

400:000.000 m^3 and installed power is 144 MW (4 x 36 MW).

Five sampling points were selected in the referred work. One point located upstream the dam (from now on: Represa point). One point in each of the well defined "arms" in the head of the lake (from now on: Cardoso and Carpintería points, named after the water streams incoming the lake in these points). One point near San Gregorio de Polanco town; and one point in the centre of the lake. Some samples were also collected in Paso Ramírez (the end of the lake). Three samples were collected in each sampling point: one near the surface, another at middle depth of the water column, and the third near the bottom of the reservoir. The right depth for each sample was defined in a reservoir bathymetric map.

Field determinations in each point included temperature, pH, dissolved oxygen and conductivity.

Laboratory determinations on the collected samples included pH; total solids, fixed and volatile, suspended solids, fixed and volatile; alkalinity; chlorophyll "a", silica as SiO_2; total phosphorous; filtered total phosphorous; orthophosphate; total Kjeldahl nitrogen NKT, ammoniac nitrogen; nitrites; nitrates.

Four sampling campaigns were done: two of them took place in winter (July and August 1993) and the others in summer (December 1993 and January 1994).

Only samples from Represa, Cardoso and Carpintería points will be taken into account in this proposal. Samples in these three points involved a whole day of work collecting nine samples (subsurface, middle depth and bottom) and its chemical analysis in laboratory. In the total work, sampling these points meant 50% of the total sampling time (two days); and 60% of the total costs -field and laboratory- of each campaign, as it represented 9 samples over a total of 15.

D. Questions to Answer

The main questions to answer for the optimisation of the number of samples to consider were:

Is the collection of samples at different depths relevant? Or is the reservoir totally mixed during the whole year?
Is sample collection in all the considered points relevant? Or are some of them not adding representative information?
Is the reservoir's water quality different between winter and summer?

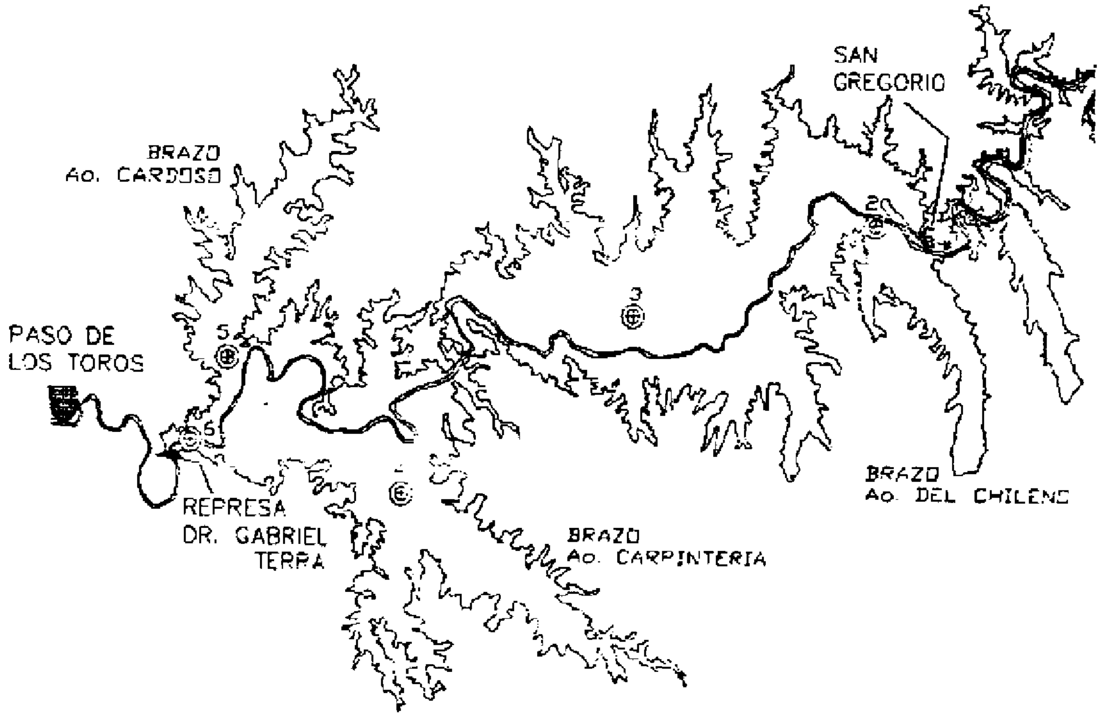
The answers to these questions were searched using statistical techniques, as intuition or visual analysis of data were not reliable methods to consider.

E. Statistics Tests Selection

First of all, normality or not of data series was determined. The selected test to do this verification was D'Agostino's. This test is regularly used in IMFIA's works, because of its reliability and easy application.

When data are gaussian, comparisons between data populations are done using parametric statistics. Choosing the right test to use depends on whether the samples are tied or not, have homogeneous variances or not, etc. These tests employ, for example, tables from Student's *t* distribution or Fisher's F distribution.

For non-gaussian data, non-parametric statistics tests must be used. These tests are usually based on data ranking and comparison with specific tables for each distribution, as χ^2 distribution.



F. Statistics Tests Application

Only Represa, Cardoso and Carpintería sampling points were considered, as their importance in the campaign's design was previously demonstrated. This process could have been done for all the sampling points, but laboratory data series of San Gregorio de Polanco, Centro and Paso Ramírez samples were incomplete.

A subgroup of eight parameters was chosen form the total available data. Phosphorous' and nitrogen's data families were considered, as well as pH and chlorophyll "a".

As a first step, all the available data of each parameter was considered together in order to study its normality, using D'Agostino' test. The results for the eight selected parameters are listed below.

Normal data:	pH; NKT; nitrites; nitrates
Non-normal data:	total phosphorous; total filtrated phosphorous; orthophosphate; chlorophyll "a"

Data analysis showed that some out layers were present in chlorophyll "a" series of data. Possible experimental errors were suspected, so it was decided not to work with these data. In order to work with the same number of normal and non-normal series, the final selected parameters to consider were pH; NKT; nitrates; total phosphorous; total filtered phosphorous; orthophosphate. Available data is shown in the table below.

Season	Point	Depth	pH	Nitrates (mg/L NO^{3-})	Total Phosphorous (mg/L P)	Total Filtrated Phosphorous (mg/L P)	Orthophosphate (mg/L P)	NKT mg/L
IN	CA	SU	6.1	0.9	0.062	0.047	0.051	2.40
IN	CO	SU	6.3	0.9	0.081	0.038	0.070	3.90
IN	RE	SU	6.4	1.0	0.063	0.046	0.059	2.40
IN	CA	FO	6.3	0.9	0.075	0.030	0.020	1.60
IN	CA	ME	6.4	1.0	0.120	0.080	0.120	3.20
IN	CA	SU	6.3	1.0	0.080	0.061	0.048	3.90
IN	CO	FO	6.7	0.9	0.126	0.105	0.106	3.20
IN	CO	ME	6.7	0.7	0.089	0.065	0.061	3.20
IN	CO	SU	6.7	0.8	0.070	0.065	0.052	3.20
IN	RE	FO	6.1	0.5	0.146	0.095	0.093	2.40
IN	RE	ME	6.7	0.6	0.120	0.080	0.093	2.40
IN	RE	SU	6.7	0.6	0.105	0.090	0.095	2.40
VE	CA	FO	6.4	1.3	0.355	0.130	0.132	< 1.5
VE	CA	ME	6.4	1.3	0.364	0.122	0.171	< 1.5
VE	CA	SU	6.4	1.4	0.248	0.127	0.137	< 1.5
VE	CO	FO	6.6	1.3	0.414	0.142	0.162	< 1.5
VE	CO	ME	6.6	1.3	0.409	0.137	0.039	< 1.5
VE	CO	SU	6.5	1.3	0.402	0.135	0.255	< 1.5
VE	RE	FO	6.6	1.2	0.417	0.303	0.273	0.50
VE	RE	ME	6.7	1.2	0.243	0.137	0.240	< 1.5
VE	RE	SU	6.7	1.2	0.169	0.046	0.162	< 1.5
VE	CA	FO	6.6	0.4	0.046	0.042	0.042	0.80
VE	CA	ME	6.7	0.4	0.132	0.050	0.086	1.00
VE	CA	SU	6.9	0.3	0.252	0.086	0.248	1.10
VE	CO	FO	6.0	0.4	0.053	0.020	0.040	0.90
VE	CO	ME	6.8	0.6	0.052	0.010	0.048	1.10
VE	CO	SU	6.8	0.6	0.102	0.082	0.076	1.10
VE	RE	FO	7.0	0.8	0.042	0.010	0.038	0.45
VE	RE	ME	7.0	0.7	0.052	0.021	0.048	0.80
VE	RE	SU	7.0	0.7	0.037	0.011	0.064	1.10

VE: Summer, IN: Winter, CA: Carpintería, CO: Cardoso, RE: Represa, FO: Bottom, ME: Medium Depth, SU: Subsurface

Stratification of the reservoir was first verified. The behaviour of different depth's data for the same parameter was analysed using Friedman test for non-gaussian series and 1-factorial test for gaussian series (this test uses Fisher's F distribution). Comparability of the whole considered data was verified for the three different sampling depths. The interpretation of this result is that the lake was not stratified during the studying period. It is important to take into account that the hydroelectric station was generating during the whole period, that is, there was always water circulating from upstream to downstream. In this condition, sampling at different depths does not increase the relevant lake's information. This conclusion allows reducing the number of samples in each point from three to one without missing relevant information. The collection is also simplified, as the only sample in each point can be collected at the subsurface level.

Then, the relevance of sampling both of the lateral arms (Cardoso and Carpintería) was analysed. Data in each of these points were compared for each analysed parameter. Using previous results, data at different sampling depths in each point were considered together. Statistical tests used were selected depending on the normality or not of data series. For normal series, comparison of media values was used, after verifying variances' homogeneity. For non-normal series, Mann-Whitney test (a non-parametric one) was used. Results showed that all the studied parameters were equivalent in both arms.

The next question appears immediately after this finding: are these arms equivalent to Represa point? Accessibility to this point close to the dam is easier than the rest, so it seems very interesting to substitute the three sampling points with only one of them. The process was analogous to the method used to verify the three sampling depths (Friedman test for non-normal series; 1-factorial test for normal series). Results evidenced the equivalence between all the considered parameters.

Finally, the available information was compared for each parameter in winter and summer campaigns. The same kind of tests used when working with data from Cardoso and Carpinteria were used in this case (for gaussian data tests for mean values were used, and the non-parametric Mann-Whitney test for non-gaussian data). The result was that both populations were always non-comparable, except for nitrates that were comparable in winter and summer. An interpretation of this result is that being nitrates the most stable compound within the poza labile of the nitrogen cycle, its concentration varies very slowly through the year, differing from NKT that shows significant seasonal differences.

G. Conclusions and Recommendations

After the application of statistic tests to water quality data available in Represa, Cardoso and Carpintería points, some relevant conclusions could be extracted:

Sampling at different depths does not give relevant information (from the physical point of view, this means that the lake is always well mixed).

From the sampling of the three points, no more relevant information is obtained than if only one of them was sampled.

The data analysed shows differences between the condition of the lake in winter and in summer, so it is interesting to emphasize these differences.

The proposal for later monitoring is to reduce the nine samples collected in each campaign in Represa, Cardoso and Carpintería points (three samples in each point at different depths), to just one surface sample in Represa point. As a result, the duration of the whole campaign (considering the far points) could be reduced to only one day, and laboratory costs would also have an important reduction. From the cost-benefit analysis, it can be concluded that the saved resources can be reassigned in order to increase the number of samples collected through time, which would improve the temporal covering of the behaviour of the lake.

It must be pointed out that the design of the sampling campaign was never put into practice because the work with UTE lost continuity for several reasons that have no relation with the results of that period of working together.

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Conflicts and Management Perspectives of Reservoirs in the Sao Francisco River (Brazil)

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Abstract

The Sao Francisco River is one of the most important rivers in Brazil, being known as the "River of National Unity". The 640.000 km^2 basin, which drains across the North East Brazil to the South West Atlantic Ocean, is well endowed with a rich variety of natural resources, including minerals, fish, wildlife, and lands suitable for agricultural development. The 3200 km river and its watershed has been subjected to intense economic development pressures.

The river has been historically operated exclusively for energy production and for water supply for irrigation projects. Modifications of the natural hydrological regime of the river which – while contributing to the production of "clean" energy for use by the people and industries of the basin and throughout Brazil – have proven especially destructive to organisms that depend, for reproduction and survival, on the quantity, quality, timing and rate of water flows (especially in the estuarine and coastal marine endpoints of the basin), and to groundwater sources that depend for recharge upon surface water flows.

The geomorphology of the river has been significantly modified by regulation (e.g., erosion of riverbanks, sedimentation, formation of islands in the delta, and erosion of the southern extreme of the delta). These modifications not only affect the estuary by altering flooding cycles, but also impact the nearshore marine environment by modifying the nutrient and sediment content of the river water, affecting marine fauna, and the sediment and turbidity dynamics of the estuary with observed, although unquantified, changes in the aquatic fauna, flora and geomorphology of the river mouth.

Some of the actions required to reduce impacts include (i) sound design engineering; (ii) quantification of water use (quantity and quality) and integrated operational criteria; (iii) multisectoral and public participation in the process of basin management; (iii) creation of basin committees and water user associations, representing different users and interests; (iv) application of modern water resources management principles such as tradable water rights, financial mechanisms (including polluter pays principle, water pricing, fines and taxes), monitoring systems, ecohydrology, Information Systems, and Decision Support Systems; (v) formulation of a watershed management program (including information sharing) and; (vi) strengthening of Federal, State and local institutions.

Keywords: Reservoir management; Watershed: Integrated inland coastal water resources management

Resumen

El Río Sao Francisco es uno de los ríos mas importantes en Brasil, llamado también como el "Río de Unidad Nacional". La cuenca de 640.000 km^2 , que drena en dirección nordeste para el Océano Atlántico, tiene una rica variedad de recursos naturales, que incluyen minerales,

pescados, vida silvestre, y manchas de excelentes áreas agrícolas. Toda la extensión de los 3200 km del río y vares partes de la cuenca fueron expuestos a presiones intensas de desarrollo económico.

El río fue históricamente operado únicamente para la producción de energía eléctrica y para abastecimiento de agua para los proyectos de riego. Modificaciones del régimen hidrológico natural del río, por un lado contribuyeron para la producción de energía "limpia" para personas y industrias en la cuenca y en todo Brasil, pero por el otro lado, fueron muy destructivos para organismos que dependen, para reproducción y para sobrevivir, de demandas de agua en cantidad, cualidad, época y duración (especialmente en el estuario y costa marina) y también para las fuentes subterráneas que dependen de la recarga da aguas superficiales.

La geomorfología del río fue modificada significativamente por la regulación (erosión, deposito de sedimentos, formación de islas en el delta, y erosión del delta). Estos cambios no solo afectan el estuarios cambiando ciclos de llena, pero también el medio ambiente marino, cambiando el contenido de nutrientes y sedimentos en el agua, la fauna marina, la dinámica y cantidad de sedimentos, fauna acuática, flora, y la geomorfología del estuario.

Algunas de las acciones necesarias para reducir impactos incluyen (i) buenos proyectos de ingeniería; (ii) identificar y medir los diferentes de usos de agua (cantidad y cualidad) y criterios de operación; (iii) participación multisectorial y publica en el proceso de manejo de la cuenca; (iii) formación de comités de cuenca y asociaciones de usuarios de agua, representando diversos usuarios y interesados; (iv) aplicación de modernos principios de manejo de agua como mercados de agua, mecanismos financieros (incluyendo el principio del pagador contaminador, tarifas, multas y impuestos de agua), redes de monitoreo, ecohidrología, sistemas de informaciones y sistema de apoyo a la toma de decisiones; (v) elaboración de un programa de manejo de agua y transferencia de informaciones y; (vi) fortalecimiento de las instituciones Federales, Estatales y locales.

Palabras claves: Gestión de embalses; Cuenca Hidrográfica: Manejo integrado de aguas interiores y costeras

A. Background information

The Rio Sao Francisco Basin, shown in Figure 1, extends over approximately 640,000 km^2, comparable to the drainage basins of the Colorado or Columbia rivers of North America, and discharges across the North East Brazil Shelf to the Southwest Atlantic Large Marine Ecosystem (LME) and Brazil Current. The river covers a large portion of the area known as the "Drought Polygon of Brazil" as it traverses climatic zones ranging from humid to arid as it flows through five states in Northeastern Brazil; i.e., Minas Gerais, Bahia, Pernambuco, Alagoas and Sergipe. The Federal District of Brasilia and the State of Goias are also sometimes included in the watershed as the headwater tributaries originate in these areas. The basin is generally divided into the Upper, Middle, Lower Middle, and Lower sub-basins, plus the oceanic end point, each with distinct environmental and socio-economic characteristics. Some 13 million people are resident in this basin, principally concentrated in the upper sub-basin.

The Sao Francisco River Basin is a very complex area, in which development has occurred in an historically haphazard and sectoral manner, with little integrated planning and a weak institutional framework, which has resulted in a less than optimal use of its water resources and degradation of the coastal zone. Large stretches of river have been regulated, altering natural river flows that coincided with fish spawning periods. In addition, flow modifications have affected the deposition of sediments, nutrients and other contaminants (by persistent organic pollutants and heavy metals) in the system; altered erosion and deposition patterns; accelerated land degradation; and, modified the delivery of nutrients to the lower reaches of the basin and the coastal zone. As a consequence, significant modifications in the freshwater, estuarine and marine fauna and flora have occurred. The lack of an integrated, holistic management approach of the Rio Sao Francisco Basin has been identified as the principle issue facing sustainable development in the basin. The objectives of this paper is to present an overview of the functioning of the Sao Francisco river system including major dams and their interrelation with the ecosystem.

B. Description of the area

The Sao Francisco River is known in Brazil as the "River of National Unity". The river has a rich cultural history and played a central role in the development of the interior of Brazil in past centuries. The estuarine wetlands located at the debouchment of the river into the South West Atlantic form a particularly important and environmentally sensitive interface between the riverine and marine environments. The ecological structure and function of this interface, as well as its physical integrity, is currently under threat, due to unsustainable hydrological and land use management practices within the basin. Except for flood flows during the wet season, flow is contributed primarily from the humid and semi-humid areas near the headwaters. Tributaries in the arid and semi-arid regions of the Middle and Lower Middle sub-basins are largely intermittent, although flood flows in these streams may cause localized problems of flooding, erosion and sedimentation which affect the entire lower portion of the river system and the coastal zone. The basin has a total population of 13 million people principally concentrated in the upper sub-basin.

The Upper Sub-basin is located in the southernmost part of the Basin, primarily within the State of Minas Gerais, in a region characterized by rolling hills and tablelands. The climate is humid temperate to sub-tropical, with an average precipitation of approximately 1,250 mm per year. This sub-basin contributes more than 70 percent of the overall flow of the river. Belo Horizonte, the capital of the State of Minas Gerais, is located in this area, as are other, moderately sized, cities including Patos de Minas, Januaria, and Betim. Development within this reach of the river includes large industrial plants, mainly for steel production and manufacturing of paper and automobiles, diversified mining, and irrigated agriculture based on the large Tres Marias Dam. Agricultural production is primarily soybeans and cattle, with higher value crops such as fruits grown within irrigated areas. This region also has large areas of cultivated forests of eucalyptus for use in the paper industry and in the production of charcoal for the steel industry. Over half of the population of the basin, or more than 7 million (1994 Census) people, lives in this sub-basin.

The Middle Sub-basin is located in the states of Minas Gerais and Bahia and is characterized by two distinct zones. The western portion of the sub-basin is fed by orographic rainfall in the elevated areas, has perennial watercourses, and is relatively fertile, supporting *cerrado* or *caatinga* vegetation and agricultural production in both private and public irrigation schemes. The eastern portion of the sub-basin is characterized by intermittent or seasonal watercourses, and supports considerably less development. *Caatinga* vegetation dominates in this semi-arid area, and agricultural production is limited to cattle and goat breeding, subsistence agriculture, and limited irrigated agriculture where water is available. Precipitation averages around 900 mm per year and there are no dams or reservoirs in this sub-basin. The population is rural and sparse, mostly involved in agricultural activities and dependent on the river for irrigation, transportation and water supply, with more than half of the families classified as indigent or poor.

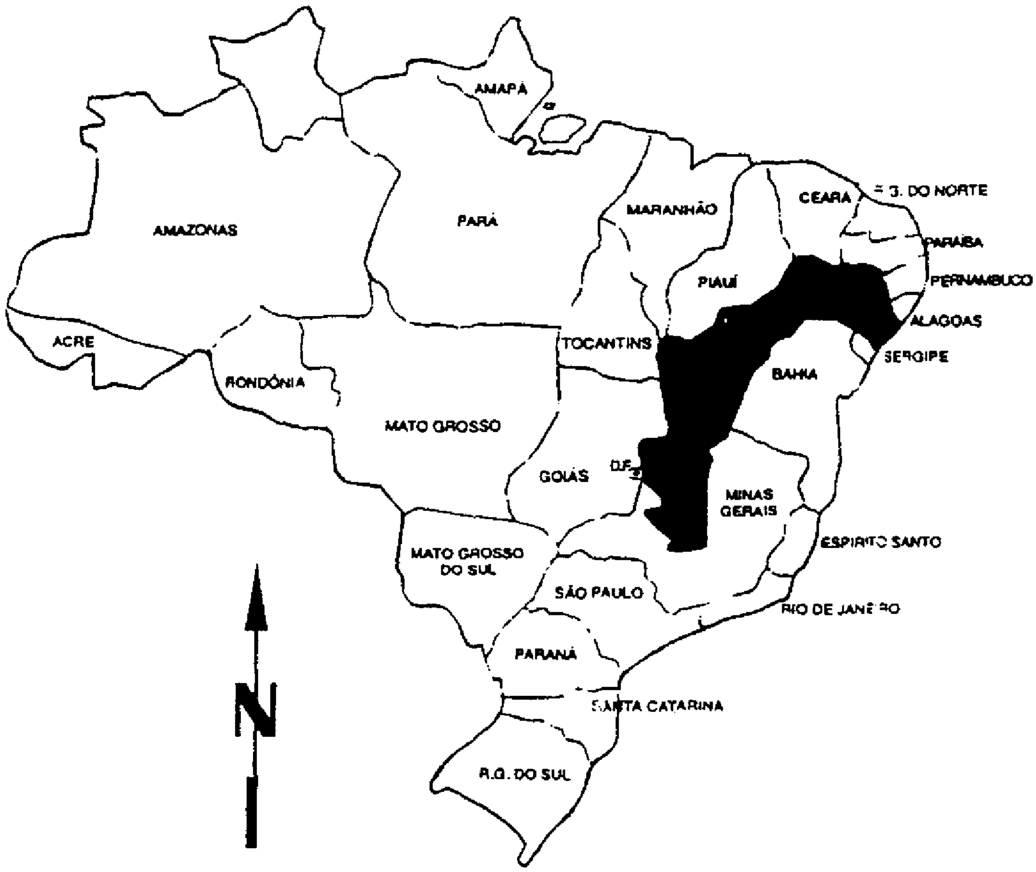

Figure 1. – The Sao Francisco River Basin in Brazil

The Lower-Middle Sub-basin is located in the states of Bahia and Pernambuco. The river is the boundary between the two states and represents a major source of irrigation water for fruit and vegetable production in the region of Petrolina and Juazeiro. Vegetation is predominantly *caatinga*, distinctive of the *sertão* region of Brazil, and the soils are mostly thin and non-productive. Precipitation averages about 500 mm per year. Development in this region has been strongly influenced by federally sponsored irrigation projects, implemented by the Companhia de Desenvolvimento do Vale do Sao Francisco (CODEVASF), which provided the base for subsequent private investment in high-value export vegetable crops. This sub-basin also contains the majority of the hydroelectric power infrastructure within the Rio Sao Francisco Basin: the Sobradinho (34.1×10^9 m^3; 1,050 MW), Itaparica (10.7×10^9 m^3; 1,500 MW), Paulo Afonso (1×10^9 m^3; 4,400 MW) and Xingo (3.3×10^9 m^3; 3,000 MW) dams provide renewable energy for most of Northeastern Brazil. This infrastructure also provides an opportunity for the development of river-borne inter-modal transportation systems, as the river was originally marginally navigable in this region through to its upper reaches. In addition, an inter-basin transfer scheme, proposed for construction below the Sobradinho Dam to supply water to the Northeastern States of Ceara, Rio Grande do Norte and Paraiba, is still being analyzed. Most of the population is located in the cities of Juazeiro in Bahia and Paulo Afonso and Petrolina in Pernambuco.

The Lower Sub-basin includes the states of Bahia, Alagoas, Sergipe and Pernambuco, the river forming the border between the states of Bahia and Pernambuco and between the states of Alagoas and Sergipe. Vegetation in this sub-basin is mostly *cerrado* (and *Mata Atlántica* in the humid lower reaches), although there are large semi-arid areas, covered by *caatinga*, in the northernmost portion of the sub-basin. Precipitation varies from 1,300 mm per year along the Atlantic coast to 500 mm per year along the upstream boundary. Population is concentrated near the coast in small municipalities and rural communities, and is generally classified as poor or indigent. Sugar and alcohol are the main agricultural products of the sub-basin, with estuarine and coastal marine fisheries forming an important source of food and income. River navigation was historically important in the transportation of sugar and other agricultural products, limestone and building materials, but has declined in recent years due to aggravation of the river channel, which forced the development of the regional road system.

The lowest reaches of the sub-basin contain an extended estuary and estuarine wetlands. The ecological regime of the delta and coastal areas represents an asset that has not been fully defined or protected. Some of this area has been developed for agricultural production using a system of polders and drainage channels. The beach to the south of the delta is a principle nesting area of threatened and endangered sea turtle species, while the oceanic end point of the river debauches across the North East Brazil Shelf to the South West Atlantic Ocean. This entire area has been significantly modified by the regulation of the river upstream of the estuary and coastal zone (e.g., erosion of riverbanks, sedimentation, formation of islands in the delta, and erosion of the southern extreme of the delta). These modifications not only affect the estuary by altering flooding cycles, but also impact the nearshore marine environment by modifying the nutrient and sediment content of the river water, affecting marine fauna, and the sediment and turbidity dynamics of the estuary with observed, although unquantified, changes in the aquatic fauna, flora and geomorphology of the river mouth.

The annual discharge of the Rio Sao Francisco at its mouth averages over 94,000,000-mil m^3 per year. The natural flow in the reaches through the middle basin below the principal perennial tributaries average between 2100 m^3/second and 2800 m^3/second, with a natural flow of approximately 3000 m^3/second near the mouth of the river in the Lower Sub-basin. Normal natural maximum flows occur during the month of March and average approximately 12,950 m^3/second at Juazeiro near the boundary between the Middle and Sub-Middle Sub-basins and 12,967 m^3/second and 12,967 m^3/second at Pao de Açucar, located near the mouth of the river. Normal minimum flows at these stations occur during the month of September and average 671 m^3/second and 842 m^3/second at these two locations respectively. As the river is operated today, the natural flows of the river are highly regulated by extensive hydroelectric developments and the flows are regulated to optimize energy production and to control flooding of the river margins.

There are a series of complex environmental, economic, social, institutional, technical problems in the Sao Francisco basin which impact the basin and the ecosystem. Some of the problems related to the presence of the dams in the Sao Francisco River include:

B.1 Problems related to poorly quantified environmental impacts

Reported problems related to poorly quantified environmental impacts include the biological consequences of modified river flows as the result of river regulation; the contamination of reservoirs and modification of the near shore marine nutrient balance due to river regulation; the changed character of the sources, sinks and composition of sediment loads throughout the basin as the result of interception and downstream scour arising from river regulation; modification of the water quality (and, thereby, the biological integrity of the system) as a result of human economic activities (e.g., mining, industrial development, and urbanization in the headwaters area of the river, and industrial development, agricultural development based on irrigated agriculture and urbanization in the lower portions of the basin) that discharge untreated or poorly-treated wastes to the system.

B.2 Problems related to stakeholder involvement

Problems related to stakeholder involvement historically have been related to the lack of an appropriate framework for encouraging stakeholder participation and the highly sectoral nature of development within the basin. In recent years, the efforts of the federal government to increase the living standards in the previously impoverished basin have focused on a top-down style of implementation that has rarely recognized the wider context of social concerns other than economic development. Recently, a wider appreciation of the success of community-based, bottom-up development approaches, such as that embodied in Brazil's federal water law 9433/97, have initiated the process of increasing stakeholder participation across traditional sectoral lines. This process, in a basin as diverse and complex as the Rio Sao Francisco Basin, will take some time to evolve and mature.

B.3 Problems related to institutions and human resources

Problems related to institutions, both legal and regulatory, and agency structures, have historically been related to a lack of appropriate laws and regulatory regimes for controlling environmental pollution, implementing and undertaking compliance monitoring, and policing of violators. Related to the lack of institutional capacity, problems related to human resources include a paucity of trained staff, lack of authority to control environmental problems, and fragmented and parochial jurisdictions that have failed to bring a comprehensive and cohesive approach to watershed management in the Rio Sao Francisco Basin. Initiatives set forth in federal law 9433/97 provide mechanisms to rectify many of these shortcomings. Funding, which has been in chronic short supply has not allowed creation of laboratories, police forces, and other necessary appurtenances to control and regulate environmental pollution and degradation. Actions that could be undertaken were fragmented among agencies and between states, and consequently often resulted in less than effective management of the river and watershed. Currently, local and national initiatives are strengthening water resources institutions in the basin.

B.4 Problems related to lack of an holistic management approach

Problems related to the lack of a unified vision of the Rio Sao Francisco Basin as an integrated whole include inter-sectoral conflicts over water usage, competing rather than complementary demands for water and a piecemeal approach to water resources development in the basin. The Senate Committee on the Sao Francisco Valley identified this lack of an integrated, holistic management approach as the principle issue facing sustainable development in the basin.

B.5 Problems of hydrology

Problems related to hydrological processes include alteration of flood regimes due to river regulation and altered land use practices, which modify the way in which water is applied to and lost from the land surface. Changes in hydrological processes create a cascade of sedimentological, chemical, and biological consequences throughout the system, which further modify the structure and functioning of the aquatic ecosystem that is the river. Likewise, the drainage of wetlands and the creation of polders in the estuarine reaches of the river have further altered river flow patterns often in negative ways.

C. Major impacts of dams in the Sao Francisco River

The oceanic end point of the Sao Francisco river has been significantly modified by the regulation of the river upstream of the estuary and coastal zone (e.g., erosion of riverbanks, sedimentation, formation of islands in the delta, and erosion of the southern extreme of the delta). These modifications not only affect the estuary by altering flooding cycles, but also impact the nearshore marine environment by modifying the nutrient and sediment content of the river water, affecting marine fauna, and the sediment and turbidity dynamics of the estuary with observed, although unquantified, changes in the aquatic fauna, flora and geomorphology of the river mouth. The ecological regime of the delta and coastal areas represents an asset that has not been fully defined or protected. Some of this area has been developed for agricultural production using a system of polders and drainage channels. The beach to the south of the delta is a principle nesting area of threatened and endangered sea turtle species.

The river has been historically operated exclusively for energy production and for water supply for irrigation projects. The operational policies hardly ever took into consideration the ecological impacts on the river. The construction of dams drastically affected fish migration river upstream (known as the "Piracema") by isolating fish from the spawning ponds in the margins of the Sao Francisco river. The flooding of the river used to replenish the spawning ponds with water, nutrients, and sediments and allowed fishes to spawn, and grown up fishes to migrate to the river. The reduction of supply of sediments and nutrients also affected fishing activities (fishes and crustaceans such as the "Pitú" shrimp) in the coastal zone. Because of temperature factors the tropical oceanic waters usually are poor in nutrients and fishing productivity usually takes place at the mouth of the rivers. Agriculture (grains and sugar cane) is one of the main activities in the lower Sao Francisco. The reduction of the floods also propitiated the proliferation of rodents in the aluvional plain, which affected agricultural production of grains and increased the index of transmissible diseases.

In addition to the impacts on fish and shrimps the regulation of flow has reduced sediment loads causing serious impacts on the geomorphology of the delta and the interaction of the river with the ocean marine currents. In the past, the interaction of the river with the ocean currents resulted on flows moving outwards into the sea. Today the resulting flows are towards the coast creating serious erosion of the beaches at the mouth of the river and destruction of native habitats. Erosion of river banks has been responsible for sedimentation problems and has impacted navigation.

Modifications of the natural hydrological regime of the river which – while contributing to the production of "clean" energy for use by the people and industries of the basin and throughout Brazil – have proven especially destructive to organisms that depend for reproduction and survival on the quantity, quality, timing and rate of water flows (especially in the estuarine and coastal marine endpoints of the basin), and to groundwater sources that depend for recharge upon surface water flows.

Human actions in the watershed have not been controlled or regulated and existing mechanisms have failed to view the basin as a unit, in which actions taken at specific sites have a cumulative effect throughout the system. Most of these shortcomings have been rectified through state, federal and external interventions and initiatives or proposals are currently being made to rectify them. However, substantial and costly actions are needed to overcome the historic lack of regulation, and lack of an holistic approach to ecosystem and economic development.

D. Major stakeholders and other interest groups

The principal federal entities with responsibility within the Basin are CEEIVASF, the Executive committee for Integrate Studies of the Hydrographic Basin of the Rio Sao Francisco; CODEVASF, the Rio Sao Francisco Development Agency; CHESF, the Sao Francisco Power Company, the major power agency of the basin; and SUDENE, an organization formed for the purpose of comprehensive planning in the Northeast.

CHESF is the agency that is responsible for the development, operation and maintenance of hydroelectric generation and the bulk energy distribution throughout the Northeast. CHESF operates plants with approximately 7,800 MW of installed capacity in the Rio Sao Francisco basin and its tributaries, with an additional 2,500 MW under construction and a planned total future capacity of over 26,000 MW. CHESF works in close cooperation with the State Electrical Companies in each state and in some instances has transferred generation responsibility to the states, i.e. Três Marias power plant, transferred to CEMIG, the State Electrical Company of Minas Gerais. CHESF has been slow to accept the principle of multiple use of the river system and continues to operate its major facilities with little regard for the comprehensive management of the system to meet multi-purpose needs. Future optimization of the use of the Sao Francisco river basin will require a major change in attitude and policy with regard to this problem of integrated management.

The present and future demands for electric energy within the basin continue to outstrip the available energy. It is estimated that the demand for electric energy will double within the next ten years. As the cities now developed on the river system, it can be assumed that further development of hydroelectric generation on this system will have increasingly greater impact on both competing demands for the water supplies and the riparian environment as well as severe conflicts with the existing land use.

The Government of Brazil will be faced with major prioritization decisions and it can be expected that each development will face increased opposition from vested stakeholders and non-governmental organizations. Increasing need for energy for irrigation, industry and municipal use will necessitate tradeoffs between these uses and increase pressure from those interested in environmental preservation and instream uses such as fish production and navigation. Increasing pressures can also be expected for restoration and preservation of the Delta and Coastal wetlands that are dependent upon the flood flows of the Rio Sao Francisco.

E. Management activities

In 1984 the Executive Committee of Integrated Studies of the Basin (CEEIVASF) was created within the framework of the Special Commission for Integrated River Basin Studies in Brazil, to undertake specific planning studies in the basin. This Committee was among the first to consider the Sao Francisco River Basin as a hydrologic unit, but the Committee was restricted by its mandate to the preparation of studies, and it lacked the institutional independence and financing to successfully implement a comprehensive program of river basin management. Other official organizations with interests in the Sao Francisco Basin include the Inter-State Parliamentary Commission for the Development of the Rio Sao Francisco (CIPE) composed of the Presidents of the Legislative Assemblies of the five riparian States, and UNIVALE, a Union of Municipal Authorities in the basin.

The valley of the Sao Francisco has been the subject of numerous planning and developmental efforts over the years. In 1989, a Master Plan for the Development of the Sao Francisco River Valley (PLANVASF) was completed by CODEVASF, with the assistance of the Organization of American States (OAS), and was designed to provide incentives to the public and private sectors for the development of the basin. This plan included proposals for the development of natural and water resources, increased food production through irrigated agriculture, increased power generation supplying the National Network, increased water and sanitation services, improved river navigation, and enhanced environmental protection. This plan was adopted as a part of Federal Law 8851/94, as the Plan of Economic and Social Development of Northeastern Brazil. Within relatively recent times, major planning studies were done by DNAEE (DNAEE 1993) and CHESF with regard to the hydroelectric potential of the river.

In 1995, the States of the Northeast, in cooperation with the National Secretariat of Water Resources, formed a group representing the water resources sectors of each state to foster legal and institutional cooperation on water resources throughout the Northeast, including the Sao Francisco Basin. The group was established formally with the signing of the "Carta de Natal" in Natal, State of Rio Grande do Norte. One of the major topics of this group was the Sao Francisco, including the potential impacts of the proposed "Transbasin Diversion Project", which would transfer water from the Rio Sao Francisco to the non-riparian Northeast States of Ceará, Rio Grande do Norte and Paraíba and to the *Sertão* region of Pernambuco. This committee continues to meet and discuss topics such as the legal and institutional framework for water and joint efforts to study integrated management of the Sao Francisco and other areas of potential cooperation between the States and the Federal Government in the water resources sector.

The Special Commission for the Development of the Sao Francisco Valley was created by Act. No. 480 of 1995 of the Federal Senate to promote discussion on strategies, policies, programs and priorities for the development of the Valley, both present and future. Included in its mandate was the alleviation of poverty and balancing of socioeconomic development and the environment in the Rio Sao Francisco Basin, including rehabilitation of degraded lands. The Commission concluded its efforts with a final report in November 1995 that recommended actions to further the coordination of the development of the Basin.

In January 1997, the Federal Government passed Law 9433/97, containing the National Policy on Water Resources and a system of public institutions (basin committees) for issuing water rights and implementing a charging scheme for water use. With the approval of the National Policy Committee on Water Resources, as established by the National Constitution, the Federal Government is promulgating criteria and guidelines to be followed by states in implementing federal law 9433/97. Presently, the States of Bahia, Pernambuco and Sergipe have passed legislation consistent with these objectives, principles and guidelines and are creating institutions to implement the new law at the State level. The States of Minas Gerais and Alagoas are presently modifying or creating water legislation in order to comply with federal regulations. Implementation of these laws will create a climate that should address many of the concerns identified by the Special Commission for Development of the Sao Francisco Valley.

Activities in the Brazilian Coastal zone are regulated by Federal Law No 7661/88, the National Environment Program. This law, *inter alia*, establishes the National Coastal Management Plan, the principle objectives of which are the sustainable uses of natural resources in the Coastal Zone and the preservation, conservation and rehabilitation of ecosystems to promote sustainable development. The Government of Brazil completed in 1996 a coastal zone inventory and "macrodiagnostic", including the Rio Sao Francisco estuary, with support from The World Bank. This study identified in a mapping format the major human uses of the coastal zone of Brazil, environmentally sensitive sites, and conservation units and reserves, which, in the Rio Sao Francisco coastal zone, are related primarily to agricultural use and conservation of endangered species, including sea turtles.

F. Integrated Management of Land-based Activities in the Sao Francisco Basin (UNEP/GEF/OAS)

GEF (Global Environmental Facility) through its implementing agency UNEP (United Nations Environmental Program), its executing agency OAS (Organization of American States), and its national executing agencies, the Ministry of Environment, Water Resources, and Legal Amazon (MMA) and the Secretary of Water Resources (SRH), are implementing the project "Integrated Management of Land-based activities in the Sao Francisco Basin". The GEF project will help the Government of Brazil to promote sustainable development of the Rio Sao Francisco Basin and its coastal zone, based upon the implementation of a watershed management program (WMP) integrating the watershed and coastal zone. The goals of this multi-phased project are (i) to assist the Government of Brazil to incorporate land-based environmental concerns into development policies, plans and programs for the Basin and for the protection of its coastal zone; and (ii) to conduct pilot demonstration activities during WMP formulation to gain information needed for management purposes.

In Phase I a strategic program of action for the integrated and sustainable management of the basin and its coastal zone was formulated, addressing the physical, biological, chemical and institutional root causes of the progressive degradation which is affecting the basin and, particularly, the coastal ecosystems. Phase II economic instruments and implementation activities are designed to facilitate sustainable development within the basin and the coastal zone. These activities will complement basin-scale interventions by the Government of Brazil, financed in part from national sources and by The World Bank through the Program for Water Development (PROAGUA) and other donors. The project forms the Latin American demonstration project under the Global Program of Action for the Protection of the Marine Environment from Land-based Activities (GPA), GEF operational program element.

G. Recommendations for future management of the river system

To effect the sustainable management of the Rio Sao Francisco Basin and its coastal zone, it is necessary for the Federal Government of Brazil and the basin states to formulate a comprehensive program of coordinated actions. The federal water law and other legislation provide a sound basis for implementing the actions necessary for achieving sustainable management in the basin. The main risk is that the legal mechanisms provided under the water law are not fully implemented and that the basin committee will not manage to implement cross-sectoral integration activities that would benefit the river system and the coastal zone. However, recent moves toward adoption of complementary legislation by the basin states would suggest that this risk is small. Emphasis should be placed on strengthening the basin committee as a means of catalyzing and encouraging cross-sectoral management of water resources and related development in the basin and achieving sustainability.

Some of the actions required include river basin and coastal zone environmental analysis; public and stakeholder participation (promotion of multisectoral and public participation in the process of basin management); organizational structure development (legal and institutional); quantification of water use, use conflicts and hydrological management; financial mechanisms for managing both water quantity and quality in the basin; and formulation of the watershed management program (including information sharing and dissemination).

Experience in other major river basins indicate that integrated management can increase benefits, reduce adverse impacts, and improve long-term resource development and management. Integrated management is difficult to achieve, however, due to the reluctance of existing agencies to cooperate and share institutional power. Incentives, resources, and demonstrations are needed that allow different interests to work together. A demonstration of effective integrated resource management would serve two purposes. First, individual agencies are able to work out mutually beneficial approaches (i.e., new solutions to old problems that improve conditions for all participants). Second, relationships and joint goals are developed that overcome fears and the reluctance to adopt new management approaches.

Sustainable river basin management requires proper study, sound understanding and effective management of water systems and their internal relations (groundwater, surface water and return water; quantity and quality; biotic components; upstream and downstream).

The aim of sustainable river basin management is to ensure the sustained multi-functional use of the basin. Basic water needs of peoples and ecosystems should be fulfilled first. Essential ecological and physical processes should be protected. Moreover, the effects on the receiving water bodies (seas, lakes, deltas, coastal zones) should be paid full attention. River basin management is often characterized by parochial interests and intractable problems. To achieve progress, leadership and political commitment are essential.

Floods not only cause suffering but also support life. Flood management should not be based solely on building dikes and dams. It needs to be based on strategies that use both structural and non-structural methods. The strategy should balance all interests involved and be based on an integrated assessment, of the environmental, economic and human costs and benefits of these alternatives, including their potential contribution to drought mitigation and including the possibilities that they offer for nature.

The ultimate goal of pollution control is to close substance cycles and in this way prevent pollution. A mix of instruments for regulation and compliance can be used to move into this direction and solve urgent pollution problems: waste control, process and emission standards, and a water quality approach. The exact mix should reflect *inter alia* the local management capacity and the availability of water quality data and other data.

Effective river basin management requires sound data, information and knowledge, including both data on surface and groundwater (quantity and quality) and social and economic data. Collection and processing of relevant data, easy accessibility and broad dissemination are eminent tasks of river basin and coastal zone management. To increase policy relevance, data should be aggregated into meaningful information, for example in the form of indicators and systems for benchmarking.
To support river basin management and operational criteria of dams, analytical model and Decision Support Systems should be developed that can aggregate socio-economic, political, institutional and technological potentials and hydrological constraints. This model should be capable of evaluating the actual management capacity and evaluate future management scenarios.

Public participation and empowerment are necessary conditions for achieving sustainable development. To ensure effective public participation, independent of the goodwill of the authorities, rights of access to information, active participation in decision-making processes, and access to justice need to be legally established.

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Rio Hondo Dam (Santiago del Estero, Tucumán, Argentina): A Conflictive Wetland

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Abstract

The strategic geographic location of the Río Hondo reservoir in terms of water reception and redistribution makes this dam play a significant functional role as a wetland within the endohreic basin of the Sali-Dulce river. For the past 30 years, this dam has been affected by an annual increase in contamination levels produced by the input of sediments (urban and industrial byproducts) that occurs mostly during low-water periods. To the present, a series of studies have focused on physical, chemical and biological aspects aiming at a diagnosis of the degree of alteration. Pollution-descriptive parameters (nutrients, DO, DBO, chlorophyll a, among others) and biological communities reflected in their specific composition and abundance a sensible impact affecting this stressed environment. Water volumen differences determined significant differences between the impact observed in the limnetic zone and the tributaries' mouth. Eutrophication is reflected by cianophyte algae blooms (*Microcystis aeruginosa*, *Anabaena flos-aquae*), abundant euglenophytes, abundant bacteria, ciliates, and bacteriophagous rotifers, all of them being indicators of high saprobiety, with dominance of macrofilter microcrustaceans ciclopoids, and decrease in the species richness at superior trophic levels (fishes and birds) as a result of a lack of a conservation policy. Management actions towards a reversion of this complex situation are analyzed and recommendations are made.

Key words: Dam-contamination; Environmental Impact; Argentina

Resumen

El embalse de Río Hondo es un humedal que cumple un rol de gran importancia en la cuenca endorreica Salí – Dulce ya que ocupa una situación estratégica de recepción y redistribución del agua. Desde hace tres décadas se produce regularmente alta contaminación generada por sedimentos, residuos urbanos e industriales que son vertidos coincidentemente con la período de "aguas bajas". Hasta el presente se encararon estudios sobre aspectos físico – químicos y biológicos que permiten diagnosticar el alto grado de deterioro. Los parámetros descriptores de contaminación (nutrientes, OD, DBO, clorofila a, entre otros) y las comunidades biológicas reflejaron en sus magnitudes, composición específica y abundancias, su sensible impacto de este ambiente "en tensión". Se aprecian diferencias significativas entre la zona limnética y la desembocadura de los tributarios ya que en la primera el volumen "amortiguó" en cierto modo su efecto. Se produce eutrofización con floraciones algales de cianofitas (*Microcystis aeruginosa*, *Anabaena flos- aquae*), abundantes euglenofitas, abundantes bacterias, ciliados y rotíferos bacteriófagos, todos elementos indicadores de alta saprobiedad, con predo-minancia de microcrustáceos macrofiltradores ciclopoideos, disminución de la riqueza específica en niveles tróficos superiores (peces y aves) como resultado de una falta de políticas de conservación. Además se analizan las acciones de gestión tendientes a revertir dicha compleja situación y se proponen sugerencias.

Palabras claves: Embalses; Contaminación; Impacto ambiental; Argentina

A. Introduction

The Río Hondo dam, which was established in 1967, is one of the most controversial water bodies of northeastern Argentina in terms of its environmental problems of contamination produced by systematic input of industrial and urban wastes without previous treatment, determining significant alterations at both local and regional scales. Its geographic location (27° 35′ S, 64° 30′ W) is strategic since it is located in an intermediate point of the Salí – Dulce endohreic basin, receiving four tributaries (Medina, Marapa, Gastona and Salí rivers) and generating the Río Dulce, which runs into Mar Chiquita shallow lake (100.000 ha). The latter has been declared a Reserve of Multiple Use (Hemispheric Site of the Hemispheric Network of Coastal Birds Reserves (Canevari et al, 1998). This wetland is inhabited by 138 bird species, many of them using the Sali-Dulce system as migration station in their way to/from the Northern Hemisphere. Worthy to mention are the large reproductive colonies of the Chilean flamingo (Phoenicopterus chilensis).

Although the dam has been subject to research since the 70s by different institutions and research centers (Obras Sanitarias de la Nación; Saneamiento Ambiental de la Provincia; Consejo Federal de Inversiones, Agua y Energía; Comité de Cuencas, Sección Medio Ambiente de la Universidad Tecnólogica Nacional; Instituto de Limnología del Noroeste Argentino – Facultad de Cs. Naturales – UNT; Universidad Nacional de Santiago del Estero – UNSE), the environmental deep problems continue.

Although being an anthropogenic environment affected both upstream and downstream (i.e impact by soil salinization, increase in phreatic levels), the Río Hondo dam is an important landscape component (Dussart, 1984; Scott & Carbonell, 1986; Frazier, 1996). From an ecological valuation, it is an environment of singular esthetic value, with multiple resources that support a significant biodiversity with species of variable distribution, threatened or under risk of extinction because of habitat destruction or modification. This aquatic ecosystem is a favorable environment for many coastal birds and – although with differences – it represents an alternative habitat to the natural wetlands of Chaco for numerous bird species (Bucher & Chani, 1998). In addition, the dam provides irrigation water for 118,000 ha; it generates hydroelectric energy (70.000 Mwh/yr) and represents an attraction center for tourism (particularly during Winter: May to September), fishing, aquatic sports and other recreational uses. It is worthy to note that this environment is used for artisan fisheries since the local population use it as protein source. Due to absence or little effective control of the fisheries, native fish species populations are threatened by overfishing. The fact that the dam occupying territory of two different states has derived in jurisdictional problems related to the control and regulation of all these activities and contamination-related issues in the Rio Hondo dam (Butí, 1999). The objective of this paper is to analyze the present situation of the dam regarding the state of the art in relation to knowledge and management actions.

B. Limnological characteristics of the dam

The Río Hondo dam (maximum water level: 274 m.a.s.l) is located in the surroundings of Río Hondo city, over a plain of cuaternary low-cohesion sediments. The climate is mesothermal, semiarid, with an average annual temperature of 20 - 22°C, average humidity 60% and average annual precipitation 736 mm. Vegetation around the lake is composed of typically altered short and tall native "monte", along with gramineous, sometimes flooded. The dam

(Fig. 1) is morphometrically characterized by having a roughly triangular outline, a large area (34.000 ha) and volumetric capacity (1.600 Hm^3); 17 Km long, maximum depth 25m, average depth 11 m, and flood plain 300km^2. From the thermal point of view it is "monomictic warm". Regarding its productivity, the dam would be included within the euthrophic – hypereuthrophic range (Vollenweider, 1968). Conspicuous fluctuations between water levels of 275 and 265 m – which causes the total area to reduce in a 25% --, produces significant changes in the metabolism of this body water.

C. Considerations on contamination issues

Contamination in the Salí – Dulce basin is produced by both natural and anthropogenic factors. On one hand, erosion and degradation in the upper and middle basin and piedmont caused by overgrazing, fire, indiscriminated logging, and expansion of agricultural lands, produces sediments for a total of 3,075,000 tn/yr, causing river high waters, floods and conspicuous dam solid deposits. The high rate of sedimentation (13.4 Hm^3/yr) (Farias & Borsellino, 1997) has been producing a annual loss in the total volume of approximately of 0.8% /yr, the total loss having reached about 22 % (Kruse *et al*, 1994), thus decreasing its "useful life span". It is worthy to note, that the strong dependency of the regional socioeconomic activities on the condition and dynamics of the basin makes that both present and future possibilities of development in the region depend on said basin environmental health (Secretary of Environment, 1996).

Tucumán presents a varied range of industries, which are the main cause of variable degree of partial contamination (Figs. 2, 3). A critical situation is triggered by the seasonality of rain precipitation, with the dry semester (winter–spring) of "low waters" coinciding with the greater seasonal industrial activity and output of liquid and solid industrial and urban wastes, discharged into the dam tributaries without any previous treatment.

The organic charge of the tributaries (34.600 Tn/yr) during the low-water period makes null the possibility of river self-depuration (11.300 Tn/yr natural depuration). During the high-water period, the contaminant discharge by the industrial effluents into the Sali river is 6.8 times the amount of contaminants produced only by urban population in Tucumán Province (Cárdenas, 1982). The reservoir would behave as a "biological stabilization pond" receiving 400.000 m^3/day of urban effluents, representing an annual volume of 146 Hm^3 and DBO of approximately 500 gr /m^3 (Perera *et al*, 1985). In addition, industries produce a total of 334.833 tn/yr of solid wastes, of which 90% are organic residuals prone to sedimentation or suspension.

Among the most relevant pollutants there are (1) the "vinazas", final residue from the distillation of fermented "mosto" for alcohol production, which is an aggressive contaminant for its high content of P and N, determining a DBO of 40.000 – 80.000 mg /l; (2) the "cachazas", dry solid residues with a high organic charge (70%) (48.541 tn/yr); (3) the waste effluent from paper industry, having an important volume all throughout the year and being highly contaminant because of the characteristics of its components (resistant to biological treatments and presenting high values of electric conductivity); and (4) the effluents from the citrus industry which is difficult to treat because of its high pH, organic charge and solid volume values (3120 tn/yr). Regional collecting networks and management systems for treatment of urban solid wastes (garbage: 151.110 tn/yr) and liquid effluents (urban outflows: 74.129.000 m^3/yr) are still highly inefficient, which represents a serious risk for human health based on their relationship with illness vectors. It is worthy to note that the presence in the Salí river basin of Lindane and Chlordane, chlorade pollutants with values above the acceptable limits (Chaile *et al*, 2000) represents an actual threat to the environment and human population.

D. Considerations about the biota

A total of 232 species belonging to the phytoplankton, zooplankton, macrophyta, bird and fish communities were recorded.

D.1 Phytoplankton community

Seventy-two phytoplankton species were identified, including 27 diatoms, 25 clorophytes, 10 cyanophytes, 1 euglenophyte, and 1 pirrophyte. The functional role of this community is that of acting as primary producers. For instance, a significant functional phenomenon involving phytoplankton is the cyclic bloom of the cyanobacteria *Microcystis aeruginosa* and *Anabaena flosaquae*. During the bloom, these non-edible algae reach densities up to 160.000 cel ml^{-1} (Tracanna *et al.*, 1996 – Pizzolon *et al.*, 1999, Riehl,W.,1984), determining a thick layer several millimeters deep in the limnetic zone, which yields to degradation processes consuming large amounts of DO. During the "zafra" period, records at the mouth of the tributaries showed high abundance of euglenids (*Euglena proxima* and *Nitzschia palea*) – which are known by their marked polisaprobiety (Tracanna *et al.*, 1996) – as well as diatoms known as pollution indicators. Variation in algae abundance between "zafra" and "pre-zafra" periods have been recorded both at the reservoir deepest point (range, 9.200 – 214.520 ind l^{-1}), and at the mouth of tributaries (range 15.260 – 41.980 ind l^{-1}). Regarding the saprobiety of known range (19 spp.), recorded values are 47% α - β mesosaprobitic spp., 26% β - mesosaprobitic spp., and 10 % α - mesosaprobitic spp.

D.2 Zooplankton community

The specific composition of the zooplankton of the limnetic zone included 20 rotifera, 8 cladocera, and 4 copepod species. Likewise, in the area of the "tail" of the reservoir, the composition included 12 rotifera, 5 cladocera, and 7 copepoda species. The community structure of the microzooplankton showed a quantitative dominance of bacteriophagous ciliated protozoa over rotifera and copepods (Villagra de Gamundi & Juarez, 1997) and macrozooplankton, a higher proportion of copepods (in particular macrophagous ciclopoids) over small cladocera, and immature forms over adult forms (Locascio *et al.*, 1998). It is noteworthy the record of *Daphnia laevis* only at middle and deepest levels of the water column. The absence of *Daphnia* can be explained either by the negative effect of the cianophyta, pollution or selective fish predation. (Villagra *et al.*, 1999).During periods of environmental high stress, the density of adult microcrustaceans was null or very low. Microzooplankton density varied between 1,08 and 853 ind/l, while macrozooplancton density ranged between 0,16 and 252,2 ind/l. Species usually associated with eutrophication processes were also recorded (Patalas, 1972; Gannon and Stemberger, 1978, Harper, 1992), as for example *Brachionus calyciflorus* (77,7%), with ranges of α and β mesosaprobiety, a species which is a recognized bioindicator of hypereutrophic environments since it feeds on cianophyta (Sládecek, 1978). In the case of the Rio Hondo Dam environment, the functional role of the zooplankton organisms is reflected by the presence of bacteriophagous or hervivorous species foraging on cianophyta algae, thus contributing to water depuration as primary and secondary consumers.

D.3 Fish community

Twenty fish species were recorded in the Rio Hondo reservoir. The species richness was relatively low in comparing with the regional diversity (i.e. species number in Tucumán Province, 66; Santiago del Estero Province, 28; Cordoba Province, 61; whole Sali-Dulce river basin, 96). Herein, on the basis of this low species richness, it is proposed an all-throughout-the-year fishing prohibition in the integration zone, and an October to December ban at the tributary mouths. The presence of *Prochilodus linneatus* (v.n.,"sábalo": sedimentivorous microphagous), *Salminus maxillosus* (v.n. "dorado": predator macrophagous) and *Pimelodus albicans* (v.n. "bagre": predator macrophagous) determines the need for the construction of an escaping channel from the reservoir (Butí, 1999). Fishes are key species within ecosystems, having functional trophic roles as planctivorous, iliophagous and ichthyophagous species.

D.4 Bird community

The bird community was composed of 78 species, being represented in particular by species of the families Anatidae (16), Rallidae (11), and Ardeidae (10). The habitats which presented higher diversity were the "palustre", in decreasing order followed by open waters, floating habitats, forest-like habitat, sediment banks. Reproduction evidence was found for 43.5 % of the species and colony abundance with more that 700 individuals (*Phalacrocorax olivaceo*) (Laredo, 1994).

Although the family composition is similar to that of related water bodies, Rio Hondo presents lower species richness (i.e. Mar Chiquita Laguna, 138 spp.; El Cadillal dam, 145 spp.). The decrease in number of species could be explained by the low habitat quality. The latter is reflected by the presence of only scattered and modified marginal vegetation in Rio Hondo compared to that of El Cadillal reservoir – which presents a greater and stronger vegetation surrounding the lake –, and also by the record of toxic chemicals in the viscera of different animal species inhabiting Rio Hondo. From the functional point of view, birds occupy trophic niches of herbivorous, sedimentivorous, and ichthyophagous, actively making use of the exceeding productivity of aquatic ecosystems, particularly in fluctuating and eutrophic systems (Margalef, 1983).

D.5 Macrophytic community

The hydrophyte community is composed of 32 species, with dominance of *Eichornia crassipes* and *Pistia stratiotes* (pleuston) in frecuency of occurrence and coverage density (75 %) (Carrizo & Gomez, 1994). From the functional point of view, they serve as nutrient pump, animals microhabitat, and toxic chemicals bio-storage.

Based on available data, it can be said that the Rio Hondo reservoir – although having a wide surface area with a range of different kinds of microhabitats, with optimum availability of macrophytia for nesting purposes–, it presents comparatively lower bird and fish species richness than other environments of the basin. This situation could be explained by the presence of sediments and toxic chemicals, which might not allow the biological success of certain populations by affecting individual size and survival.

Significant differences were detected among "pre-zafra", "zafra" (reaping of sugar cane), and "post-zafra" periods. Highest stress values were recorded for July-September ("zafra" period), with 0 DO values, DBO reaching 1220 mg/l in the Sali river, an a remarkable increase in nutrient content, low transparency, foam, greenish or brownish water color, sediment consolidation in granules, sulphydric acid odour, all these typical characteristics of conspicuous eutrophication. Toxic algae blooms occurred together with bacteria increasing density, abundant euglenophytes, mites, chironomids, and nematods.

In addition, significant differences were recorded between the tributaries zone with high values of contamination. The Sali river showed the greatest environmental impact, presenting the highest chemical pollution and sediment charge, lowest species richness, lower species frequency, higher DBO values and total coliforms (their density being above all admissible limits). The reservoir water quality is not apt for human consumption based on sediment charge, bacterial content, and toxic chemicals. The integration zone was also affected by a gradual environmental alteration with increasing values of those physical, chemical and biological indicator parameters with extended blooming periods.

E. Present Situation – Recent contributions

Although pollution in Tucuman has represented a serious problem for a long time, a series of actions are being taken by the State Government in order to subvert the critical situation (personal communication of Dr. Juan A. Gonzalez, Secretary for Environmental issues in Tucumán -2001).

The following is an account of recent legal actions extracted from "Central guidelines for an integral plan on quality restoration and preservation of the Salí –Dulce river watershed", which compiles the outcome from a 1998 Workshop on Pollution of the Salí – Dulce Basin (El Mollar, Tucumán).

The "cachaza law" has been effective since October 2000. This law prohibits the use of the Sali river for waste elimination of solid byproducts of sugar-cane industry (140.000 tn/yr, equivalent to 25% of total solids), which are now being used as fertilizers. A program for treatment of the "vinaza" (liquid byproduct of sugar-cane industry) has led to reducing contamination (30%) produced by alcohol industry (121 liters of obtained alcohol– 400000 m^3/yr). The "vinaza" now is conducted into stabilization ponds and biologically treated to reduced DBO (Ingenios Aguilares y Marapa).

The treatment of byproducts from citric industry is now under a pilot period, with agreements signed between the National University of Tucumán and the private companies Trapani and Citromax (under primary treatment), San Miguel (20% of efficiency when starting secondary treatment), and Citrusvil (which agreed to reach 0 contamination in May 2002). The company Papel del Tucumán has been declared in situation of emergency, having been inabilitated and confronting two legal actions.

Programs for controlling inorganic contamination in the region have started in November 2000 with the opening of a waste treatment plant for DP2 elimination in the mineral factory La Alumbrera, therefore, reducing the risk of heavy metal toxicity. It is worthy to note that although at the moment there are no mines for metal exploitation in Tucuman Province, the presence of several pediments (Oro del Calchakí, El Alisal) represents a potential environmental risk considering the geomorphological characteristics of the region.

It is pending an agreement among the provincial governments of Santiago del Estero and Tucumán and the National Board for the Environment, aiming at setting a National Plan for Contamination Control.
Ongoing research on toxicity includes both laboratory bioessays with algae (Seeligman, 1998) at the moment at the preliminary stage for EPA protocols – and evaluation of demographic parameters of zooplankton in situ. The results of a doctoral thesis presently in progress will contribute with new elements for evaluation of the Rio Hondo water quality as a function of fish parasitism ("Fish nematode parasites in Río Hondo Reservoir").

F. Recommendations

Herein, on the basis of this state-of-the-art regarding the environmental condition of the Rio Hondo dam, a series of measures to be taken in the short and mid-term are proposed:
Considering the basic components of any evaluation of ecological impact, it can be said that to the moment the items "water quality " and "aquatic communities" have been covered by research, still pending the "evaluation of habitat modification" and "terrestrial communites", which have been only indirectly addressed.
To intensify studies on abiotic changes but particularly the research on the most conspicuous biotic communities of the dam and its basin, looking for the temporal and spacial scales that will allow the most accurate interpretation of the elasticity of those communities.
To consummate the judicial procedures involving aquatic ecology issues within the frame of the relatively new legislation (established in the 80s). The latter, despite factual precedents found in the National Constitution, the Penalty Code of Argentina, the State legislations of Tucumán and Santiago del Estero, municipal ordinances of the cities of Santiago del Estero and Rio Hondo, and the Water Code, among other legal statutes.
To intensify research on chemicals that represent the highest risk in terms of the environment health.
To continue with the application of biological indexes as biological indicators of the communities.
To study the bioaccumulation at superior trophic levels (fishes, birds, mammals).
To settle treatment plants for byproducts of citric industries (lemon), since to the moment there is a lack of appropriate technology. Test-studies using ciliates are in progress (Juarez *et al*, 2000).
To offer training courses to lake police personnel or ecological police, to NGO and other volunteer-based organizations, to school teachers and community organizations, having as ultimate goal fostering environmental conscience in relation to water.
Water as a resource needs to be protected for both ecological and economical reasons, thus, it is proposed to continue the integrated and exhaustive analysis that will allow the evaluation and the reduction of contamination, which - quoting Margalef - is a process that constraints the sucesion or phenomenom of self-organization.
To increase the control the input of pollutants into the dam by the tributaries, a control which -- based on the evaluation of research results – appears to be crucial. The situation at the tributaries' mouth is so critical that, even during periods of apparent improvement of the physico-chemical parameteres, the impact on the communities is still important.

G. Final Considerations

Based on the previous analysis, it can be said that the ecological situation of the Rio Hondo dam responds to the conditions of "complex systems", that is systems that require consideration of multiple interacting factors in order to get a systemic vision of the entire ecosystem. (Jorgensen, S. E. & R.A. Vollenweider, .1989; . Margalef, R. 1976 – 83 MAB . 1984). This wetland is one more example of how difficult it is to implement management actions in a country in which the environmental issue has not been acknowledged as it deserves.

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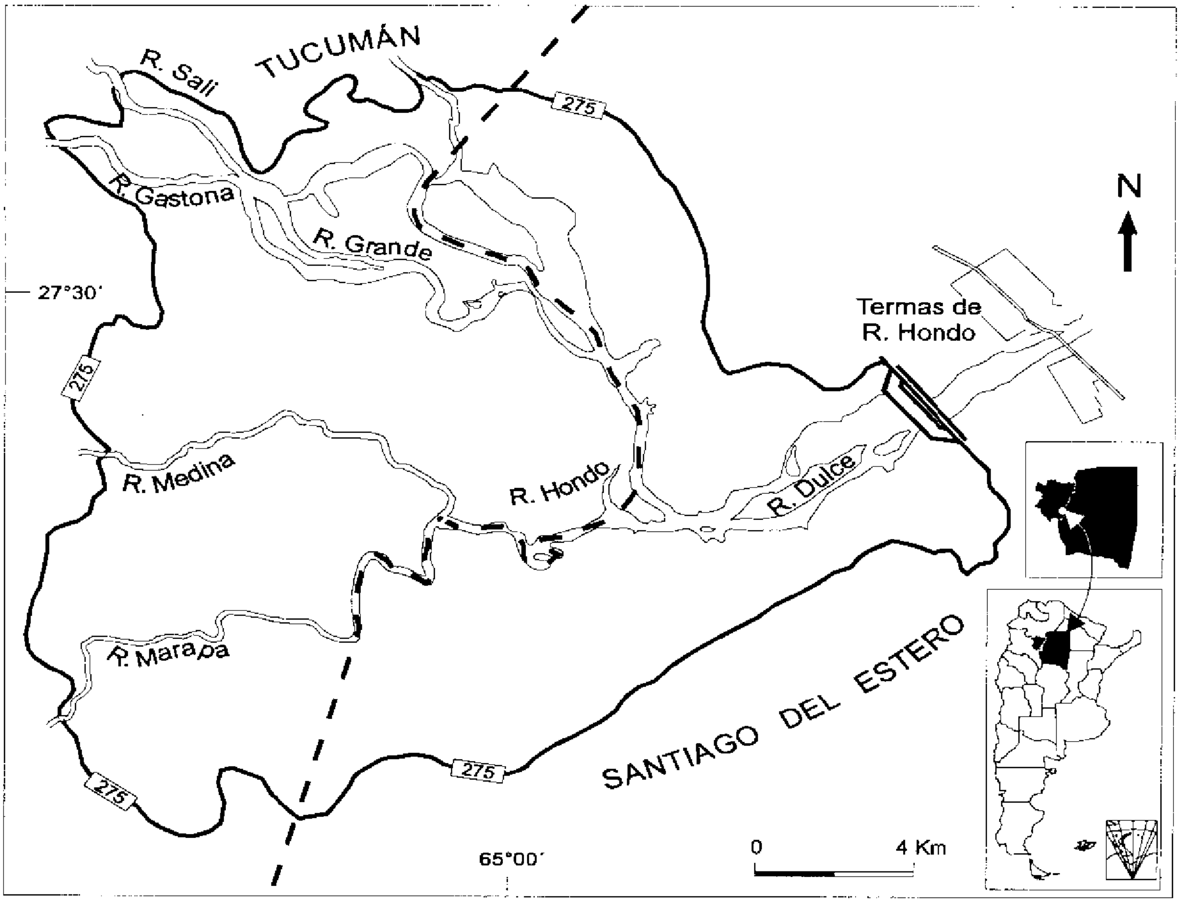

Figure 1 Rio Hondo Dam.

Parameter	Mouth Of Tributaries	Integration Zone (Limnetic)
Secchi (cm)	0, 09 – 1.47	0.3 – 1.9
PH	5 - 7.5	6.8 – 7.7
NO_2 mg l^{-1}	0.1 – 0.3	0.01 – 0.3
NO_3 mg l^{-1}	0.01 – 405	0 – 121
NH_4 mg l^{-1}	0.2 – 5.2	1 -1.2
PO_4	0.4 - 3.74	0.9 – 3
Total P mg l^{-1}	4.1	0.4 – 0.8
Chlorophyll "a" (average)	0.41 – 24.69μg/l	0.85 – 33.69μg/l
OD mg l^{-1}	0 – 8.6	7.6 – 9.1
DBO mg l^{-1}	3 – 1220	3.5 – 92
Total solids	274 – 4 22	63 - 666
Total coliform bacteria (average) NMP/100 ml	1.8 – 6.5	1- 3.5
Bacteria (average) NMP/100 ml	1.5 – 5.2	1 – 3.2

Table 1: Some physicochemical variables and bacteriological (Romero *et al*, 1997, Tracanna *et al.* 1994).

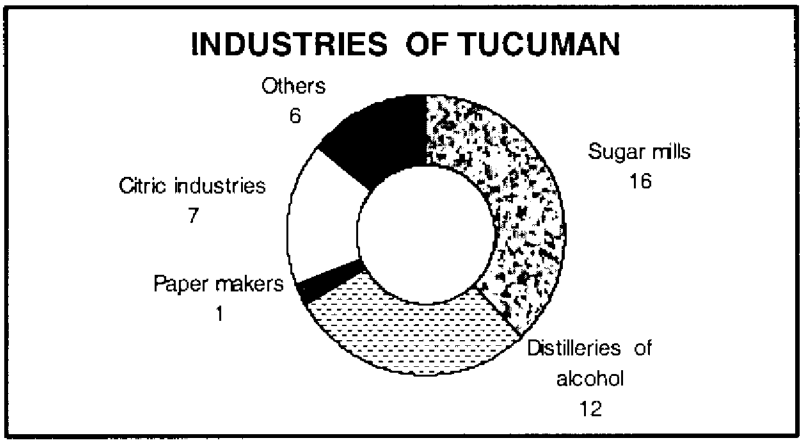

Figure 2: Industries (Environmental Reparation of Province, Tucumán, Argentina)

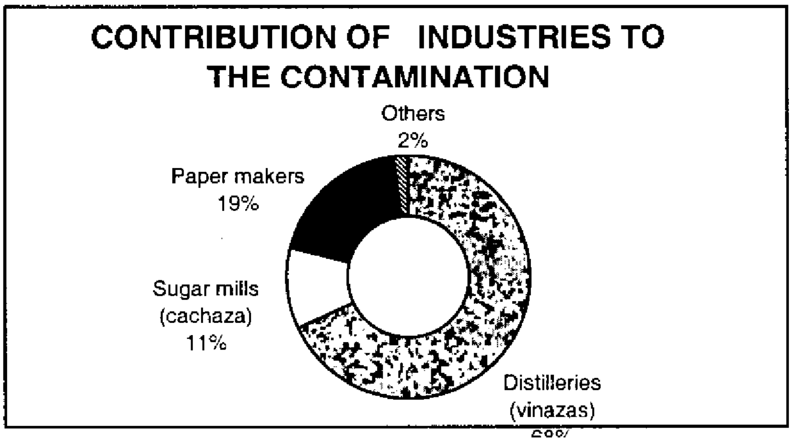

Figure 3: Contribution of industry's type to the contamination

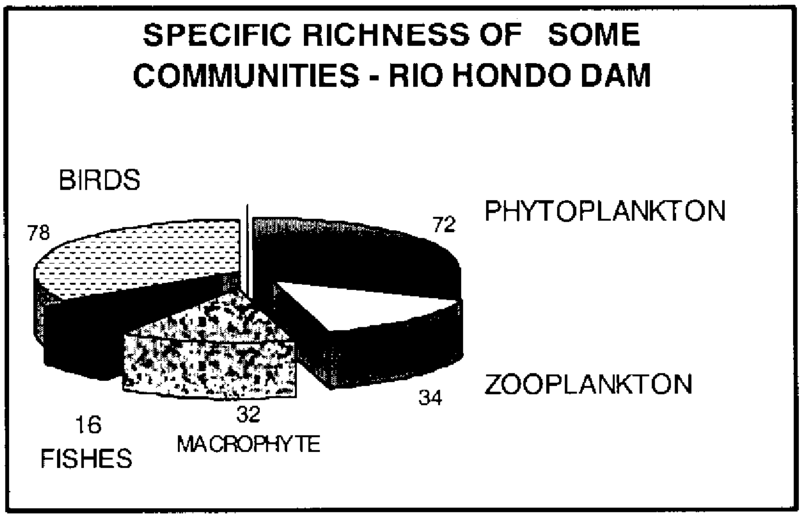

Figure 4: Specific richness of communities

Ayui Reservoir: a joint venture for water management

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Abstract

Design and environmental studies, in the framework of Provincial Law 5067/96, are carried out by a consortium of agricultural producers (COPRA S.A. and others UTE) lying adjacent to Ayui River, close to the city of Mercedes, Corrientes Province, Argentina. The project is compared against the alternative operational mode presently used in the region, i.e., small dams in the upper zone of the tributaries managed by a single producer.

A description of the project and a quantification of the most significant negative and positive environmental impacts are included. The affected ecosystem is also described. A diagnosis about the evolutionary trends of environment, including the effects of human activities is made. Mitigation measures taken into account from the very beginning of the design process and those recommended as a complement are described. Finally, the recommended environmental management plan is briefly introduced.

Keywords: Risks-Dams-Operation-Impact-Management

Resumen

Se presentan el proyecto y los estudios ambientales de la *Presa de Embalse Ayuí*, desarrollados de acuerdo a los términos de la Ley Provincial N° 5067/96, y emprendidos en forma conjunta por un consorcio de establecimientos agropecuarios (COPRA S.A. y otros UTE) ribereños del arroyo Ayuí, en la zona de la ciudad de Mercedes, Corrientes, Argentina. Se lo compara con las alternativas implementadas hasta el momento en la región, consistentes en pequeños embalses en cabeceras de arroyos, manejados unilateralmente por los productores.

Se incluye una descripción del proyecto y una cuantificación de sus impactos ambientales negativos y positivos más significativos. También se describe la porción de ecosistema intervenida por el proyecto. Se efectúa un diagnóstico en cuanto a las tendencias de evolución observadas, tanto en el medio natural como en lo que hace a la intervención antrópica. También se describen las medidas de mitigación que fueron incorporadas desde el inicio del diseño de la obra, así como las recomendadas como complemento. Por último, se esboza el plan de gestión ambiental recomendado.

Palabras claves: Riego; Presa; Operación; Impacto; Gestión

A. Introduction

Copra S.A., Pilagá S.A., Estancias Santa Clara y Yuquerí S.A., Heptagro S.A., Tupantuva S.A. and *Ayuí S.A.*, companies that undertake agribusiness in the Province of Corrientes, Argentina, have jointly developed a project for the design and construction of a dam on the Arroyo Ayuí Grande (Fig. 1), close to its confluence with the Miriñay river. The purpose of this project is irrigation for rice production. An area of approximately *20.000 hectares* will be developed for irrigation in successive stages. The reservoir will have a surface area of 11.680 ha, an overall length of 25 km and a live storage of 206 hm^3. Pumping stations and a channel distribution system will be used for irrigation water distribution.

B. Description of the works

The project includes the following items:

a) A homogeneous earth *dam* , with rip rap slope protection on upstream and downstream slopes The length of the dam is 1650 m, the maximum height of the embankment is 13 m and the average height is 7 meters. The elevation of the crest of the dam is 62.50 meters IGM.

b) A *bottom outlet* with discharge control by means of 3 plane gates. The maximum discharge is 70 m^3/s. These gates will allow the outflow of a minimum discharge of 5 m^3/s to the ecosystem downstream of the dam (this is not guaranteed at present), and the control of the level of the reservoir. Also the bottom outlet gates allow the partial emptying of the reservoir in case this should be required for maintenance and/or the construction of auxiliary works.

c) A *spillway channel* for flood discharge when the reservoir level exceeds elevation 60 meters IGM. The flow from the spillway channel is discharged directly to the Miriñay river. This channel is excavated directly in a natural saddle formation on the left bank topography upstream of the dam closure. The discharge capacity of the flood spillway is 450 m^3/s. This is the required discharge capacity that corresponds to a 770 m3/s peak of the inflow hydrograph (see Figure 3).

C. Geography

On a regional scale, the works are located in the "Gran Región Oriental", and the subregion is known as the "Región de los Malezales del Iby-Baí". The project is located on the arroyo Ayuí Grande in the Ayuí basin. This basin has a surface area of 265.000 ha (see Figure 2). The ecosystem of the dam and reservoir area can be described as relatively low lying lands subject to flooding. The vegetation and fauna are adapted to seasonal and long term flooding.
The main economic activities in the region are cattle rearing on natural pastures, and more recently the development of rice cultivation. The latter implies the transformation of natural ecosystems to agricultural land, the removal of the natural vegetation in the cultivated areas, and also the modification of natural drainage patterns due to the modification of water courses and the construction of dams. The drainage system is also modified due to the irrigation channel system.

D. Water Use

The source of irrigation supply is surface water, which at present is used by impoundment in the headland areas of secondary streams. From these storage areas and from direct pumping from streams, water is distributed. The proposed scheme introduces two significant changes in the current modus operandi, as indicated below:

- Storage is shared in one large impoundment area, replacing the requirement for a large number of smaller works.

- The proposed reservoir is located at the outlet of the stream basin, and only partial use is made of the resource. A major proportion of the runoff volumes is discharged downstream of the works. This is a different approach to the existing impoundments in the headwaters of the streams, which are generally designed to provide total regulation of the flow in the watercourse downstream of the embankment.

The *alternative approach* to these works would be the continuation of the current impoundment strategy, that is, the *construction of additional dams in the upstream areas of the secondary streams*, possibly in a series system (within the limits imposed by water yield), and an increase of direct withdrawal from the main watercourses. The main channels are the arroyo Ayuí Grande and the Miriñay river (in accordance with the availability of water).

E. Environmental Impact

In the following table the principal environmental impacts of the proposed works and their alternatives are listed. Also it is indicated whether said impacts are positive or negative as well as the better environmental performance of works alternatives. A short explanation of each of the impacts is given below:

a) *Changes to the flow regime of the Miriñay river:* The proposed reservoir will attenuate and delay flood peaks due to storage effects. This effect would be much smaller in the case of the alternative works, due to the location of the dams in the basin and the smaller reservoir volumes.

b) *Water withdrawal from the Miriñay river:* The water withdrawn from the reservoir for irrigation is a water loss for the Miriñay river.

c) *Discharge reduction in the controlled watercourse:* the planned works guarantee a minimum discharge of *5* m^3/s, to be discharged through the bottom outlet gates. This amounts to *58%* of the volume of the impounded waters, and between *17* and *27%* of the flow volume of the Ayuí Grande. The water quality conditions are more than adequate. Given that during a large part of the time, inflows to the reservoir will be larger than the storage capacity, the outflow from the Ayuí Grande dam will frequently be of a magnitude larger than the minimum guaranteed discharge and less than 70 m^3/s (twice the mean annual flow), which is the maximum capacity of the bottom outlet. On the other hand the impoundments in the headwater areas of the smaller streams the dams tend to retain the major part of all runoff and only the minimum legal required (ecological) discharge is released. That is *5%* per annum of the impounded volume.

d) *Permanent flooding of dry land:* In the case of the planned works, the major part of the area to be flooded are existing swamps and flood plains (esteros y bañados), which are extremely common in this eco-region. The vegetation which develops in these areas are reeds, "pirizales" and formations of rooted or floating vegetation (such as water hyacinth) which are not exclusive to the Ayuí basin. The same type of vegetation is found in many basins, which implies that no unique ecosystem will be lost in this case. If the water surface area of the reservoir (11.680 ha) is compared only with the existing "Esteros del Iberá" surface area (1.200.000 ha), the former amounts to less than 1%. In the case of the alternative development, although the sum of the surface areas of the impoundments would be smaller than that of the proposed reservoir, a significant part of this area would be made up of high lands of a greater value for agriculture. On this basis the negative impacts of both development strategies is considered equivalent for both cases.

Comparison of the environmental "performance" of the projected works and the alternative works

Impact	***Type***	***Best environmental performance***
Changes to the flow regime of the Miriñay river	Negative	Alternative
Water withdrawal from the Miriñay river	Negative	Alternative
Lowering of the discharge of a certain stream	Negative	Projected
Permanent flooding of dry lands (not wetlands)	Negative	Comparable
Potential eutrophication of impounded waters	Negative	Alternative
Flood abatement in the Miriñay river	Positive	Projected
Increase of rice production In the province	Positive	Projected
Increase of local employment in the area	Positive	Projected
Integrated water management of the basin	Positive	Projected

e) *Potential for eutrophication of impounded waters:* the proposed works will receive the total runoff and sediment yield of the whole Ayuí Grande basin , with the nutrient load resulting from the fertilization of the agricultural lands. On the other hand in the case of the alternative development the impoundment areas are smaller and the sub-basins have a lower percentage of agricultural lands.

f) *Flood abatement in the Miriñay river:* The proposed reservoir will reduce the flood peaks of the Ayuí Grande and will therefore also reduce the flood levels and maximum flooded areas in the Miriñay river. In the case of the alternative development the flood abatement due to the water impoundments will be of low significance due to their location in the basin and impoundment volume.

g) *Increase in provincial rice production:* Due to the size of the project the increase of agricultural production will be larger and faster than in the case of the alternative scheme. The increase in production and the socio- economic effects of the project are the main positive impacts of the project.

h) *Increase in local employment:* Due to its scale the proposed project will generate a greater number of permanent and temporary work opportunities, than in the case of the alternative scheme.

i) *Integrated management of the basin:* The projected works will in fact require the joint water resource management of the reservoir waters. The alternative scheme would be developed following the existing method of individual ownership and management of the water impoundments. The joint management will create a management scenario where more rational and balanced management solutions will have to be agreed between the parties. These are precisely the conditions required for a joint management of water in the basin.

The result of this analysis is that the positive environmental impacts of the proposed development are clearly greater than those of the alternative scheme. In the case of the negative impacts the proposed development has greater negative impacts in relation to the change of the flow regime, the withdrawal of water from the río Miriñay and the potential risk of eutrophication of the impounded waters.

The quantification on the effects of the changes in the flow regime and water withdrawal from the río Miriñay, due to the proposed works, was undertaken with a reservoir operation model. Simulations were made for four different characteristic hydrologic years. The flood storage effect of the reservoir is not very significant, due to the fact that it is used mainly for irrigation water storage. It should be clearly noted that this is a result of the reservoir being used for water storage and not for the detention of flood flows. The effects flow attenuation due withdrawal for irrigation is more significant. The loss of flow volume of the Miriñay river at Paso San Roquito, has been computed to be slightly less than 20% of the annual flow volume in the case of a mean flow year. In the case of a low flow year the withdrawal volume can be as large as 35%. On the other hand in a high flow year the weight of water withdrawal may be less than 10%. These water withdrawals do not compromise the basic ecological characteristics of the river. Also these withdrawals do not interfere with the water volumes required by downstream users in mean and high yield water years. It must be added that in low water years the project provides a low flow discharge of 5 m^3/s, on a continuous basis during the growing season, which would not be the case in the no project scenario. This is a net benefit for downstream users.

In relation to the risk of eutrophication of the reservoir (see Fig. 4), a simulation was made. It was concluded that the total phosphorous concentration in the reservoir waters, resulting from the inflow of phosphorous from the basin will be about 0.55 μg/l. This concentration level is well below the critical value for eutrophication which is 40 μg/l.

The final conclusion is that the negative environmental impacts in relation to changes in the flow regime, water withdrawal from the río Miriñay and the potential risk of eutrophication of the impounded waters can all be assimilated by the system, *therefore this justifies the choice of the projected works which are the most beneficial from an environmental point of view.*

In order to complete the comparison between the proposed works and their alternative it is appropriate to make an economic evaluation, at least at a primary level. Then economic analysis can be an indicator of environmental costs, since the cost of the project is related to the volume of materials and works required to achieve a certain effect. In order to compare the cost/benefit ratios for the two schemes, an analysis was made of the of existing impoundments within the properties of the members of the joint venture who already are active in the Ayuí basin. If the ratio between the surface area of the reservoir (which is an indicator of the volume of water stored for irrigation) and the length of the dam (which is an indicator of the cost of the dam) is used as an economic index, it is concluded that the proposed works is clearly the most efficient alternative. The proposed dam is 6 times more efficient that the best existing impoundment (Ita-Caabó), *14 times* more efficient than the Don Antonio impoundment and approximately *24 times* more efficient than the Bay, Aguaceros and Caneto impoundments. These comparisons are sufficient to prove that, by following the current pattern of works it will not be possible to obtain an efficiency ratio comparable to that of the proposed reservoir. This analysis indicates that the economic cost (and consequently the environmental cost) of building many small dams will be significantly greater than the proposed joint scheme.

With reference to socio-economic aspects, the proposed works will allow a greater and faster increase in agricultural production than the alternative (currently applied) system. Therefore it is concluded that the proposed joint scheme will create more permanent and temporary employment than the alternative scheme.

To summarize the detailed environmental impact analysis, the only severe negative impact of the proposed reservoir is related soil micro fauna (4). In the case of positive impacts, the net impact on agricultural production (including the related factors such as social and economic impact) are the most significant. In the case of road infrastructure and social acceptance of the works the positive impacts are significantly high. If the net impacts are considered by environmental category it is observable that the largest negative impact lies in the field of water resources, however the level is considered moderate (3). There is also a moderate positive impact in the field of the economics of the project. The net impacts on the natural and human environment are acceptable (2), however they are negative and positive respectively. Finally the overall net impact of the project is neutral, due to the balance of positive and negatives aspects.

In conclusion, the balance of integrated environmental effects show very few strong negative impacts, and the positive impacts clearly compensate for the negative impacts.

The project does not create any threat to biodiversity as described by the key aspects identified by the *World Resources Institute*, which are:

- No destruction, degradation or fragmentation of habitats utilized by species in danger of extinction and it does not involve the exploitation of any of these species.
- It does not involve the use of resources nor does it introduce disturbances in protected areas.
- It does not involve the transformation nor degradation of primary forests.
- It does not introduce new species nor variants of existing species.
- It does not reduce the availability of land for local communities.
- It does not produce any degradation nor interference on the ancestral domains of indigenous groups.

F. Environmental design parameters

As from the start-up of this project environmental aspects have been taken into account in the design. Consequently the following mitigation measures have been considered in the design stage :

- A guaranteed minimum discharge of *5 m^3/s* discharged through the bottom outlet will ensure adequate environmental conditions downstream of the works. Given that frequently the inflow discharge cannot be stored in the reservoir, the discharge to the arroyo Ayuí Grande will be higher than this minimum value and will reach a maximum of 70 m^3/s (the design discharge of the bottom outlet which is approximately twice the mean annual discharge).

- In the case of dry water years, during the irrigation period, the reservoir will supply a base flow of 5 m3/s to the arroyo Ayuí Grande. This would not be the case without the reservoir, and this is clearly a beneficial effect for water users downstream of the project.

- The filling of the reservoir will only commence when inflow is in the order of 100 m^3/s (these are hydrographs associated with weekly rainfall of approximately 100 mm). In this manner a large initial rise of BOD is avoided, and consequently the concentration of oxygen will remain above the limit value for aquatic flora and fauna.

- Given that the borrow pits are located inside the reservoir area, there will be no morphology changes in the landscape.

- The erosion control measures downstream of the outlet works will avoid local scour problems.

The flora and fauna studies recommend the setting up of a "buffer zone" or "periphery reserve area" of 100 to 200 meters width along the outside perimeter of the reservoir (at elevation 60 meters). This area will serve as a corridor which will avoid any discontinuities between habitats, and in this manner will sustain and regenerate the existing ecological and wildlife systems. Also this will act as a stabilizing factor on the edge of the lake and will assist migration of fauna within the limits of the dam and reservoir area. It is considered that human access to the buffer zone should be restricted, and a inspection path should be included as a fire guard. The path should be designed for use on horseback or light vehicles, and access of livestock is disallowed. This area should be defined before the reservoir is filled and it should be planted to a certain extent with native species in order to compensate for the loss of some woods on islands and on the bunds and banks long the stream channels.

G. Environmental risks

A direct risk of the works is a structural failure (the consequences of a dam break scenario were made). The recommendations to manage this risk are as follows:

a) ***Design:*** The slopes of the earth dam have been chosen to avoid slope failure, and to ensure that controlled seepage takes place within the body of the dam with exit velocities that ensure no erosion of fine materials will occur. Also the upstream and downstream slopes are to be protected against erosion due to wave action and rainfall. Both the foundations and the body of the dam have been designed to minimize the possibility of settlements.

b) ***Construction:*** A rigorous inspection of the construction stage of the works is indicated by means of onsite inspection and laboratory tests, in order to ensure that the design procedures are applied in practice.
c) ***Continuous Monitoring:*** Sensors will be installed in the dam in order to provide timely indication of potential problems.
d) ***Dewatering capability:*** In the case of the need to undertake repairs, maintenance or for the construction of auxiliary works, an adequate bottom outlet is to be constructed. In this case the bottom outlet has a design discharge of 70 m^3/s (approximately twice the mean flow of the stream).

The risk of the development of *new centres of water related illnesses* cannot be disregarded. The recommendation in this case is to monitor the illnesses of the staff who are working in the new micro environment, in order to obtain early warning of any cases of infection arising from vectors located in the reservoir.

Although in principle no effects of the works are foreseen on the *composition of the local habitats and ecosystems*, this should be verified by consistent monitoring of the flora and fauna. Also, although there is relative certainty that there will not be high levels of contamination in the impounded waters, it will be necessary to monitor the water quality in the reservoir to confirm this prediction.

H. Environmental management Plan

The main components of the proposed *environmental management plan* are the following:

- Environmental Control Plan.
- Monitoring Plan.
- Operation Plan of the reservoir (water level control).
- Contingency Plan.
- Social Communication Plan.

The environmental control plan is designed to ensure that the mitigation measures for negative impacts of the project are complied with effectively. The required activities are as follows (for each stage of the project):

I Construction stage:

- o Water quality control of the of the Arroyo Ayuí Grande downstream of the dam at Paso San Roquito on the río Miriñay. Location of borrow pits, wind erosion and resulting gully or rill erosion, damage due to heavy equipment (soil compaction, excessive or unnecessary vegetation removal, spills), air quality and noise pollution at the works site, and the behaviour of local fauna.

II Filling stage of the reservoir:

- o Control of initial filling of the reservoir for inflow hydrographs wit peaks larger than 100 m^3/s, of minimum outflow discharge of (5 m^3/s) to the Arroyo Ayuí Grande, the water quality in the reservoir, the structural stability of the dam, the water level in the reservoir, and the behaviour of local fauna.

III Construction stage of pumping and water distribution system:

- Control of wind erosion of soils, stability of embankments, damage due to use of earth moving and other equipment

IV Soil preparation stage for sowing:

- Control of wind erosion of soils, stability of embankments, damage due to use of earth moving and other equipment (unnecessary soil compaction, spills).

V Operation stage of the dam:

- Water quality control, minimum release discharge (5 m^3/s) to the Arroyo Ayuí Grande downstream of the dam, discharge at Paso San Roquito on the Miriñay river, possible local scour, sedimentation in the reservoir, structural stability of the dam, stability and maintenance of the flood spillway channel, the distribution of aquatic fauna, fito and zooplancton upstream and downstream of the dam.

VI Sowing and harvest stage

- Control of wind erosion of soils, stability of embankments

The monitoring plan is directed to supply data and information on the following components of the system: water balance, sedimentation, water quality, the biota, dam safety.

The following databases are required:

1) Water: rainfall, water levels, gate positions, outflow discharge, etc.
2) Sedimentation: cross sections of the reservoir, bathymetric data, grain size distributions, etc.
3) Water quality: temperature, ph, conductivity, transparency, turbidity, OD, Nutrients, Phosphorus total, BOD or COD, total coliforms , total suspended solids, poisons from plague control, heavy metals, etc.
4) Biota: plancton, water plants, benthic organisms, chloroform, ictiofauna, local land fauna.
5) Dam instrumentation: pore pressure, total pressure, ground settlement.

The following operation rules were developed for the simulation of water flow control from the reservoir:

1) The pumped discharge is set at the required value for irrigation and the minimum release discharge (5 m^3/s) is complied with.
2) If the water level drops below the minimum level (57,5 meters IGM), the irrigation discharge is reduced. If this is not sufficient irrigation discharge is stopped, the minimum release is maintained and the reservoir volume is allowed to drop below the minimum level.
3) If the level rises above the normal operation level (60 meters IGM), the outflow discharge is increased up to a maximum of 70 m^3/s which is the design discharge. If this is not sufficient to maintain the operation level, the reservoir level will increase and outflow through the flood spillway will commence.

The two scenarios for dam break are as follows:

- A flood larger than the design flood occurs
- Structural deficiencies set the dam at risk

For each of these two scenarios alert criteria and guidelines for contingency plans have been developed.

The social communication plan has two components:

- o Channels of communication with the relevant authorities (DRNGA and ICA) during the construction stage and the operational stage of the works
- o A second line of communication with the local press media in order to provide adequate information of stages of the works, production and environmental results of the project.

The environmental management of the project is made up of three main responsible parties: management, operation and communication. The management will be undertaken by a centralized unit, with technical responsibility for the reservoir operation. The responsibility for communication with authorities has two levels: a political level and a technical level and this will be matched by the corresponding responsibilities within the joint venture. Communication with the media will be handled by staff with adequate training and experience in this field.

In conclusion it can be stated that the project is sustainable from a environmental point of view. The elements of the environmental management plan which has been presented are considered to fairly simple and should be an effective means to detect possible divergence from the scenarios foreseen during the design stage of the project.

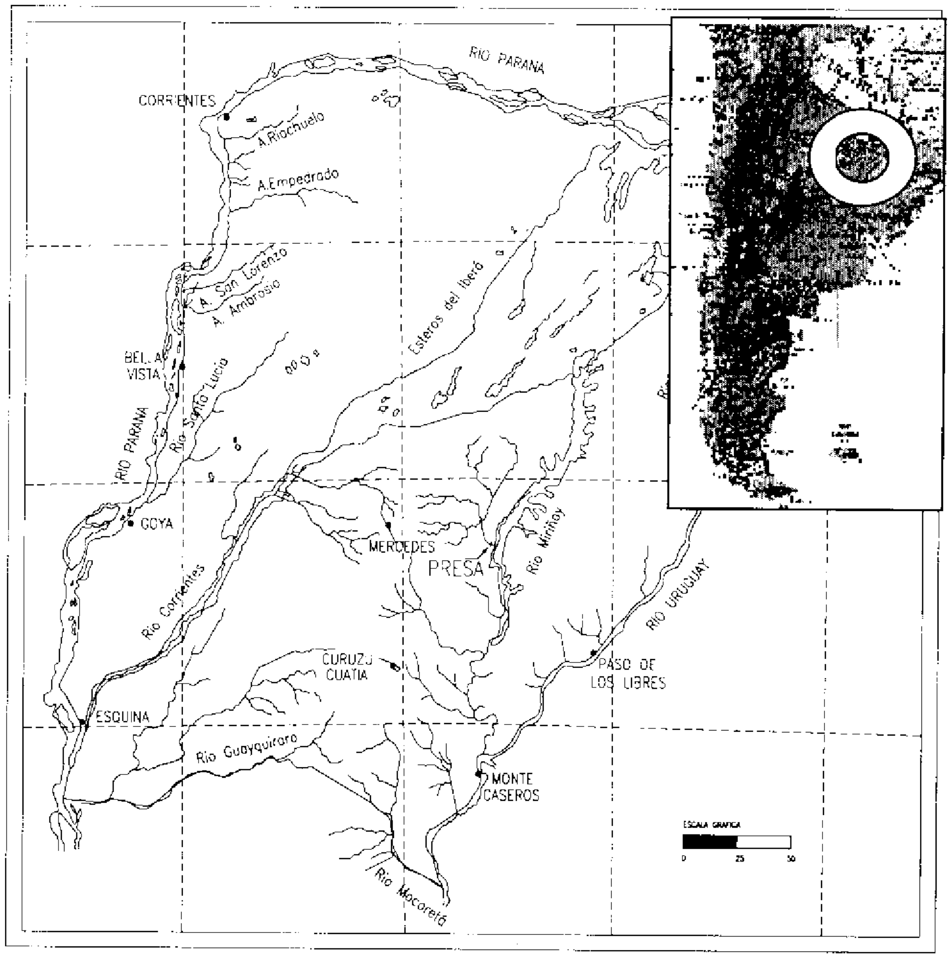

Figure 1: Location map of the Ayuí project

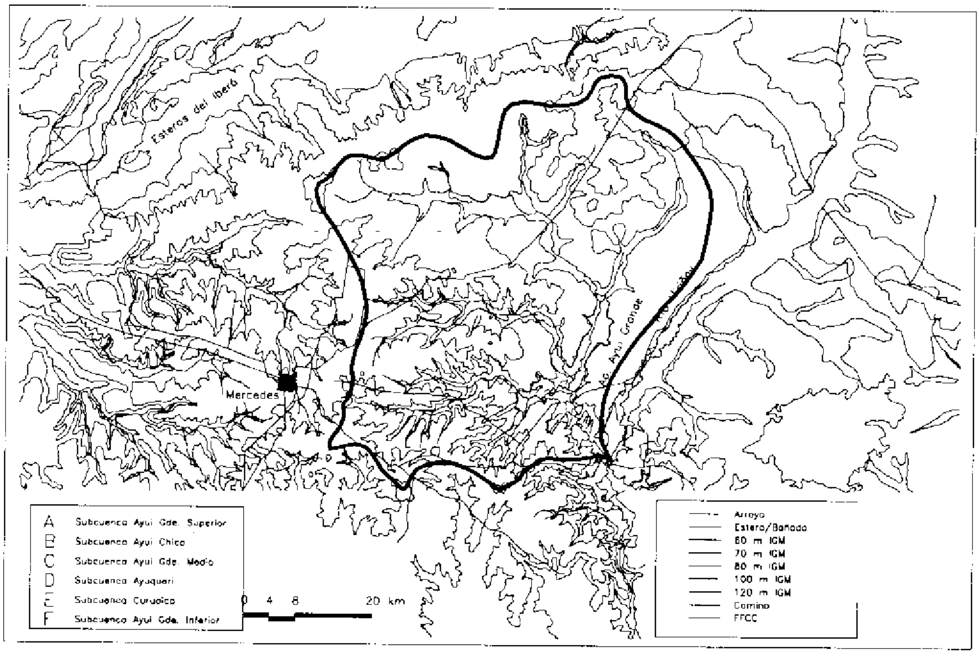

Figure 2: Arroyo Ayuí basin and reservoir

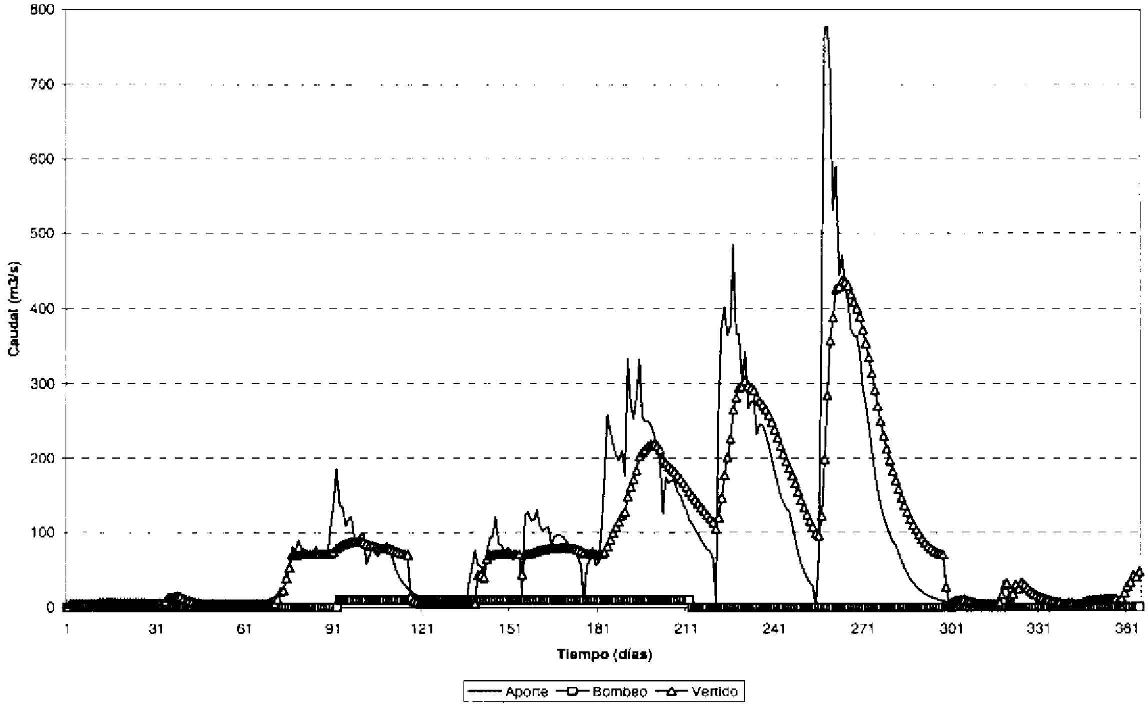

Figure 3: Regulation of the design flood hydrograph (water year 1997-1998)

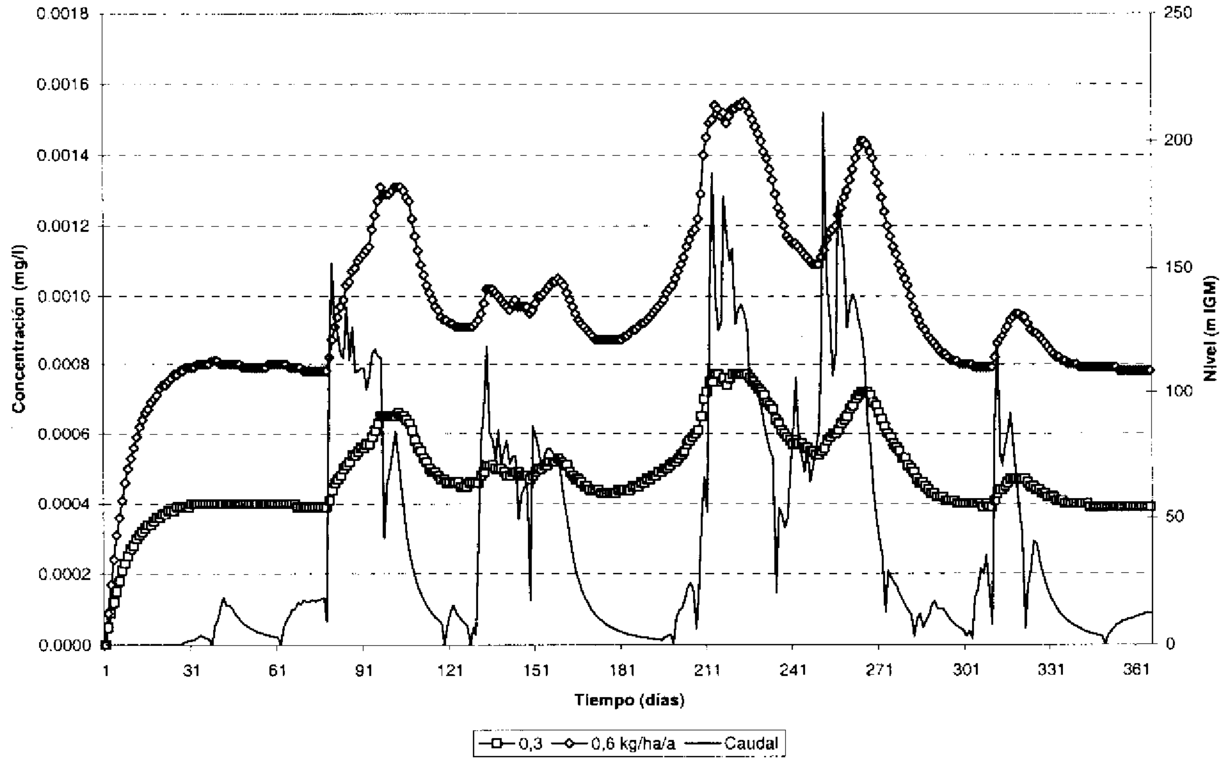

Figure 4: Eutrophication during reservoir operation

Funcionamiento de los Sistemas de Transferencia para Peces en Represas de la Baja Cuenca del Plata: Resultados y Perspectivas

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Resumen

Las especies migradoras constituyen un rasgo característico de los grandes ríos de Sudamérica. Estas especies difieren en varios aspectos ecológicos importantes de las del hemisferio norte, para los cuales se han diseñado y construido la mayoría de los sistemas de transferencia de peces del mundo. En la baja cuenca del Plata, la represa de Salto Grande posee un sistema de esclusas Borland, mientras que en la represa de Yacyreta se ha construido dos elevadores para peces. Los resultados observados muestran que los sistemas de la baja cuenca, no han favorecido el pasaje de especies que migradoras importantes y que constituyen la base de las pesquerías regionales. Por el contrario, han privilegiado la transferencia de especies de pequeño porte, distribución ubicua y escaso interés pesquero. La baja eficiencia para las especies migradoras obedece a problemas estructurales y funcionales de diseño. En Yacyreta, ello genera un elevado costo de transferencia para cada pez migrador. La piscicultura de repoblamiento para recuperar los stocks de peces migratorios en la alta cuenca (Brasil), no ha dado los resultados esperados por lo que resulta indispensable asegurar la construcción de sistemas mas eficientes. Los futuros pasos para peces en la cuenca, deberán diseñarse a partir de información bioecológica específica obtenida de manera apropiada, e integrada con criterios ingenieriles e información ambiental.

Palabras clave: Transferencia de Peces; Presas; Cuenca del Plata

Abstract

Migratory fish species constitute a main feature in large rivers of South America. These species present different ecological characteristics from their counterparts in the North Hemisphere, for which most of the fishway systems in the world have been developed. In the lower De la Plata River basin, Salto Grande dam has two Borland locks and two fish elevators were installed in Yacyreta dam. Results showed that such systems had limited success for transferring large amount of important migratory species, which are the basis of the regional fisheries. In turn, these systems primarily passed small non-migratory species, with ubiquitous distribution and without fishery importance. Low efficiency of fish passage facilities for migratory species can be attributed to functional and structural design limitations. In Yacyreta, low performance of fish elevators implies high costs for transferring migratory fishes. Stocking policies developed in the upper basin (Brasil) failed to restore migratory stocks, implying that sound fishway designs are required. Future fishways in the basin should be developed based on an integrated approach, that includes specific bioecological information obtained in an appropriate way, engineering criteria and suitable environmental information.

Key words: Fish facilities; Dams; La Plata River Basin

A. Introducción

La construcción de represas ha experimentado un importante crecimiento en todo el mundo en los últimos 50 años. Hasta 1998, en Sudamérica, se contabilizaron 979 obras, estando el 66 % localizadas en Brasil (World Commission on Dams, 2000). El impacto de las represas, en el caso de la ictiofauna, se advierte tanto aguas arriba como debajo de su emplazamiento. En los embalses se modifica la estructura de la comunidad original del río y se pierden hábitats para la reproducción, el desove y la cría de larvas y juveniles. Aguas abajo, se altera el régimen hidrológico, el transporte de sedimentos, la concentración de gases, la temperatura y se modifican los hábitats que utilizan los peces orientarse en sus migraciones (Tundisi *et al.*, 1993). La mayoría de las represas en Sudamérica carece de pasos para peces, lo cual constituye un serio impedimento para los desplazamientos de las especies migradoras y favorecen su declinación.

En este trabajo se considera el funcionamiento general de los sistemas de transferencia de peces instalados en represas de la baja cuenca del Río de la Plata, con relación a su contribución para mitigar el impacto de estas obras sobre las especies migradoras de mayor importancia. Se presenta una síntesis de los resultados disponibles y se detallan algunas de las limitaciones de funcionamiento observadas, realizándose además recomendaciones para optimizar su diseño a partir de integrar información bioecológica específica integrada aspectos ambientales relacionados con la distribución de los peces.

B. Los peces migradores de los grandes ríos de Sudamérica

Las especies migradoras constituyen un rasgo característico de las comunidades de peces de los grandes ríos de Sudamérica, sobresaliendo por su importancia en la cuenca del Plata *Prochilodus lineatus* y *P. scrofa* (sábalo), *Salminus maxillosus* (dorado), *Leporinus obtusidens* (boga), *Luciopimelodus pati* (pati), *Pseudoplatystoma coruscans* (surubi), *P. fasciatum*, *Piaractus mesopotamicus* (pacú), *Paulicea lutkeni* (manguruyu), etc. Estas especies realizan varias y repetidas migraciones a lo largo de su ciclo de vida (e.g. Bayley, 1973; Bonetto, 1963; Bonetto y Pignalberi, 1964; Bonetto *et al.*, 1971; Bonetto *et al.*, 1981; Tablado y Oldani, 1984; Delfino y Baigún, 1985; Espinach Ros *et al.*, 1998). Las migraciones de peces adultos.superan por lo general los 200 km (Welcomme,1985), y a diferencia de lo que se observa en los salmónidos, pueden ocurrir en ambas direcciones (Petrere, 1985). En la alta cuenca, se ha observado que la interrupción de estos desplazamientos genera la desaparición de los stocks y el colapso de sus pesquerías (Machado, 1976, Milward de Andrade, 1976).

Las especies migradoras de los grandes ríos de Sudamérica difieren en varios aspectos importantes a las del hemisferio norte, en particular si se los compara con las características bionómicas de los salmónidos, para los cuales se han diseñado y construido la mayoría de los sistemas de transferencia d.' mundo. Entre las diferencias mas notables, se destaca la capacidad de realizar varias migraciones a lo largo del ciclo de vida, seguidas del desove (especies iteróparas) y la ausencia de procesos de smoltificación en los peces juveniles. La Tabla 1 compara ambos tipos de especies.

C. Características de los sistemas de transferencia para peces en la baja cuenca del Plata

A diferencia de los observado en la alta cuenca del Plata (Brasil), las represas construidas o planificadas en la baja cuenca (Argentina, Uruguay y Paraguay), poseen sistemas de transferencia o en todo caso, están previstos. Para Corpus (38 m), a construirse en el río Paraná, se propuso una combinación de escalones-tanques y elevadores (Castello, 1982).

Tabla 1: Características comparativas entre las grandes especies migradoras de ríos de Sudamérica y los salmónidos migradores (adaptado de Oldani, 1998 a)

	PECES	
CARACTERÍSTICA	SALMONIDOS	SUDAMERICANOS
Iteroparidad	Rara	Usual
Semelparidad	Común	Nunca
Anadromía	Común	Nunca
Nicho térmico	Esteno y de aguas frías	Euri y de aguas templado-cálidas
Hábitos reproductivos	Nidificación	Desove libre en aguas abiertas
Procesos de smoltificación	Si	No
Area de refugio y cría de juveniles	Cabecera de ríos	Lagunas de inundación, madrejones marginales
Migraciones activas aguas arriba de adultos	Si	Si
Migraciones activas aguas abajo de adultos	Raras	Frecuentes
Migraciones activas de juveniles	Si	No
Areas de desove	Ríos de bajo y moderado órden	Grandes ríos y sus tributarios
Homing	Muy especifico	Desconocido
Sensibilidad a bajos niveles de oxigeno durante las migraciones	Alta	Baja
Sensibilidad a cambios de nivel hidrológico y temperatura durante las migraciones	Alta	Baja

Para la represas de Paraná Medio (18 m) se había considerado un sistema de rejas-elevadores (Poddubnyi *et al.*, 1981), mientras que para Garabí (37 m), en el río Uruguay (37 m), se recomendó esclusas del tipo Borland (Boiry y Quirós, 1985)

En la represa de Salto Grande (30 m), localizada en el río Uruguay, se instaló un sistema de esclusas Borland, que operan desde 1984 y están ubicadas geográficamente en la parte central de río, con las entradas hacia el vertedero. Los peces para ser transferidos, primero deben ingresar a la cámara de acumulación situada a nivel del rió, atraídos por una corriente de llamada. Pasan luego a la esclusa propiamente dicha, donde son retenidos por la acción de una compuerta móvil. Mediante el llenado de la esclusa, los peces ascienden hasta alcanzar una cámara superior. Posteriormente, y mediante un sistema de compuertas se genera una corriente de agua en la esclusa que estimula el desplazamiento de los peces hacia el embalse (Delfino *et al.*, 1986).

Los sistemas de transferencia para peces de Yacyretá, por su parte, consisten en elevadores ubicados en los extremos de la central, y operan acoplados a un canal de atracción y de concentración de peces. Las entradas a los mismos se encuentran hacia la las turbinas. Actualmente funcionan dos de estos elevadores, pero existe capacidad de instalar dos mas adicionales. El elevador de la margen izquierda comenzó a operar en setiembre de 1992 y el de la derecha en julio de 1995. Los peces que se desplazan por el río aguas arriba son atraídos y guiados por una llamada continua hacia el sistema de transferencia. Al ingresar en el mismo, recorren el canal de atracción y ya cerca de los tanques elevadores, son obligados a ingresar a los mismos, mediante la operación de una reja concentradora. Cada elevador posee na capacidad de 15 m^3. Cuando los peces llegan al nivel superior, son transferidos a una báscula y posteriormente, a un canalón de descarga hacia el embalse.

D. Resultados Observados

Los escasos resultados disponibles de los estudios realizados en Salto Grande indican que en las esclusas ingresan hasta un máximo de 30 especies, de las cuales entre el 24 y el 30 % pertenecen al grupo de grandes migradores. Sin embargo, los ciclos de transferencias están dominadas por anchoitas (*Lycengraulis olidus*) y pequeños bagres (*Auchenipterus nuchalis*). Ocasionalmente y de manera irregular, entran al sistema sábalos, bogas y dorados de porte moderado, siendo muy rara la presencia de grandes silúridos como manguruyú y surubí (Espinach Ros *et al.*, 1997). Delfino *et al.* (1986) describieron las rutas de aproximación de los sábalos hacia la representa notando que se desplazaban por las orillas y atravesaban los flujos de agua turbinada, antes de ingresar a los cuencos de acumulación, o bien se desplazaban por el centro del cauce para concentrarse en la zona de vertederos. Otras especies como surubí y dorados respondían predominantemente a la atracción generada por las corrientes de agua turbinada (Figura 1a).

En Yacyreta, los únicos resultados disponibles del funcionamiento de los elevadores pertenecen a Oldani *et al.* (1988b), y abarcan el periodo de 1995 a 1998. Estos autores estimaron que el número de peces transferidos en 1995 fue de 1.212.376 (631 tm), en 1996 de 3.613.732 (1989 tm) y en 1997 de 1.973.121. Ello representó una media por transferencia que varió entre 220 y 350 peces. En los elevadores se detectaron 36 especies, lo que constituyó el 44 % de las especies capturadas aguas abajo mediante pesca experimental. Las transferencias estuvieron caracterizadas por la gran abundancia de bagre amarillo (*Pimelodus clarias*) que alcanzó un 73 % en número y 45 % en biomasa, y por armados (*Pterodoras granulosus*), con porcentajes del 12 y 25% respectivamente.

Entre las especies objetivo (grandes migradores de importancia pesquera), la mas abundante fue el sábalo que constituyó el 2.5 % del número de las especies transferidas. Es interesante notar que las especies objetivos representaron un 30 % de las capturas experimentales realizadas aguas debajo de la represa (Oldani *et al.*, 1998 b), lo que sugiere que las mismas arriban al pie de la represa, pero no ingresan masivamente en los sistemas de transferencia. Las tallas de los peces migradores que ingresaron a los elevadores estuvieron comprendidas entre 35 y 55 cm, lo que demuestra la presencia de ejemplares adultos y con comportamientos migratorio. Se estimó en base a registros acústicos practicados en el área adyacente a las entradas a los cuencos de acumulación, que la eficiencia de los sistemas de transferencia no superó el 1% y para todas las especies alcanzó casi un 2 %. Esta eficiencia es mucho menor que la presentada por Colin (1997), quien consideró un 7 %.

Las máximas concentraciones de peces en Yacyretá se observaron en áreas alejadas de las entradas a de los sistemas de transferencia sobre el antiguo cauce del río (Figura 1 b). En las otras dos zonas profundas (aguas abajo de la central-vertedero y en el canal de la esclusa de navegación) y en la porción inferior del área de estudio, se observaron bajas probabilidades de encontrar altas concentraciones de peces. En la zona de la central-vertedero los peces se distribuyeron próximos a la ribera izquierda y sobre todo el frente de obra. En este caso, los factores limitantes serían las altas velocidades de corriente generadas por el funcionamiento de la central, mientras que en el canal de la esclusa de navegación se debería a la muy baja circulación del agua.

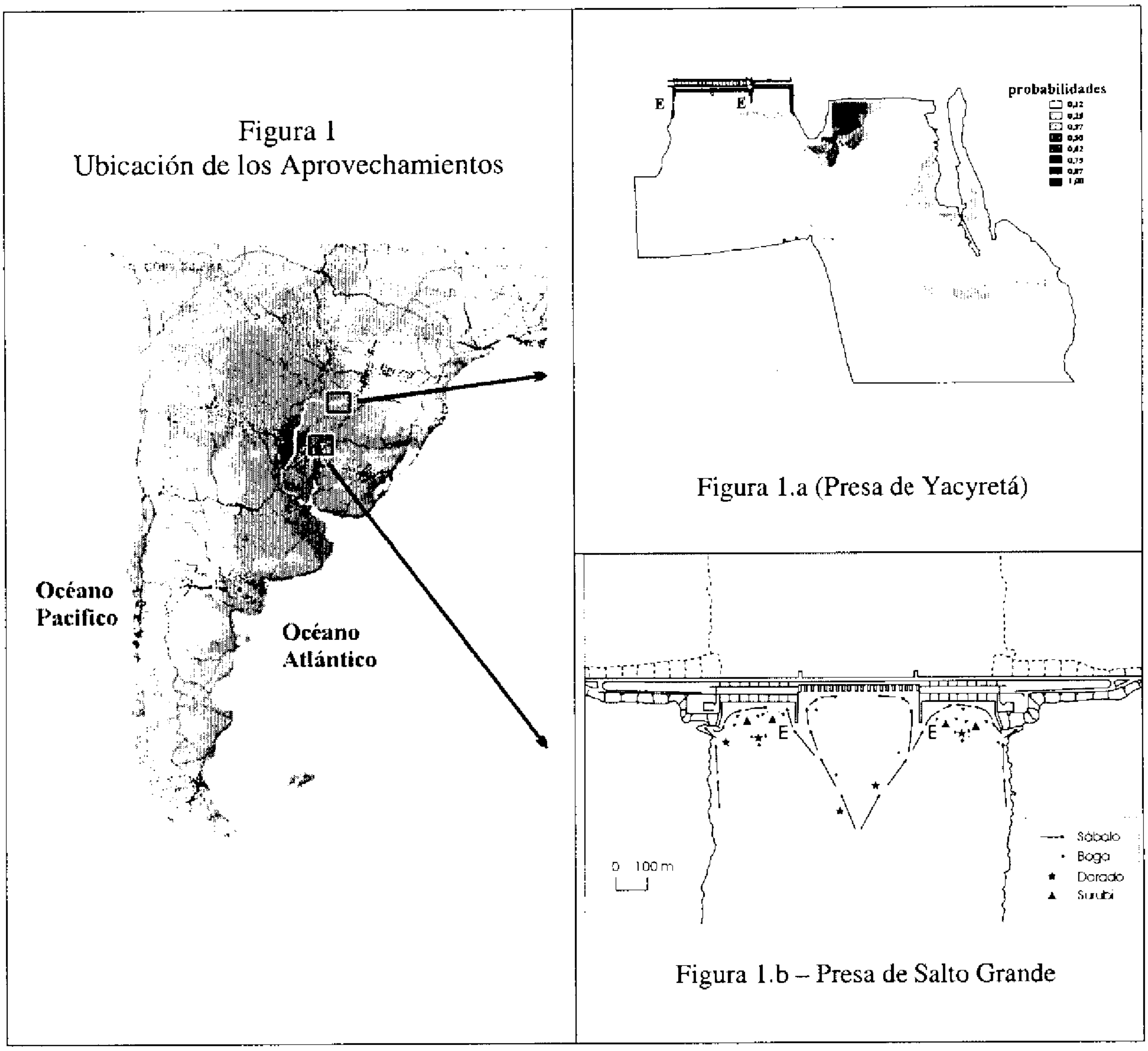

Figura 1: Localización geográfica de las represas de Yacyretá (A) y Salto Grande (B). A: Distribución de abundancia de peces aguas debajo de la represa en función de sus probabilidades de ser encontrados en un determinados ambiente. B: Distribución de diferentes especies migradoras aguas debajo de la represa (adaptado de Delfino *et al.*, 1986). E: escalas para peces

E. Discusión

El escaso éxito observado en la transferencia de peces migradores, de Salto Grande y Yacyretá debe ser considerado como un importante antecedente en del desarrollo de futuras represas. Bajo las condiciones de operación observadas, ninguna de las represas de la baja cuenca del Plata posee un funcionamiento adecuado para mitigar el impacto que representan estas represas. Ambos sistemas poseen diseños que han sido desarrollados para especies, que en algunos casos, poseen muy diferentes características ecológicas. El hecho que las entradas de los pasos para peces estén ubicados demasiado próximas a la obra, representa aparentemente una desventaja para los peces migradores de la cuenca del Plata, pero es considerado apropiado para salmónidos (Rochester *et al.*, 1984).

Las esclusas Borland operan con suceso en ríos de Escocia e Irlanda, y han sido construidos para permitir el pasaje de salmónidos anádromos (Clay 1995). Poseen como principal desventaja su dependencia de los niveles hidrológicos y una limitada capacidad de transferencia de peces. En Salto Grande, precisamente, se ha observado que la operación esta acotada a los niveles de restitución del río y el nivel del embalse. Por su parte, los elevadores para peces se utilizan mayormente en ríos de Rusia, para transferir peces de los géneros *Acipenser, Abramis, Clupea, Cyprinus, Coregonus*, etc (Pavlov, 1989). La eficiencia de estos elevadores, en el mejor de los casos, no ha superado el 10 %.

En la alta cuenca del Plata, los escasos sistemas de transferencia existentes son del tipo escalones-tanques, muy comunes en América del Norte y Europa. Parecen apropiados para permitir el ascenso de ciertas especies en represas de baja altura, idealmente no mayor a 10-15 m (Pereira de Godoy, 1985). En Cachoeria de Emas (rio. Mogi Guassu) se ha observado un pasaje continuo de bogas, sábalos y dorados (Pereira de Godoy, 1975), aún cuando su eficiencia real nunca ha sido efectivamente medida (Agostinho y Gomez, 1997). Estos sistemas, de todas formas, no resultan atractivos para los grandes silúridos.

La muy baja eficiencia notada en Yacyreta para transferir especies migradoras, obedece asimismo a limitaciones funcionales y estructurales que poseen estos sistemas. Un problema aparentes es que las entradas parecen estar localizadas muy próximas a los flujos originados por las turbinas, relativizando o minimizando así los efectos de la corriente de atracción. Con temperaturas de 25 °C y considerando una talla de 40 cm, por ejemplo, los peces ingresarían fácilmente a los sistemas utilizando velocidad de punta, pero dentro de un radio no mayor a 30 m de las entradas (véase Beach, 1984). Por su parte, los canales colectores se encuentran a 15 m sobre el fondo del río, lo que dificultaría el ingreso de los peces que se desplazan cercanos al fondo. A este respecto, se observó que cuando se realizaban tareas de mantenimiento en las turbinas, se advirtió que el manguruyu ingresaba masivamente en los tubos de aspiración (A. Fortuny, com, pers. 1997), siendo casi nulo su presencia en los sistemas de transferencia. Asimismo, los elevadores poseen una capacidad de transporte muy limitada, asociada al tamaño del tanque elevador en relación al tamaño de los stock migradores, y al número de ciclos diarios que puede realizar. Cuando en los elevadores ingresan especies con espinas (bagres), otras especies sufren heridas durante el ascenso.

La baja eficiencia de los sistemas de transferencia de Yacyreta se traduce en un altísimo costo de transferencia de peces migradores. Considerando que la inversión realizada en estos sistemas hubiese sido entre 30 y 50 millones dólares, cada pez de valor ecológico económico y deportivo, podría representar un costo no inferior a US$ 4 (Figura 2). Estos valores no justificarían construir un sistema de estas características, por lo que es fundamental comprender cual es el objetivo de la construcción de los pasos para peces. García (1999) expresa que los pasos para peces de Yacyretá han sido construidos con el fin de permitir el flujo génico entre poblaciones aguas arriba y abajo. Se trata de un planteo equivocado porque las poblaciones de peces migradoras, que constituyen el objetivo de desarrollo de los pasos para peces, poseen unicidad reproductiva. En condiciones naturales del río (sin represa), la reproducción normal de los individuos maduros de la población preservará las frecuencias génicas de la población, pero bajo condiciones de obstrucción de dichas migraciones (con represa), el bajo número de peces transferidos, afectará drásticamente la capacidad de reproducción, generando deriva genética y cambiando, en sucesivas generaciones, las frecuencias génicas. Tanto en Salto Grande como en Yacyreta, así como en otras represas del mundo, los sistemas de transferencia de peces, han sido construidos con el principal fin de asegurar un desplazamiento aguas arriba del mayor número de reproductores posibles, para garantizar que se mantenga un intercambio genético continuo entre los individuos de la población migrante, lo que tiene lugar aguas arriba de muchas represas. Esto permite mantener en el pool génico de cada población, aquellas adaptaciones mas ventajosas producidas a lo largo de la evolución por la selección natural, lo cual, en última instancia, permite preservar el tamaño de las poblaciones y sus características bioecológicas. Si ello no se cumple, estos sistemas deberían ser modificados o reemplazados, porque representan un potencial factor de extinción para las especies migradoras.

Por último, es importante mencionar que, históricamente, la construcción de represas en toda la cuenca del Plata, ha estado acompañada por la planificación de proyectos de .piscicultura de repoblamiento. Se ha argumentado que la piscicultura, entre otras ventajas, puede restablecer el balance original de especies en los embalses con costos inferiores a los pasos para peces, que es posible seleccionar las especies a introducir en el embalse y que estas actividades no generan conflicto con el uso del agua y poseen un valor económico y social (Machado y Alzuguir, 1976). Los resultados obtenidos en embalses del Brasil, sin embargo, indican que estos emprendimientos no brindaron soluciones satisfactorias para mitigar los impactos de la represas (Pereira de Godoy, 1985) y por el contrario, estimularon la siembra de especies exóticas. Por otra parte, en los embalses de baja cuenca no existen aún estudios sobre densidades de siembras requeridas a gran escala y tallas óptimas para minimizar la mortalidad por predadores y que permitan establecer la conveniencia y factibilidad de estos emprendimientos. En todo caso, parece razonable que la piscicultura de repoblamiento sea utilizada como un complemento de los pasos para peces para ciertos tipos de embalses, pero nunca como reemplazo definitivo (Bonetto, 1980).

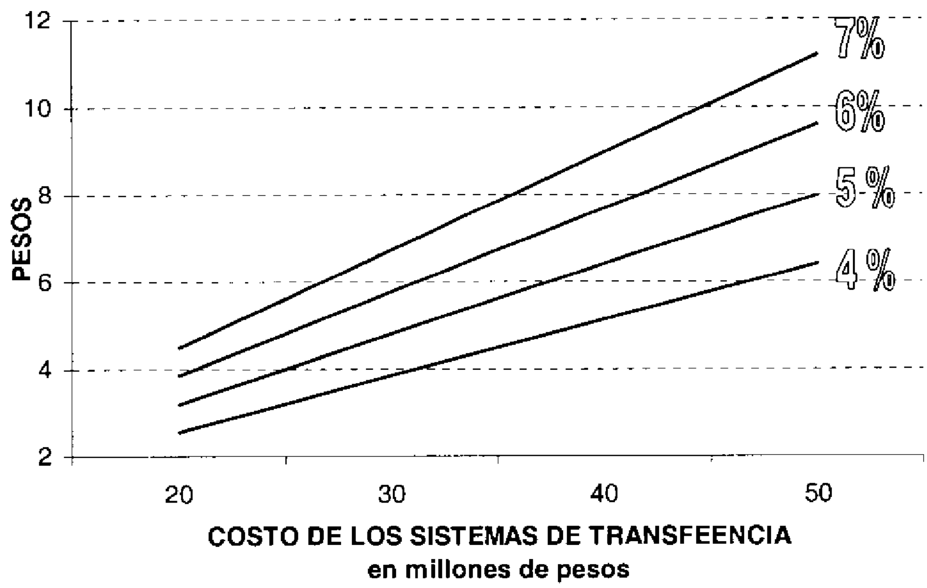

Figura 2: Costo de la transferencia de cada pez objetivo en Yacyretá, considerando distintos montos de obra de los elevadores y tasas de los servicios de la deuda.

F Conclusiones y Recomendaciones

El deficiente funcionamiento de los pasos para peces de Salto Grande y Yacyreta demuestra que la estrategia de construir sistemas desarrollados para especies con diferentes características bioecológicas y que habitan en otros ríos del mundo debe ser abandonada, para impulsar el desarrollo de criterios basados en información sobre las especies locales. No es casual que las entradas de estos sistemas no se encuentran bien localizadas, o que el número de especies migradoras que ingresan a los mismos sea muy bajo.

Para construir sistemas de transferencia eficientes, es indispensable realizar estudios de comportamiento mediante técnicas de biotelemetría que permita caracterizar las preferencias de uso de r hábitats y determinar las rutas de aproximación a las obras Asimismo, se deberán estudiar las característica natatorias de los peces para determinar sus respuestas a las distintas velocidades de corriente que encuentra en su desplazamiento. Estos aspectos, a su vez, deberán relacionarse con la hidrología, la calidad del agua y la topografía de la zona, e integrarse en modelos bi o tridimensionales que permitan determinar el adecuado emplazamiento de las entradas y ser compatibles con criterios ingenieriles. Por otra parte, se deberá analizar como resolver el problema de las migraciones descendentes, ya que ningún paso para peces construido o planificado en Sudamérica, ha considerado la necesidad de facilitar el descenso de los peces que ascendieron previamente para reproducirse y que al año siguiente repetirán el ciclo..

Finalmente, es esencial remarcar que los muestreos biológicos deben ser apropiados para garantizar la validez de los resultados sobre evaluación de impacto en la comunidad de peces y poder brindar pautas para diseñar sistemas eficientes. Ello no se ha observado en los casos de las represas de la baja cuenca. En el área de Salto Grande, por ejemplo, no existen antecedentes de estudios de las migraciones de los peces y de las características de su comunidad previo al embalsado, mientras que en Yacyreta, apenas se realizó un muestreo previo breve (Oldani *et al.*, 1992). En esta represa, la inminente construcción de un paso para peces en el brazo secundario (Aña Cua), requerirá disponer de la información previamente mencionada, pero insertada en el contexto espacial y temporal adecuado. Las escalas de análisis de los procesos migratorios, con su natural variabilidad interanual, difieren de aquellas vinculadas a los aspectos meramente hidrológicos. Por ello será fundamental definir cual será la base de información mínima requerida y los requerimientos estadísticos generales, para garantizar, con márgenes de incertidumbre aceptables, que la información lograda resulte apropiada para contribuir a un diseño de paso para peces eficiente.

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Hydrological monitoring and reservoirs operation management in the State of Paraná, Brazil

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Abstract

In order to get a most efficient hydraulic and energetic operation in a Generation Company reservoir's system, it is important that the information and the necessary steps for a decision making are available at all the areas involved in a fast, secure and synchronized way. Regarding that COPEL (State of Paraná Energy Company) has been working on computer systems, models and tools since the 70'. Recently in 1997, the Hydrology of Operation Department proposed the development of a storage, processing, data consulting and decision support system – The HMS System –, integrating several data and software used in reservoirs monitoring.

The system development and installation were gradual, started with the Caxias' reservoir. In December of 1999 all the reservoirs operated by COPEL were already being monitored by the HMS System.Among the benefits that the project brought to the company, stand out: a) convergence of information for an homogeneous database; b) automation of procedures: collecting of data, calculations and supporting process for decision making (automated operative rule); c) fast results; d) improvement of the quality of information; e) system integration; f) technological evolution.

Keywords: hydrological monitoring, reservoir operation, decision suport system.

Resumen

Para alcanzar una operación hidráulica y enérgetica más eficaz de un sistema de embalses de una Compañía de Generación, es importante que la información y los pasos necesarios en la toma de decisión estén absolutamente disponibles en las áreas implicadas de una manera rápida, segura y sincronizada. Con respecto a esto, COPEL (Brasil) ha estado trabajando en sistemas informáticos, modelos y herramientas desde los años 70. Recientemente en 1997, la Sección de Hidrología de la Operación propuso el desarrollo de un sistema (Sistema HMS) de consulta, procesamiento, almacenamiento y suporte a toma de decisión de datos integrando varios datos y software usados en la vigilancia de los embalses.

El desarrollo e instalación del sistema eran graduales, empezado con el embalse de Caxias. En diciembre de 1999 todos los embalses operados por COPEL eran supervisando ya por el Sistema HMS. Entre las ventajas que el proyecto trajo a la compañía, destaque: a) convergencia de la información para un banco de datos homogéneo; b) automatización de procedimientos: el recoger de datos, cálculos y proceso de apoyo para la tomada de decisión (regla operativa automatizada); c) resultados rápidos; d) mejora de la calidad de información; e) integración del sistema; f) evolución tecnológica.

Palabras claves: Monitoreo hidrológico; Operación de Embalses; Sistemas Soporte de Decisión

A. Introduction

A.1 COPEL. State of Paraná Energy Company

It is one of the major utility companies actuating in power generation, transmission and distribution, in Brazil, and is considered one of the best companies in the field of hydraulic technology in Latin America.

For more than 40 years, the company has acquired a huge experience in managing water resources, planning, building and operating hydropower plants, transmission facilities and power lines in all over the State of Paraná (200,000 km^2). Along this period, COPEL has carried out several studies in river basins hydrology, hydraulic and design of dams, water resources regulation, dams safety and power plants and reservoirs assessment environmental impact. It has already managed the construction of 4 large hydro power plants which provide its 4,600 MW of own power generation.

COPEL has been rendering consulting services related to hydropower in other countries, like in the 2,000 MW Shibuya project in China, the hydraulic studies for the 12,600 MW Itaipu Brazil-Paraguay power plant and for the 2,400 MW Bakun project in Malaysia.
In the distribution area, COPEL has rendered technical assistance services to the Government of Zimbabwe, in energy losses, per IBRD's indication, and to Eskom (South Africa), for customer management systems.

Along with the above, COPEL has more than 6,000 km of power lines, covering the entire Paraná state (200,000 km2). The company itself has been responsible for design, planning, construction, and operation of this network. Besides these regular features of a high standard utility COPEL has other branches as telecommunication. COPEL manages an optical fiber ring, which cover Paraná State.

In the area of environment, COPEL was the first Brazilian power utility to develop and implement environmental programs and the monitoring of its reservoirs and since then has conducted many environmental impact studies and projects in Brazil.
COPEL has also managed many activities concerned with GIS technology, including Parana´s digital mapping, which is available to the community.

To allow COPEL to monitor its reservoirs system and the basins in which ones they are located and forecast emergency situations, on real time basis, a highly skilled staff has been working since the 70's developing software, models and computer tools. Recently it had developed a telemetric network, modeling and software System for data acquisition, processing and storage.

A2. History

Before 1986, the Operational Hydrology Data Base was formed up by records of rainfall, rivers and reservoirs levels and discharge (1 and 2 checking a day) stored in the mainframe computer. There was also, a computer program (Fortran Language) which calculated inflow and outflow to Foz do Areia reservoir, but there wasn't any storage system.
From 1986 to 1989 a new system for reservoir operation calculating was developed to mainframe computer using PL1 language with introducing of the first operating data storage system for all reservoirs monitored.

From 1990 to 1993 a new system for microcomputer (OHR System- Hydraulic Operation of Reservoir) was developed by CEHPAR (State of Paraná Federal University's Hydraulics and Hydrology Center) and COPEL's Hydrology of Operation Department. This system has been used up to these days in post-operation processing after being updated for Caxias' reservoir and 2YK bug.

A.3 New Advances

- Between 1993 and 1996 several advances in technology of information defined new directions to the reservoirs hydraulic operation management:
- **1993** - Creation of SIMEPAR – (Technological Institute of SIMEPAR), State of Parana´s Meteorological System. It is an organ of Autonomous Social Service of Paraná Tecnologia. SIMEPAR, today is one of the most up-to-date institutions in the collecting, analysis and distribution of hydrometeorologic information. It uses automated stations, that send information through satellite (GOES) to the database in Curitiba.
- **1995** - Installation of Net microcomputers in COPEL;
- **1995 - 1996**:
  - SPDH system: Developed by CEHPAR the System for Hhydrologic Data Processing worked with fluviometric and pluviometric data processing and storage in microcomputers.
  - Acquisition of ADCP (Acoustic Doppler Current Profile). Since 1996, using this highly accurate sonar equipment, thousands of measurements were performed in rivers, artificial channels, estuaries harbors and power plants. The information was used specially to establish rivers discharge curves and to validate hydraulic studies in site. An important result is the rivers and hydro projects flow data quality improvement (stations discharge tables).
- **1997-1999**:
  - Start of SIMEPAR's the Telemetric Hydrometeorologic Net operating that presently monitors 33 hydrologic and 50 meteorological stations (Figure 1);
  - High Iguaçu Basin Hydrologic Monitoring home page (www.copel.br/~rio/iguacu.htm) - It was developed to publish SIMEPAR Telemetric Hydrological Network data and forecasts. This system is very important to alert urban (União da Vitória City) and rural population in flood prone areas.
  - Proposition and development beginning of a computer system model for the hydraulic operation data storage, processing and visualization - HMS System (Hydraulic Operation Management System) ;
  - Further prominent applications also were developed in that period:
  - Foz do Areia and Segredo Reservoirs Hydraulic Operation Modeling – It is a decision support model. Operation rule studies, simulation , model development and operative rule automation with the real time information was developed.
  - Capivari Reservoir Hydraulic Operation Model.
  - Vossoroca Reservoir Hydraulic Operation Model.
  - GIS (Geografic Information Systems) on Water Resources and Environment Management. Two projects were developed using GIS:
    - GIS Application on Environmental Studies for Hydroelectric Projects - Case Study of Tibagi River
    - Flood Mapping Using GIS Case Study of União da Vitória City: The scope of this study was to create a geographic information system for flooded areas, applying digital mapping techniques (GIS), producing automatically, high quality

flood maps. The study was applied to the cities of União da Vitória (PR) and Porto União (SC) and the resulting maps will be used to develop an Automatic Flood Warning System and to support the Urban Planning.

- **1999 - 2000:**
  - OHRS System updating - Hydraulic Operation of Reservoirs (post-operation) in function of the year 2000 and the beginning of Salto Caxias operation;
  - SISPSHI System - Developed for SIMEPAR, the system of hydrologic forecast is based in the semi-distributed rain-flow-propagation modeling, with telemetric use, monitoring of estimated rain by meteorological radar in real time, and rain forecast with numeric forecast of time models, to produce the forecasts of the natural affluence to the reservoirs with horizons varying of hours to months. The operating system of hydrologic forecast, in its current version has horizon of forecast of 5 days. With daily resolution.

B. HMS system. Hydrological Management System

Motivation

The reasons that motivated this system development were: a) Updating of the systems used, which were dispersed in several platforms; b) Development of a new Supervising System in the Control Center (SCADA). This new System hadn't the Hydrology Function c) The Salto Caxias' reservoir filling in October of 1998; d) Acquisition of a new data platform (ORACLE); e) Integration of the company database and the data base used for the telemetric network. (SIMEPAR)

C. Development

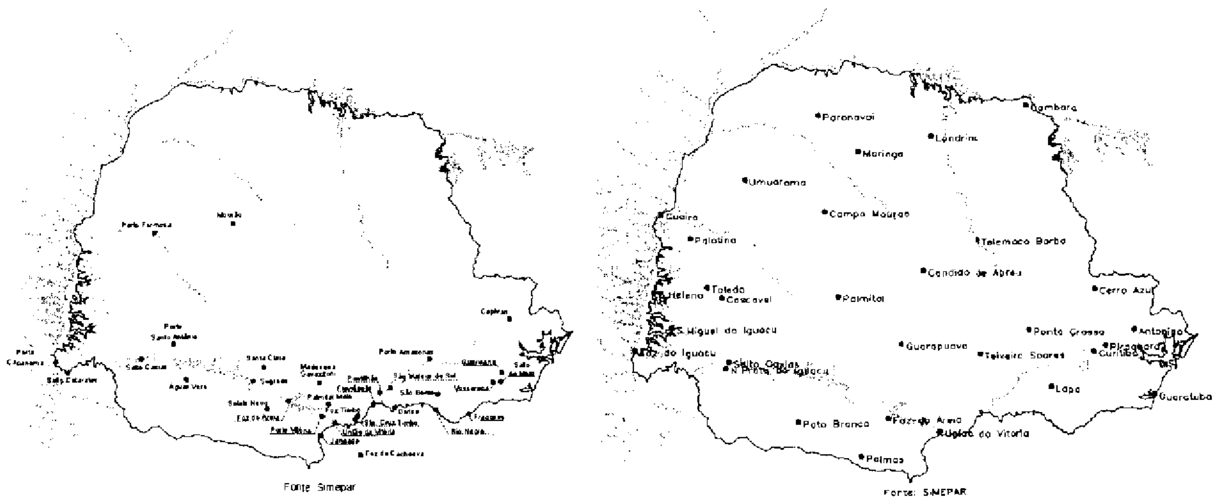
C.1 Methodology

Initially a survey on the operating computational system was accomplished to get a general view of the system net, the input data and the resulting products worked as a subsidy to propose the new HMS system model.
The main activities for the analysis, project and development were: a) Hydrometeorologic data base current survey; b) New ORACLE database modeling ; c) Database implementation; d) Input Database Program elaboration and updating; e) Development and adaptation of the calculating functions on water volume balance.

The first system module was developed with the results of the initial analysis to assist the monitored filling of Salto Caxias reservoir October of 1998 and the trading operation start. From that time the HMS System has grown in capacity and potencial.

C.2 Algorithms

The most important variable for this real time planning and operation is the reservoir inflow esteemed by the calculation of the reservoir water volume balance which consists on flows evaluation based on the data measured in the reservoir and in the plant, such as the reservoir water levels, generations and of floodgates opening. By the water levels floodgates openings it is possible to esteem the surface spillways or bottom spillways outflow, and the turbined flow can be calculate through the generations.



Picture 1 – Hydrologic and meteorological stations of SIMEPAR

To get this variable calculation is necessary to know the plant physical facilities data , such as dimensions of discharge structures and the turbines turbo capacity.

C.3 Water volume balance

The water volume balance equation, for a certain period of time in a basin, can be adapted to any specific case of " volume of control" formed by the reservoir which borders are the dam, the land and the water free surface . (Streeter, 1966):

$$\mathbf{Q_A = Q_T + Q_V + (\Delta_V / \Delta_T) + Q_P} \qquad (1)$$

Where:

- $\mathbf{Q_A}$ average net inflow in the considered interval;
- $\mathbf{Q_T}$ average turbined flow in the considered interval;
- $\mathbf{Q_V}$ average spilled flow in the considered interval;
- Δ_V/Δ_T volume stored in a time corresponding flow;
- $\mathbf{Q_P}$ infiltration, percolation and evaporation loss corresponding flow.

Due to the difficulty in representing correctly the values of evaporation, infiltration, percolation and the reservoir's direct precipitation the daily flow calculated is the net real flow, considering the effects of precipitation , evaporation and infiltration. Percolation loss is too insignificant so it can be disregarded with no risk to the calculation precision.

It is important to point out that evaluation errors in the turbined flow and outflow can top the neglected loss values. These calculations are frequently based on model testing results or, whenever they are not available, theoretical approaches not always checked on a prototype are used. The equation 1 is applied firstly on average hourly values and then the average daily value is calculated.

C.4 Volume stored ($\Delta V/\Delta T$)

The volume stored in the period of time shown in equation 1 is valued through the "level x volume" tables of each reservoirs. The tables are fed to the HMS system at intervals short enough to properly represent the reservoir's shape. The basic hypothesis in this case, is the reservoir surface to remain plane and horizontal, which is quite acceptable for a great depth reservoir, where the speed and the declivity of the water line is almost null .

C.5 Spilled Flow

The discharge structures, as spillways and bottom discharges are geometrically described through the "fixed data" stored on a text file. These data comprise all the hydraulic characteristics as: a) discharge coefficients obtained through model testing; b) physical dimensions of the structures, like : reference levels floodgates, width , spillways outline, etc. Thus the hydraulic calculations can be analytically accomplished through traditional equations of free or controlled surface flow, in the case of floodgate spillway and bottom discharges.

When the structures hydraulic and geometrical characteristics of are not known or in cases of more complex analytic process as for unconventional discharges the outflow calculation is made by interpolation in tables embedded in the HMS System.

The HMS System allows two tables patterns: a) single entry tables in which ones the flow rates are function only of the reservoir level; b) double entry table which must be supplied with the reservoir level and the floodgate opening. The total outflow is the sum of the outpouring flows calculated for all the surface spillways and bottom discharges.

C.6 Turbined Flow

In the HMS System, the turbined flow can be performed by two ways. When the turbines performance curves are available, an iterative process accomplishes the calculation. In this case, it is used a group of performance curves that supply the turbined flow in function of the turbine potency developed, for certain net head values tested or studied by the designer. In those curves the performance values for each net head are implicit. In the net head determination, the escape channel level and the hydraulic losses in the intake are used.

Direct calculation with constant productivity coefficient: When the performance curves are not available, the turbined flow calculation is accomplished directly dividing the generation values by a constant productivity coefficient.

D. The Water Volume Balance Computational Implementation

The data entry to the HMS System are divided in three groups: fixed data, reservoir data and generation data.

The **operative data** are the reservoir and generation data, which can be available in several formats, according to the operational routine of each plant. They can be transmitted by telephone, radio or through an automatic transmission (telemetric net) to the electric system operation center.

Nowadays the reservoir levels are obtained automatically through consulting applications on the SIMEPAR database (reservoirs levels , rivers levels and rainfall). The power generated comes from the Supervisor System (**XA-21**) installed in the COPEL´s Control Center (CCC) connected to the Intranet. The floodgates opening and availability and conventional levels readings are supplied by telephone for CCC operator that types those information in the HMS System' screens .

The **fixed data** group supplies the HMS System with all the necessary information to describe the discharge structures, reservoir and dam geometry. It also supplies the hydraulic characteristics of the drains and turbines, besides incoming data of the turbine-generator group. These data are stored in a text file. The main data are described below: a) Reservoir or station Identification; b) Location; c) Hydrographic Basin; d) Characteristics: d.1) Dam; d.2) discharge organs (surface spillway, bottom gate);d.3) operative data; d.4) reservoir(level x volume table) d.5) generation

The generation data are the power plants hourly energy production (MWH). In the same way as the reservoir data are supplied, the generation data can be inserted through screens for manual data entry or by transfer data from the XA-21 System.

E. Water Volume Balance Computational Design

The water volume balance calculation is divided in four stages: calculation of the spilled flow, turbined flow, transferred flow and accumulated volume variation .

E.1 Spilled Flow (Qv)

The resulting operation data, as reservoir levels and floodgates opening, are usually supplied in schedules, that facilitates the instantaneous spilled values calculation.

Usually, a reservoir level record is accomplished in the initial instant of a floodgate maneuver and the time spent to complete that maneuver is also registered. When there is no level reading , that value is interpolated in function of the closest readings and, in case of the time maneuver values are lacking the HMS System adopts 2 minutes.

The hypotheses used in the calculation are commented below:

- The reservoir level variation is considered linear in time, being this hypothesis used to determine the beginning and the end of the spilled flow in spillways without control and to determine the head in controllable discharge gates when there are no reservoir level readings.
- Among the spilled hydrographic calculated points , the flow variations are considered linear. That hypothesis is better than considering the levels linear variation when it would be necessary to use a more sophisticated numeric integration process to obtain the spilled volumes, since, in general, the discharge curves are non-linear.

With the values of the levels and floodgate openings the instantaneous spilled flow values are calculated. In cases of spillways without floodgates, the spilled flow calculation is accomplished based on the observed levels. After the instantaneous spilled flow calculation, hourly medium flows are calculated. They are used in the hourly water volume balance calculation.

E.2 Turbined Flow (Qt)

As the power plants energy generated data are obtained in hourly values, the turbined flows are calculated in hourly scale using reservoirs and escape channel levels interpolated in the medium point of the considered hour.

E.3 Transferred Flow (Qdr)

Jordão's river reservoir transfers a part of its inflow to Segredo reservoir through a tunnel. The flow that goes by the tunnel is function of the difference between the two reservoirs levels and its value is calculated by interpolation in the tunnel discharge table.

E.4 Stored Volume Variation ($\Delta V/\Delta T$)

To calculate the stored volume variation calculation (ΔV) in the reservoir during the time (ΔT = 1 hour), the levels are interpolated in the beginning and end of the interval. With the level values, the stored volume is obtained by interpolation in the level-volume tables. The precision in the stored volumes evaluation is improved with the increase of the level reading frequency , because in short intervals of time, the hypotheses of linear variation are very close to what really happens. This is the reason why an inadequate level readings frequency can cause great mistakes in the evaluation of stored volumes, mainly when there are great level variations in the reservoir.

E.5 Water volume balance

The equation 1, of the **simplified water volume balance**, is applied at hourly level and daily level. For the hourly calculation, the portions of spilled flow are simply added to the turbined flow, transferred and stored volume ($\Delta V/\Delta T$) calculated as described previously. For the daily water volume balance calculation, daily averages of the same portions are calculated.

F. SIMEPAR

The use of the hydrometeorological information from SIMEPAR by COPEL is regulated by a cooperation contract. The Paraná State Meteorological System - SIMEPAR was established to provide high quality and continuos monitoring of meteorological and hydrological parameters related to the weather forecast, hydrological modeling activities that need to make an optimum decision in a relatively short time fashion and researchers in need of a historical data base.

In order to bring benefits to the largest number of users possible, among them agriculture and energy, SIMEPAR defined the data collection infrastructure necessary and is now operating a system that encompasses a telemetric (satellite based) hydrometeorological network composed of 69 stations being 34 hydro and 35 met, a Doppler S-band Radar, a Satellite Imagery for GOES and NOAA, a Lightning Detection Network and an Intelligent Nucleus to integrate and distribute information. Further information on SIMEPAR can be obtained on the site http://www.simepar.br.

G. The HMS System Architecture

G.1 Historical and main characteristics

Totally developed by COPEL's technology, including technical and scientific knowledge of the Generation, Transmission and Information Technology areas, the HMS System has as main characteristics:

- Executable under Windows Operational System®.
- Database capacity to store a great volume of data (ORACLE®) - nowadays the database contains level and flow information since the 70's;
- Integrated database with all interesting hydraulic operation information:
  - Telemeasured, conventional and consisted levels, floodgate maneuvers, and generation for all the reservoirs;
  - Calculated flows;
  - Levels, flows and precipitation for all the hydrologic stations in the telemetric net;
  - Levels and flows of some reservoirs from GERASUL (a related Utility);
- Hourly and daily medium flows historical series, statistics and reports of data;
- Calculates the hourly water volume balance and update historical series of hourly medium flows, averages of four hours and daily averages;
- Real time operation (consults the on-line database);
- Great amount of users simultaneously;
- Security, when allowing that the applications are configured in agreement with the user's profile, allowing several access levels to the information;
- Speed and precision ;
- Information access through microcomputer network for all authorized users;
- Allows manual data entry;
- Home Page updated automatically;
- Operative rule model for Caxias, Foz do Areia and Segredo reservoirs;
- Hydraulic Calculations made analytically through traditional flow equations;
- Uses a model for hydraulic calculations improved by the hydrology area of COPEL, since 1987;
- Uses modern concepts of objects orientation technology (OOP), supported by the language Delphi®

G.2 The database

The system database is composed basically by two groups of tables, to store reservoirs information , and hydrometeorologic data. They are basically constituted of the following structures:

- **Reservoirs Fixed Data**: meteorological , pluviometric and fluviometric stations;
- **Reservoirs Hourly Data**: with levels, flows, volumes and generation;
- **Daily Reservoirs Data**: with closing information of hourly data (final level, total generated, stored volume);
- **Maneuvers in floodgates Data**: it allows accompanying each floodgate maneuver on the reservoirs (beginning time , end time, value of the opening);
- **Floodgates opening** together with the maneuvers data, allows to calculate the spilled flow in the reservoirs;
- **Hydrometeorologic Hourly Data**, that contains hourly pluviometric and fluviometric information;

- **Telemeasurement Adjustment Data**: contains information for automatically telemetric record adjust. Then, if some instrument is not configured correctly, the differences between the values read and the real value are defined in this table, allowing this stored data schedules level correction.
- An exclusive server assists the database and, in case of hardware failure, another backup machine is available to give services continuity . Any way, there is a systematized backup procedure of the whole database.

G.3 Feeding the database

There are three forms of feeding the database:

- **Level information and telemetric hydrometeorological** collected automatically starting from the database of SIMEPAR;
- **Level information and generated values** collected automatically starting from the dedicated mainframe of COPEL (XA-21) that assists the operation of the electric system;
- **Manual data entry** through the operational module, when there is fail in the telemetric, or even when certain information doesn't have its automated origin;
- Finally a model that classifies the levels upstream/downstream in three categories:
  - **Telemetric level** - it is the level collected automatically starting from the stations (in this case, starting from the database of SIMEPAR;
  - **Conventional level** - it is the resulting level of visual reading, informed to the system by the operator, through the operational module (manual data entry);
  - **Consisted level** - it is a derived level of both previous information, that is to say, it is the level used in the showing information and in the decision making.
  - Besides, when the information quality is doubtful the system can be informed then it should not consider this telemetric data.

G.4 Administrative module - Administering the data system structures

Called as administrative module, it has the function of maintaining reservoirs and stations fixed data, as well to emit some reports and consulting for several purposes.

In the reservoirs fixed data tables, for example, the consisted information accepts maximum and minimum limits of values (levels, generation), amounts of hours used for calculating the averages, limits, location, and description.

G.5 Operational module - Using the system

The operational module possesses two purposes:

- Works as mechanism so that the operation personnel can interact with the system, informing levels visually collected, as well the generation and floodgates opening . In this user profile the application calculates flows and other derived information automatically, once presents the necessary information for such;
- Works as an interface between the final user and the database and as a data consulting tool to aid in the process of decision making . This profile user cannot change any data. It allows to consult levels, flows, floodgates opening, rainfall and river level data, conventional and telemetric readings quality , water volume balance, as well to emit reports.

G.6 Sharing information with other systems

Now the HMS System accomplishes exchange of information with some external entities, as for example ANEEL (National Agency of Electric Energy), ONS (National Operator of the System), GERASUL and ITAIPU and YACYRETÁ.
These information are exchanged in the following way:

- A dedicated personal computer begins a hourly process, that looks for the most recent information in the database and it generates a file with these data;
- Afterwards using FTP, sent this file to a WEB server, so that it can be looked for by the respective entity.
- Depending on the case, the opposite process is made, a file is looked for automatically, through FTP, starting from some entity WEB server , converted and stored in the HMS data base.

Besides the information exchange processes, the system has the capacity to maintain specific Home Pages. that collects information from the database, it transforms these data into tables and graphic and update automatically an Internet site.

H. Conclusion

The hydraulic operation database created in ORACLE server and water volume balance automatic calculating integrated into that new platform (HMS System) represents a technological progress to the Company.

This System implementation allows the data storage the and the reservoirs hydraulic operation management of the system monitored by COPEL, besides supplying data for the models of decision making gives efficiency, quality and speed in the process.

As a System future improvement activity the GIS (Geographic Information System) use as a support to hydrological analysis will be developed.

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Notes:

ORACLE is trademark of ORACLE Corp., Windows is trademark of Microsoft Corp. and Borland Delphi is trademark of Inprise Corp.

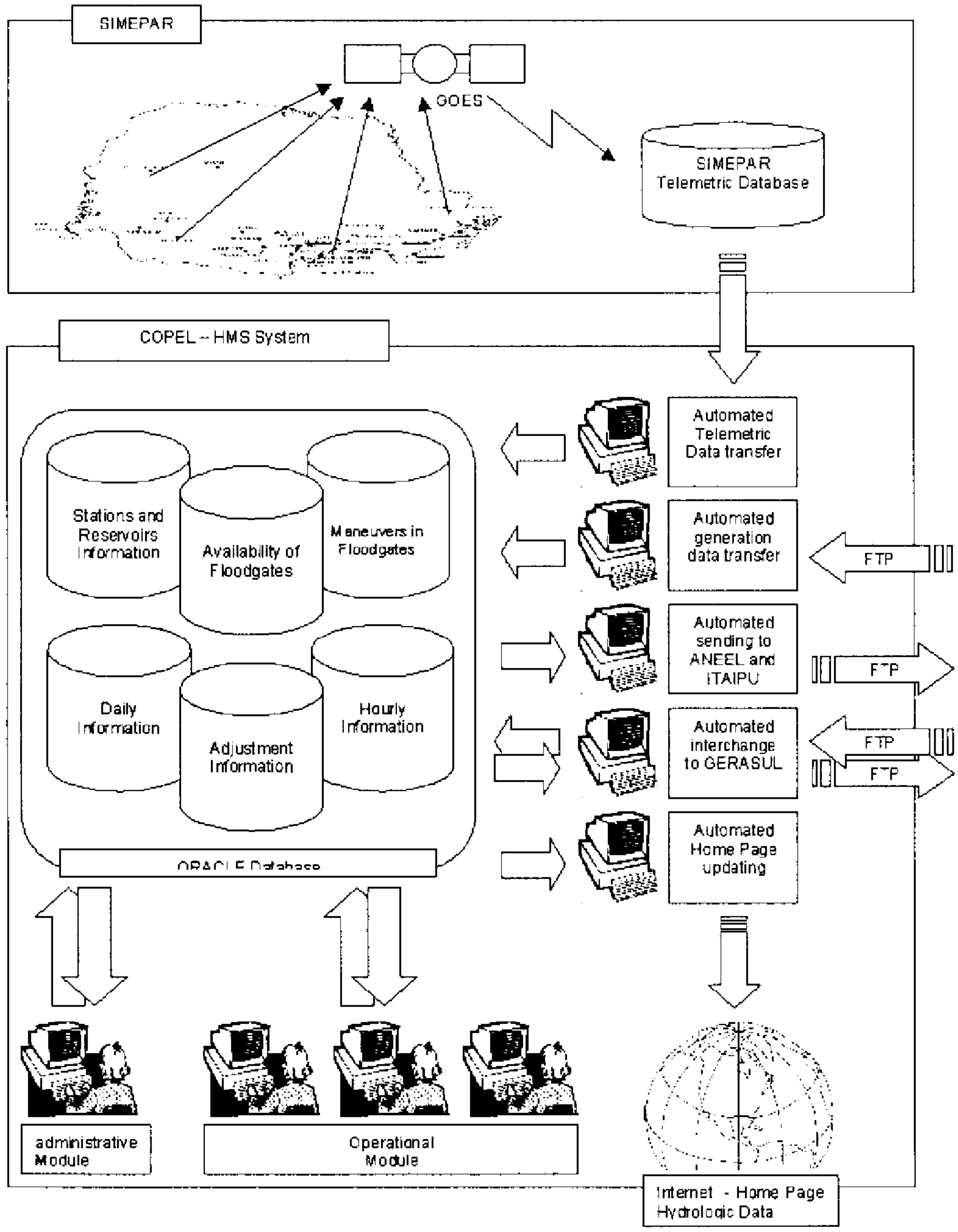
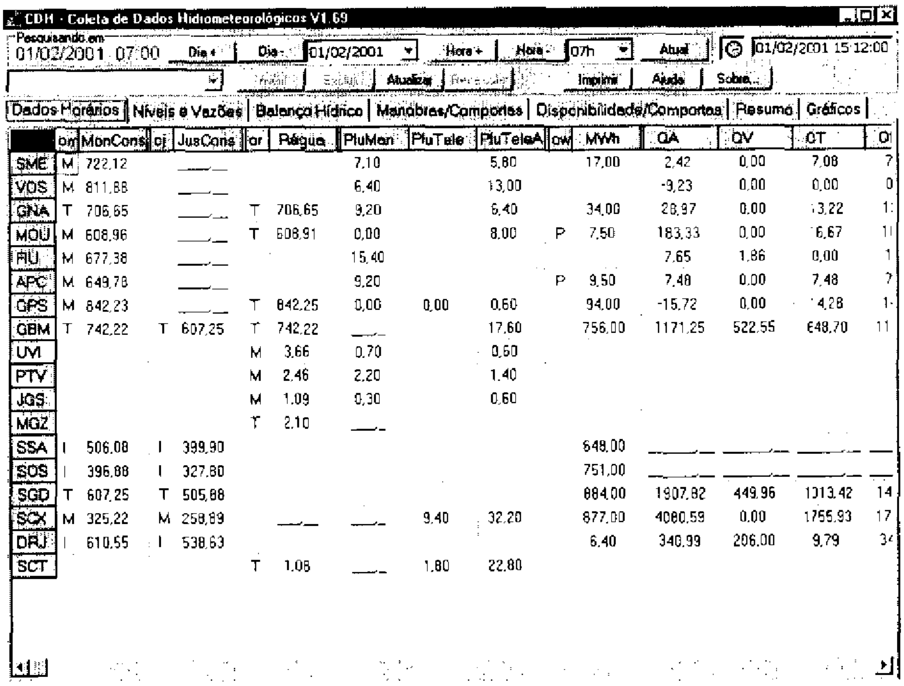


Figure 2 – Structure and internal data flow in the HMS System



CDH - Coleta de Dados Hidrometeorológicos V1.69

Pesquisando em 01/02/2001 07:00 | Dia+ | Dia- | 01/02/2001 | Hora+ | Hora- | 07h | Atual | 01/02/2001 15:12:00

Atualizar | Imprimir | Ajuda | Sobre...

Dados Horários | Níveis e Vazões | Balanço Hídrico | Manobras/Comportas | Disponibilidade/Comportas | Resumo | Gráficos

	om	MonCons	oj	JusCons	or	Régua	PluMon	PluTele	PluTeleA	ow	MWh	QA	QV	QT	Q
SME	M	722,12		—			7,10		5,80		17,00	2,42	0,00	7,08	7
VOS	M	811,88		—			6,40		13,00			-9,23	0,00	0,00	0
GNA	T	706,65		—	T	706,65	9,20		6,40		34,00	28,97	0,00	3,22	1
MOU	M	608,96		—	T	608,91	0,00		8,00	P	7,50	183,33	0,00	6,67	11
RIU	M	677,38		—			15,40					7,65	1,86	0,00	1
APC	M	649,78		—			9,20			P	9,50	7,48	0,00	7,48	7
GPS	M	842,23		—	T	842,25	0,00	0,00	0,60		94,00	-15,72	0,00	4,28	1
GBM	T	742,22	T	607,25	T	742,22	—		17,60		756,00	1171,25	522,55	648,70	11
UVI					M	3,66	0,70		0,60						
PTV					M	2,46	2,20		1,40						
JGS					M	1,09	0,30		0,60						
MGZ					T	2,10	—								
SSA	I	506,08	I	399,90							648,00	—	—	—	—
SOS	I	396,88	I	327,80							751,00	—	—	—	—
SGD	T	607,25	T	505,88							884,00	1907,82	449,96	1313,42	14
SCX	M	325,22	M	258,89		—	—	9,40	32,20		877,00	4080,59	0,00	1755,93	17
DRJ	I	610,55	I	538,63							6,40	340,99	206,00	9,79	3
SCT					T	1,06	—	1,80	22,80						

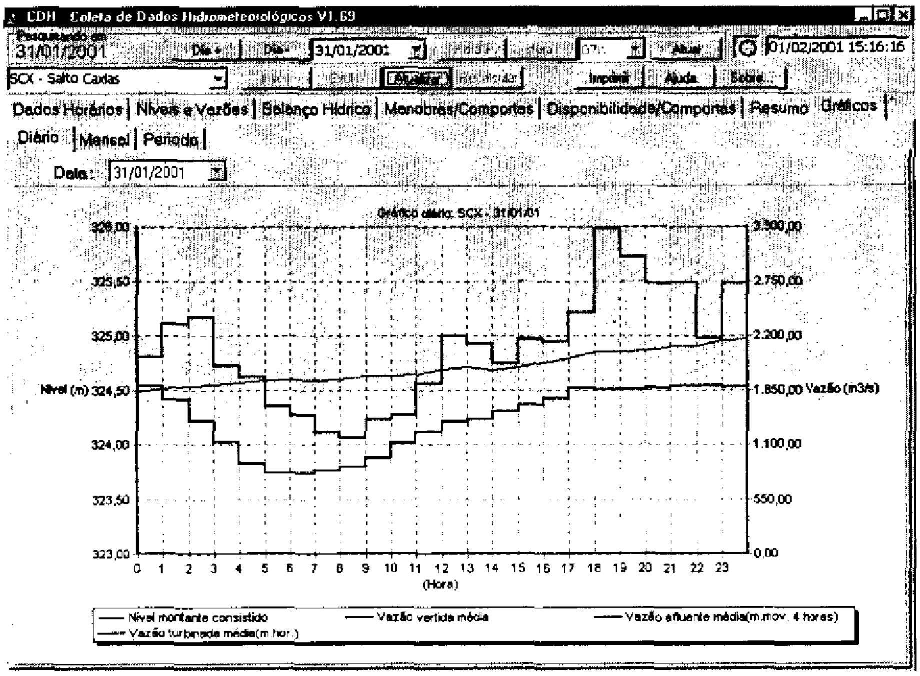


Figure 3 – The HMS System (Resume Screen and Graphics Screen)

Integrated Water Resources Management: Formulation of Multi-objective Optimization on Water Quantity and Quality of Storage Reservoir

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Abstract

Short and long-term operation of a storage reservoir, focusing on quantity & quality assessment, is formulated in this paper. The objective is to improve benefits of a storage reservoir for all stakeholders involved with the water issues. Future scenarios under changing situations will be analyzed as this research progresses. Fuzzy dynamic programming (Fuzzy DP) is considered to be the most suitable tool to handle the posed problem. A case study is presented for the Barra Bonita Reservoir in the state of São Paulo, Brazil.

Keywords: Multi-objective Optimization; Dynamic Programming; Fuzzy Theory; Water Quality Model; Barra Bonita.

Resumen

En este trabajo se formula la operación de corto y largo plazo de un embalse de regulación, con énfasis en la evaluación de la cantidad y la calidad. El objetivo es incrementar los beneficios del embalse para todos los actores con intereses en los cuestiones de agua. Se analizarán escenarios futuros ba,o situaciones cambiantes a medida que la investigación progrese. Se considera que la Programación Dinámica Difusa (Fuzzy DP) es la herramienta mas apropiada para resolver el problema planteado. Se presenta un estudio de caso para el Embalse de Barra Bonita, Estado de San Pablo, Brasil.

Palabras clave: Optimización multiobjetivo; Programación dinámica; Teoría difusa; Modelo de Calidad de Agua; Barra Bonita

A Introduction

Water environment issues, related to water quality and quantity, involving large areas, have highly complex aspects. Such issues includes increasing water demand, multiple-use, water pollution due to rapid urbanization, high development of water resources, eutrophication and degradation of water bodies, increasing costs related to water treatment, and so on.

Recently, other problems have surfaced; such as the discharge instability due to abnormal climatic behavior and increase of water withdraw from the rivers and reservoirs, causing long periods of drought and augmentation of water related conflicts.

Assessment of seasonal, social and ecological changes in the practical reservoir management has become more relevant recently. Use of Stochastic approach and Artificial Intelligence

(AI) techniques, such as fuzzy set theory, in the development of decision support systems can provide a suitable method to analyze all these complex connections and uncertainties.

The history of reservoir management has been developed basically based on single-objective and single-purpose problems. This approach has been used in many countries worldwide mostly based on economic cost-benefit analysis. As a consequence many water related problems have arisen, creating the need for a better and more comprehensive evaluation process. The consideration of various purposes (e.g. recreation, environment and navigation) has to be addressed from an integrated water resource management point of view.

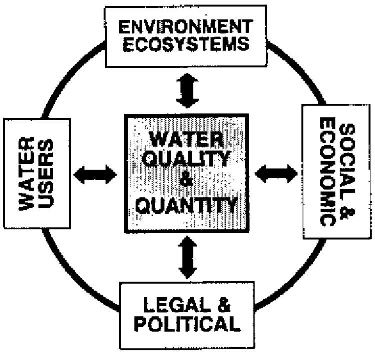


Figure 1. Basic concept of Integrated Water Resource management

B. Objectives

The aim of this research is to integrate the management of water resources regarding quantity and quality issues with social, economic, and environment characteristics. Considering the short and long term analysis, it is decided to divide the research plan into two steps:

First Step: annual planning assessment. Impact factors such as inflow, water demand, pollutant inflow and climate conditions can be obtained from average annual values even though those variables are basically stochastically related.

Second Step: long-term planning assessment. Impact factors with uncertainty (as mentioned above) can be predicted by using stochastic techniques to support future water related decisions.

B.1 Expected achievements from this research

- Arrangement and preparation of the necessary data for the purposeful reservoir operation analysis: historical changes; multi-purpose uses; formulation of the multi-purpose planning;
- Optimization for the long and short term (Deterministic and Stochastic DP);
- Optimization under the condition of uncertainty and abnormality (Stochastic and/or Fuzzy DP);
- Risk assessment based on the optimized rules and storage capacity analysis.

C. Multipurpose Analysis

Traditional multi-objective optimization techniques applied to multiple purpose reservoir operation include: the weighting method, the ε-constrain method, the surrogate worth trade-off method and goal programming. Recently some approaches are using a combination of multi-objective optimization methods and discrete multi-criterion decision analysis methods for reservoir operation.

As most of the problems faced have a great portion of vagueness and subjectivity, the principles of fuzzy sets provides a suitable approach. The objectives can be described as fuzzy concepts, which can be determined by different methods. For example, based on actual field surveys with decision makers and stakeholders; expert experience, or derived from historical data analysis, etc.

A multi-criterion rating scale measures the degree of satisfaction of an alternative compared to a criterion. Perceptions of degrees of satisfaction of linguistically described reservoir's objectives can be modeled as fuzzy membership functions of selected state variables. The measure of performance of each objective is expressed on a 0-1 scale, with higher degrees of satisfaction indicated by values closer to 1.

The method to categorize reservoir objectives using linguistics values, such as "suitable" environment quality, "adequate" water supply and "proper" storage for flood control, can be handled by fuzzy set allowing a gradual transition from a situation that completely fulfills a concept to a situation that does not.

D. Model Structure

The basic structure for the proposed model is displayed in Figure 2. Inflow quantity and quality, water demand and climate condition are variables with stochastic characteristics. However, it can be initially assessed assuming annual average values. The values concerning the reservoir characteristics are physical constants and will be related to each reservoir on an individual basis.

For the water quality (WQ) analysis within a reservoir, there are a number of different models that can be used within the proposed optimization model. Basically it can be said that simple models, which do not require great computational effort, are the most suitable for the first step of this research. Another important reason to propose a simple model is that the optimization process by itself may already face problems related to computational restrictions.

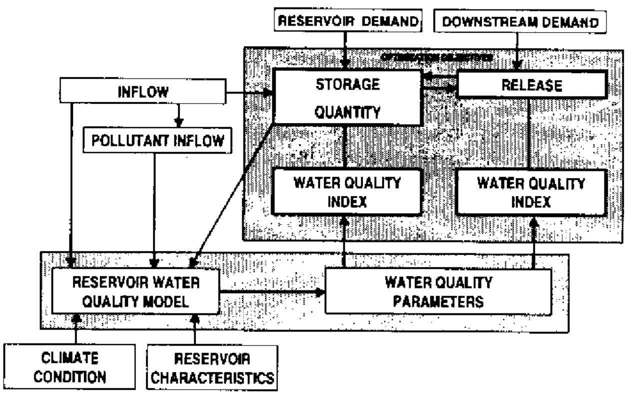


Figure 2. Integrated Water Resource Evaluation Model Structure

The WQ model gives basic water parameters as output. Based on those parameters, a water quality index can be obtained. Further description of the WQ model will follow later. Lastly, storage and release are the state and decision variables, respectively, which are used in the optimization model. The arrows in Figure 2 represents the flow of information within the model, such as inputs and outputs, interactions among the system's parts and the like.

E. Optimization Framework

Dynamic programming (DP) was developed in the 1950's by RAND Corporation sponsored by the US Air Force. It was named and described in a series of papers by Richard Bellman. DP will be one of the optimization methods used in the resolution of the optimization problem posed in this paper. DP presents various advantages over other methods to approach water resource management aspects and can be associated with other programming methods, named such as Stochastic DP, Fuzzy DP, and so on. The basic characteristics of water resource and reservoir operation that leads to the use of DP can be cited as: stage-wise structure and non-linearity of the system. DP can also be divided in two different approaches depending on the problem. It can be continuous or discrete. The later is chosen to be applied for the present case.

Dynamic programming converts a large, complicated optimization problem into a series of interconnected smaller ones, each containing only a few variables. The result is a series of partial optimizations requiring a reduced effort to find the optimum. The DP algorithm (objective function F) can be applied to find the optimum of the entire process by using the connected partial optimizations of smaller problems.

The deterministic DP will be used for the formulation of the first stage objective. In deterministic models there is one (on average) value for each situation and/or unit of time. The calculations are based on physical, chemical, biological and economical formulations, and so on.

A unit of time can be represented as a stage. An example of the DP functional diagram with some stages is presented in Figure 3. Every stage has a variety of variables and functions. The return function (R) gives the measure of profit or cost for the stage. These are decision and state variables. Decision variables (d), are ones that can be manipulated independently. State variables (S and Q), are ones that are inputs to the stage from an adjacent stage. Consequently, they cannot be manipulated independently.

Figure 3. Basic functional diagram, functions and variables in DP

Decision variable: d (Release from reservoir)

State variable: S (Storage Volume) and Q (Water Quality)

Transition Function: st = T1t (St, dt) = St-1 => St-1 = St - dt - Dt + I

(D: demand, I: inflow, t: time Smin < St < Smax dmin < dt < dmax

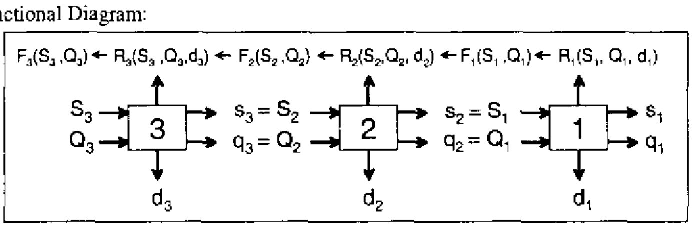
qt = T2t (Qt, St, dt) = Qt-1 => WQ Model

Return Function: Rt (St, Qt, dt)

Object Function: F(St,Qt) = max_{dt} [Rt (St, Qt, dt) + Ft-1 (St, Qt)]

Constrain Equations: related to the reservoir's limitable characteristic

Functional Diagram:



The transition function for the storage state variable is based on the continuity equation. The water quality state variable is based on the results given by the Water Quality Model. The return function depends on the decision and state variables. It is necessary to exhaustively list individual values of state variables and to search for decision variables to determine the return function. The objective function is based on the maximum or minimum from the sum of the return functions for each stage.

As for the second stage formulation, due to the stochastic and uncertainty characteristics of the variables, the stochastic and fuzzy logic approach will be used. In stochastic models a range of values can be expected for each situation and/or each unit of time. The fuzzy-stochastic approach can be applied when the probabilities of the occurrences are known (risk) and unknown (uncertainty). In fuzzy logic based models, variables are imprecise or vague and the source of uncertainty is not merely due to randomness of a natural event.

Another advantage is that fuzzy optimization approach can address the problem of subjective and noncommensurable objectives in an easily interpreted way, indicating relatively how each objective have been satisfied. Fuzzyfication allows decision makers to pose the goals and/or constraints in subjective, linguistic terms. In a Fuzzy DP, decision and state variables as well as constraints, can be set as fuzzy membership functions.

F. Water Quantity Assessment

One of the objectives of this research is to assess the multi-uses of water quantity within the storage reservoir. It was decided to evaluate the water quantity and quality characteristics using indices, based on the fuzzy set theory.

For each water use, a sub-index is formulated, which can be unified into a single index. This index provides a global assessment within the optimization model. This approach was used for both conditions within and downstream of the reservoir. The maximum and minimum values of the functions can be appropriately decided by experts, such as operators, stakeholders, society representatives and the like, related to the decision-making process. The fuzzy indices that can be used for the water quantity release and storage assessment, respectively, are shown in Figures 4.a and 4.b. See also Kojiri (5) and Fontane (6).

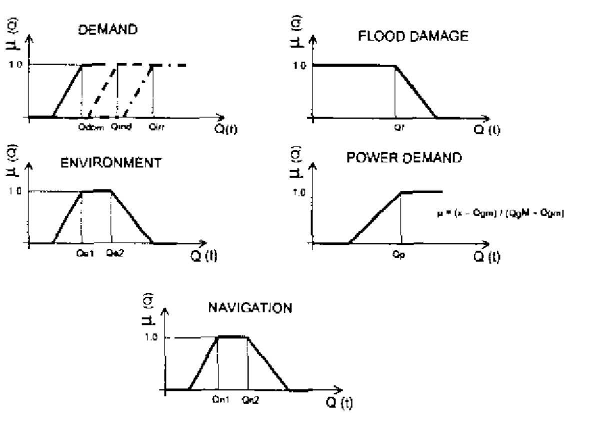


Figure 4.a. Water quantity sub-index for release evaluation (where good = 1 and bad = 0)

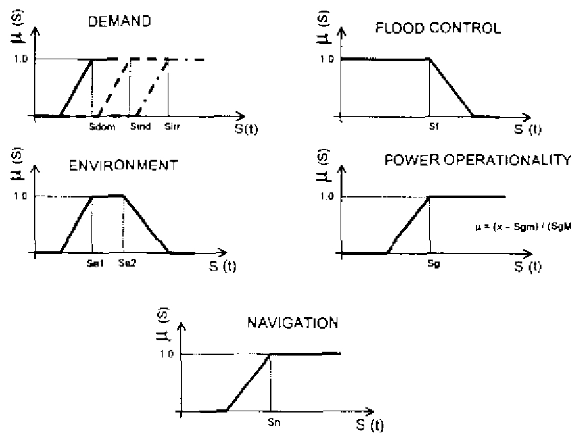


Figure 4.b. Water quantity sub-index for storage evaluation (where good = 1 and bad = 0)

The formulation of these functions is quite complex and involves much subjective judgment, especially when dealing with different units, like environment and economic units. Conflict analysis, trade-offs and cost-benefit theory can be applied to better formulate and solve this problem. However, it is not described in this paper. Some of these conditions can be placed as constraints, decreasing the degree of subjectivity or the number of variables that compose the indexes.

G. Water Quality Assessement

As stated previously, water quality aspects are also evaluated using a number of sub-indices for each water quality parameter (e.g. phosphorus, dissolved oxygen). A water quality index (WQi) for the global characterization of the water conditions can be calculated based on the different sub-indices. Due to the large number of water quality parameters and their high variability, a water quality index may help to describe the overall condition of the reservoir.

The indices to be use here are obtained based on Brazilian experience and indices currently in use, as well as, on international references, reservoir WQ model characteristics and computational and/or mathematical constraints.

An example of the formulation process of a WQ index to be used within the Optimization Model is displayed in the following charts, Figure 5.a and 5.b. Here, the formulation of this sub-index is based on two parameters. The parameters phosphorus and chlorophyll-a are used in the formulation of the eutrophication sub-index, considering equations already used for the Eutrophication Index used by CETESB (Companhia de Tecnologia de Saneamento Ambiental), São Paulo State.

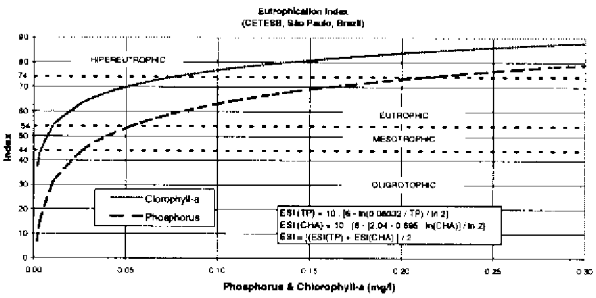


Figure 5.a. CETESB eutrophication index used for the WQ evaluation of the state's water bodies

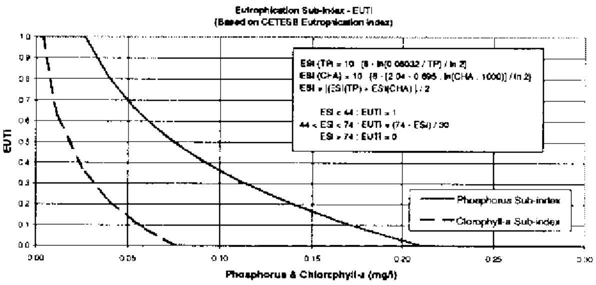


Figure 5.b. Proposed sub-indices for Phosphorus and chlorophyll

With the objective to obtain a general picture of the water quality conditions, a water quality index (WQi) can be proposed. The idea of this index is the same as the Water Quality Index used by the National Sanitation Foundation of the USA, but in this case the weighting method is not considered, resulting in a simple average of the sub-index. Therefore, other sub-indices can be easily elaborated and annexed to the WQi.

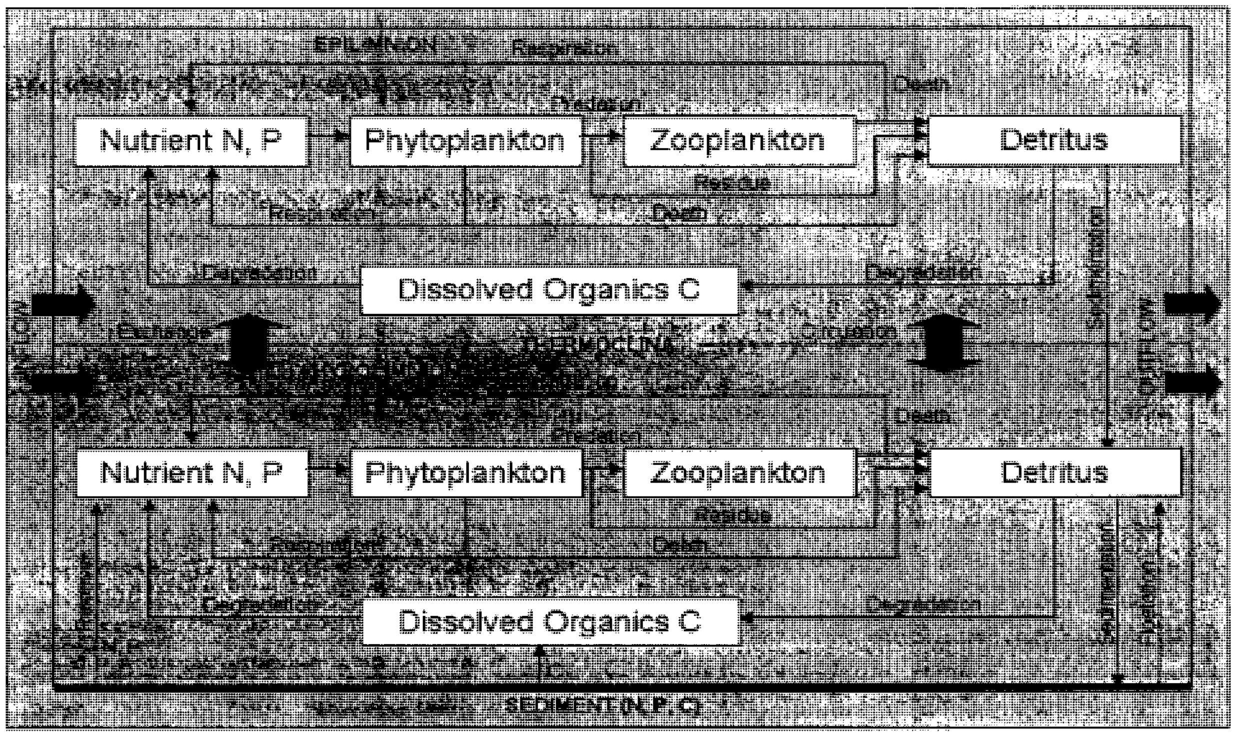
The average method was used, however any other methods could have been applied. The selection of the method is basically related to the focus of the water quality assessment and water use. For example, another method possible to assess water quality would be such that the minimum or maximum values of parameters (or sub-indices) are used to give the final classification of water quality conditions. Such an approach is used for the classification of water bodies by the Brazilian federal authorities.

H. Water Quality Model

For the quantification of the water quality parameters there are a variety of WQ Models that can be applied associated with the optimization concept presented here. However, as DP already has some constraints regarding the computational effort and the main objective of a general water quality assessment, it is decided here to use a simple WQ model, for example, a unidimensional 2-layers model with basic parameters as outputs. A unidimension multi-layer model could be another suitable option to assess stratification problems and quality conditions. In a furtherer step, a 3-D model can also be used, being much more efficient for the assessment of problems regarding spatial distribution for the WQ within the reservoir.

Initially, a box-type, unidimensional, 2-layer WQ model elaborated by UNEP/ILEC (PAMOLARE) is to be adopted, which a priori fulfills the basic needs for the optimization process. A basic concept of the model is shown in Figure 6.

Figure 6. UNEP/ILEC box-type, one-dimensional, one-layer WQM conceptual diagram



The output parameter for the WQ model are as follow: nitrogen, phosphorus, diatom, blue-green algae, other phytoplankton, zooplankton, detritus, COD, DO and sediment's nitrogen, phosphorus and carbon

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I. Case study: Barra Bonita Reservoir

I.1. Basic Characteristics

The Barra Bonita reservoir is located in the middle Tietê River basin, São Paulo, Brazil, (22°29' S and 48°34' W) with surface water at an altitude of 453 m. Some other basic characteristics of the reservoir can be found in the table below:

Surface area	340 km^2
Volume	3.6 x 10^6 m^3
Maximum and mean depths	25 and 10 m
Length	50 km
Average water fluctuation	5 m
Primary use	Power generation
Other uses	Water supply Recreation Navigation
Filled in the year	1963

The Reservoir is the first of a series of six reservoirs, around 300 km downstream from Brazil's biggest city, São Paulo. It can be classified as a subtropical/tropical reservoir with intermediate retention time.

Air temperature normally varies within a range of only 15°C between winter and summer. Wet season occurs between September and March. Annual cumulative precipitation is around 1400 mm, with maximum wind velocity of 5 to 7 m/s during winter. Rainfall, wind and flushing rates are the major forcing functions in this reservoir.

Water level and volume are related to both climatologic conditions and water use. The average annual flushing rate is 344 m^3/s. Changes in release discharge rates are an important driving force in this system, rapidly modifying ecological conditions within the reservoir and, as well as, downstream area.

The case study may also not present stratification problems due to the reservoir's medium residence time and its shallowness characteristics. Two main rivers, Tietê and Piracicaba, flow into the reservoir. Due by the considerable difference of water quantity and quality of the two rivers, the reservoir presents some spatial heterogeneity.

General source of impacts to the Reservoir are as follows: N and P input form non-point and point sources; Input of suspended material from agricultural activities and runoff during precipitation; Navigation, tourism and recreation; Deforestation in the watershed and Introduction of exotic species of fishes. Consequences of these impacts include: Eutrophication; Siltation; Blooms of Cyanophyta (Microcystis, specially in summer and Anabaema, in tropical winter – this impact may be minimized by controlled operation of the spill water and Loss of native fish species. Most of the above information gathered about the Barra Bonita Reservoir was extracted from Tundisi (3).

I.2. Methodology

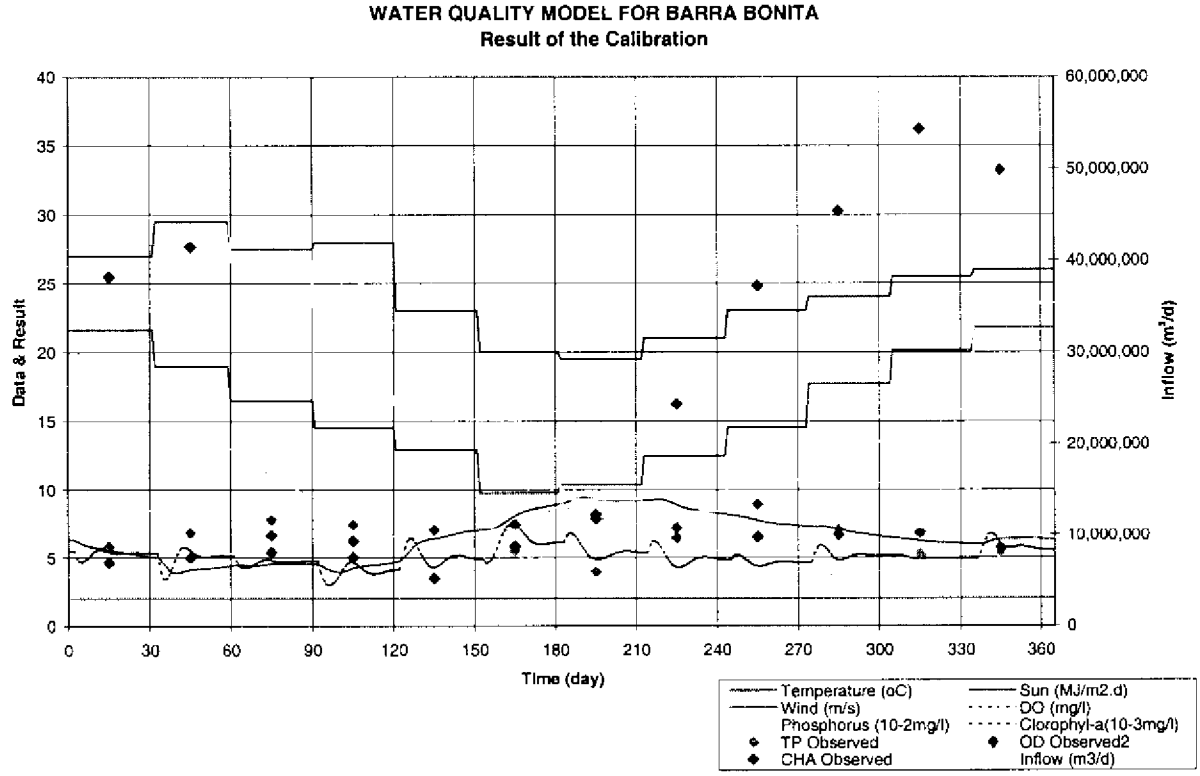
From Tundisi (7), some characteristics of Barra Bonita reservoir can be quoted:

- "Limnology events in Barra Bonita seems to be dominated by climatologic factors and by flushing rates and residence time". This points to the need to better understand and identify such interrelation.
- "Nitrogen is not a limiting factor for the eutrophication". That is the reason nitrogen was not analyzed.
- "During most of the year, stratification is short and weak". To better represent this characteristic in the model a high mix rate was used.

As for the first step of this research, monthly date for an annual analysis with constant values of climate, discharges and pollutant inflow was used. This is an attempt to better understand the system's behavior.

Firstly, the WQ model was calibrated. Three years with same input data were simulated to achieve the model's stability. The last year was used as the final average result. It was calibrated for three state variables: OD, TP and chlorophyll-a.

Figure 7. Result from calibration



As the model does not include variation of storage capacity with time, it was decided to simulate the reservoir for each month separately with the some boundary conditions as used for the calibration (Figure 7).

To avoid problems with the model's stability, for each month, it was necessary to run the model for a period of six months using the same monthly data. Besides, a four step discrete variation of storage was considered. The discrete values used for storage were 100, 70, 52 and 37 % of the reservoir's total capacity. The sub-indices for OD, TP and CHA were calculated from the monthly simulation. Then, the WQ index was obtain by the average of the three sub-indices. These results are showed below.

Figure 8.a. Results of Simulation for OD

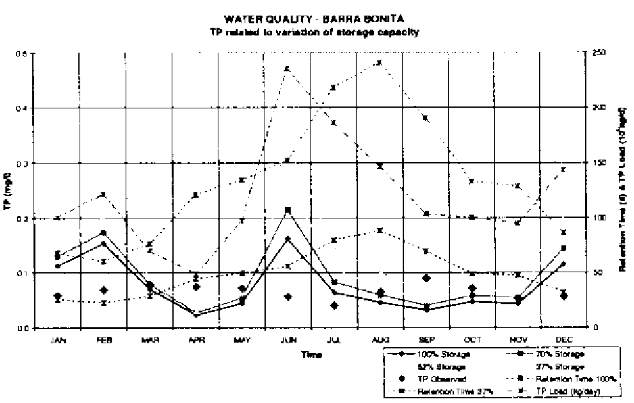
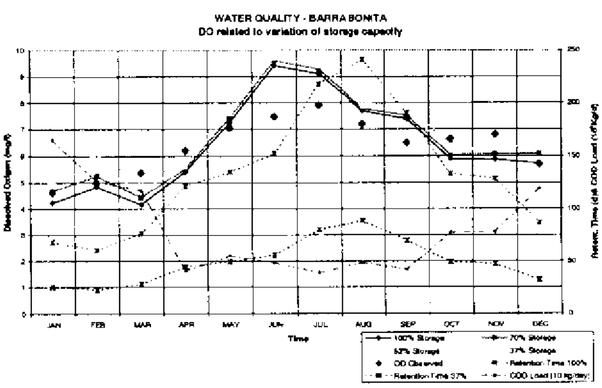


Figure 8.b. Results of Simulation for TP



I.3. Results

From the results shown above we can make some basic conclusions. WQ characteristics within the reservoir are greatly influenced by inflow concentration and volume, especially for OD and TP. However, chlorophyll did not present substantial changes during the seasonal cycle as was expected. Better results might be obtained after sensitive analysis on the estimation process of model's parameters. OD presented strong relation not only with COD loads but also with the retention time. WQ Parameters also showed considerable relation with variation of storage volume. In the case of OD, low water levels may present more desirable values. On the other hand, decrease of storage might induce high concentration of TP and chlorophyll.

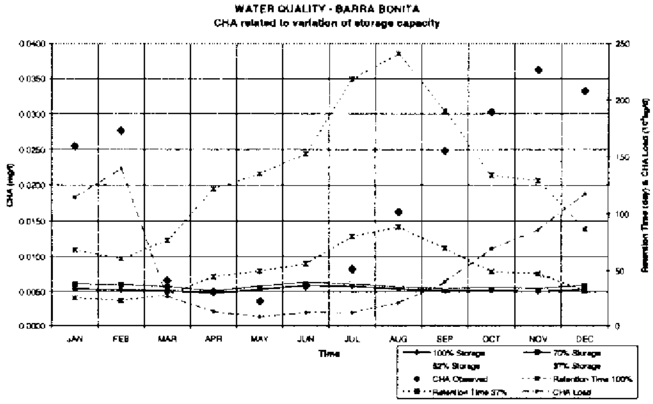


Figure 8.c. Results of Simulation for Chlorophyll

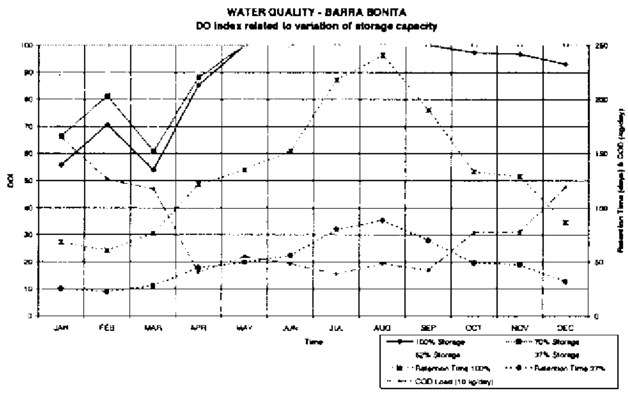


Figure 9.a. Dissolved Oxygen Sub-index (DOi) calculated from simulated results.

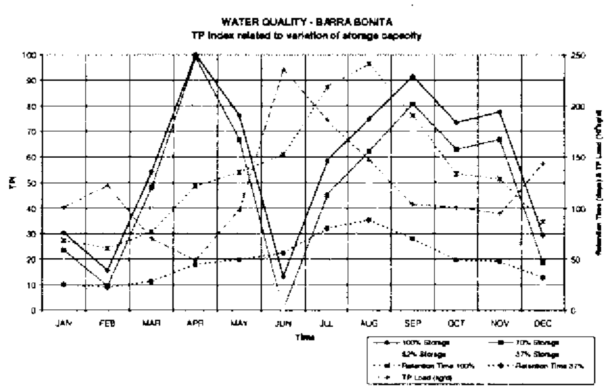


Figure 9.b. Phosphorus Sub-index (TPi) calculated from simulated results

This points to the need for evaluation tools that can indicate the most suitable release rate and consequently water levels in the reservoir. Looking at Figure 10, the combination of all three sub-indices, we can have a basic idea of how these evaluation methods works. Note that values near to 100 represent good WQ conditions. For this case, volumes equivalent to half of the storage are the most suitable ones.

It is important to remember that this was only an average annual analysis. Basically, it demonstrates the capability of the WQ model to be integrated with the water quantity assessment. Moreover, future analysis on the relation between model's parameters and storage volume will be considered. Furthermore, multi-objective water quantity analysis will be developed and combined to the reservoir's operation process.

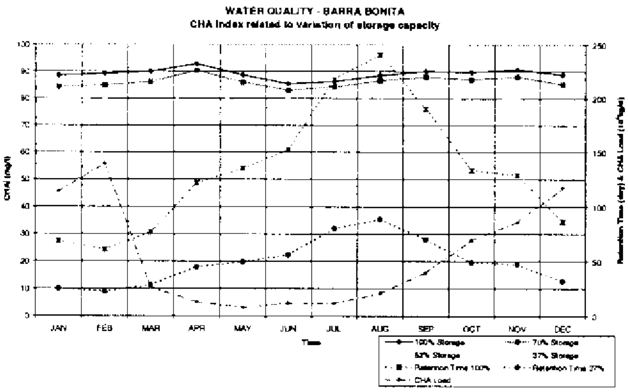


Figure 9.c. Chlorophyll Sub-index (CHAi) OD, calculated from simulated results

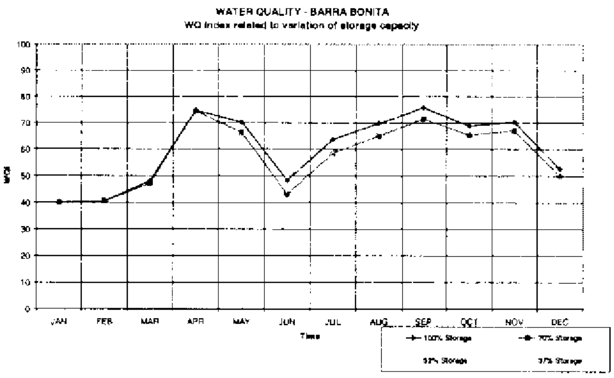


Figure 10. WQ index as a combination of TP and CHA sub-indices

J. Conclusion

This paper presents a formulation for the optimization of storage reservoirs considering aspects related to the integration of water quantity and quality. As stated, water management shows a great deal of complexity especially where water quality issues are assessed. Certainly, many other measures and decisions can also contribute to the augmentation of the reservoir environment quality such as watershed management, control of point source pollution and so on. The optimization process can face some difficulties related to the course of dimensionality due to the great number of water quality parameters if a simplification method, such as the use of WQ Index, is not used. In a further stage, regarding the sensitivity analysis, the relationship between parameters and water uses will be developed for practical evaluation and management.

Suitable Objective Function (OF) has definably great influence in the optimization model. The closer OF is to reality and society's needs, the better will be the results from the Optimization Model. OF and membership functions should be developed with a focus on the purposes and objectives of the reservoir, in collaboration with Brazilian experts and decision makers. Also, functions should be kept always updated with changes in relegations, society's needs, technology, and so on. It can be seen from experience and model result that the way a reservoir is operated can have great influence on environment conditions and people's life. Therefore, proper methods to deal with reservoir operation are of great importance.

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Modelación matemática del transporte de sedimentos y la evolución del lecho de embalses

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Resumen

Se presenta un modelo matemático para predecir el proceso de sedimentación en un reservorio y simular el crecimiento del delta. El modelo está basado en una forma parabolizada y lateralmente integrada de las ecuaciones de movimiento. Para la resolución numérica se utiliza el método de los elementos finitos. La formulación del modelo y el esquema numérico de resolución se explican brevemente. El modelo es validado mediante comparaciones con datos de campo del lago Mead (EE.UU.). Se estudian la evolución longitudinal del perfil del lecho como así también la estratificación de la composición del suelo. Se explican tanto la formación como el crecimiento de las formas del fondo. Se muestra que la evolución del fondo del reservorio depende fuertemente de diversos parámetros: la geometría del reservorio, el ciclo hidrológico, el nivel de embalse, la carga de sedimentos y el tamaño de las partículas.

Palabras clave: Sedimentación en embalses. Modelación matemática. Simulación numérica. Crecimiento del delta. Evolución morfológica.

Abstract

A mathematical model to predict the sedimentation process in a reservoir and to simulate the delta growth is presented. It is based on a parabolized and laterally integrated form of the governing equations. For the numerical resolution the finite element method is used. Model formulation and numerical scheme are both briefly explained. The model is validated through comparisons with field data from lake Mead (USA) surveys. The evolution of the longitudinal bottom profile as well as the resulting deposit stratification are studied. The formation and growth of bottom forms are explained. It is concluded that the reservoir bottom evolution depends strongly on several parameters: the geometry of the reservoir, the hydrological cycle, the lake level, the sediment load and the sediment size.

Keywords: Reservoir sedimentation. Mathematical modeling. Numerical simulation. Delta growth. Bottom evolution.

A. Introducción

Cuando se construye una presa sobre un río, se produce un corte abrupto de la capacidad de transporte de sedimento, de forma tal que las condiciones hidráulicas conducen a la deposición.

En la zona donde el río vierte sus aguas al reservorio, denominada boca o cabecera, el incremento de la sección de flujo produce la disminución de la fuerza de arrastre ejercida sobre las partículas del lecho, de forma tal que el material grueso (arena) tiende a depositarse, formando un delta (Figura 1). La forma y localización del delta depende de diversos factores: pendiente del valle, longitud del reservorio, tamaño y distribución del sedimento, forma del cauce, operación del reservorio, caudal líquido y sólido, etc. Además, el delta crece en ambas direcciones (aguas arriba y aguas abajo de la cabecera), y puede estar sumergido parcial o totalmente. Cuando el delta está superficialmente expuesto, se desarrollan uno a varios canales de flujo, dependiendo del nivel de embalse, el caudal entrante y las características del sedimento. En general, cuando aumenta el caudal se forma un solo canal, en lugar de diversos brazos (Sloff 1991). De todas formas, la predicción de estos procesos es extremadamente difícil.

En la parte del delta donde el río penetra en el reservorio tiene lugar un flujo de transición entre las condiciones netamente fluviales y las del reservorio, y la carga de fondo se acumula formando la cola del delta. La pendiente en esta zona es alrededor del 50 al 66% de la pendiente original, permaneciendo aproximadamente constante durante el crecimiento del delta (que, entonces, se eleva en capas paralelas). A una cierta distancia la cola se continúa abruptamente en el frente del delta, cuya pendiente es del orden de 6.5 veces la pendiente de la cola. A partir de experimentos, Schalchli (1987) concluye que (sin corrientes de turbidez) el frente se vuelve más empinado, hasta alcanzar cierto ángulo.

La progresiva reducción de la turbulencia produce que las partículas más finas (limo y arcilla) se depositen aguas abajo del delta, incluso llegando hasta la presa, formando los depósitos de fondo (Figura 1). Estos están más esparcidos por el reservorio, acumulándose en capas que tienden a consolidarse en el tiempo, debido a la acción de la sobrepresión ejercida por las capas superiores y la columna de agua. El transporte del sedimento fino depende primariamente de la circulación de agua, que en el reservorio está manejada, mantenida y amplificada por el flujo entrante desde el río. Eventualmente, una concentración elevada de material fino es capaz de inducir el desarrollo de una corriente de turbidez, que puede alcanzar la presa y formar un depósito o lago de lodo en la zona del volumen muerto del reservorio (Figura 1).

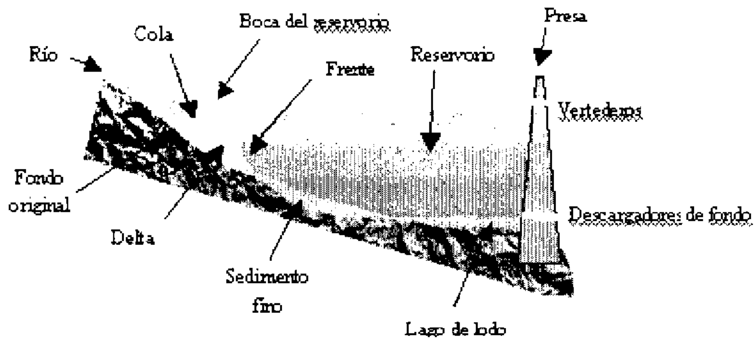


Figura 1. Esquema del proceso de sedimentación en un embalse.

Como consecuencia del proceso global de sedimentación, el reservorio sufre la pérdida de capacidad de almacenamiento. Este proceso ocasiona la colmatación progresiva del embalse, reduciendo la vida útil de la obra, cuyo cómputo es un parámetro de diseño primordial. Además, puede tener efectos económicos tanto de corto como de largo plazo. La severidad del problema ha sido confirmada por un informe del Banco Mundial, que estima la pérdida de capacidad mundial en alrededor de 50.000 hm^3, equivalentes a $ 6.000 millones anuales (Fan y Springer 1993).

Por otro lado, el crecimiento de un depósito en forma de delta, en la boca del reservorio, produce el desarrollo de un remanso en la dirección aguas arriba, el cual induce la acumulación de sedimento. El depósito se extiende gradualmente aguas arriba, y puede ocasionar el incremento del nivel de inundación durante las crecidas, en el área aguas arriba

del reservorio, o elevar el nivel freático en el tramo afectado por el remanso. El remanso fluctúa de acuerdo a las variaciones en el nivel de embalse, por lo cual la región afectada tiene características duales: tipo reservorio (artificial, con tendencia a la deposición) para niveles de embalse altos, y tipo fluvial (natural, con tendencia erosiva) durante las etapas de bajo nivel.
Por lo mencionado, la cuantificación del proceso de sedimentación en reservorios resulta de gran importancia, a los efectos tanto de estimar la factibilidad de una obra como de manejar su funcionamiento. En ambos casos se requieren herramientas de predicción de uso ingenieril. Entre las metodologías utilizadas a estos fines y referidas en la literatura se pueden señalar (un detalle de ellas se puede hallar en Tarela 2001):

- Métodos empíricos
- Estudios de campo y laboratorio
- Modelos matemáticos

De estos últimos, los más difundidos son los unidimensionales. Para el problema de la sedimentación en reservorios, los modelos 2D integrados en la vertical (2D-H) rara vez han sido empleados, mientras que prácticamente no existen referencias de modelos 2D integrados en la lateral (2D-V). Respecto de los modelos matemáticos 3D, los pocos desarrollos que involucran el transporte de sedimentos han sido enfocados a otro tipo de problemas. Cabe mencionar que la diversidad de escalas físicas espaciales y temporales involucradas en la evolución morfológica de un embalse los vuelve inapropiados por su altísimo costo computacional.

Así, en este trabajo se presenta un modelo 2D-V desarrollado con el doble objetivo de mejorar las predicciones de los modelos unidimensionales (a través de una descripción más precisa de los fenómenos involucrados) y operar con una herramienta computacional que no requiera hardware altamente sofisticado pero que proporcione información ingenierilmente útil en tiempos de cálculo razonables. En lo que sigue se describe someramente el desarrollo y validación del modelo.

B. Modelo matemático

Para obtener las ecuaciones de movimiento se utiliza el método RANS (*Reynolds Averaged Navier-Stokes*), que emplea el concepto clásico de promediar los efectos de la turbulencia y resolver sólo el flujo medio. Además, suponiendo que el flujo bajo estudio está caracterizado por una dirección principal de movimiento y que las variaciones laterales son poco significativas, resulta conveniente realizar una integración sobre esa dirección lateral, lo que conduce a una *descripción bidimensional según el plano vertical.*

Teniendo en cuenta que el flujo es incompresible, el proceso de promediación en el ensamble de estados turbulentos e integración lateral conduce a un sistema de ecuaciones de advección-difusión que se puede expresar en la forma reducida

$$\frac{\partial \mathbf{A}}{\partial t} + (\mathbf{u}\nabla)\mathbf{B} + \nabla \cdot \mathbf{C} = \mathbf{Q} \qquad (1)$$

con

$$\mathbf{A} = \begin{pmatrix} 0 \\ \mathbf{u} \end{pmatrix}, \ \mathbf{B} = \begin{pmatrix} \ln B \\ \mathbf{u} \end{pmatrix}, \ \mathbf{C} = \begin{pmatrix} \mathbf{u} \\ -\tau/\rho \end{pmatrix}, \ \mathbf{Q} = \begin{pmatrix} \sigma_B/\rho B \\ \mathbf{g} \end{pmatrix} \qquad (2)$$

donde t es el tiempo, $\mathbf{u}=(u,w)^T$ con u y w las componentes horizontal y vertical de la velocidad, respectivamente, B el ancho local de flujo, □ la densidad del agua, σ_B el aporte líquido lateral, $\mathbf{g}=(g_x,g_z)^T$ la aceleración de la gravedad y $\tau = \mathbf{T} - p\mathbf{I}$ - □$\mathbf{D}$ el tensor de tensiones efectivas (de segundo orden), con $\mathbf{T}$ el tensor de tensiones viscosas (difusión viscosa), p la presión, $\mathbf{I}$ el tensor unitario y $\mathbf{D}$ el tensor que contiene las correlaciones entre las fluctuaciones turbulentas (difusión turbulenta) y aquellas debidas a la interacción de los términos de desviación (dispersión), estas dos últimas provenientes de los procesos de integración temporal y lateral, respectivamente.

El sistema anterior se puede someter a un análisis dimensional en el cual se utilizan las escalas características del flujo en un embalse, pero teniendo en cuenta la dualidad entre el régimen fluvial en la entrada y el régimen tipo lacustre en el reservorio propiamente dicho. Si, además, los términos turbulentos se modelan a través del concepto de viscosidad de torbellino, entonces la forma dimensional no conservativa de las ecuaciones que gobiernan el sistema hidrodinámico bajo estudio es:

$$\frac{\partial u}{\partial x}+\frac{\partial w}{\partial z}+u\frac{\partial \ln B}{\partial x}+w\frac{\partial \ln B}{\partial z}=\frac{\sigma_B}{\rho B} \tag{3}$$

$$u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}+\frac{1}{\rho}\frac{\partial p}{\partial x}-\frac{\partial}{\partial z}\left(\nu_{tz}\frac{\partial u}{\partial z}\right)=g_x \tag{4}$$

$$u\frac{\partial w}{\partial x}+w\frac{\partial w}{\partial z}+\frac{1}{\rho}\frac{\partial p}{\partial z}-\frac{\partial}{\partial z}\left(\nu_{tz}\frac{\partial w}{\partial z}\right)=g_z \tag{5}$$

Ya que las escalas de tiempo de las excitaciones externas del sistema (régimen hidrológico del aporte y operación del nivel de embalse) son largas en relación a la escala de tiempo de adaptación del flujo a la nueva condición, el sistema anterior no depende del tiempo. De esta forma, la evolución morfológica del lecho del reservorio se puede representar a partir de una sucesión de estados cuasi-estacionarios.

En las expresiones (3), (4) y (5), el eje cartesiano x se toma paralelo a la pendiente media inicial del lecho, mientras que z resulta perpendicular al anterior y, por lo tanto, casi vertical. Obsérvese que el término de difusión horizontal está ausente en las ecs. (4) y (5), ya que resulta despreciable frente a la difusión vertical.

La distribución de la viscosidad de torbellino se representa mediante:

$$\nu_{tz}=k\,hu_*\,\frac{z}{h}\left(1-\frac{z}{h}\right) \tag{6}$$

con k la constante de von Karman, h la profundidad local y u_* la velocidad de corte.

Como condiciones de contorno, en el lecho se impone impenetrabilidad y no deslizamiento:

$$\mathbf{u}_b=0 \tag{7}$$

mientras que en la superficie libre se tienen:

$$\frac{\partial \zeta}{\partial t} + u \frac{\partial \zeta}{\partial x} - w = \sigma_\zeta \qquad (8)$$

$$p|_\zeta = p_0 \qquad (9)$$

$$\tau_{zx}|_\zeta = \tau_W \qquad (10)$$

donde $z = \zeta(x,t)$ define la posición de la superficie libre, siendo σ_ζ el balance neto entrante entre las tasas de precipitación (positiva) y evaporación (negativa), p_0 la presión atmosférica y τ_W el esfuerzo de corte ejercido por el viento. La superficie libre en sí misma se determina utilizando las ecuaciones de Saint-Venant para flujo unidimensional (Henderson 1966) y se impone como una tapa rígida sobre el dominio de flujo.

Como se resuelve la subcapa interna, se toma el borde coincidiendo con la altura (virtual) donde se anula la velocidad, z_0

$$z_b = z_0 = \frac{k_s}{30} \qquad (11)$$

siendo k_s la altura efectiva de rugosidad del fondo (por grano y formas). Para determinar este último parámetro se utiliza un predictor de formas de fondo, no descripto aquí por razones de espacio (Tarela 2000).

Ya que el sistema (3)-(5) es parabólico en la dirección principal del flujo, en el borde aguas arriba se imponen como condiciones "iniciales" los perfiles de velocidad y presión, mientras que en el borde aguas abajo (presa) se impone el nivel de embalse.

Para el transporte de sedimentos se considera separadamente la carga de fondo y la carga en suspensión. La primera se cuantifica a través de alguna de las fórmulas tradicionales, mientras que para la segunda se utiliza la siguiente ecuación de transporte:

$$\left(u + w_{sj} \sin\theta\right)\frac{\partial s_j}{\partial x} + \left(w - w_{sj}\cos\theta\right)\frac{\partial s_j}{\partial z} = \frac{\partial}{\partial z}\left(\nu_{tz}\frac{\partial s_j}{\partial z}\right) \qquad (12)$$

donde s_j indica la concentración promediada estadísticamente e integrada lateralmente de la fracción j de material con diámetro característico □$_j$ y velocidad de caída de las partículas w_{sj}, siendo □ el ángulo comprendido entre el eje x y la horizontal. Se ha supuesto que las concentraciones son lo suficientemente bajas como para no influir sobre la hidrodinámica, esto es, las partículas son transportadas pasivamente por el flujo. Además, en (12) sólo existe difusión vertical, y debido a la interacción despreciable entre partículas, se toma el mismo coeficiente de difusividad que para partículas de agua.

Como condición de borde en la superficie libre se impone flujo neto de partículas nulo:

$$-\nu_{tz}\frac{\partial s_j}{\partial n_{fs}} - \cos\chi_{fs}\, w_{sj}\, s_j = 0 \qquad (13)$$

donde χ_{fs} es el ángulo entre la normal a la superficie libre, n_{fs}, y la vertical.

Por su parte, en un fondo ficticio se impone una relación general entre la tasa de resuspensión y la concentración:

$$-\nu_{tz}\frac{\partial s_j}{\partial n_b} = \cos\chi_b w_{sj}(1-P_{dj})s_j + E_j \tag{14}$$

donde χ_b es el ángulo entre la normal al fondo, n_b, y la vertical, E_j la tasa de erosión y P_{dj} la probabilidad de deposición, definida como la proporción de sedimento cercano al fondo que alcanza el lecho y se "pega" al mismo (Partheniades 1988).

La altura del fondo ficticio se toma como el 50% de la altura efectiva de rugosidad para el caso en que existen formas de fondo, y justo encima de la capa de transporte por rodamiento y salto (carga de fondo) cuando no.

Para material grueso (arena y grava) se toman:

$$P_{dj} = 0 \qquad \delta_j > 62\mu m \tag{15}$$

$$E_j = \cos\chi_b w_{sj}(s_{eq,j} - s_j) \qquad \delta_j > 62\mu m \tag{16}$$

donde la primera indica no adhesión y la segunda considera que la tasa neta de erosión es proporcional al decremento de la concentración respecto del valor de equilibrio local $s_{eq,j}$. Para cuantificar este último se utiliza la expresión estocástica de van Rijn (1987).

En el caso de material más fino (limo) las fuerzas de cohesión fisicoquímicas al momento de la deposición aumentan mientras el tamaño de las partículas disminuye. Teniendo en cuenta este efecto, y que el flujo es en general desacelerado, se impone la siguiente condición:

$$E_j = 0 \qquad 4 < \delta_j < 62\mu m \tag{17}$$

mientras que para la probabilidad de deposición se toma (Partheniades 1988):

$$P_{dj} = \begin{cases} 0 & \tau_* > \tau_{dj} \\ 1 - \dfrac{\tau_*}{\tau_{dj}} & \tau_* < \tau_{dj} \end{cases} \qquad 4 < \delta_j < 62\mu m \tag{18}$$

donde τ_* es la tensión de corte local y $\Box_{dj}$ su valor crítico para deposición. Este último parámetro no está establecido en forma precisa, obteniéndose de la literatura valores típicos en el rango $0.06 \le \Box_{dj} \le 1.1$ N/m^2 (Ziegler y Nisbet 1995).
Si las condiciones de floculación no son alcanzadas (por ejemplo, los contenidos de materia orgánica y sal son bajos) entonces la arcilla puede tratarse como el limo, esto es, (17) y (18) se aplican al rango entero de partículas finas ($\delta_j < 62\mu m$).

Cuando el proceso de sedimentación comienza, el fondo se modifica de acuerdo a

$$\frac{dz_b}{dt} = -\sum_j \frac{1}{(1-\pi_j)B}\frac{dQ_{sj}}{dx} \tag{19}$$

donde π_j es la porosidad del material y Q_{sj} el caudal sólido total, que incluye la carga de fondo. Finalmente, en la sección aguas arriba se especifica el perfil de concentración para todo tiempo.

C. Esquema numérico

Para hallar las soluciones del modelo matemático se emplea un esquema numérico en elementos finitos. Aprovechando el carácter parabólico del problema diferencial, se utiliza un proceso de marcha para obtener los campos de velocidad, presión y concentración en cada paso de tiempo. Es decir, dadas las distribuciones verticales de dichos campos en una sección de flujo, se determinan las incógnitas en la sección inmediatamente aguas abajo, y se repite el procedimiento desde la sección de entrada al modelo (aguas arriba) hasta la última sección de cálculo aguas abajo.

Se emplean elementos finitos cuadrangulares de 6 nodos, con 3 nodos en cada cara vertical, distribuidos sobre una malla estructurada que se densifica hacia el fondo (donde existen los mayores gradientes de velocidad y concentración). Para estabilizar las presiones se usa interpolación mixta en la vertical, aunque las velocidades y las presiones se interpolan linealmente en la dirección principal de flujo. Las velocidades quedan estabilizadas por el carácter de upwinding implícito que surge del esquema de marcha. Para determinar la tensión de corte en el lecho se emplea un esquema iterativo similar al propuesto por Jin y Kranenburg (1993). Además, se ha mostrado que el esquema numérico es consistente y estable (Tarela 2000). En la referencia mencionada se dan más detalles del método numérico de resolución.

Para tener idea del esfuerzo computacional cabe mencionar que una corrida típica (como la mostrada más adelante) involucra unos 100 elementos en la vertical, 1000 elementos en la horizontal, alrededor de 2000 pasos de tiempo y entre 5 y 10 fracciones de sedimento, lo que equivale a unos $3\ 10^9$ grados de libertad. Tal corrida puede requerir unas 20 horas de CPU en una máquina PC PIII de 500MHz, con un promedio de 24 □s por grado de libertad. Los requerimientos de RAM son menores.

D. Simulación del crecimiento del delta del lago Mead (USA)

Como caso de estudio se empleará el lago Mead, producto de la construcción de la presa Hoover sobre el río Colorado, en el sudoeste de los EE.UU. Frecuentemente se señala que el informe técnico de la inspección del lago Mead, realizado por Lara y Sanders (1970), es el de más detalle de entre los de su tipo disponibles públicamente. En ese trabajo se pueden encontrar datos prácticamente continuos durante un período de unos 30 años, a partir del cierre de la presa. Ese fue el período simulado.

Una gran cantidad de muestras de fondo y enterradas ha sido analizada en detalle, dando lugar a una importante recopilación de información, que permite generar una base de datos relativamente completa, incluyendo hidrograma, nivel embalse y caudal sólido (series a 30 años), características físicas de muestras de sedimentos obtenidas por perfilaje vertical (composición porcentual, diámetros característicos y porosidad), volumen sedimentado, perfiles longitudinales (1948/49 y 1963/64) y perfiles verticales en distintas secciones.

Se modeló un tramo del lago comprendido entre la intersección de los antiguos cauces de los río Colorado y Virgin hasta unos 150 km aguas arriba, es decir, una fracción de la extensión total del lago (ya que la información histórica del brazo del lago debido al cauce del río Virgin es escasa).

El caudal medio mensual que ingresa al lago es de 436 m^3/s, con máximos en junio (entre 400 y 2.600 m^3/s) y mínimos en diciembre/enero (menos de 100 m^3/s). La serie del nivel de embalse para el período simulado muestra un transitorio del llenado del vaso de unos 3 ½ años. Para el período de régimen de operación del embalse el nivel medio es de 354.3 msnm, oscilando entre los niveles 330.7 y 372.5 msnm, es decir, una excursión máxima en todo el período de 41.8 m. La excursión anual del nivel de embalse oscila entre 10 y 20 m, aproximadamente.

Para la serie completa de 30 años, la cantidad total de sedimento pasando a través del Gran Cañón alcanza los 3171 millones de toneladas, con un promedio de 8.8 millones de toneladas mensuales. El máximo registrado alcanza los 95 millones de toneladas mensuales, con mínimos del orden de 250.000 toneladas al mes. El análisis de la serie indica que durante los primeros 15 años se transportaron las dos terceras partes de la carga total, y en los últimos 15 años solamente un tercio. Es decir, en la primera etapa el caudal sólido total duplicó al de la segunda mitad de la serie. La información batimétrica se completa con una serie de secciones relevadas a lo largo del lago en los años 1935, 1948/49 y 1963/64.

Del análisis global de la información registrada en todo el lago Mead, Lara y Sanders (4) concluyen que los depósitos están formados, en su conjunto, por un 60% de arcilla, un 28% de limo y un 12% de arena. Estos valores incluyen el aporte del río Virgin. Teniendo en cuenta solamente la región modelada, un análisis propio arrojó una composición global con 30% de arcilla, 48% de limo y 22% de arena.

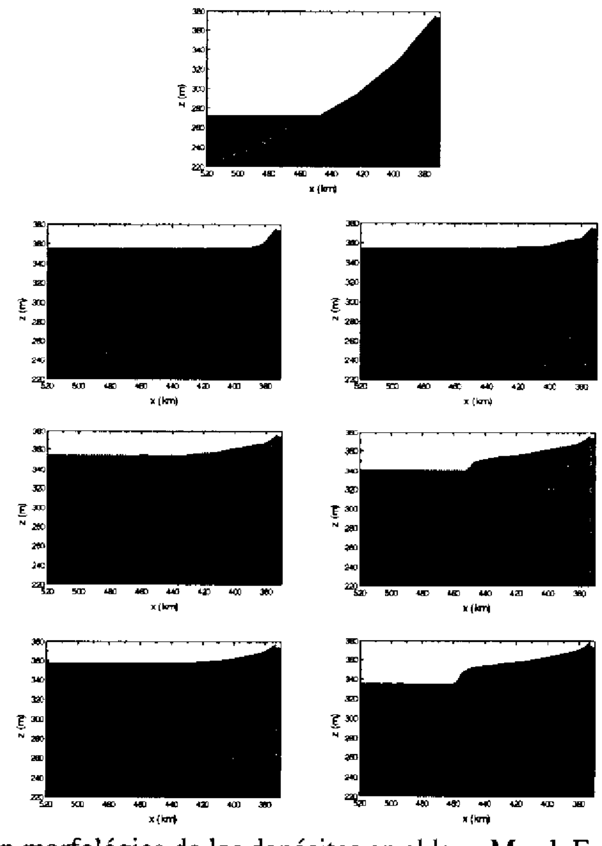
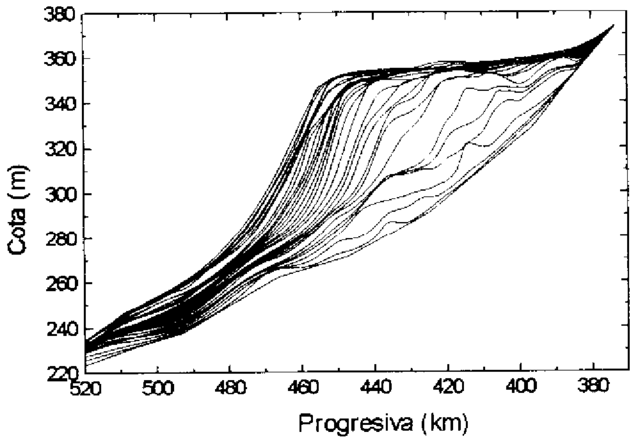


Figura 2. Evolución morfológica de los depósitos en el lago Mead. En orden lexicográfico: estado a enero 1935 (inicial),y diciembre de los años 1939, 1944. 1949, 1954, 1959 y 1964.

La Figura 2 muestra distintos momentos del crecimiento del delta, y en la Figura 3 se presentan los perfiles anuales calculados durante los 30 años de simulación. Durante los primeros años se observa la formación de un depósito extendido, que crece aguas arriba en la medida que se llena el reservorio. Luego sigue un período de crecimiento acelerado en la zona del delta, donde la arena llena rápidamente el vaso hidráulico, que allí presenta los anchos menores. El tope del delta tiende a estabilizarse con el tiempo, alrededor de la cota 355, y su frente avanza más lentamente, en la medida que el depósito llega a lugares de mayor sección. Al pie del delta aparece una formación suave, debida a la deposición del material fino (limo y arcilla).

Figura 3. Perfiles anuales del lecho del lago Mead (modelo).



En la Figura 4 se presenta la comparación entre los perfiles relevados a los 15 y 30 años del cierre de la presa y los perfiles calculados. Se observa un muy buen acuerdo en el tope y el frente del delta, donde la cuantificación de niveles medios y pendientes arroja los resultados de la Tabla 1. Al comienzo del pie del delta el acuerdo es satisfactorio, pero se detectan diferencias significativas a medida que se penetra en el lago. Este efecto se supone debido a que en el lago se han detectado eventos de formación de corrientes de turbidez, que producen el transporte del material más fino hacia la presa y, por efecto de remanso, dan lugar a la formación de un fondo de lodo más o menos uniforme.

Figura 4. Comparación entre los perfiles relevados y los calculados a los 15 años (izquierda) y 30 años (derecha).

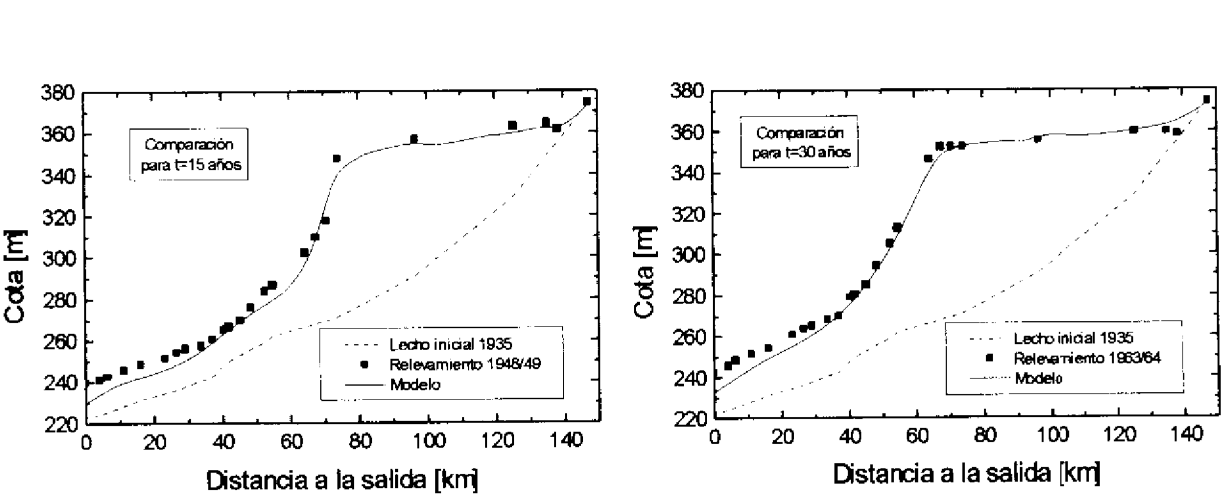


Tabla 1. Análisis cuantitativo de los perfiles medidos y calculados

Zona	Parámetro	15 años		30 años	
		medido	calculado	medido	calculado
Tope del delta	Pendiente (m/km)	0.23	0.24	0.15	0.15
	Cota media (m)	358	356	355	356
Frente del delta	Pendiente (m/km)	7.6	3.9	3.5	3.4

A partir del relevamiento de los años 1948/49 Gould determinó que en el depósito se podían distinguir dos regiones, una formada por arena y limo grueso, y la otra por limo fino y arcilla. La Figura 5 muestra la interfase determinada por Gould (Howard 1953) y la composición del depósito según los cálculos, observándose un buen acuerdo entre ambas. Finalmente, en la Figura 6 se presentan los resultados medidos y calculados para una perforación de 60 m de profundidad llevada a cabo en la progresiva 447 km. Más allá de que se trata de una sola muestra, se aprecia una correspondencia razonable en la composición del suelo a través de la identificación de estratos constituidos por material grueso y fino.

E. Conclusiones

Se ha presentado un modelo matemático 2D-V para simular el proceso de sedimentación en un reservorio. Su formulación y resolución están íntimamente ligadas a las escalas físicas involucradas en el problema.

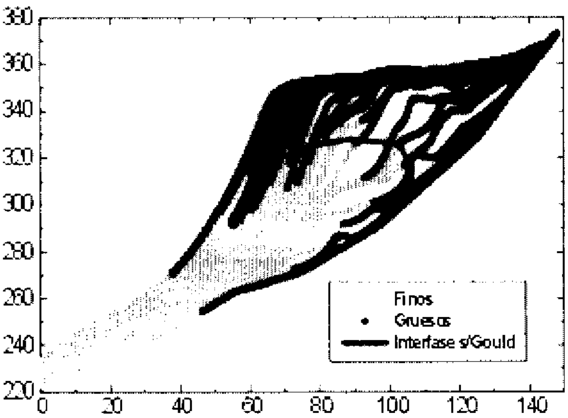


Figura 5. División de los depósitos en zonas compuestas por material fino ($\delta < 16\mu m$) y grueso ($\delta > 16\mu m$)

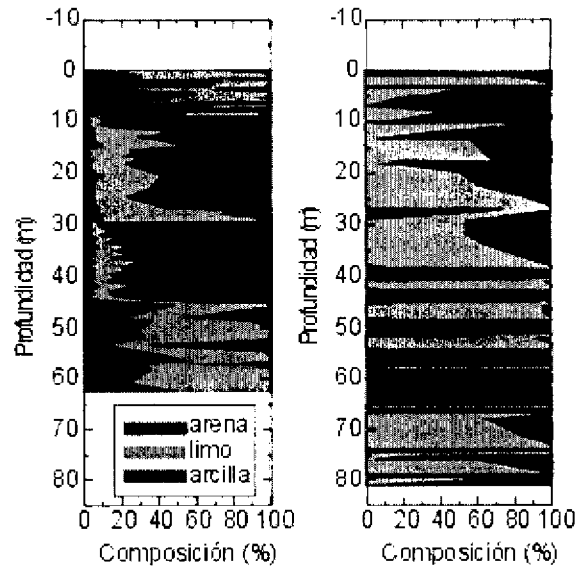


Figura 6. Comparación de la composición del suelo por tamaño de partículas entre las mediciones (izquierda) y los cálculos (derecha)

El grado de detalle que se puede alcanzar supera al de los modelos 1D usualmente utilizados en esta problemática. La aplicación a un caso de campo extensamente relevado mostró una gran capacidad de predicción, tanto en la forma de los depósitos como en su composición. Las diferencias detectadas pueden deberse a la existencia de fenómenos de transporte (corrientes de densidad) no incluidos en el modelo, aunque el mismo está desarrollado de forma tal que pueda incorporarlos.

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Monitoreo de calidad de agua y sedimentos del embalse Los Molinos I, Córdoba, Argentina.

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Resumen

El Embalse Los Molinos I está ubicado en la Provincia de Córdoba (Argentina), a 65 Km al sur de la Ciudad Capital. En la actualidad, a través de un sistema de canalización se utiliza para complementar el suministro de agua potable a la Ciudad de Córdoba, por lo que merece especial atención su preservación y adecuado manejo. En los últimos años este reservorio ha presentado claros signos de problemas derivados del estado de eutrofia, tales como escasa transparencia, presencia de anoxia hipolimnética y frecuentes eventos de floraciones algales, con el consiguiente deterioro del recurso.

Con el objetivo de lograr un estudio integral y sistemático de la calidad del agua y los sedimentos abordado en forma interinstitucional e interdisciplinario y generar una base de datos para la aplicación futura de modelos de eutroficación que contribuyan a la adecuada gestión, se iniciaron en el año 1.999 una serie de campañas de monitoreo de agua y sedimento del embalse y sus cuatro tributarios principales. El objetivo del presente trabajo es presentar los avances y los resultados preliminares de los parámetros físico-químicos y biológicos de calidad correspondientes al embalse, conjuntamente con la utilización del programa PROFILE para el análisis y resumen de datos.

Palabras claves: eutroficación, embalse, monitoreo, nutrientes, *Ceratium sp.*

Abstract

The reservoir Los Molinos I is located in the Province of Córdoba, Argentina, at 65 km at the south from the capital, Córdoba City. The preservation and appropriate use of this reservoir deserve special attention because it is connected to the city through a canal and is used to complement the drinking water supply. In the last years, Los Molinos I has shown clear signs of problems related to eutrophication, such as low transparency, very low concentration of oxygen in the hypolimnion, and frequent algal blooms.

Since 1999, various field campaigns to monitor water, sediment and four main tributaries were started in order to achieve a comprehensive and systematic understanding of the status of water and sediment. This interdisciplinary and inter-institutional study also intends to generate data bases that allow to apply eutrophication models, aiming an appropriate management of the resource. The aim of this work is to present the advances and preliminaries results obtained so far. Physicochemical and biologic parameters related to water and sediment quality are shown by using the program PROFILE to analyze and summarize the data.

Keywords: Eutrophication; Reservoir; Monitoring; Nutrients; *Ceratium Sp.*

A. Introducción y antecedentes

El primer aprovechamiento del potencial hídrico de la Cuenca Alta del Río Xanaes (Córdoba; Argentina) en el año 1.953 a través de la **PRESA LOS MOLINOS I**, destinada fundamentalmente a la producción de energía hidroeléctrica y, como en las obras de este tipo, existen usos múltiples del recurso, destacándose la regulación y el control de crecidas aguas abajo, su utilización como fuente de agua potable y con fines turísticos. Su cuenca de alimentación se extiende entre las cumbres de las Sierras Grandes, al oeste y los cordones de las Sierras Chicas, al este, la cual se canaliza a través de los aportes principales de los **ríos San Pedro, Los Espinillos, Del Medio** y **Los Reartes**. El Río Los Molinos I se origina en el embalse homónimo.

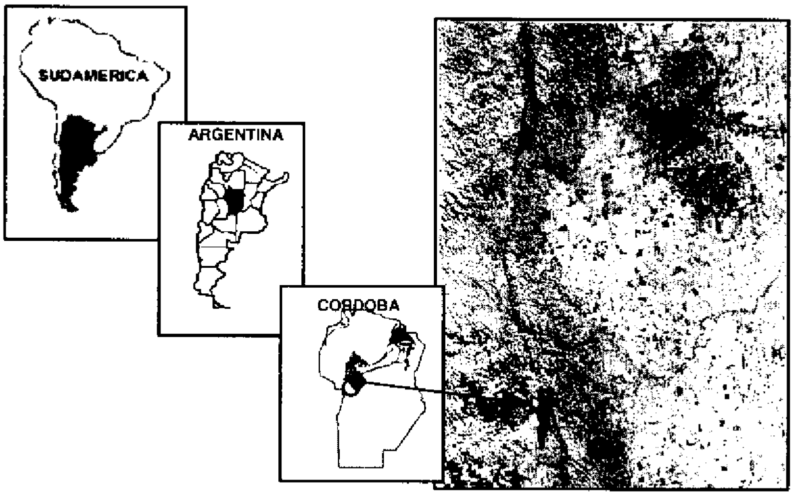


Figura 1: Localización del embalse Los Molinos I

La Ciudad Capital y su zona de influencia (Gran Córdoba) tienen como principal fuente de agua para uso múltiples y especialmente para abastecimiento de agua potable, a la cuenca del río Suquía. Hoy este sistema es insuficiente y frágil, tanto por la escasa disponibilidad del recurso hídrico superficial típico de esta región, como por el grado de deterioro de la calidad del agua. En la actualidad, a través de un sistema de canalización se utilizan las aguas del embalse Los Molinos I para complementar el suministro de agua potable a la Ciudad de Córdoba. El caudal requerido es de aproximadamente 5,2 m^3/s, para una población abastecida de alrededor de un millón y medio de habitantes, de los cuales 4,7 m^3/s son provistos por el embalse San Roque y el resto, de aproximadamente 0,5 m^3/s es abastecido desde el embalse Los Molinos I. En la Tabla N° 1 se detallan las características más relevantes del embalse Los Molinos I.

Existen estudios realizados en el Embalse Los Molinos I en los cuales ya se habla de las características eutróficas de este cuerpo de agua (Bonetto, *et. al.*,1.976; Donatti, 1.997). Los antecedentes más recientes señalan claros signos de problemas derivados del estado de eutrofia tales como el agotamiento del oxígeno hipolimnético, evidencias de incremento de nutrientes cerca del fondo, el crecimiento excesivo de cianofíceas con posibilidad de generación de toxinas, un descenso acentuado en la transparencia y proliferación reciente de algas dinoflageladas, del género *Ceratium sp.*, con un bloom que se presentó en el mes de noviembre de 1.999, que tuvo como consecuencia bajos tenores de oxígeno y mortandad de peces (Cossavella, 2.000).

CARACTERÍSTICA (*)	EMBALSE LOS MOLINOS I
Coordenadas geográficas	La: 31° 50'S-Long. : 64° 30'W
Curso de agua	Río Los Molinos
Propósito	AAP-R-GE(CLMI)-AC
Area de la Cuenca de alimentación	978 Km^2
Módulo erogado	9,5 m^3/s(Serie 1952/80)
Cota labio de vertedero	665 m.s.n.m.
Superficie cota labio de vertedero	2110 Ha
Superficie a nivel máximo	2451 Ha
Volumen cota labio vertedero	307 Hm^3
Longitud máxima (N-S)	13,5 Km
Profundidad máxima normal	52,00 m
Profundidad media normal	14 m
Tiempo máximo de residencia	1.06 año

(*) Fuente: Dirección Provincial de Hidráulica, M.O.S.P, Córdoba
(APP: Abastec. de agua potable; R:Riego: GE: Gen. de Energía Central Los Molinos I; AC: aten. de crecidas)

Tabla 1: Características del embalse Los Molinos

Como principales fuentes externas de nutrientes en la cuenca del embalse Los Molinos I se destacan las actividades agrícolas, forestales y ganaderas, el empleo de agroquímicos en el perilago y su cuenca de aporte e infraestructura para el turismo destacándose la baja densidad poblacional en la cuenca, con valores que no superan los miles de habitantes.

Es clara la importancia de contar con un conocimiento acabado del estado trófico del embalse Los Molinos I y la influencia de fuentes internas y externas de aportación de nutrientes, a fin de poder contar con elementos válidos que permitan adoptar medidas tendientes a prevenir, atenuar o corregir la pérdida de la calidad del cuerpo de agua para los usos a los que está destinado.

B. Objetivos

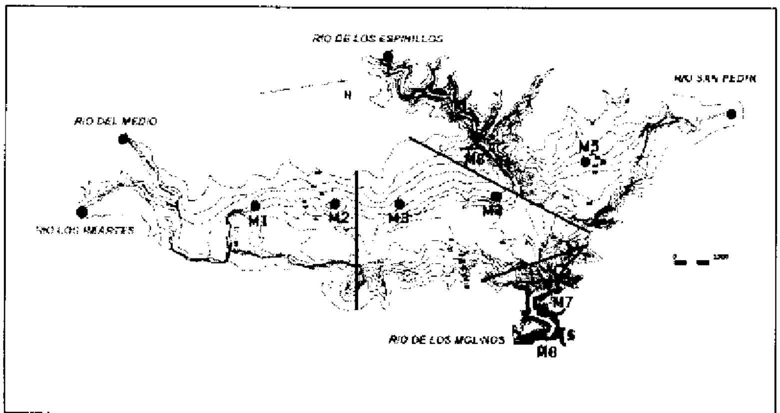
Los objetivos del presente trabajo son mostrar el diseño de monitoreo adoptado y algunos de los resultados preliminares y comparativos de las campañas correspondientes a las cuatro estaciones desde primavera de 1.999 a invierno de 2.000, así como la utilización del programa PROFILE (Walker, 1.996) para el análisis preliminar y resumen de datos.

C Materiales y métodos

Se realizaron hasta la fecha siete campañas de monitoreo, las que fueron iniciadas en el mes de octubre del año 1.999, y fueron llevadas a cabo en forma estacional. Hasta la fecha se cuenta con resultados parciales de los trabajos realizados correspondientes a las cinco primeras. El grupo participante incluyó profesionales del arrea de ingeniería civil, hidrología, química y biología.

C.1. Metodología y diseño de monitoreo

La selección de los lugares y la frecuencia de muestreo dependen en gran medida de las propiedades morfométricas e hidrodinámicas de la masa de agua (OCDE, 1.982 citado en Ryding y Rast, 1.992) y la selección de los lugares de muestreo debe tener en cuenta la posibilidad de una distribución heterogénea de la calidad del agua. Para un monitoreo con objetivos múltiples lo razonable es distribuir estaciones en todas las áreas representativas del embalse sugiriéndose un mínimo de tres: una en la parte superior, otra en el medio y una tercera cerca de la presa (Walker, 1996). A continuación se detalla el diseño adoptado para el embalse y los tributarios, teniendo en cuenta las características del reservorio y los antecedentes existentes (Figura 2). Se fijaron nueve estaciones de monitoreo (M1 a M8 y S), teniendo en cuenta las desembocaduras de ríos, puntos intermedios, centro, garganta, presa y área de toma.



M1: desembocadura del Río los Reartes y del Medio.
M2, M3: puntos intermedios a lo largo del embalse
M4: centro
M5: desembocadura Río San Pedro.
M6: desembocadura Río Los Espinillos.
M7: inicio de la garganta.
M8: frente al paredón del dique.
S: área toma central hidroeléctrica (la toma se halla a cota 736 s.n.m.).

Figura 2: Localización de las estaciones de monitoreo

En cada estación se midió *in situ* las coordenadas de ubicación geográficas utilizando un GPS, la trasparencia con disco de Secchi, pH, temperatura del agua y del aire, oxígeno disuelto y conductividad utilizándose una sonda marca Horiba U-10. Las determinaciones se realizaron en perfil cada 1 metro hasta los 10 m y posteriormente cada 5 m hasta el fondo en las estaciones M1 a M8. En la estación S, se midieron estos parámetros sólo a la profundidad de la toma para la Central Hidroeléctrica Los Molinos I. Para la extracción de muestras de agua en profundidad se utilizaron muestreadores tipo botellas Van Dorn. En las estaciones correspondientes a la desembocadura del Río los Reartes y del Medio, centro, desembocadura Río San Pedro, garganta y presa, se extrajeron muestras para determinaciones de laboratorio.

En laboratorio se analizaron los siguientes parámetros Físico-Químicos y Biológicos: turbiedad alcalinidad, cloruros, fósforo total, ortofosfato, nitrógeno de nitritos, nitrógeno de nitratos, nitrógeno amoniacal, fitoplancton, clorofila a, sílice, hierro, aluminio, manganeso, calcio, bacterias coliformes totales y fecales. Las muestras para análisis de fitoplancton, clorofila a y sílice se obtuvieron a tres profundidades: superficial, a la profundidad del disco de Secchi y a 2,5 veces este valor y para la determinación de los restantes parámetros se obtuvieron de dos profundidades para el primer monitoreo (a 0,50 m del pelo de agua y a 0,50 m del fondo) y a partir del segundo monitoreo se agregó una tercera profundidad (a 2,5 veces la profundidad del disco de Secchi o punto medio del metalimnion en caso de estar estratificado).

Los lineamientos para la metodología de toma de muestra, almacenamiento y preservación se tomaron de APHA, AWWA and WEF (1.995): "Standar Methods for the Examination of Water and Wastewater", al igual que las técnicas analíticas empleadas en laboratorio.

Para la extracción de las muestras de sedimentos se utilizó una draga tipo Ekman. Se tomó la primera capa de sedimentos, la cual se recibió en un recipiente plástico limpio trasvasándose luego a frascos de vidrio estériles y manteniéndolos a 4°C durante su traslado al laboratorio para el procesamiento. Las determinaciones bacteriológicas realizadas en sedimentos fueron: coliformes totales y fecales. Los sedimentos se secaron a 45°C para la posterior determinación de fósforo total, fracción de fósforo débilmente adsorbido, fracción unida al aluminio, fracción unida al hierro, fracción unida al calcio, nitrógeno de amoníaco, nitrógeno de nitratos, aluminio, hierro, calcio, manganeso y carbono orgánico total. No se cuenta con los resultados de estas determinaciones a la fecha.

Se seleccionaron 5 puntos, representativos de las distintas zonas, para la obtención de las muestras de sedimentos, todos ellos situados en el interior del mismo. El primero de ellos en la zona de la desembocadura de río Los Reartes, el segundo en la zona central del embalse, el tercero en la zona de la desembocadura del río San Pedro, el cuarto en la zona de la desembocadura del río Los Espinillos, y el último en la zona de la garganta cerca del dique.
Días previos a la primer campaña se llevó a cabo un relevamiento en el perilago para fijar el recorrido de los accesos a los tributarios, de acuerdo a la cota del embalse (761,67 m) en ese momento.

Se realizó el muestreo y aforo de los cuatro tributarios principales. La metodología utilizada para la toma de muestras, almacenamiento y preservación fue similar a la aplicada para las muestras extraídas en el embalse. Se aforó cada uno de los tributarios principales adoptando la sección adecuada para lo cual se emplearon dos molinetes y contadores y se obtuvieron muestras instantáneas de agua en cada tributario para análisis y cuantificación de: alcalinidad, cloruros, turbiedad, fósforo total, fósforo reactivo soluble, nitrógeno de nitrito, nitrógeno de nitrato y nitrógeno de amonio y bacterias coliformes totales y fecales.

C.2. Análisis de los resultados

La evaluación de los datos que se obtuvieron en las distintas campañas se realizó con una Serie de Procedimientos y Técnicas Simplificadas para la Evaluación y Predicción de la Eutroficación (Walker, 1996) que facilitan el análisis, resumen de datos y la implementación de modelos de procesos de eutroficación simplificados. Dichas herramientas proveen un marco para la interpretación de datos de monitoreo de calidad de agua y la predicción de los efectos debido a cambios en las cargas externas de nutrientes.

Consta de tres módulos:

FLUX: estimación de la carga másica promedio de los tributarios a partir de datos de concentración de las muestras y el registro continuo de caudales. Además cuantifica errores.

PROFILE: diagrama y resumen de los datos de calidad de agua del embalse. Incluye un algoritmo para el cálculo de la tasa de deplexión de oxígeno hipolimnético.

BATHTUB: implementación del balance de nutrientes y modelos de eutroficación. Este programa permite el cálculo del balance de nutriente y balance hídrico en estado estable de una red de embalses segmentados espacialmente y considera el transporte advectivo y difusivo y la sedimentación de nutrientes.

D. Descripción de resultados

D.1. Parámetros Físico-Químicos e indicador biológico

En el presente trabajo se aplicó el programa PROFILE para el almacenamiento y análisis de datos parciales correspondientes a las cinco primeras campañas. Con los resultados obtenidos in situ y los correspondientes a las determinaciones de laboratorio se construyó la base de datos que requiere el programa PROFILE, junto con la morfometría del embalse, las estaciones y la segmentación del embalse (agrupando estaciones con características similares o que se encuentran cercanas). El programa realiza un resumen de los datos almacenados en archivo apropiado, con lo cual se obtienen valores mínimos, percentiles, máximos y el coeficiente de variación CV para los distintos parámetros. En la Tabla 2 se sintetiza la información de los siguientes parámetros correspondientes a la capa de mezcla hasta los 5 metros de profundidad: temperatura, oxígeno disuelto, pH, conductividad, transparencia, clorofila a, compuestos de nitrógeno y fósforo, alcalinidad y turbiedad.

Parámetro	T (°C)	Oxíg Dis. (mg/l)	pH	Cond. (µS/cm)	Transp. (m)	Cl "a" (µg/l)	N-NO3 (µg/l)	N-NO2 (µg/l)	N-NH4 (µg/l)	P T (µg/l)	PRS (µg/l)	Alcal (mg/l)	Turb. (UNT)
Mediana	18	9.3	8.5	124	1.1	37.8	247	6.2	156	73.8	3.1	56	3.7
Mínimo	9.7	4.3	6.3	101	0.4	0.5	8	2.2	23	19	<1	39.5	1
Máximo	25.3	20	9.7	160	2.5	635	764	8.5	1055	330	16	71	33
CV	0.308	0.218	0.132	0.138	0.229	0.998	0.8	0.687	1.127	0.741	0.786	0.2	0.387

Tabla 2: Parámetros Físico-Químicos e indicador biológico

Del análisis de los resultados que se resumen en la Tabla 2 surgen los siguientes aspectos destacables en las variables indicadas: la transparencia mostró una gran variabilidad en sus valores extremos. Similar comportamiento se registró con los nutrientes y la clorofila a que alcanzó un valor máximo de 635,5 µg/. En los gráficos de caja o "box plot" de la Figura 3.2 se resumen las variaciones de la transparencia, permitiendo visualizar rápidamente el centro, la variabilidad y el rango total de distribución de los valores de este parámetro en cada estación. El programa acompaña el gráfico de una tabla con los percentiles, media, mediana y CV para cada grupo.

Las estaciones indicadas en el gráfico como 1, 4 y 8, correspondientes a la confluencia de los ríos Del Medio y Los Reartes, desembocadura del río San Pedro, la estación centro y estación correspondiente a la presa, son las que mayor variabilidad en los valores de transparencia han presentado, observándose en esta última un valor mínimo de 0,4 y un máximo de 2,5. Se ha demostrado que la reducción en la transmisión de la luz en relación con las medidas de transparencia de Secchi está bastante relacionada con un incremento de la dispersión debida a la materia particulada en suspensión (Wetzel, 1981). Esto se verifica sobre todo en cuerpos de agua muy productivos y ha sido utilizado de manera muy generalizada para estimar la densidad aproximada de las poblaciones de fitoplancton. Los valores más bajos de transparencia y la heterogeneidad observada para una misma fecha de muestreo son coincidentes con las floraciones de Dinoflagelados que se presentaron en la primavera y verano, las que se manifiestan en forma de "parches" de mayor concentración, dejando áreas intermedias con pocos individuos. A través de la Figura 3.1 se puede observar que en otoño e invierno hay un aumento de la transparencia con valores más homogéneos en la superficie del embalse. Diferencias de 1 a 3 en los valores de transparencia entre primavera-verano y otoño-invierno son indicativos de un grado de eutroficación regular (Straskraba *et. al.*, 1993).

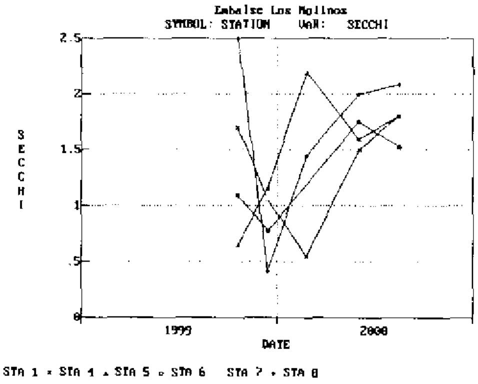


Figura 3.1

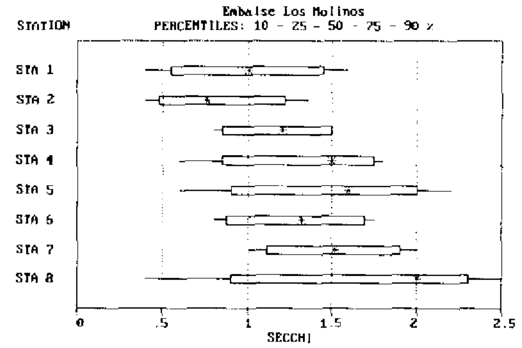


Figura 3.2

Figura 3: Variación espacial y temporal de la transparencia medida con Disco de Secchi

La Figura 4 muestra los perfiles de temperatura y oxígeno disuelto obtenidos en la estación garganta y desembocadura de los ríos Los Reartes y del Medio. En primavera y verano los niveles de oxígeno disuelto obtenidos en superficie alcanzaron valores cercanos al 200% de saturación (coincidentes con floraciones algales) observándose una disminución de estos valores en profundidad, llegando a tenores de oxígeno de 1,25 y 2 mg/l en estaciones más profundas. Esta situación se presenta en la estación correspondiente a la desembocadura del río Del Medio y Los Reartes, en el mes de febrero, coincidiendo con floraciones de *Ceratium sp.* en ese área.

Esta distribución vertical puede ser explicada por el hecho que la actividad fotosintética está restringida a una delgada capa superficial eufótica y por la acción del viento en superficie. El mismo perfil muestra la temperatura, con termoclinas superficiales inestables y estratificación térmica lábil en primavera-verano y distribución vertical homogénea durante el otoño e invierno (Figuras 4.2 y 4.4). La acción fotosintética produce una elevación el pH, coincidiendo en vertical los picos de pH con los de oxígeno disuelto (Figuras 4.5 y 4.6).

La concentración de fósforo total en la capa de mezcla correspondiente a los 5 primeros metros, fue superior en el período de primavera-verano en todas las estaciones con respecto a los valores de otoño e invierno (Figura 5.2). Similar comportamiento tuvo la Cl"a" (Figura 5.1).

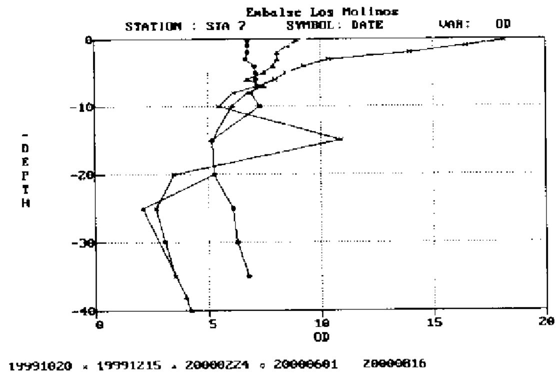


Figura 4.1 (Estación Garganta)

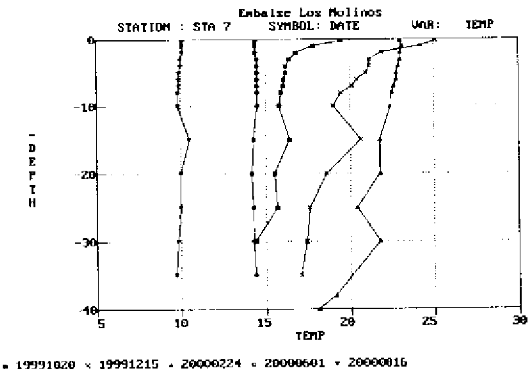


Figura 4.2 (Estación Garganta)

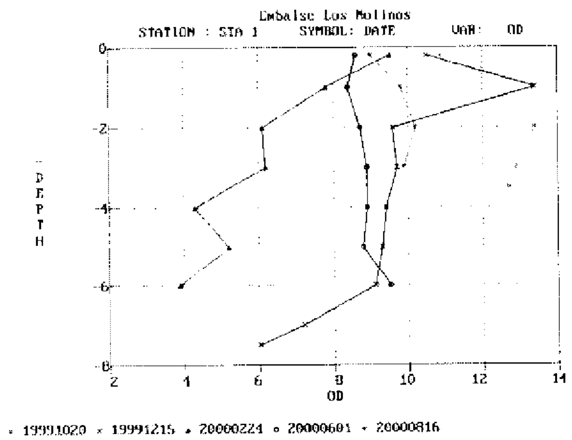


Figura 4.3 (Estación desemb. Río DM y LR)

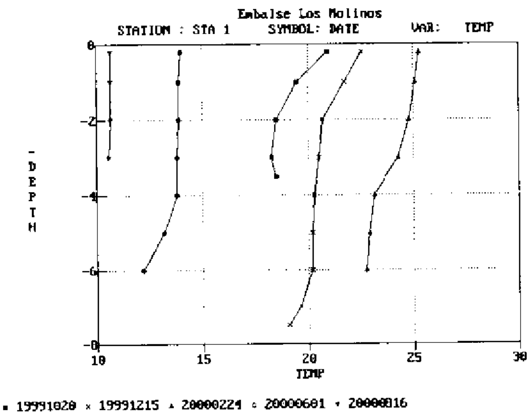


Figura 4.4 (Estación desemb. Río DM y LR)

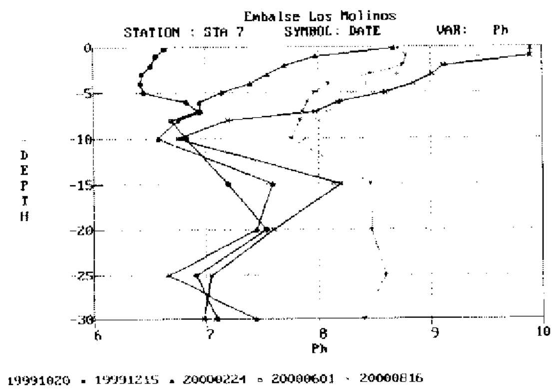


Figura 4.5 (Estación Garganta)

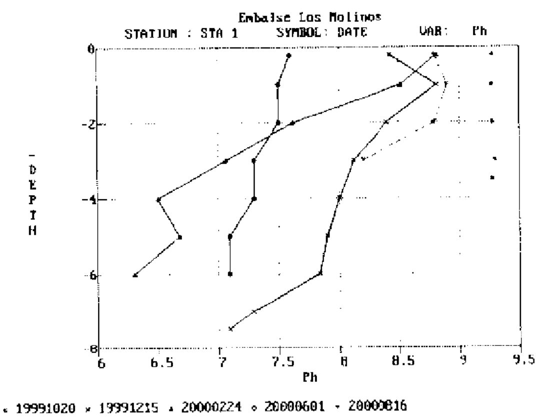


Figura 4.6 (Estación Desemb. Río DM y LR)

Figura 4: Perfiles de oxígeno disuelto, temperatura y pH

El perfil vertical de nutrientes muestra en febrero un marcado incremento en la cantidad de fósforo total en el hipolimnion (Figura 6.1). Esta situación se observa normalmente durante las últimas fases de la estratificación térmica y este aumento también se produjo en la forma de fósforo reactivo soluble (Figura 6.2) cerca de los sedimentos, en las estaciones más profundas, centro y garganta, lo cual podría ser el resultado de la resuspensión desde el fondo. Igual comportamiento tuvo el amonio, como consecuencia de la anoxia de las zonas profundas.

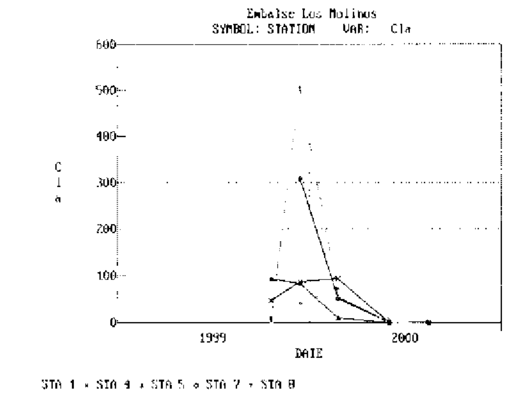


Figura 5.1

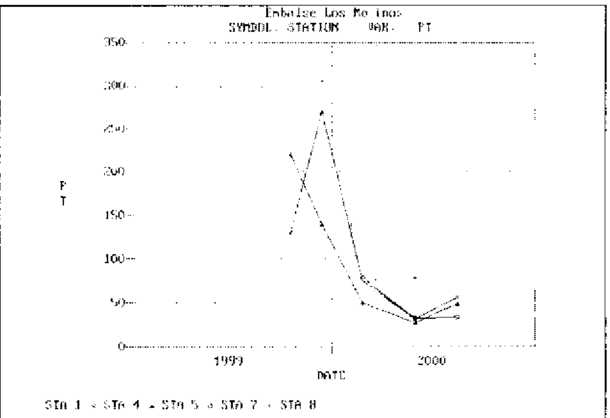


Figura 5.2

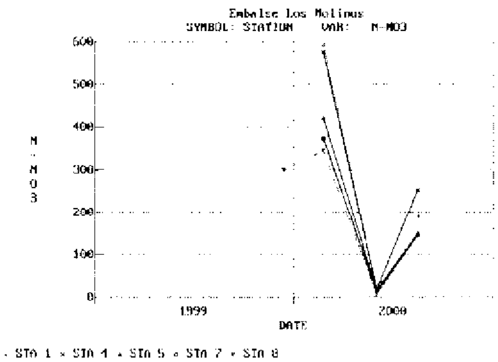


Figura 5.3

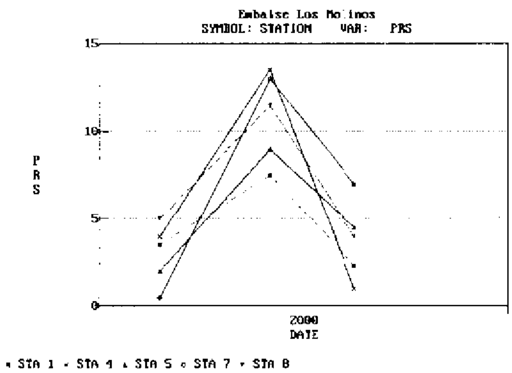


Figura 5.4

Figura 5: Variación temporal de nutrientes y Clorofila "a"

La relación entre las formas "biológicamente disponibles" de fósforo y nitrógeno (NIT/PRS), de importancia a la hora de definir el nutriente limitante del crecimiento algal cuando las concentraciones absolutas no han disminuido hasta cantidades limitantes se mantiene en verano-otoño e invierno superiores a 10, con la diferencia que en verano la relación es unas diez veces mayor.

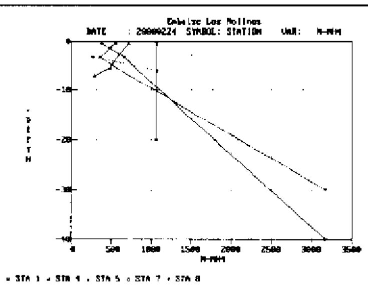


Figura 6.1

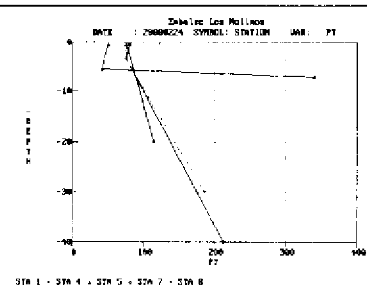


Figura 6.2

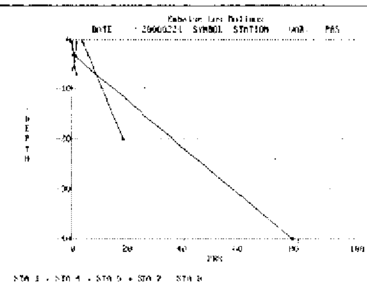


Figura 6.3

Figura 6: Perfiles de N-NH4, PT y PRS en período de estratificación

El fósforo reactivo soluble muestra un comportamiento similar en todo el embalse en las distintas estaciones, en verano con valores menores o igual a 5 $\mu g/l$, considerado como limitante para el crecimiento (Figura 5.4) y picos en otoño, estación en la cual el nitrógeno de nitrato toma valores muy bajos, cercanos al límite de detección (Figura 5.3), pero el NIT se mantiene todo el año por encima del valor de 20 µg/l, considerado como limitante (Ryding y Rast, 1992), permitiendo inferir que el fósforo sería el potencial limitante del crecimiento en primavera-verano.

D.2. Dinámica de los principales grupos de fitoplancton

En el centro del embalse a nivel superficial, el desarrollo de la comunidad fitoplanctónica mostró un comportamiento con pocas variantes con respecto al resto de la superficie. Los dinoflagelados tienen a *Ceratium hirundinnella* como forma dominante que incrementó su número de primavera a verano (1999-2000) (Figuras 7.1; 7.2; 7.3).

Durante la primavera se presentó en la desembocadura del río San Pedro (Figura 7.1) con valores altos apareciendo en forma de parches o manchones rojos. Ya en el verano, conforma una floración, que le confiere a toda la superficie del Embalse el color rojo característico, alcanzando su mayor abundancia en la garganta y zonas próximas a la presa (Figura 7.3).

El alto nivel de cota del embalse, debido a las precipitaciones registradas tanto en la cuenca como en el Embalse mismo, determina la evacuación por el vertedero, hecho no habitual, mostrando la espuma el color rojo. A partir de Febrero se observó un descenso importante en el número de dinoflagelados y es notable la presencia de células sin contenido. En otoño su presencia casi es insignificante (Figura 7.4) y en invierno se observó un leve incremento de este grupo sin embargo no alcanza a llegar al nivel detectado durante el verano (Figura 7.5).

Las crisófitas son escasas, tanto en diversidad, como en cantidad de individuos por especies en primavera y verano. A fines del verano se inicia un pequeño aumento en el número de individuos: *Aulacoseira sp* es el género dominante, aunque no se incrementa la diversidad de especies. En otoño alcanzan una mayor diversidad de géneros, y su importancia relativa con respecto a los otros grupos es mayor (Figura 7.4).

Las clorófitas están representadas por pocos géneros entre ellos *Staurastrum sp*. El número total de organismos es muy bajo en primavera y verano. En Febrero no se detectan y en Junio están representadas principalemente por *Monoraphydium sp.* pero en un número muy bajo.

Las cianófitas no aparecen hasta Febrero: *Anabaena spiroides* se mantiene hasta finales del otoño como la especie característica y se mantienen hacia el invierno.

Con respecto a la distribución vertical del fitoplancton, a la altura del disco de Secchi y límite de la zona fótica en Diciembre los dinoflagelados se encuentran en gran número y también sus quistes Las crisófitas, presentan poca diversidad, para aumentar en número durante el invierno, siendo *Aulacoseira sp* dominante .

Las clorófitas no están a estas profundidades de la columna de agua, pero aparecen en Junio. Las cianófitas representadas por *Anabaena spiroides*, están en muy poco número y persisten hasta Agosto.

En el mes de Junio se encontraron las formas resistentes de *Ceratium sp* a 10 metros por encima del fondo en el centro del Embalse. Se observa una correspondencia lógica entre la concentración de clorofila a y la cantidad de algas (org/l) (Figura 7.6).

D.3. Bacterias coliformes totales y fecales

En lo que respecta a la carga de bacterias coliformes totales y fecales, tanto en agua como en sedimentos, se desprende que el embalse Los Molinos I muestra contaminación luego del período de lluvias. La confluencia de los ríos Los Reartes y Del Medio, y del río Los Espinillos, fueron las zonas de mayor aporte de bacterias coliformes, coincidiendo con el área de pastoreo, no obtante ello, los valores encontrados en agua no superan los valores guías para agua de recreación que establece la CE. En sedimento las cifras encontradas fueron muy superiores a los valores reportados en agua, para la misma estación de monitoreo.

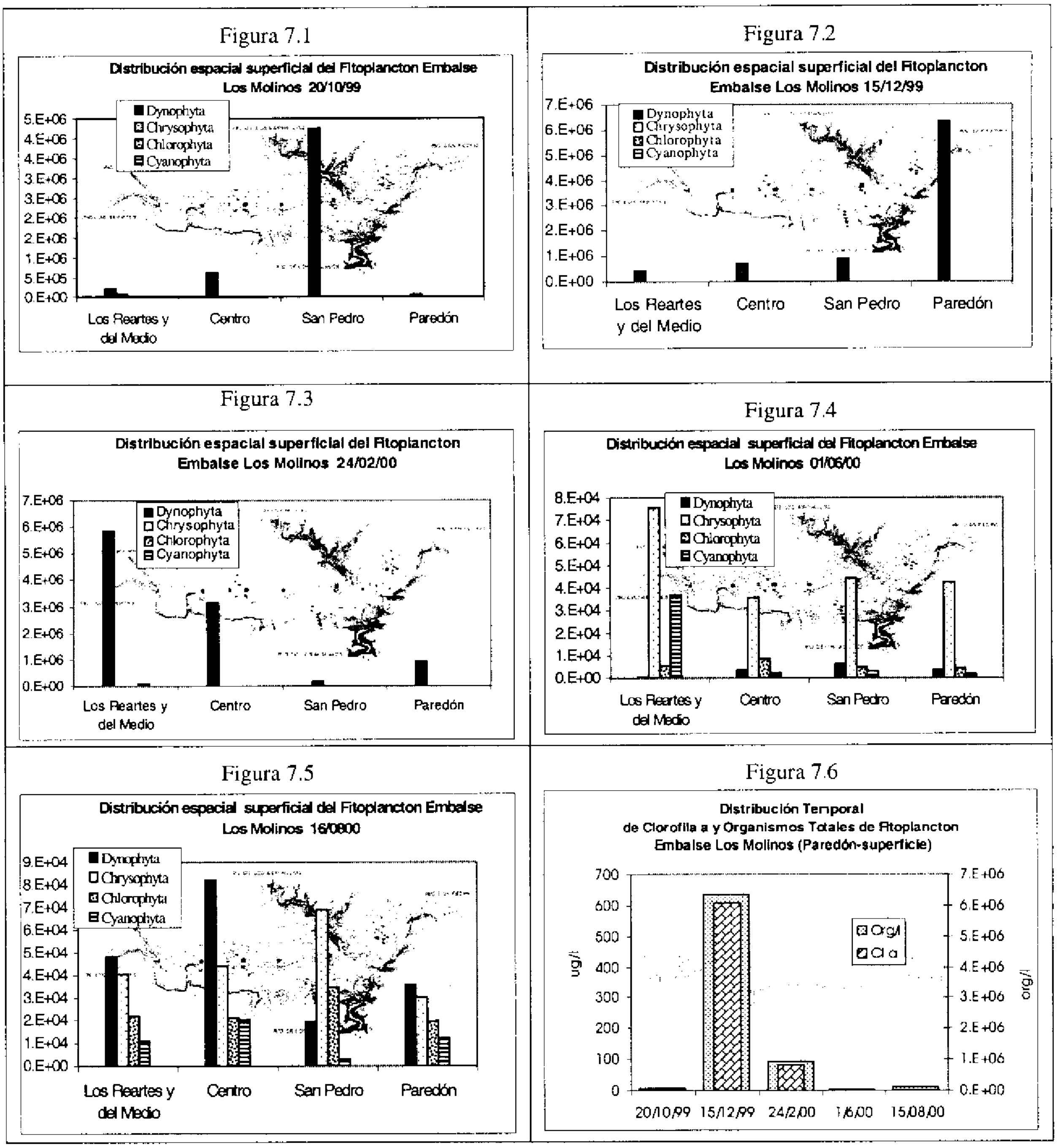


Figura 7: Distribución espacial y temporal del Fitoplancton

E. Conclusiones y trabajo futuro

Se observaron características que afirman las condiciones eutróficas del embalse Los Molinos I. En primavera-verano fue notable la sobresaturación de oxígeno en superficie como resultado de la acción fotosintética, anoxia hipolimnética, altas concentraciones de nutrientes, clorofila a, baja transparencia y una marcada disminución en la diversidad fitoplanctónica en primavera-verano. Las bajas concentraciones de oxígeno disuelto cerca del fondo producida en este período es uno de los problemas más serios que afecta la calidad de agua del reservorio, ya que se conoce que bajo condiciones anóxicas se liberan sustancias desde los sedimentos, como el fósforo, aumentando su disponibilidad para el crecimiento algal.

El crecimiento excesivo de algas dinoflageladas del género *Ceratium sp.*, tuvo una distribución no homogénea en primavera-verano con un aumento de la turbidez en los sectores de mayor densidad con el consecuente deterioro del recurso.

Este estudio se encuentra en ejecución a los fines de estimar las cargas de nutrientes hacia el embalse, a través del programa FLUX y aplicar el modelo de eutroficación BATHTUB a fin de mejorar el conocimiento del estado trófico del embalse Los Molinos I para establecer relaciones entre las variables físico-químicas, y biológicas, tanto en agua como en sedimento, que permita una adecuada gestión de este recurso.

F. Agradecimientos:

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Plano de Gerenciamento Integrado da Várzea do Parelheiros

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Resumo

O presente trabalho trata do Plano de Gerenciamento Integrado para o Sistema Produtor Taquacetuba – Guarapiranga (Brazil), com ênfase no Plano de Manejo da Várzea do Parelheiros, contratado pela Sabesp e elaborado pela Empresa Geotec Geologia e Engenharia, contendo as alternativas e as intervenções propostas com o objetivo de possibilitar a transferência de água da Represa Billings para a Represa Guarapiranga, melhorando a qualidade das águas aduzidas de forma a garantir a qualidade do manancial representado pela Represa Guarapiranga.

Palavras chave: gerenciamento, várzea, manejo, wetlands

Abstract

This paper is about the Integrated Management Plan of the Producing System Taquacetuba-Guarapiranga (Brazil), with focus on the proposed Plan for Management the Fertile Valley of River Parelheiros. The study was commissioned by SABESP and completed by the"Geotec Geologia e Engenharia Co.". The Plan includes also the description of alternatives as well as of works proposed for the transfer of water from Billings Reservoir to Guarapiranga Reservoir. The purpose is to improve the quality of input water and thereby also ensure good water quality at the source, which is the Guarapiranga Reservoir.

Keywords: Management; Wetlands; Works

A. Histórico

Para atender à necessidade de se garantir o abastecimento público da Zona Oeste da Região Metropolitana de São Paulo (Brazil), a Sabesp recebeu Licenciamento Ambiental para transferir água do Braço Taquacetuba para a Represa Guarapiranga. Em 28 de Agosto de 2000 iniciou-se a transferência de 2 m^3/s e atualmente pretende-se que este valor totalize 4 m^3/s.

O sistema é composto por captação flutuante, tubulação de captação, estação elevatória de água bruta, adutora de água bruta (14.015m e diâmetros de 1200 e 1500mm) sendo que a chegada na várzea é através de uma caixa de dissipação e uma área de remanso.

Dentre as exigências da Secretaria do Meio Ambiente para obtenção da Licença de Operação constou a apresentação de um estudo que contemplasse as medidas necessárias para a minimização dos impactos decorrentes do aumento de vazão no que se refere à capacidade de tamponamento da várzea.

B. Introdução

O presente trabalho trata do Plano de Gerenciamento Integrado para o Sistema Produtor Taquacetuba – Guarapiranga, com ênfase no Plano de Manejo da Várzea do Parelheiros, contratado pela Sabesp e elaborado pela Empresa Geotec Geologia e Engenharia, contendo as alternativas e as intervenções propostas com o objetivo de possibilitar a transferência de água da represa Billings para a Represa Guarapiranga, melhorando a qualidade das águas aduzidas de forma a garantir a qualidade do manancial representado pela Represa Guarapiranga.

C. Estudos realizados

C.1 Hidrologia

Estudos hidrológicos efetuados pela Sabesp e pela Geotec em 1998 destacaram os seguintes pontos:

- A capacidade máxima estimada de escoamento da seção sob a ponte da Estrada do Jaceguava era de 5,5 m^3/s;
- Havia transbordamento do fluxo por sobre o leito das vias mesmo antes de o nível da água atingir o tabuleiro da ponte, visto que o leito carroçável da Estrada do Jaceguava possui pontos até 15 cm mais baixos do que a soleira inferior do tabuleiro da ponte;
- A reversão de 2 m^3/s aumentava os riscos de inundações na estrada, tendo-se recomendado a realização de intervenções que pudessem ampliar a capacidade de escoamento sob a ponte, além da criação de uma nova passagem sob a estrada do Jaceguava.
- Visando proteger a região quando da entrada em operação do sistema de reversão, a Sabesp executou obras de ampliação do canal do Rio Parelheiros, a montante e a jusante da ponte da
- Estrada do Jaceguava, ampliando a capacidade de escoamento nessa seção.

Novos estudos hidrológicos mostraram que ocorreu uma sensível ampliação da capacidade de escoamento dessa seção. No referente ao alagamento dos pontos baixos das vias lindeiras tem-se que na situação anterior o nível de água atingia essas cotas com vazões da ordem de 5,5 a 6 m^3/s e na situação atual (após as intervenções) essas cotas somente serão atingidas com vazões superiores a 15 m^3/s.

As intervenções já realizadas resultaram em alterações nas condições hidráulicas no trecho entre a descarga da Adutora do Taquacetuba e a ponte da Estrada do Jaceguava, onde agora prevalecem condições de escoamento em canal, com velocidades mais elevadas e a conseqüente diminuição do efeito de várzea no abatimento das cargas poluidoras.

C.2 Cartografia

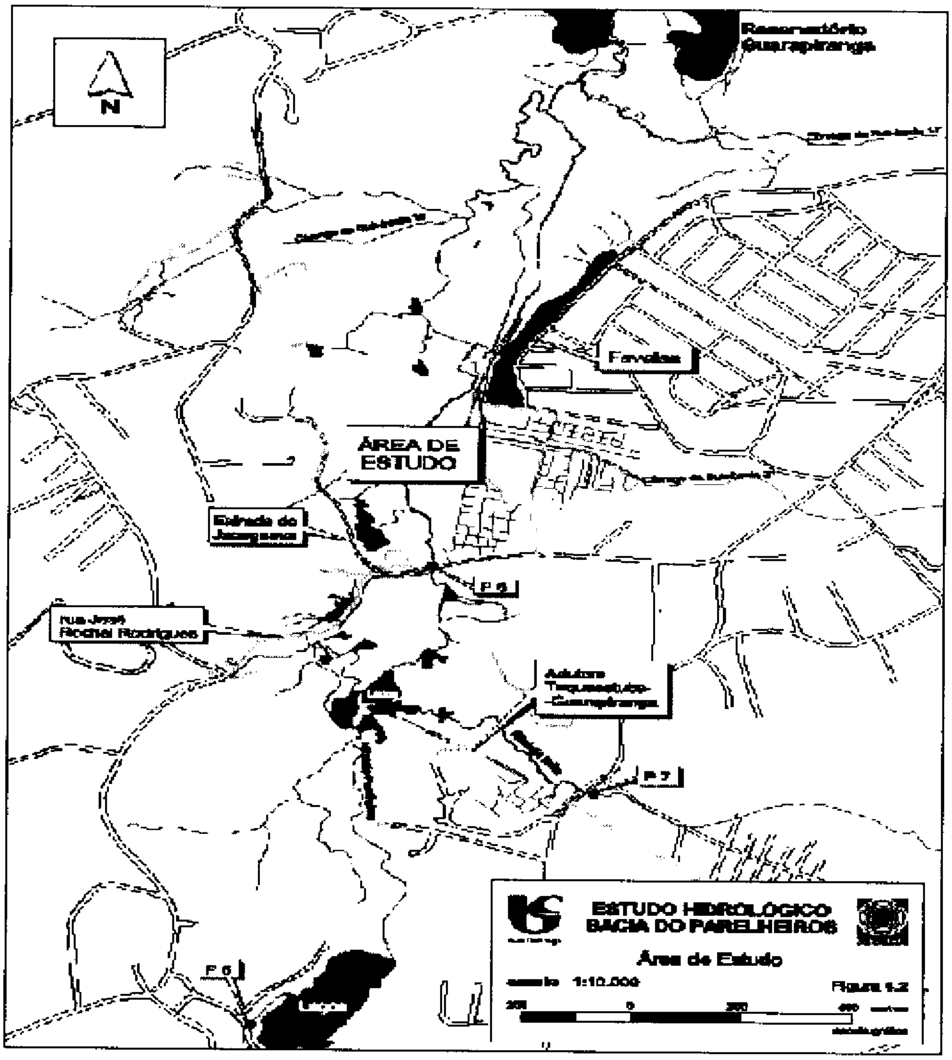
Para permitir que os estudos fossem levados a efeito sobre um fundo recente, foi elaborada uma nova base cartográfica da região da Várzea do Rio Parelheiros, com geração de imagens aéreas e restituição digital a partir de fotografias e levantamento aerofotogramétrico.

C.3 Qualidade das águas

Como o estudo visou dimensionar a Várzea do Parelheiros (Sistema Guarapiranga) para funcionar como uma "estação de tratamento biológica" das águas recebidas do braço Taquacetuba (Sistema Billings), para determinar o estado atual das águas em ambos os locais foram utilizados dados históricos de parâmetros de qualidade hídrica (físico-químicas, toxicológicas e biológicas) de órgãos oficiais (CETESB – Companhia de Tecnologia de Saneamento Ambiental ou da própria Sabesp).

Foram consideradas as vazões autóctonas e exógenas. As autóctonas, naturalmente afluentes à Várzea do Rio Parelheiros, provenientes do Rio Parelheiros e seu afluente Itaim, nas proximidades da caixa de dissipação da adutora que bombeia as águas do Taquacetuba. Essas águas de rios e riachos que chegam à várzea drenam bacias com algumas indústrias e diversos núcleos habitacionais, sendo que alguns, não legalmente constituídos, não dispõem de sistemas de coleta e afastamento de esgotos sanitários. A vazão exógena à várzea é aquela representada pelo bombeamento das águas do braço Taquacetuba da Billings.

De maneira genérica pode-se afirmar que os sedimentos do reservatório Guarapiranga,



próximo do local de afluência do Parelheiros, são orgânicos e apresentam baixos teores de nutrientes.

Figura 1: Área de Estudo

C.4 Caracterização da várzea

O Rio Parelheiros aflui para a Represa Guarapiranga e em seu trecho final forma uma extensa várzea com 930.000 m² desde o local de entrada das águas da Billings até a Guarapiranga.

A várzea possui elevado poder de depuração de nutrientes (P e N), coliformes e alumínio. A vegetação predominante é "capim-santa-fé" (Panicum rivulare) e "taboa" (Typha augustifolia) cobrindo respectivamente 50% e 19% da área total da várzea. Nos últimos 10 anos verifica-se uma degradação da qualidade hídrica, devida ao aumento da ocupação antrópica.

A Figura 1 apresenta a área de estudo da Várzea do Parelheiros.

D. Intervenções na várzea do parelheiros utilizando sistemas de wetlands construídas

As *wetlands* construídas são ecossistemas artificiais com diferentes tecnologias, utilizando os princípios básicos de modificação da qualidade da água das *wetlands* naturais.
Os sistemas de *wetlands* construídas têm sido utilizados em diversos países para recuperação dos recursos hídricos. No Brasil, as principais utilizações e recomendações têm sido:

- pré-tratamento de água para diversas finalidades;
- tratamento secundário e terciário de esgoto urbano;
- abastecimento de água industrial e urbano;
- purificação de grandes volumes de água para enquadramento de rios na Classe 2 a partir de rios atualmente com qualidade de rio Classe 3 ou 4;
- recuperação das funções das várzeas naturais.

Pelos estudos realizados até o momento, a utilização de *wetlands* construídas tem como principais vantagens em relação aos sistemas convencionais o seu baixo custo de implantação e operação e a alta eficiência na remoção de nutrientes, poluentes e contaminantes, especialmente quando se trata da recuperação de recursos hídricos com grandes volumes de água.

Existem várias técnicas de *wetlands* construídas, sendo que estes sistemas podem ser classificados como:

- Sistemas que utilizam macrófitas aquáticas flutuantes (Figura 2).
- Plantas aquáticas emergentes. Neste caso existem 3 variações básicas de projeto indicadas esquematicamente nas Figuras 3, 4 e 5.

Além dos sistemas acima citados, um outro foi projetado por SALATI (1987), utilizando solos filtrantes denominado Sistema DHS (Despoluição Hídrica com Solos). Este sistema sofreu uma variação para aumentar sua eficiência e para utilização em situações especiais de águas muito poluídas e que é conhecido como sistema DHS de fluxo ascendente (SALATI FILHO *et al*, 1996). Estes sistemas estão indicados esquematicamente nas Figuras 6 a 8.

A finalidade da intervenção, utilizando sistemas de *wetlands* construídas, no sentido de melhoria da qualidade da água afluente à várzea do Parelheiros é aumentar o tempo de residência da água que passa pela mesma.

Tecnicamente, isto implica em construções que direcionem os fluxos afluentes, distribuindo-os na várzea de uma forma ordenada e racional, procurando utilizar o máximo da área possível da região considerada.

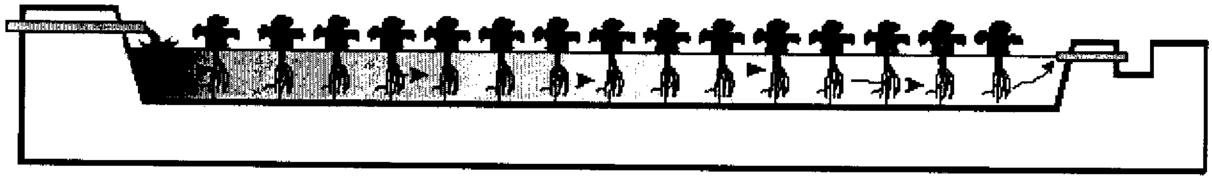


Figura 2: Desenho esquemático de um canal com plantas aquáticas flutuantes. São construídos normalmente canais longos e estreitos com aproximadamente 0,70 m de profundidade.

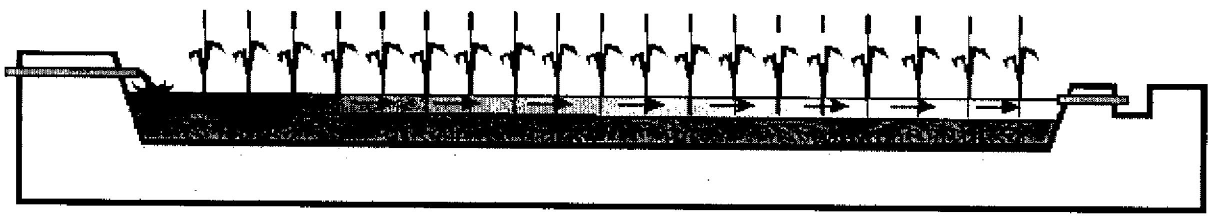


Figura 3: Desenho esquemático de um sistema com macrófitas emergentes com fluxo superficial. A água a ser tratada escorre pela superfície do solo cultivado com plantas emergentes. Geralmente são construídos canais longos, sendo a lâmina de água variável.

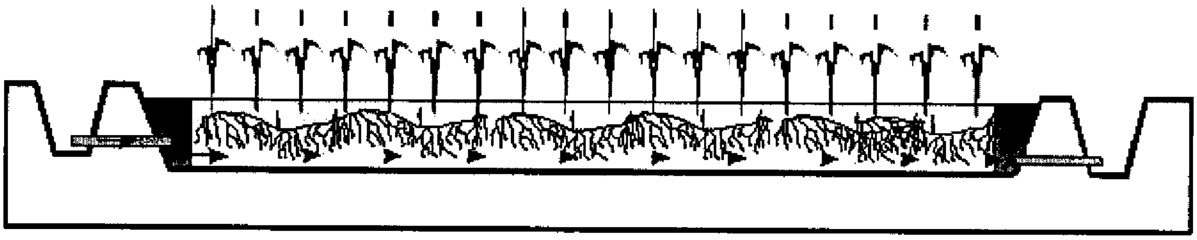


Figura 4: Desenho esquemático de um sistema com macrófitas emergentes com fluxo sub-superficial. A água a ser tratada é mantida com fluxo horizontal em substrato formado por pedras, sendo cultivadas plantas emergentes. Em geral são construídos canais longos, sendo a espessura da camada das pedras variável, porém da ordem de 0,50 cm.

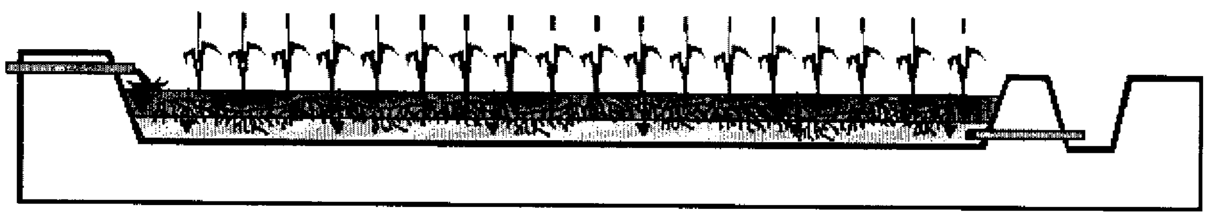


Figura 5: Desenho esquemático de um sistema com macrófitas emergentes com fluxo vertical. A água a ser tratada dever ter um fluxo vertical em uma camada de solos sobre brita, no qual são cultivadas plantas emergentes. O desenho é variável, porém predominam os sistemas de canal longo com pouca profundidade.

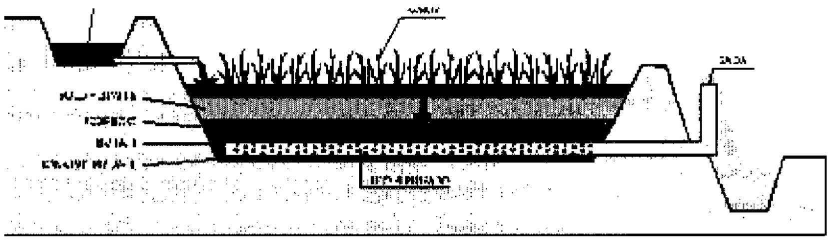


Figura 6: Desenho esquemático de um solo filtrante com fluxo descendente. A água a ser tratada é lançada sobre solo cultivado com arroz ou outra macrófita emergente

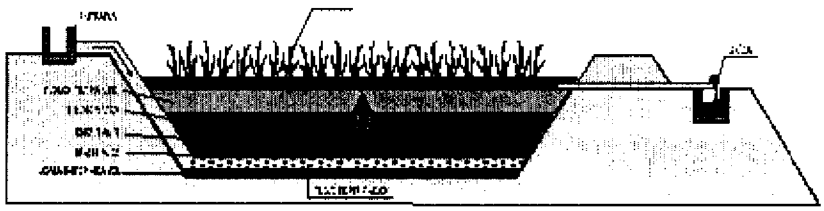


Figura 7: Desenho esquemático de um canal de solo filtrante com fluxo ascendente. A água a ser tratada é introduzida sob o sistema de drenagem sobre o qual está colocada a camada de solo filtrante

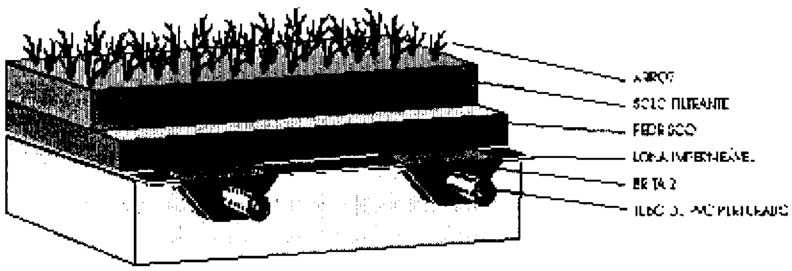


Figura 8: Desenho esquemático da estrutura de um solo filtrante. Este tipo de configuração é utilizado tanto para solos filtrantes de fluxo ascendente como para fluxo descendente.

Além do mais são necessários cuidados para que não se percam as funções básicas da várzea, tais como, áreas de proteção à fauna e à flora, especialmente a avifauna. Por outro lado, as intervenções devem ser realizadas de tal forma a permitir o manejo dos fluxos nas diferentes áreas e também minimizar os investimentos. As diversas intervenções propostas também poderão ser implementadas de uma forma progressiva, maximizando a eficiência em cada fase e minimizando os investimentos das mesmas.

E. Medidas de curto, médio e longo prazo

Tendo em vista que as intervenções serão implementadas por etapas, o projeto proposto contemplou as necessidades de agilização preparando o sistema para as intervenções futuras.

E.1. Medidas de Curto Prazo

- desapropriar as áreas demarcadas na várzea;
- cercar as margens do canal de saída da caixa de dissipação da água bruta na várzea e a área da várzea a ser aproveitada (montante e jusante);

- plantar uma faixa ciliar para delimitar os limites da várzea a ser utilizada e para servir, no futuro, quando da consolidação e crescimento da mesma, como barreira biológica capaz de reter poluentes e material em suspensão que iriam ter ao corpo hídrico;
- fazer a limpeza das áreas a serem alagadas e outras mais elevadas, removendo os detritos sólidos ali depositados e encaminhando-os a destinos compatíveis com sua natureza;
- construir diques para contenção das águas na várzea à jusante da ponte do Jaceguava, no sentido de aumentar o tempo de retenção (maior eficiência) das águas dentro do sistema, aumentando a área alagada e criando os compartimentos principais de jusante;

A várzea do Parelheiros deverá ser segmentada, através da construção de 4 diques de contenção, em cinco sistemas de wetlands construídos, que irão operar em série.

Dentre as técnicas existentes em sistemas de wetlands optou-se pela utilização de fluxo superficial livre e cultivo de plantas aquáticas emergentes. A escolha das espécies de plantas baseia-se em sua adaptabilidade à área além de habilidades depurativas. A partir da análise das espécies pré-existentes na área, a *Typha sp* foi escolhida (espécie a ser dominante nos sistemas) levando-se em consideração sua comprovada interferência na melhoria da qualidade de água, facilidade de reprodução e posterior manejo de biomassa.

Desde que a qualidade da água que chega ao Guarapiranga mantenha-se dentro da desejada (o monitoramento será feito em pontos ao longo dos sistemas de wetlands), recomenda-se a inserção de outras espécies de plantas adaptadas ao ambiente terrestre/aquático com o intuito de se aumentar a diversidade de habitats, ou seja, a diversidade de fauna.

a) Sistema 01

O primeiro sistema de wetlands compreenderá uma área de 82.408,00 m^2. A lâmina d'água será mantida na cota 739,50 resultando em um volume de água retido de 28.842,6 m^3. Considerando a vazão do bombeamento de 2,0 e 4,0 m^3/s, o tempo de retenção estimado neste sistema será de aproximadamente 3,5 horas e 2 horas respectivamente.

A formação deste sistema de wetlands será obtida através da construção de um dique no vão da ponte de cota 739,50 (parte mais alta). Serão utilizadas pedras como material de construção e o formato dos diques será trapezoidal. A medida da base maior será de 5,00 m, a base menor de 3,00 m e a altura média de 0,50 m. Entre o dique e a ponte permanecerá um vão de 0,86 m.

b) Sistema 02

O segundo sistema de wetlands compreenderá uma área de 137.710,00 m^2. A lâmina d'água será mantida na cota 738,50 resultando em um volume de água retido de 48.198,50 m^3. Considerando a vazão do bombeamento de 2,0 e 4,0 m^3/s, o tempo de retenção estimado neste sistema será de aproximadamente 5,5 horas e 3 horas respectivamente.

A formação deste sistema de wetlands será obtida através da construção de um dique de 376 m de comprimento, paralelo à ponte. Serão utilizadas pedras como material de construção e o formato dos diques será trapezoidal. A medida da base maior será de 5,00 m, a base menor de 3,00 m e a altura média de 0,50 m.

Outro dique deverá ser construído em uma das laterais do sistema 02 que corresponde à comunidade carente existente.

b) Sistema 03

O terceiro sistema de wetlands compreenderá uma área de 210.493,00 m^2. A lâmina d'água será mantida na cota 738,00 resultando em um volume de água retido de 73.672,55 m^3. Considerando a vazão do bombeamento de 2,0 e 4,0 m^3/s, o tempo de retenção estimado neste sistema será de aproximadamente 8,2 horas e 4,5 horas respectivamente.

A formação deste sistema de wetlands será obtida através da construção de um dique de 585 m de comprimento, paralelo ao dique anterior. Serão utilizadas pedras como material de construção e o formato dos diques será trapezoidal. A medida da base maior será de 5,00 m, a base menor de 3,00 m e a altura média de 0,50 m.

d) Sistema 04

O quarto sistema de wetlands compreenderá uma área de 58.825,00 m^2. A lâmina d'água será mantida na cota 737,50 resultando em um volume de água retido de 20.588,75 m^3. Considerando a vazão do bombeamento de 2,0 e 4,0 m^3/s , o tempo de retenção estimado neste sistema será de aproximadamente 2,5 horas e 1,5 horas respectivamente.

A formação deste sistema de wetlands será obtida através da construção de um dique de 213 m de comprimento. Serão utilizadas pedras como material de construção e o formato dos diques será trapezoidal. A medida da base maior será de 5,00 m, a base menor de 3,00 m e a altura média de 0,50 m.

e) Sistema 05

O quinto sistema de wetlands compreenderá uma área de 99.335,00 m^2. A lâmina d'água será mantida na cota 735,50 resultando em um volume de água retido de 34.767,25 m^3. Considerando a vazão do bombeamento de 2,0 e 4,0 m^3/s , o tempo de retenção estimado neste sistema será de aproximadamente 4 horas e 2,5 horas respectivamente.

A formação deste sistema de wetlands será obtida através da construção de um dique de 357m de comprimento. Serão utilizadas pedras como material de construção e o formato dos diques será trapezoidal. A medida da base maior será de 5,00m, a base menor de 3,00m e a altura média de 0,50m.

Para a avaliação da eficiência de depuração da várzea do Parelheiros após a construção dos diques, foram calculados os valores das concentrações na saída da várzea, para as principais variáveis monitoradas, tendo como valores da qualidade da água de entrada os resultados médios obtidos no período de agosto a novembro de 2000 em pontos de captação na Billings e no rio Parelheiros onde os dados obtidos representam a mistura da água bombeada do braço Taquacetuba com a água do primeiro terço da várzea.

Foram estimadas as eficiências de reduções para diversos parâmetros de qualidade de água, baseadas nas eficiências médias de remoção obtidas em sistemas de *wetlands* construídas utilizando-se plantas emergentes (principalmente a *Typha sp*, conhecida popularmente como taboa), obtidos em trabalhos científicos publicados na literatura nacional e internacional.

As eficiências utilizadas estão também correlacionadas com o tempo de residência da água na várzea. Assim, considerando-se a área dos vários sistemas a serem formados após a construção dos diques, com uma lâmina d'água variando de 0,10 m a 0,50 m, foram realizados os cálculos do tempo de residência para um fluxo total de entrada na várzea de 2,5 m^3/s e 4,5 m^3/s, sendo 2 m^3/s e 4m^3/s a vazão do bombeamento da reversão do Taquacetuba, acrescido da vazão média da várzea (antes do bombeamento) que é de aproximadamente 0,5 m^3/s para o período de seca. Não foram realizados cálculos para o período de chuva, pois se pressupõe que neste período não haverá bombeamento.

O tempo de residência total da várzea para as vazões de 2,5 m^3/s e 4,5 m^3/s será de aproximadamente 24 horas e 13,5 horas, respectivamente.

f) Complementando o exposto serão implementadas outras medidas de curto prazo:

- dar continuidade ao monitoramento do sistema e instalar novos pontos de amostragem, capazes de retratar de forma mais precisa o comportamento do todo;
- implantar um sistema para monitoramento da qualidade hídrica em tempo real na chegada de água bruta, na ponte sobre a estada do Jaceguava, ao longo e ao final da "wetland";
- aprimorar o sistema de coleta e processamento de dados hidrológicos, intensificando a rede de postos pluviométricos e fluviométricos existentes e promovendo um rápido tratamento dos elementos coletados;
- elaborar um projeto detalhado da "wetland" piloto.

E.2 Medidas de Médio Prazo (12 meses)

- iniciar o aproveitamento da várzea de montante da ponte da estrada do Jaceguava, mediante obras hidráulicas sob a ponte e na estrada, visando elevar o nível das águas naquele compartimento sem comprometer as obras civis existentes na área, inclusive sem afogar a caixa de dissipação da SABESP;
- dar início às obras de construção e de infra-estrutura necessárias ao centro de educação ambiental - CEA;
- dar início às atividades florísticas destinadas à introdução e/ou replantio de espécies dentro da área de várzea, no sentido de melhorar sua eficiência; executar diques laterais para proteção de áreas ocupadas sujeitas a inundação;
- equipar os diques com comportas;
- dar início à implantação da "wetland" piloto;
- aprimorar a rede de coleta de dados hidrológicos, promovendo a instalação de equipamentos "on line" com a SABESP, capazes de fornecer informações em tempo real;
- realizar estudos hidrológicos com os diques principais já implantados, no sentido de precisar o comportamento hidráulico do novo sistema;
- realizar estudo sobre a poluição difusa e pontual incidente sobre a várzea estimando as cargas adicionais a serem depuradas pela "wetland".

E.3 Medidas de Longo Prazo

- após 12 meses de operação e coleta de dados, reavaliar o sistema, objetivando dar continuidade aos trabalhos na "wetland" piloto, de forma a precisar a melhor configuração para a várzea;
- dar continuidade aos trabalhos florísticos. Manejo da vegetação;

- dar início à sub-divisão das áreas alagadas, visando melhor aproveitamento e eficiência, em função dos resultados até então obtidos pela "wetland" piloto;
- dar início à realização de cursos e campanhas de educação ambiental no CEA.

F. Conclusões

Tendo em vista os estudos realizados, o bombeamento de 2 a 4 m^3/s está provocando efetivamente mudanças significativas no comportamento da várzea de Parelheiros, evidenciando a necessidade do manejo da várzea, de modo a aumentar o tempo de residência.

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Programa de Monitoreo del Embalse San Roque (Cordoba, Argentina), Período 1999-2000

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Resumen

Desde hace ya varios años el embalse San Roque muestra signos evidentes de eutrofización. Esto se manifiesta mediante altos contenidos de P en el agua y de elevadas concentraciones de clorofila-a como consecuencia del aumento de nutrientes, provenientes tanto de fuentes externas como internas. Surge la necesidad entonces de conocer y mejorar la calidad del recurso que abastece a la mayoría de la población de la Ciudad de Córdoba (70%). Para tales fines se desarrolló un programa de monitoreo sistemático sobre el embalse San Roque de parámetros de calidad de agua y ambientales con la finalidad de realizar el seguimiento de la evolución del fitoplancton. El presente trabajo tiene el objetivo no solo de mostrar el diseño y la metodología de trabajo de se llevó a cabo entre Septiembre de 1999 y Enero 2001 sino también los principales resultados obtenidos hasta el presente.

Palabras clave: Embalse San Roque; Monitoreo; Calidad del Agua; Fitoplancton

Abstract

In the last years the San Roque Reservoir is showing evident signs of eutrophication. This is a consequence of high contents of phosphorous and chlorophyll "a" in water characterized by an increase of internal and external sources of nutrients. As a result of this, the need to know and evaluate the principal water resource which provides drinking water to 70% of the people of Cordoba City comes up. A systematic monitoring program was developed in order to achieve environmental and water quality information to evaluate the phytoplankton evolution. The program includes campaigns in the water body between September 1999 and January 2001. The objective of this paper is to show not only the work planning and methodology but also some results.

Keywords: San Roque Reservoir; Monitoring; Water Quality; Phytoplankton

A. Introducción

La construcción del Embalse San Roque en una zona semi-árida donde el recurso hídrico es limitado no sólo resulta de suma importancia para la provisión de agua para distintos destinos, sino que adicionalmente ha llevado al desarrollo de asentamientos urbanos en la zona, con un marcado crecimiento de la actividad turística. Esta situación ha convertido al Embalse en receptor directo a través de sus afluentes de descargas cloacales y material orgánico e inorgánico proveniente de la cuenca de drenaje, la cual muestra un grado de alteración debido a la deforestación del ambiente natural, pastoreo intensivo de verano y el desarrollo urbano principalmente.

Este enriquecimiento ha llevado al Embalse San Roque a un progresivo y rápido proceso de eutrofización, que queda de manifiesto por el desarrollo frecuente de densas floraciones o "blooms" algales. Se conoce que el enriquecimiento en nutrientes de las aguas naturales induce a una variedad de cambios biológicos y químicos que pueden ser perjudiciales, según los usos que de ella se hagan.

La determinación del estado trófico y de la calidad general del agua constituye la parte central de cualquier valoración para lo cual se necesita una base segura de información en el tiempo. Se diseño y desarrolló un Programa de Monitoreo Sistemático en el Embalse San Roque con el propósito principal de reunir información para:

- Evaluar, caracterizar la masa de agua durante un intervalo específico
- Determinar el estado trófico del Embalse
- Evaluar la relación Carga/Respuesta
- Predecir y estimar cambios mediante la aplicación de modelos matemáticos

B. Antecedentes

La bibliografía disponible sobre este cuerpo de agua era fragmentaria y en algunos casos parcial. El primer estudio realizado sobre el fitoplancton de este embalse corresponde al de Guarrera (1948). Posteriormente se realizaron otros estudios como el de Boneto et al (1976), Cachi (1975), Gavilán (1977), García de Emiliani (1977) y Busso y Ormeño (1986). Este último muestra un análisis de la distribución espacial, diversidad específica y capacidad productiva del fitoplancton del embalse en muestras mensuales recogidas durante 1972.

Desde el primer estudio realizado por Guarrera en 1948 , el fitoplancton del Embalse, se ha visto alterado gradualmente hasta la actualidad reduciéndose a la dominancia de escasas especies propias de lagos eutróficos. Durante 20 años, se ha observado periódicamente un crecimiento desmedido de algas azul-verdosas durante la primavera – verano y de Diatomeas y Dinoficeas (Peridinium) en el otoño – invierno. Las condiciones hidroquímicas del recurso, permiten explicar y predecir la aparición de estas floraciones, sin embargo en los pasados períodos estivales de 1998-1999 y 1999-2000, el desarrollo desmedido de algas Dinofíceas (Ceratium hirundinella) desplazó a los grupos mencionados. En el período estival actual 2000-2001, nuevamente se hicieron visibles floraciones de algas azul-verdosas en el embalse.

C. Características del embalse

El Embalse San Roque (31° 22´ S, 64° 27´ W), se localiza en el Valle de Punilla entre las Sierras Grandes y las Sierras Chicas en la Provincia de Córdoba (Argentina) a 600m sobre el nivel del mar (Figura 1). Fue construido por primera vez en 1888. A raíz de temores vinculados con la estabilidad de este primer cierre, en 1944 se construyo la presa actual de Hormigón y tipo Gravedad, planta curva con el objetivo de abastecer de agua a la Ciudad de Córdoba (actualmente con 1.500.000 habitantes). Recibe el aporte de cuatro tributarios, siendo su único emisario el Río Suquia. En la Tabla N° 1 se resumen las principales características del Embalse.

Actualmente, en tiempos de sequía puede verse el coronamiento del antiguo cierre construido hace más de un siglo. Muy próximo y entre ambos paredones se encuentra la actual toma de agua que mediante tuberías a presión y canales y, luego de pasar por la central Hidroeléctrica

La Calera (actualmente en desuso), conduce las aguas finalmente a las plantas potabilizadoras para abastecer de agua potable a la mayor parte de la población de la ciudad de Córdoba.

Area de Drenaje:	1750 Km^2
Tipo de presa:	Hormigón. Gravedad, Planta curva
Superficie cota labio vertedero:	15,01 Km^2
Volumen cota labio vertedero:	201 Hm^3 (reducido a 190)
Máxima profundidad cota labio vertedero:	35.30 m
Profundidad media:	13 m
Nivel del Agua:	Regulado
Fluctuación anual del nivel (aprox)	6 m
Tiempo de residencia	0.1-0.7 año (0.637)
Tributarios (caudal medio anual aprox):	
Río San Antonio	2.7 m^3/seg
Río Cosquín	4.4 m^3/seg
Arroyo Las Mojarras	0.48 m^3/seg
Arroyo Los Chorrillos	0.73 m^3/seg

Tabla 1. Principales características del Embalse San Roque.

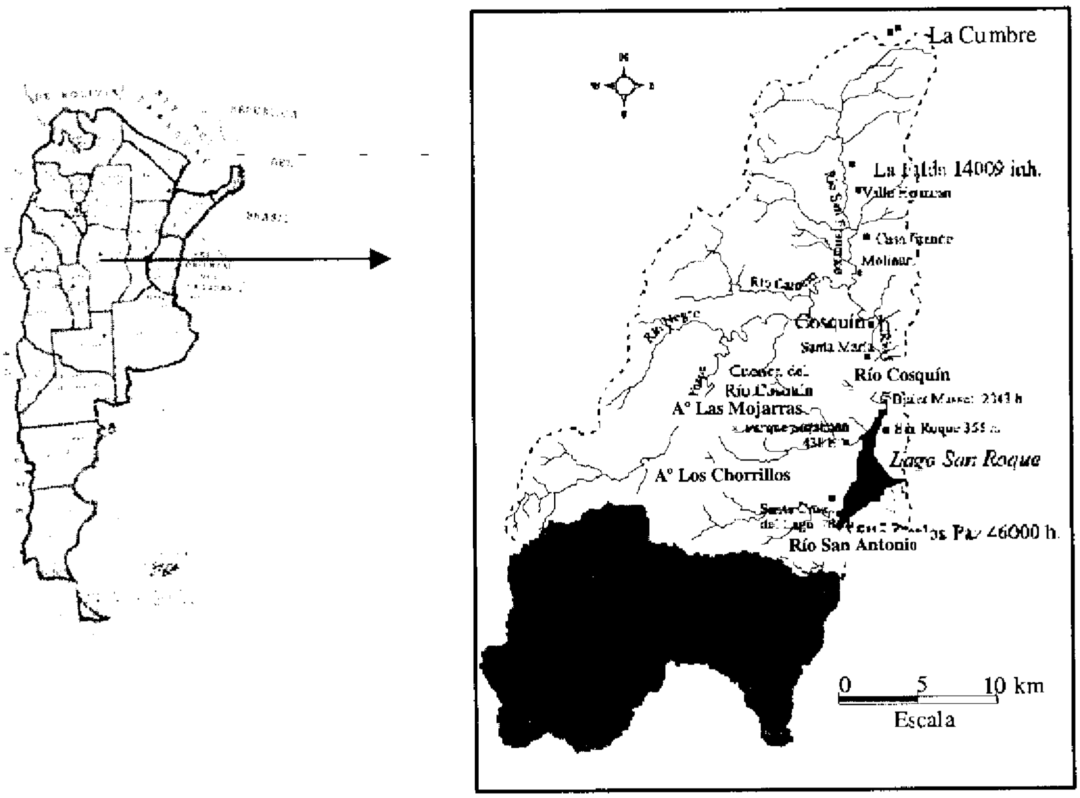


Figura 1. Cuenca del Embalse San Roque

D. Identificación de los problemas de eutrofización

D.1 Factores naturales relacionados con la cuenca.

La cuenca de drenaje está formada por las subcuencas del Río San Antonio de 500 km^2, Río Cosquín de 820 km^2, Arroyo Las Mojarras de 85 km^2 y Arroyo Los Chorrillos de 160 km^2. El

Río Cosquín, a su vez, recibe las aguas del Río Grande, que es uno de sus mayores tributarios, transportando residuos (especialmente cloacales) desde las comunidades de la Alta Cuenca, los que van a depositarse, en consecuencia, al Lago San Roque. El río San Antonio recibe desde la alta cuenca la contribución de afluentes que drenan ecosistemas naturales con bajo impacto cultural (Bustamante, 2001). Posteriormente recorre parte de la ciudad de Carlos Paz antes de la desembocadura en el lago.

Desde el punto de vista climático, se observa a nivel anual una alternancia de años muy húmedos (precipitaciones anuales superiores a 1000mm) con otros secos que apenas superan los 400mm. La precipitación media anual de 650 mm y la humedad media del 65%. El área se encuentra dentro del dominio moderado con invierno seco y una temperatura media anual de 14° C. Los vientos predominantes son del cuadrante sur y norte, pero están sujetos a las variaciones propias de la morfología del relieve. Desde un punto de vista geológico, la cuenca está constituida por un basamento cristalino antiguo metamórfico-plutónico. Las rocas ígneas que lo componen están representadas por una intrusión granítica regional y las metamórficas por un complejo en el que la roca netamente dominante es un gneis (Barbeito, 1997). Según la Clasificación Fitogeográfica de Córdoba (Vazquez, 1979), la vegetación en la Cuenca del Embalse San Roque corresponde a la del Bosque Chaqueño (Distrito Occidental de la Provincia Fitogeográfica Chaqueña).

D.2 Factores culturales

Los ríos que conforman la cuenca de aporte, drenan una región montañosa de gran importancia turística, con un uso de las tierras principalmente en actividades ganaderas intensivas de verano, deforestación y actividades varias. Los cursos de agua transportan al embalse material orgánico e inorgánico generado en las subcuencas (La turística ciudad de Carlos Paz ubicada en el perilago como de otras ciudades en presentes en la cuenca, las cuales no poseen un sistema eficiente de tratamiento de los líquidos cloacales). A esto se le suma el aporte de ambietes naturales y el de los eventos de lluvia repentinos que ocasionan importantes crecientes de los cursos de agua en período estival, más el aportado por el ambiente natural y a pesar de que existieron algunas estimaciones sobre los aportes de fósforo y nitrógeno estas fueron puntuales en el tiempo, sin continuidad alguna. Estas características apoyan la hipótesis de una variabilidad espacial y temporal en el aporte de fósforo al embalse eutrofizado de elevada importancia. El área que recorren posee baja permeabilidad del material rocoso, suelos discontinuos y superficiales que facilitan un drenaje excesivo con rápida concentración de las aguas.

E. Metodología de trabajo

E.1 Resolución Espacial y Temporal

Para la planificación del Monitoreo (sitios, parámetros y frecuencias) se tuvieron en cuenta:

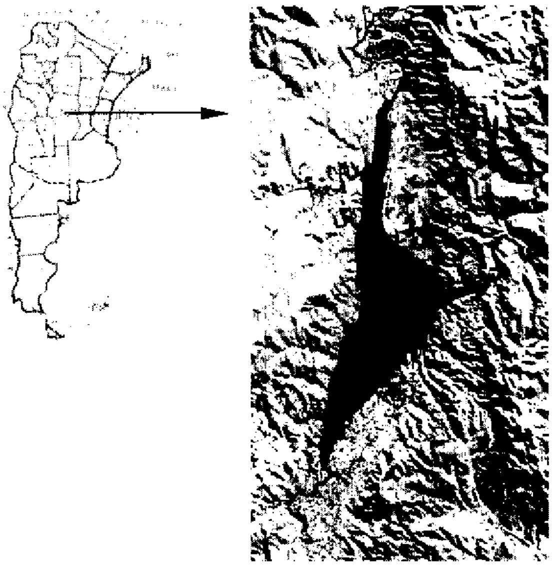
- Propiedades morfométricas e hidrodinámicas del cuerpo de agua.
- Entradas y salidas
- Cortocircuitos y zonas de estancamiento
- Perfiles verticales
- Estacionalidad
- Estratificación

En base a los antecedentes existentes y teniendo en cuenta los items anteriores se ubicaron ocho estaciones de estudio en el centro del embalse, cercanías al antiguo y nuevo paredón, en las desembocaduras de los 4 tributarios y en el efluente (Río Suquía). Figura 2

E.2 Medición de variables de calidad y ambientales

En el embalse se efectuaron mediciones in situ cada metro en la vertical (perfiles) y se tomaron muestras de aguas a nivel subsuperficial (0,20m), fótico y fondo con una botella de tipo Van Dorn de 2 litros de capacidad para la determinación de parámetros físico-químicos y biológicos. La frecuencia fue quincenal y semanal en los meses de verano. Se midieron in situ las concentraciones de oxígeno disuelto (OD), pH, temperatura del agua (T°) y conductividad del agua con sonda multiparamétrica, la transparencia se midió con disco de Secchi. Analíticamente en laboratorio se midieron los sólidos suspendidos (SS) por gravimetría, fósforo total (PT) por digestión con persulfato, fósforo reactivo soluble (PRS) por reducción con ácido ascórbico, nitrógeno de amonio ($N\text{-}NH_4^+$) por el método de la sal del fenol, nitrógeno de nitrito ($N\text{-}NO_2^-$) por el método de diazotación y nitrógeno de nitratos ($N\text{-}NO_3^-$) mediante columna de cadmio. Asimismo el Nitrógeno Inorgánico Total (NIT) se consideró como $N\text{-}NH_4^+ + N\text{-}NO_2^- + N\text{-}NO_3^-$. La composición iónica (Na^+, K^+, Ca^{++}, Mg^{++}, Cl^-, $SO_4^=$) del agua fue analizada por Cromatografía Iónica, y Manganeso e Hierro por Absorción Atómica.

Figura 2. Estaciones de monitoreo del Embalse San Roque



1 Desembocadura Río Cosquín

2 Desembocadura Arroyo Las Mojarras

3 Desembocadura Arroyo Los Chorrillos

4 Desembocadura Rio San Antonio

5 Centro

6 Antiguo Paredón

7 Toma de Agua

8 Usina (Río Suquía)

Conjuntamente también se identificaron tipos de algas hasta la categoría de géneros según protocolos de la empresa Aguas Cordobesas S. A.(c/ claves de identificación de Burrely y Tell). La determinación de la biomasa algal se efectuó mediante recuento del número total de organismos por filtración con membrana (0.45 de diámetro) y sedimentación y la medición de la clorofila por técnica espectrofotométrica (APHA, 1992).

F. Resultados y discusión

En el período de estudio la estratificación térmica se desarrolló entre Septiembre de 1999 y Abril del 2000 y la oxiclina a partir de diciembre de 1999 en coincidencia con el máximo gradiente de temperatura, cuando la capacidad inhibidora de mezcla es máxima. Las precipitaciones de primavera (Figura 3) causaron un aumento del volumen total en el lago el que fue calculado para la estación del centro, siendo muy significativo durante el período Noviembre-Diciembre de 1999. Como consecuencia de algunas precipitaciones puntuales se evidenció el aumento del volumen de hipolimnion. Contrariamente en Febrero el volumen del epilimnion se vuelve más importante que el volumen del hipolimnion debido al efecto térmico. Mediante el empleo de parámetros adimensionales como el número de lagos (L_N) se estimó una marcada estratificación entre Enero y Marzo, un agotamiento del oxígeno en 38 días y una duración de la anoxia hipolimnética de 65 días al año. Para la aplicación del mismo se utilizaron 28 mediciones de campo correspondientes al centro del lago, datos obtenidos de batimetrías y datos hidrometereológicos. Las estimaciones fueron corroboradas con los datos reales obtenidos en campo.

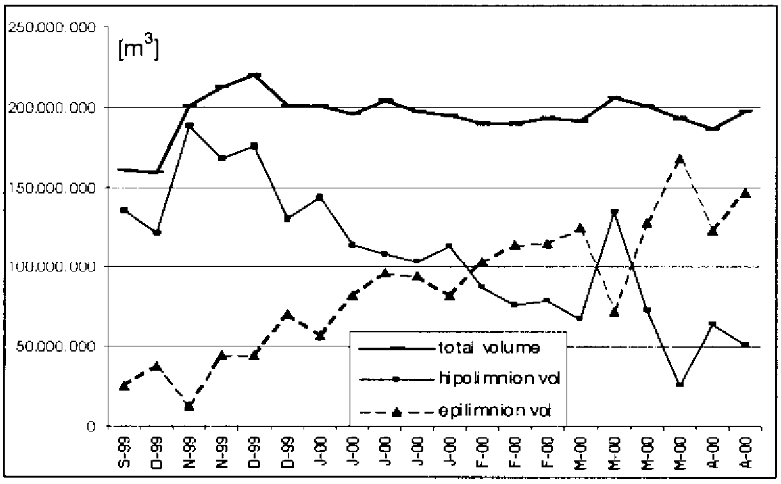


Figura 3. Variación de volumen en el Embalse San Roque

Con el aumento del volúmen total las concentraciones de nitrato, nitrito, amonio y la relación de N:P disminuyen por efecto de dilución mostrando una correlación inversa con la profundidad. Las concentraciones de NIT y PT (por aumento del amonio y del fósforo reactivo soluble) en la columna de agua aumentan en el hipolimnion hacia el verano sugieriendo una relación consecuente con condiciones de anoxia (UNEP-IETC 1999). Las Figuras 3 y 4 muestran los porcentajes de fósforo y nitrógeno distribuidos en el fondo y en la superficie de la estación centro del embalse San Roque.

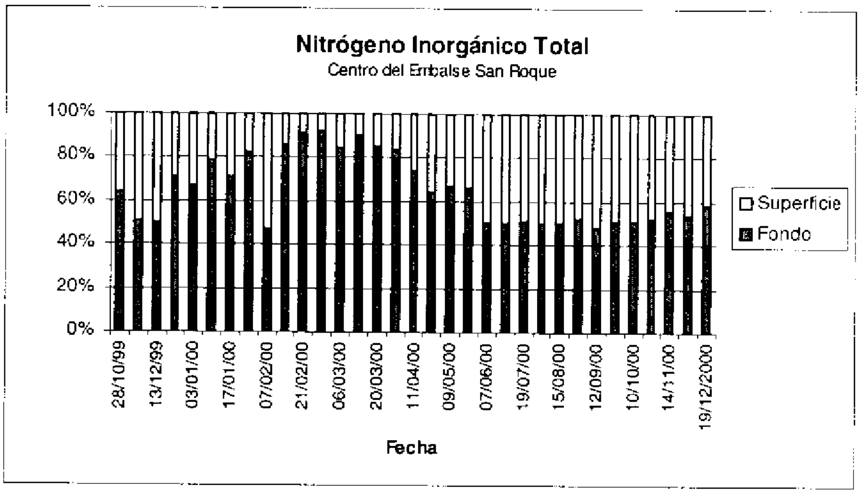


Figura 4. Distribución de NIT en el Embalse San Roque

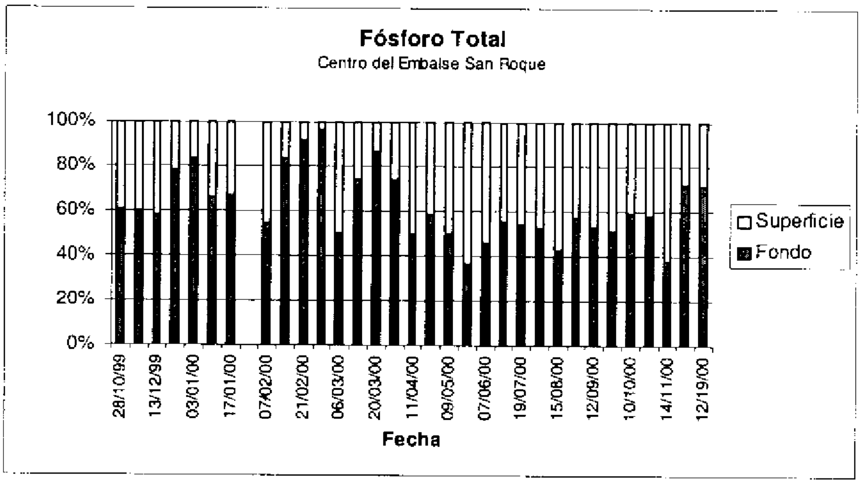


Figura 5. Distribución de PT en el Embalse San Roque

Microcystis, Anabaena, Aulacoseira, Melosira, Closterium and *Ceratium hirundinella* representan los componentes dominantes del fitoplancton del embalse durante el período estudiado. En la estación ubicada entre ambos paredones altas densidades de algas fueron observadas superficialmente entre Septiembre 1999 y Mayo 2000 mostrando relación con la chlorofila-*a* y en el fondo se relaciona con la concentración de nitrógeno inorgánico total (NIT) preferentemente con las concentraciones de amonio. Durante este período de estratificación predomina una disminución del NIT así como también de la relación N:P coincidente con la dominancia de las algas fijadoras de N (*Anabaena)* por lo cual existirían períodos de limitación del crecimiento de algas por este nutriente. En la etación de la toma de aguas altas densidades de *Microcystis sp* fueron observados entre Octubre y Enero y en el período Mayo-Junio relacionándose con parámetros ambientales como la velocidad del viento la temperatura del agua, el oxígeno disuelto Por otra parte *Anabaena sp* fue observada entre Noviembre y Enero y Agosto-Septiembre mostrando una relación directa con la radiación solar *Ceratium hirundinella* efectuó la mayor contribución a la biomasa algal total entre Noviembre y abril con una mayor densidad de células en la capa superficial y alta correlación con la concentración de clorofila-a.

A través de estudios estadísticos pudo determinarse la influencia del antiguo paredón en la calidad del agua en la zona de la toma. Se encontraron diferencias significativas en parámetros como la temperatura y el oxígeno disuelto medidos a ambos lados del centenario murallón.

Tanto la constante diferencia de temperaturas observada entre las estaciones así como la no equitativa intensidad de estratificación, pueden fácilmente explicarse en base a las circulaciones medias, flujos turbulentos difusivos así como a la existencia de ondas internas (tipo Kelvin y Poincaré) con energía cinética turbulenta resultante de la ruptura de las mismas. En efecto, la radiación solar de onda corta incidente produce un calentamiento y expansión del fluido, fenómeno que resulta atenuado a medida que aumenta la profundidad, siendo afectado además por el flujo inducido por el viento y las turbulencias generadas por corrientes internas.

G. Conclusiones

La cuestión del incremento global del desarrollo masivo de algas o blooms, tanto en aguas dulces como en zonas costeras, debe ser una preocupación constante y conducir a la toma de decisiones que lleven a una solución o mitigación del problema.
Los programas de monitoreo permiten caracterizar un recurso a fines de implementar medidas correctivas a corto y mediano plazo.

La evolución del fitoplancton debe estudiarse de forma integral, abarcando procesos biológicos, químicos y físicos que intervienen en su desarrollo.

El tratamiento de los efluentes cloacales de las diversas localidades, con la finalidad de poder contener, en parte, el avance de la degradación ambiental a nivel de cuenca y descargarlo al cuerpo receptor según las pautas fijadas en las normas de volcamiento, es una de las soluciones para el tratamiento de fuentes contaminación puntuales.

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Small Hydropower Plants in La Plata River Basin Tributaries: A Feasible Alternative for Water Power Development

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Abstract

The new regulatory scenario for small hydropower projects in Brazil resulted in a large number of new projects with this characteristic, after new rules were established by the Brazilian Electric Power Agency, redefining the required characteristics of a hydropower plant in order to be considered as a small hydropower plant, for which the concession for exploitation is granted by the Agency without bidding process. Many of the projects under study are in the tributaries of the main rivers in the La Plata River Basin. Some of these projects are already under construction.

Small hydropower plants differ from the large hydropower projects not only for their power production capacity: their impacts on the surrounding environment are deeply different, what makes them to be an attractive alternative for increase of electric power offer in for the energy-hungry Brazilian market. As the number of projects increases, the knowledge on their environmental impacts is better developed. The current status of the development of small hydropower projects and their most frequent impacts are analyzed in this paper.

Keywords: Hydropower plant, Reservoir; Environment.

Resumo

As novas regras definidas para as pequenas centrais hidrelétricas no Brasil tem resultado num grande número de projetos com esta característica, após o estabelecimento de nova regulamentação pela Agência Nacional de Energia Elétrica, redefinindo as características necessárias para uma hidrelétrica ser classificada como pequena central hidrelétrica, com dispensa de processo licitatório para a concessão do direito de exploração. Vários dos projetos em estudo estão localizados nos tributários dos rios principais da Bacia Hidrográfica do Rio da Prata. Alguns destes projetos encontram-se já em construção.

As pequenas centrais hidrelétricas diferem dos projetos de grande porte não apenas pela sua capacidade instalada: seus impactos sobre o meio ambiente são profundamente diferentes, o que as torna atrativas para o aumento da oferta de energia para o mercado brasileiro. Com o aumento no número de projetos, o conhecimento sobre seus impactos ambientais também vem se desenvolvendo. O estágio atual do desenvolvimento de pequenas centrais hidrelétricas no Brasil e seus impactos mais freqüentes são analisados neste trabalho.

Palavras-chave: Centrais hidrelétricas; Reservatórios: Meio Ambiente

A. Introduction

The new rules of by the Brazilian Electric Power Agency (Agência Nacional de Energia Elétrica – ANEEL), set in December 1998, redefined the required characteristics of a hydropower plant in order to be considered as a small hydropower plant (SHP), for which the concession for exploitation is granted by the Agency without bidding process.

This new definition and other advantages offered to investors interested in the SHPs caused a boom in the number of projects under study in Brazil, many of them in the tributaries of the main rivers in the La Plata River Basin. Some of these projects are already under construction.

Small hydropower plants differ from the large hydropower projects not only for their power production capacity: their impacts on the surrounding environment are deeply different, what makes them to be an attractive alternative for increase of electric power offer in for the energy-hungry Brazilian market.

As the number of projects increases, the knowledge on their environmental impacts is better developed. The current status of the development of small hydropower projects and their most frequent impacts are analyzed in this paper.

B. Current situation of small hydropower plants in Brazil

B.1 General

The status of the small hydropower plants in Brazil was drastically changed by ANEEL with the issuing of Resolutions Nr. 394 and 395 from December 1998. These legal instruments defined the required characteristics need for a hydropower plant in order to be classified as a SHP, and the procedures to receive authorization to build and exploit it.

The conditions to be satisfied by a project, in order to be considered a small hydropower plant, are:

- the installed capacity must be in the range between 1 and 30 MW;
- the reservoir area must not exceed 3 km^2.

For plants below the lower limit, a simplified process was defined. For plants larger than 30 MW or with lakes that have areas of more than 3 km^2, a competitive bid process must be set. In order to be authorized by ANEEL to exploit a certain site, an investor must go through the following steps:

- develop the inventory studies of the river (if this was not yet done);
- elaborate the Preliminary Design[1] of the Plant;
- elaborate the Environmental Impact Studies for the project.

Once the preliminary design is approved by ANEEL, and the Preliminary Environmental License – LAP[2] is obtained from the environmental agency[3], the investor can apply for the Authorization of ANEEL to exploit the site for 35 years, including the construction period.

[1] Projeto Básico.
[2] Licença Ambiental Prévia.

As investment requirement in a SHP is substantially smaller than in a large hydropower project, a broader universe of potential investors was created with the new market regulations for SHP. These investors include: industrial groups, investment banks, pension funds, small power generation and/or distribution companies, construction companies and cooperatives. These investors may primarily act as independent power producers or self-producers.

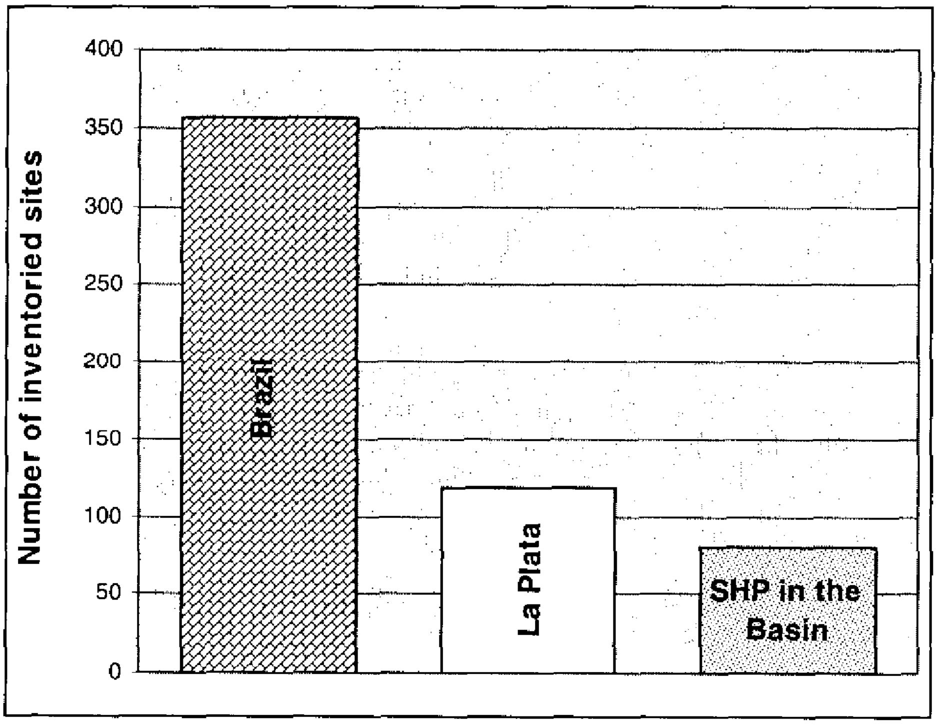
As there is not a competitive process for achieving an Authorization to build and own a SHP, ANEEL, with the purpose of providing transparency to the process, publishes on its internet site[4] almost real time updates on the status of all projects under study in the country, and periodically along the year, issues a Report on all registered studies on hydropower projects (ANEEL, 2001).

B.2 Estimated capacity

Although the total available capacity for small hydropower plants in Brazil is not totally known, ANEEL's Report provides an outline on the near future perspectives for these projects in Brazil.

Out of a total of 356 inventoried sites for a total capacity of 27.870 MW identified in the country, 118 sites, with capacity for 3.775 MW are in the La Plata River Basin tributaries. From these, 80 sites, with 738 MW of capacity, fall within the definition of SHP. A total of 21 rivers in the Basin are currently under inventory studies. Other 29 sites in the La Plata Basin (with installed capacity of around 420 MW) have already received approval from ANEEL for construction, and 6 projects (93 MW) are being analyzed. Figures 1 and 2 summarize these numbers.

Figure 1: Inventory Studies in the La Plata River in Brazil



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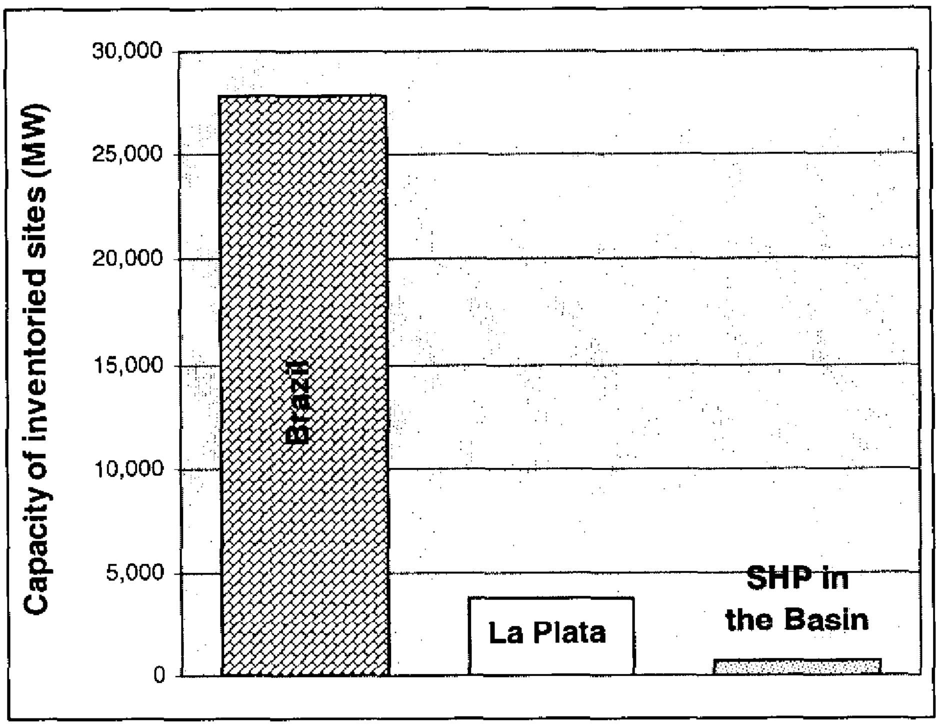
[3] In Brazil, the environmental licensing process is conducted by the environmental agency of each federative State, and criteria for issueing Environmental Licenses vary from State to State.

[4] www.aneel.gov.br

Figure 2: Installed Capacity of Inventoried Sites in the La Plata River in Brazil



As can be observed from the figures shown, although the installed capacity of the SHP projects may not be too large, the total number of projects is quite impressive. As expected by ANEEL, many of these projects are due to be built in the next 3 years. Therefore, a deeper understanding of the effects to be caused by these projects is of highest importance.

C. Technical features of small hydropower projects

As a consequence of the definition adopted by the ANEEL, the SHP projects mostly have the following characteristics:

- are run-of-the-river plants, with almost no accumulation;
- have small reservoirs, mostly restricted to the natural river bed.

As such, the power output of the SHPs is dictated by the hydrological conditions at the site, more than the electricity demand. Thus, they work as a complementary source of power for the Brazilian existing large power projects. Nevertheless, they have a strategic role for the distribution grid, due to the fact that are often located at edges of the grid, where the quality o supplied power is often poorer.

In some cases, when the investor is a power distribution company, the presence of a SHP in the grid allows the company to reduce its purchases from large power producers or from the spot market. However, backup arrangements are usually required, for the dry hydrological periods. As an alternative for that, plant owners may buy complementary power in the spot market, but at a price that may drastically reduce the profitability of the project.

From the knowledge gained from a century-long tradition of building hydropower plants of all scales, Brazil has a broad set of engineering companies, manufacturers and constructors which are capable of providing the equipment and services needed for the construction of SHPs.

C.1 Small versus large

As the "Guidelines for design of SHP" (ELETROBRÁS, 2000) recommend, the technology used in large hydropower projects cannot be adapted to SHPs. A SHP is not a large plant in reduced scale.

However, the development process o a SHP project demands most of the steps required for a large project, and from this arises one of the main difficulties faced by developers: the development costs prior to approval of the project (surveys, engineering, licensing, etc.) are comparatively heavier for smaller projects, since they lack of the scale effect that privileges the large projects.

D. Environmental impacts associated to SHPs

D.1 Public perception

The public opinion in most of the countries often associates the idea of hydropower projects with the impacts caused my large, misevaluated projects developed in the past, like some Brazilian projects of the 1970 and 1980´s in Amazon basins.

In the recently published report of the World Commission on Dams (WCD, 2000), almost no mention was made on the impacts caused by small hydropower plants. This certainly is due to the fact that public opinion and multilateral financing agencies concern mostly with the enormous impacts that often are caused by large projects.

However, the relevance of the small hydropower plants cannot be disregarded. In China, for instance, there are thousands of SHP, providing comfort and development conditions for millions of people. Coming closer to our area, we have several examples of the benefits resulting from small plants in providing power in remote areas.

The impact of these projects as a whole was not yet properly assessed. In Brazil, in particular, where in the last decades, various large hydropower projects were developed, impounding large areas and displacing thousands of people, the notion of hydropower projects is associated with heavy environmental impacts.

Developers, when approaching the community to discuss a SHP project, often observe this fact. Despite the dimensions of the project, the communities generally put in mind that the project will have impacts that are comparable to those of larger projects. This view is often observed within the environmental agencies too.

D.2 Methodology for impact assessment

Considering the small scale of the projects and their consequent reduced impacts on the environment, the impact assessment of SHPs requires more straight-forward methodologies for impact evaluation and proposal of measures (FIRTA & FOES, 2000).

The adequate selection of a methodology for assessing the impacts of the project will lead to two very desirable effects: the maximization of the completeness of the studies, resulting in a better understanding of the short, mid- and long term impacts of the project on the various environmental attributes, and a rational and right-to-the-point use of the available resources.

D.3 Common impacts of SHPs

Arising from the definition set by ANEEL for a SHP, which includes the area limit of 3 km^2, these projects in general do not have serious impacts related to the formation of reservoirs, as usually happens in large projects.

The residence time[5] of small hydropower reservoirs is short, often in the range of a few days or even hours[6]. Thus, their effects on depreciation of water quality is often neglectable. The same happens with sediment retention.

And most important, people displacement from reservoir areas is incomparably smaller than in large projects – as a matter of fact, investors usually seek sites in which this can be avoided.

On the other hand, as the more attractive projects are those associated to natural river falls, based on river flow diversion, the projects may result in flow reduction along a reach of the river, between the dam and the tailrace channel. This reduction is usually associated to impacts on the aquatic fauna and on the livelihood of riverine people and on the dilution of pollutants, in the case of more populated areas.

In addition to these effects, this reduction may represent conflicts with natural touristic attractions such as waterfalls. Finding an acceptable way of dealing with this sort of impact usually represents a point of discordance between developers and the environmental agencies. In some cases, specific operational rules have been set in order to accommodate the divergent interests.

Fish migration, river flow fluctuations, lost of archeological and touristic sites, changes in the underground flow and slope instability are some of the most frequent environmental concerns of SHP projects.

D.4 Mitigation and compensation measures

In spite of the reduced scale of the impacts associated to SHPs, the proposal of adequate solutions for their mitigation and compensation must be one of the purposes of the developers. If the environmental aspects of the project are properly addressed, the implementation of the project will be faster and easier.

A well done environmental impact assessment, regarding the impacts of the project on the environment and of the environment on the plant and its reservoir, predicting and implementing the required measures and mitigation, compensation and control programs, are fundamental. This will avoid deadlocks between the developer and representative sectors of the society such as non-governmental organizations (NGOs).

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[5] Residence time is defined here as the rate between reservoir volume and average flow rate.

[6] In the example shown in the case study, the residence time is as low as 0.6 days.

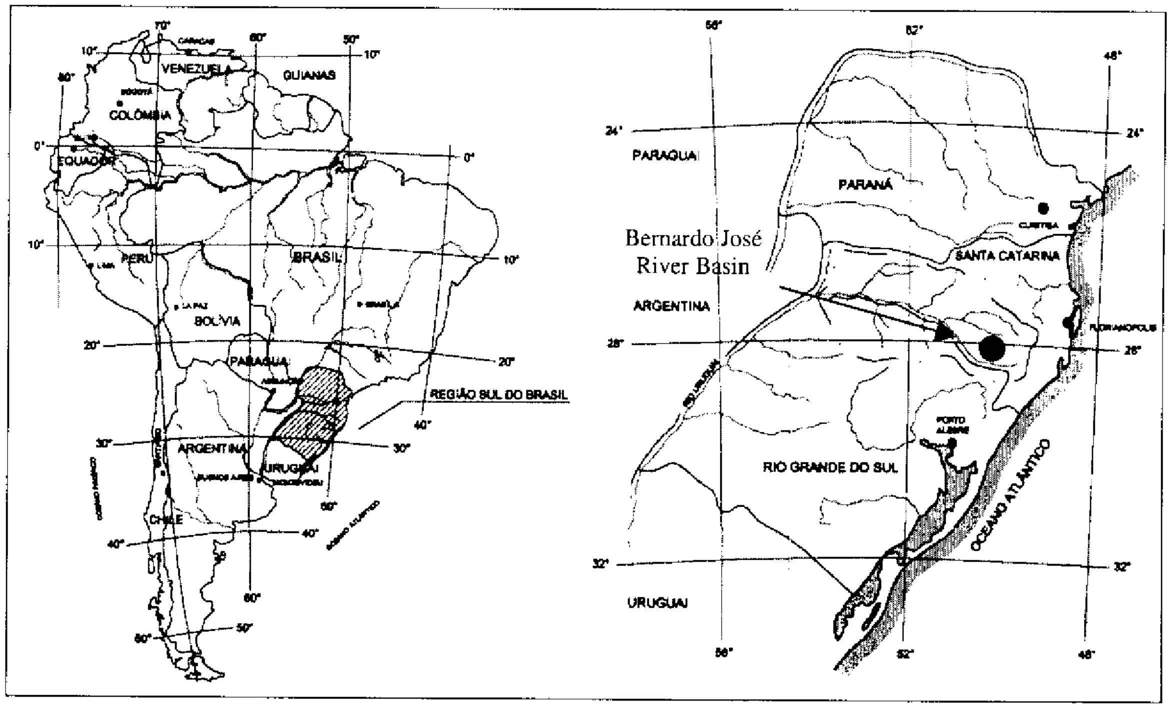
With that purpose, one of the most important measures to be taken by the developers, is to establish an efficient communication channel with the society. This usually will result in the reduction of the community's expectations on the impacts of the project.

E. Case study: the Bernardo José River Basin development

To illustrate the concepts and conclusions presented in this paper, a case study picturing river basin that is now being developed in Brazil is shown.

The Bernardo José River is a tributary of the Pelotas River, which, along with the Canoas river, forms the Uruguay River, which runs between the states of Santa Catarina and Rio Grande do Sul in Brazil. Figure 3 shows the location of the Bernardo José Basin.

Figure 3: Situation of the Bernardo José River in the Southern Region of Brazil



The inventory studies of the Bernardo José River Basin (RTK, 2000) were concluded in August 2000.

The Bernardo José River springs at elevation 860 m, in the Plateau of the State of Rio Grande do Sul, the southernmost State of Brazil. It runs from South to North, until its mouth on the Pelotas River, at elevation 470 m. The river has two very distinct reaches: until the km 25, the slope is very steep, and the topography is complex, with meanders in a deep valley and some waterfalls of up to 20 m height. From the km 25 onwards, the slope is reduced, and the ground is fairly plain. The total drainage area of the basin is of around 1000 km^2.

The reach between the river mouth and km 25 was than selected for hydropower development, in a cascade of four SHPs, as shown in Table 1 and Figure 4.

The selected projects proved to be economically feasible, and out of them, São Bernardo was the first one to have its Preliminary Design (RTK, 2000) and Environmental Impact Studies (JFOES, 2000) concluded. The preliminary design demonstrated that the project was technically feasible, and the environmental impact studies assessed the consequences of the project implementation and proposed mitigation and compensation measures.

The reduced reservoir area gave to the project a strategic advantage. Since most of this area (18 ha) is represented by the natural river bed, the flooded area is small, and its effected on the livelihood of the riverine population is almost nule.

As compared to other hydropower projects, the reservoir has a very small area. Its specific production, represented by the rate between the installed capacity and the reservoir area, is as low as 0,083 MW/km^2.

No serious impact was detected in association with the project, and the proposed mitigation measures did not represent serious cost increases. Further to that, a strong community support for the project was detected during the realization of the studies.

Table 1: SHPs in The Bernardo José River

PLANT	**NORMAL WATER LEVEL (m)**		**GROSS HEAD (m)**	**FLOODED AREA (km^2)**
	UPSTREAM	**DOWNSTREAM**		
São Bernardo	530	480	50	0,18
Moinho	578	530	48	0,27
Esmeralda	661	578	83	0,25
Barracão	701	661	40	3,00

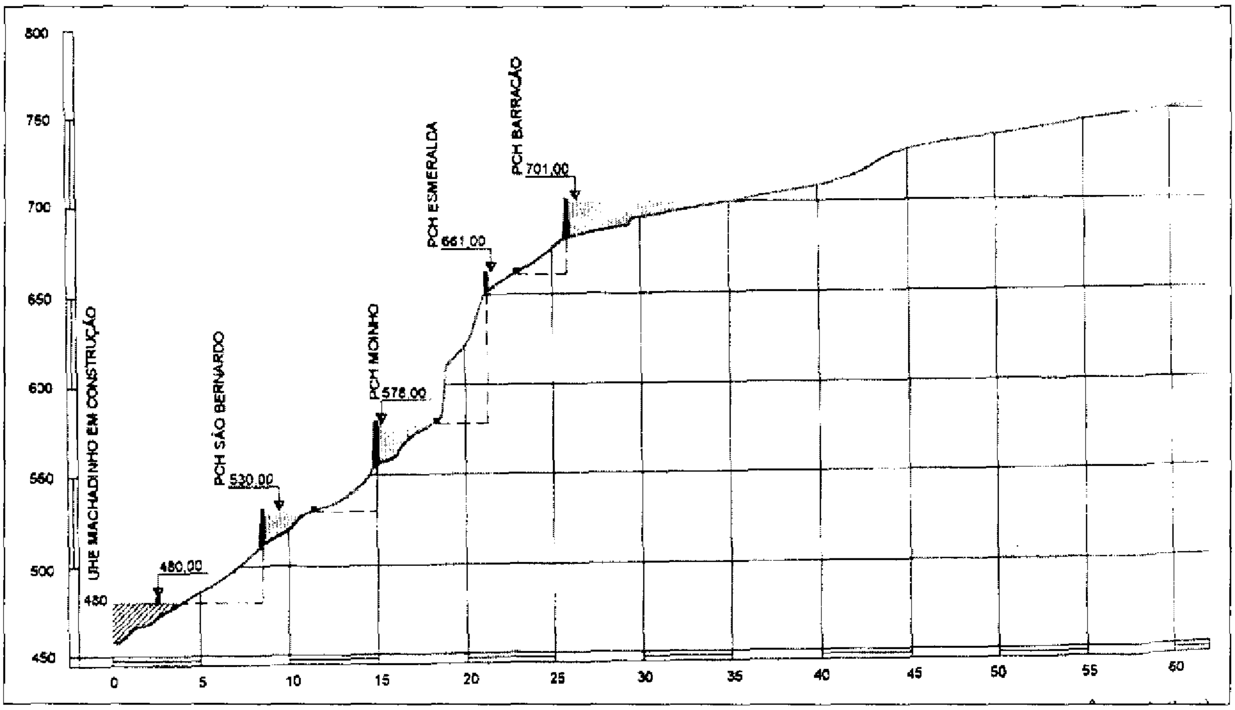
F. Conclusions

The new regulation on small hydropower plants introduced strong interest among investors in Brazil on the development of such projects.

Although the impacts of these projects on the environment are not yet completely assessed, experience has shown that most of them are environmentally sound, and do not pose any serious threat on the environment.

As perspectives are that a large number of these type of hydropower projects are due to be implemented during the coming years, there is a need for more practical and effective methodologies for assessing the impacts and proposing mitigating, compensating and control measures for the impacts caused by small hydropower projects.

Figure 4: River Profile and Selected Cascade



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Variabilidad espacial y temporal de los parámetros físicos - químicos en el embalse de Ullum.

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Resumen

Se da cuenta de investigaciones efectuadas relativas al Estudio de la Evolución temporal y espacial de los parámetros físicos y químicos de Calidad de Agua que caracterizan el sistema lacustre Embalse Quebrada de Ullum, Provincia de San Juan, proponiendo una metodología para medir las variables aconsejadas por Organismos Internacionales (EPA, ADEQ), aplicando las técnicas de monitoreo actualizadas desarrolladas por estos Organismos y por otros Centros de Investigación, que norman Estudios del Medio Ambiente con métodos de Laboratorio.

Palabras Clave: Embalses - Calidad de Agua - Parámetros Físicos - Parámetros Químicos

Abstract

This paper deals with investigations carried out relative to the study of the temporary and spatial evolution of the physical and chemical parameters of water quality that characterize the lacustrine system in Ullum Reservoir, Province of San Juan. A methodology to measure the variables advised by International Organizations (EPA, ADEQ) is proposed and updated techniques of monitoring developed by said organizations and other research centers, which standardize environmental studies with laboratory methods, are applied.

Keywords: Reservoirs; Water Quality; Physical parameters; Chemical parameters

A. Introducción

La actividad humana, agrícola, urbana o industrial, afecta invariablemente a los cuerpos de agua próximos, que son los receptores de los desechos más o menos contaminantes. Sus efectos generalmente son cambios graduales y lentos que suelen hacerse evidentes cuando el grado de deterioro alcanzado es muy importante y su remediación requiere de una gran inversión (Dr. Alejandro J. Mariñelarena, 1998).

En los ambientes en que no se realizan controles de rutina, las alteraciones repentinas de la calidad del agua (una floración algal o una mortandad de peces) generan alarma y pedidos de estudios de los que, bajo esas circunstancias, suelen obtenerse resultados que no representan la normalidad y conducen a conclusiones erróneas. (Dr. Alejandro J. Mariñelarena, 1998).

Los cambios graduales en la calidad del agua y los consecuentes cambios en la estructura de sus comunidades, sólo se pueden evaluar por medio de estudios ambientales de largo plazo. Sobre los resultados de estos programas se pueden establecer las "condiciones normales" de funcionamiento y sus desviaciones típicas debidas a variaciones climáticas cíclicas y la acción antrópica. La línea de base así trazada es imprescindible para contrastar cualquier alteración aislada que ocurra en el ecosistema y para definir o evaluar los resultados de cualquier programa de manejo o biomanipulación de la cuenca.

La mayoría de las alteraciones de calidad de agua se pueden detectar en forma temprana por medio de monitoreos ambientales periódicos. Este tipo de estudios permite establecer "la situación normal" o "el estado trófico", definiendo una línea de base de calidad de agua del embalse, que contenga entre otros aspectos:

- Las condiciones físicas y químicas típicas de verano e invierno.
- Las características bióticas de las comunidades que se desarrollan.
- Las especies dominantes, su numerosidad y variación numérica a lo largo del año.
- La carga anual de los nutrientes del sistema.
- Los balances de masas entre lo que ingresa, egresa y se acumula en la cubeta.

Con dicha información se pueden detectar las tendencias de cambio, cuando todavía no se observan signos macroscópicos de deterioro de calidad.

Cuando se obtienen evidencias de perdida de calidad en forma temprana, se pueden aplicar técnicas de manejo o biomanipulaciones para revertir el proceso de eutrofización, sin que ello implique costos muy elevados.

El objetivo de este proyecto es el de evaluar la calidad del agua en el embalse a través de la determinación de parámetros físicos, químicos y biológicos. Esto permitirá brindar la información necesaria para la optimización futura del uso sustentable del recurso. Estas determinaciones se llevarán a cabo por nuestra Unidad, en conjunto con otras Instituciones del Estado Provincial.

La cuenca del Río San Juan de unos 26.000 Km2, se extiende hasta la Alta Cordillera, incluyendo las estribaciones del Cerro Aconcagua. Los caudales afluentes al Río San Juan, provienen de: fusión de nieve estival, lluvia invernal, lluvia estival sobre la cuenca inferior y lluvia estival sobre la cuenca superior (aluviones), siendo el módulo del Río de 60 m3/s. Por ser una zona árida la cuenca es poco vegetada y escasamente poblada, sin desarrollo industrial. El uso del suelo en la cuenca es prioritariamente para producción agrícola bajo riego y el la parte alta de la misma para pastoreo de ganado caprino.

El Valle de Tulúm es desde el punto de vista agrícola el más importante de la Provincia de San Juan. La precipitación media anual es de 90 mm por lo que el área en condiciones de ser cultivada, próxima a las 100.000 Has depende exclusivamente del riego artificial desarrollado a partir de la Presa de Embalse Quebrada de Ullum, que permite regular parcialmente los aportes del río San Juan.

El Embalse cubre un área aproximada de 3.200 Has. Con un volumen de embalse de 440 Hm3, una profundidad máxima de 35 metros, profundidad media de 8 metros y un tiempo de retención entre 90 y 120 días.

El destino fundamental del agua embalsada está orientado para **Agua Potable y Regadío** y como usos alternativos la producción hidroenergética (Central a Pie de Presa – 47.000 KW) y el desarrollo de actividades recreativas y de turismo. El uso turístico es el de mayor incidencia social - económica en el perilago.

B. Antecedentes del proyecto

Siguiendo una Línea de Investigación relativa al Estudio de Ecosistemas en Zonas Aridas que se lleva a cabo en el Instituto de Investigaciones Hidráulicas de la Universidad Nacional de San Juan, (Proyecto I079), desde el año 1996, se trabaja en el estudio de Ecosistemas Lacustres. Como fruto de estos estudios se cuenta con un relevante aporte innovador que hiciera un grupo de investigadores del IDIH (Gutiérrez y otros, 1998), sobre la metodología para obtener la morfología del vaso de embalse, donde en reemplazo de perfiles batimétricos, los estudios se orientaron a obtener una adecuada densidad de puntos por kilometro cuadrado dispuestos de un modo aproximadamente uniforme y la generación de un banco de datos con las coordenadas x, y, z, correspondientes, derivándose del mismo atributos topográficos tales como la curva Volumen - Cota, Area - Cota, Cortes, etc.

C. Materiales y métodos

El área de influencia del proyecto es el emplazamiento del Embalse Quebrada de Ullum. El estudio de monitoreo se inició en el segundo semestre del año 2000 y se extenderá durante los años2001 y 2002.

Hasta Diciembre del 2000 se han realizado dos tipos de campañas de orientación:

✓ Muestreo Superficial. Se han realizado 11 (once) campañas
✓ Muestreo de Perfiles Verticales. Se han realizado 2 (dos) campañas

C.1 Campañas de muestreo superficiales

La ubicación de las estaciones de muestreo, responde a los objetivos del Programa de muestreo y se ubicaron frente a los sitios del perilago con mayor actividad turística, o bien a los sitios con menor actividad turística pero con menor infraestructura de soporte a la actividad (menos controlados), o como en el caso del canal de descarga de la Central 1-2, por atravesar éste, la Villa cabecera del Departamento Ullum y ser posible receptor de líquidos y sólidos residuales. Se determinan como estaciones de muestreo también, un punto cercano al lago sobre el Río San Juan y un punto aguas abajo de la presa sobre el Río, para evaluar la calidad del agua de ingreso y egreso del embalse. Las coordenadas de los puntos de muestreo se obtuvieron con GPS.

Los estaciones de muestreo son:

- Río san Juan, aguas abajo de la presa, frente a la Fabrica de Cerámicos (output).
- Playa sobre la Margen Derecha de la Presa
- Embarcadero
- Playa Hermosa (balneario y zona de paso de las bajadas de creciente del piedemonte y drenaje natural de la zona irrigada de Ullum).
- Canal de descarga de la Central 1-2
- Río San Juan, aguas arriba del embalse a la altura de Calle las Moras (input).

En cada punto de muestreo, sobre la superficie del embalse ,se determina Ph., Conductividad, Oxígeno Disuelto y Temperatura, con equipos portátiles de campo.

Además durante la campaña se toman los datos:

- Apariencia del agua:
- Condiciones de viento:
- Condiciones del tiempo:
- Información general:
- Temperatura del aire
- Temperatura del agua
- Caudal de Ingreso por el río San Juan (Estación de Aforo Km. 47)
- Caudal turbinado (dato aportado por AES - Central Pie de Presa)
- Cota de embalse (dato aportado por Departamento de Hidráulica)

C.2. Campañas de muestreo de perfiles verticales

Las estaciones de muestreo se ubican, de igual manera que en el apartado anterior, frente a los sitios de mayor actividad turística, a una distancia de la costa de aproximadamente de 300 metros.

En la campaña del 6 de diciembre además se establecieron una serie de puntos de muestreo sobre la línea que atraviesa al espejo de norte a sur, distanciados entre si aproximadamente 500 metros (las coordenadas de los puntos se determinan con GPS).

- Playas Complejo de la U.N.S.J. (Salida)
- Cuatro Estaciones cada 500 metros sobre la línea descripta.
- Frente al Cerro Tres Marías.
- Frente al Paredón del Dique (punto más profundo ± 35 metros)
- Playas Complejo Bahía de las Tablas
- Embarcadero
- Entrada del Río San Juan.

Se toman muestras en superficie y a profundidades de 5, 10 y 15 metros con un dispositivo adaptado en nuestro laboratorio. El líquido recolectado se vuelca en envases plásticos limpios de 0.5 lts, desbordando y cerrados posteriormente sin dejar cámara de aire. Estos se trasladan a la costa con cierta periodicidad y son ensayados de inmediato con los equipos portátiles de campo.

Se determinan los mismos parámetros y datos que en las campañas de superficie: PH; Oxigeno Disuelto; Conductividad y Temperatura, datos de: Apariencia del agua, Condiciones de viento, etc.

Es objetivo del proyecto obtener también, la variabilidad y estratificación tridimensional de la temperatura, para lo cual hemos intentado adaptar una serie de instrumentos ya que las posibilidades de financiamiento para las tareas nos han impedido la adquisición de una sonda específica de temperatura en profundidad.

C.3 Equipos disponibles

- MEDIDOR DE CONDUCTIVIDAD, de lectura Digital, multi rango Digital y Portátil Con sonda potenciométrica de PVC de 4 anillos, con 1 metro de cable. Con sensor de temperatura incorporado y compensación automática de temperatura Rangos de medición: 0 a 19,99; 0 a 199,9; 0 a 1.999 µS y 0 a 19,99 mS. Precisión 1% fondo de escala

Operación con baterías de 9 V (incluidas). Gabinete construido de plástico de alto impacto.

- MEDIDOR DE pH, Phmetro electrónico digital portable. Compensación automática de los valores de PH por medio de sensor de temperatura interno, de 0 a 100 ° C. Rango de 0 a 14. Resolución 0,01 pH. Funcionamiento a batería alcalina interna de 9 VDC. Monitor de cristal líquido LCD para visualización instantánea de los datos. Soluciones para calibración de la sonda de medición. Marca COLE PALMER.

- MEDIDOR DE OXÍGENO DISUELTO, Galvanic dissolved oxigen meter Portátil, peso 1Kg. Rango 0.1 a 80 ppm., a temperatura de 0. a 40 °C, Resolución DO 0.1 ppm. A temperatura. °C 0.1, Precisión DO $\pm$ 0.1 ppm. Temperatura T $\pm$0.2 .°C. Marca LAMOTTE.

- MEDIDOR DE OXÍGENO DISUELTO, Galvanic dissolved oxigen meter Portátil, peso 1Kg. Rango 0.1 a 80 ppm., a temperatura de 0. A 40 °C, Resolución DO 0.1 ppm. A temperatura. °C 0.1, Precisión DO $\pm$ 0.1 ppm. Temperatura T $\pm$0.2 .°C. Marca ORION.

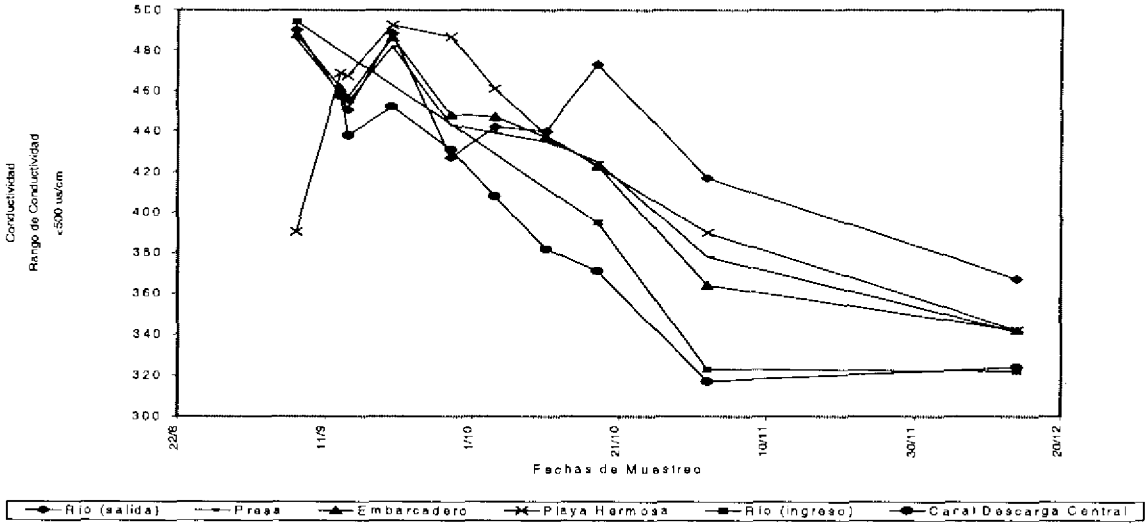
Para la realización de estas campañas el Instituto de Hidráulica cuenta con: Lancha hidrográfica para mediciones hidrométricas y sedimentológicas. Motor EVINRUDE de 35 HP. Utilitario tipo Combi marca VOLKSWAGEN, modelo 82/83, patente N° 59904 con equipamiento para lancha. Pick-up marca PEUGEOT 504 GRD modelo 94, patente N° 79242. con equipamiento para lancha.·

C.4. Información existente

Se cuenta con información de campañas de muestreo efectuadas por el Instituto Tecnológico Provincial. En estas se realizo, durante los años 1996, 1997 y 1998, una determinación mensual de los parámetros: PH; Conductividad Específica a 25 °C, Residuo Salino, Carbonatos, Bicarbonatos; Cloruros; Sulfatos; Calcio; Magnesio; Sodio; Potasio; Boro; Dureza Total; Dureza Permanente; Dureza Temporal; Oxigeno Disuelto; Bacterias Coliformes Totales, Arsénico y DBO.

Cuadro 1 Resultados de ensayos Instituto Tecnológico Provincial.

Parámetro	**Valor Mínimo**	**Valor Máximo**	**Media**
DBO, O (mg/l)	0.1	4.3	0.62
OXIGENO DISUELTO, O (mg/l)	6.85	12.8	8.68
CONDUCTIVIDAD ESPECÍFICA a 25 °C (µs/cm)	322	610	482.77
PH	7	8.32	7.90
DUREZA TOTAL en CaCo3 (mg/l)	143	1981	213.05
DUREZA PERMANENTE en CaCo3 (mg/l)	10	300	95.37
BACTERIAS COLIFORMES TOTALES-NMP	3	240	26.71
ARSENICO, As (mg/l)	0.01	0.02	0.01
POTASIO K (mg/l)	1.2	8.8	4.02
MAGNESIO Mg (mg/l)	1.3	16.92	8.26
SULFATOS SO4 (mg/l)	19.69	173	114.74
CLORUROS CL (mg/l)	12.36	52.31	30.59
BICARBONATOS HCO3 (mg/l)	22.04	235.7	140.40
RESIDUO SALINO CALCULADO (mg/l)	271.15	476	398.61



Las estaciones de muestreo fueron: Murallón, Embarcadero, Costa Magna, Playa Hermosa, Dique Lateral, Centro del Embalse, Bahía de las Tablas y el canal de Descarga de la Olla Ullum 1-2

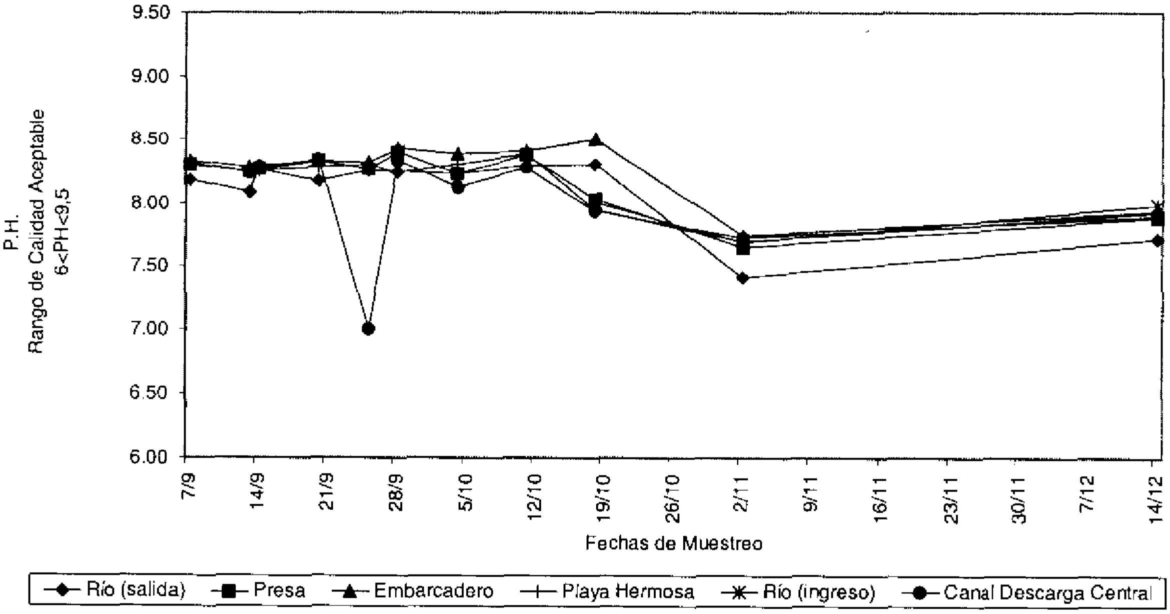
Además se recabo la información, para la fecha de los muestreos, de: Cota de Embalse, caudal de ingreso por el Río San Juan y caudales turbinados por la central a pie de Presa y erogados por vertedero.

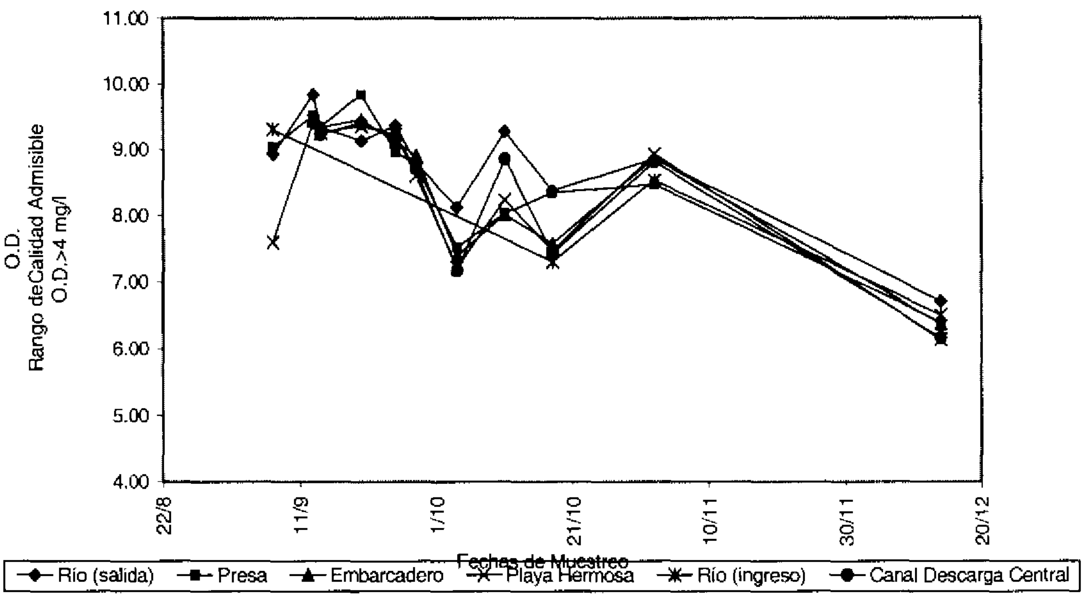
D. Resultados de los trabajos desarrollados a la fecha

D.1 Campaña de muestreo superficiales

a) Conductividad

Como muestran la tabla y el gráfico, la conductividad es muy baja de 350 µs/cm de promedio





en todas las estaciones de muestreo y a las diferentes profundidades, inclusive por debajo de los valores históricos del Río San Juan (500 µs/cm).
Se mantiene en un valor muy aceptable sin grandes variaciones espaciales y en profundidad. En cuanto a su variación temporal, observamos que desciende muy levemente hacia el verano.

b) P H
Los valores de P H se encuentran entre 8.3 -7. se observa en el gráfico y la tabla, que en todos los casos los valores son inferiores a 8.5, máximo admisible para el desarrollo de la vida acuática.

c) Oxigeno disuelto

El 100% de las muestras, tanto de superficie como de profundidad, están por encima de 8 ppm, con porcentajes de saturación de más de 90%, es decir son valores que reflejan muy buena calidad. No se evidencia para el periodo de muestreo que exista estratificación del O.D. en profundidad al menos hasta los 15 metros.

D.2 Campaña de muestreo de perfiles verticales.

El Cuadro 2 presenta los resultados de los muestreos de perfiles verticales.

E. Comentarios

Como parte de las tareas del proyecto se ha realizado una importante recopilación de información existente relacionada tal como:

- ✓ Calidad del agua del Río San Juan
- ✓ Normativa vigente sobre las actividades recreativas a realizar en el embalse (motonautica, balsas)
- ✓ Normativa general de la Provincia en relación con el agua superficial y el embalse.
- ✓ Normativa sobre disposición de los efluentes líquidos y sólidos producidos en los Complejos Turísticos habilitados.

Cuadro 2 Resultados de los muestreos de perfiles verticales

Estación	Profundidad	Oxigeno Disuelto			P.H.		Conduc-tividad
		ORION			COLE PALMER		CORNING
		Temp (° C)	Conc.(ppm)	% Sat	Temp.	Ph(° C)	1999 microS/cm
Esta.1 – Salida UNSJ	5 m.	30.00	8.13	112.00	30.10	7.46	368
	10m.	29.70	8.06	99.50	28.30	7.65	379
Esta.2 – 500 metros	5 m.	30.40	7.49	107.70	28.60	7.77	383
	10m.	30.30	7.99	98.90	28.90	7.79	379
	15m.	30.20	7.91	105.80	29.40	7.75	380
Esta.3 – 1000 metros	5m.	29.80	8.06	106.50	29.20	7.90	376
	10m.	30.00	7.92	104.50	28.10	7.94	380
	15m.	30.50	7.94	105.90	29.40	7.87	375
Esta.4 – 1500 metros	5m.	29.40	8.36	110.10	28.40	8.01	374
	10m.	29.50	8.17	107.10	28.70	7.97	372
	15m.	29.30	7.82	103.10	27.20	7.96	379
Esta.5 – 2000 metros	5 m.	29.00	7.93	99.40	28.80	8.01	367
	10m.	29.00	7.83	101.70	28.90	8.01	366
	15m.	28.70	7.77	100.60	29.80	7.59	366
Esta.6 – Frente Cerro	5m.	29.00	7.79	102.10	28.70	8.02	365
	10m.	28.90	7.92	102.10	28.60	8.04	366
	15m.	28.80	7.78	101.20	28.60	8.01	366
Esta.7 – Paredón	5m.	29.20	7.42	103.70	29.80	8.14	366
	10m.	29.60	9.51	109.00	28.80	8.10	372
	15m.	29.10	8.70	112.50	29.60	8.90	374
Esta.8 – Bahía de las Tablas	5m.	29.10	7.83	101.70	29.70	8.12	371
	10m.	29.00	8.07	108.50	29.80	8.06	378
	13m.	29.60	8.02	107.30	29.90	8.05	370
Esta.9 – Embarcadero	5m.	29.80	8.05	107.90	30.00	8.11	369
	8m.	29.60	8.07	108.50	30.10	8.16	368
Esta.10 - Entrada Río	60 cm.	30.90	8.18	112.40	29.90	8.17	384

Este trabajo esta en etapa de ejecución, recientemente iniciado. Los resultados obtenidos hasta el momento permiten inferir que los parámetros evaluados se encuentran en los rangos admisibles para los usos propuestos para el embalse.

El próximo paso es , con el análisis de la información recopilada, diseñar el Monitoreo Sistemático, definiendo las escalas de espacio y tiempo, los parámetros a monitorear y las metodologías de trabajo en campo y gabinete.

F. Resultados esperados

A través de la evaluación de las determinaciones de PH, conductividad, Oxigeno Disuelto, Temperatura y otros parámetros, a ser aportados por otras Instituciones, se espera conocer la variabilidad y estratificación tridimensional de la calidad del agua en el embalse, validando metodologías de muestreo y análisis, que puedan ser utilizadas en otros embalses de la zona

(Cuesta del Viento, Caracoles y Punta Negra, en ejecución)y que permitan lograr la Línea de Base Ambiental.

Los cambios futuros para hacer sustentable la gestión de los recursos hídricos (Veltrop J, 1996) (Whipple W, 1996) requiere de actividades como las propuestas, generando a través de un trabajo de investigación multidisciplinario, el desarrollo de metodologías y técnicas avanzadas con sustento científico, susceptibles de ser aplicadas mediante acciones de transferencia tecnológica a mejorar las condiciones de vida de la Sociedad y preservar la calidad del más importante de los recursos naturales, "El Agua".

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Nitrogen Balance in Forest and Integrated Watershed Management: A Case Study of Lake Biwa in Japan

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Abstract

It is very required to estimate nutrient inflow from non-point sources, like forests, into lakes to prevent eutrophication. In this paper, the quantity of total nitrogen reduced by the forest around Lake Biwa, Japan is estimated. After that, the value of nitrogen removal is calculated in monetary terms. Although the result is not such a large amount of money, it should be noted that the advanced waste treatment system cannot treat storm runoff. Another important point is the fact that the estimation is based only on a function of nitrogen reduction. Forests have a lot of benefits for human and nature, as already mentioned before; therefore, we should maintain forest adequately.

A Introduction

Point sources of pollutants are easily measured where the contaminations come from household, industry drainages and so on. These are main nutrient sources to aquatic systems and can be reduced by waste treatment systems. Non-point pollution, on the other hand, is not clearly distinctive contamination sources originating, for example, from forests, fields and storm-water. It is not easy to examine the quantity of pollutant for non–point sources, therefore, it becomes more difficult to make efficient measures for their control.

Lake Biwa is the largest lake in Japan, has a surface area of 675 km^2 and a volume of 27.5 billion m^3. Lake Biwa is supplying water to 14 million people; it can be regarded as one of the greatest water sources in the world. Typical water quality indices, such as COD (chemical oxygen demand), phosphorus, and nitrogen, show that the lake-water quality has not been improved despite a number of the environmental programs implemented before. To be concrete, while the phosphorus concentration has been decreasing, the COD concentration has been still increasing. This suggests that the programs for point-source pollution reduction are not satisfactory and non-point source reduction measures are becoming more important in order to reduce nutrient loads to the lake. Fig. 1 shows nutrients loads inflowing into lake Biwa by sources. 'Natural Source' in the figure refers to 'Mountainous forest', 'Rainfall', 'Pond', 'Groundwater' and 'Urban and Highway Runoff'. The figure indicates the discharge from the non-point sources amounts to 60% of total-nitrogen loads, and 35% of total-phosphorus loads. It is predicted; therefore, that water quality measurements will certainly put emphasis on nutrients runoff from non-point sources in near future. Non-point source especially nitrogen inflow from forests is becoming a great concern for Lake Biwa. As the first step in our analysis, we will focus our attention on mountainous forest around the Lake Biwa, since 67% of terrestrial area is occupied by mountainous forest in Japan.

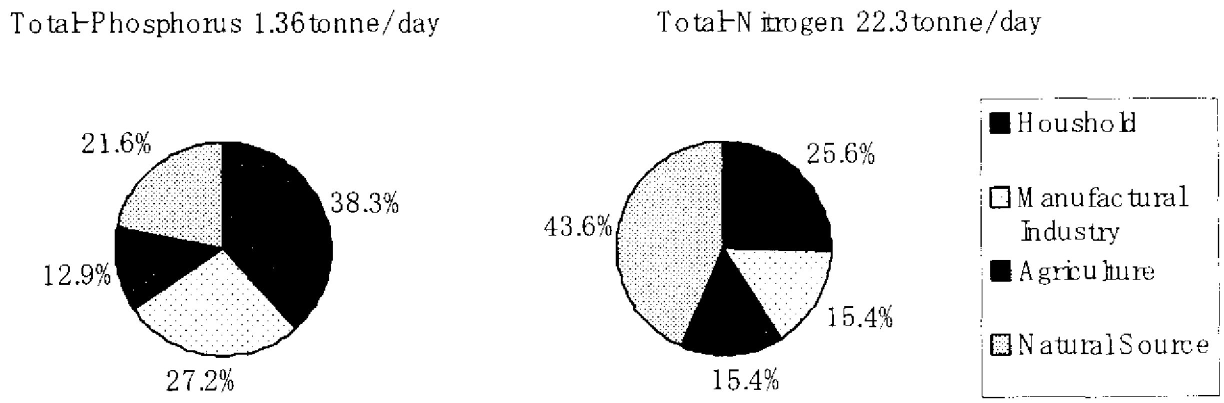

Fig. 1 Nutrients sources inflowing into Lake Biwa (1997).
Source: Shiga prefecture comprehensive environmental program

Forest management also needs to be reconsidered. As the grow of economic activity, the land has been developed into cities. Fig. 4 shows how drastically forests and fields have been turned into residential areas since the late 1960's. Furthermore, wood price has been decreasing since the 1980's because cheap timber has been imported from foreign countries. As a result, forestry does not provide a satisfactory living for local populations, and forestry is on the decline. There arises an important problem of sustainable forest management. This will affect lake water quality in the near future. It is essential to manage watersheds properly and integrate the management of not only water quantity but also quality.

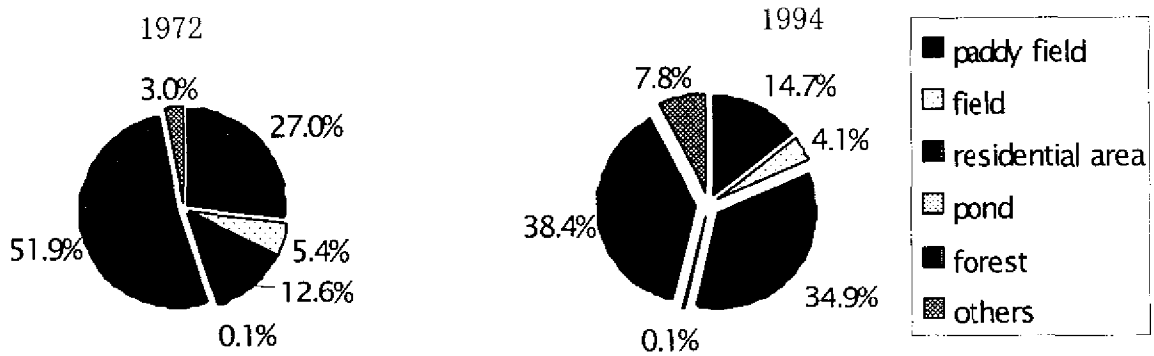

Fig. 2 Land use in the Lake Biwa - Yodo River basin

B Economic Evaluation of Forests

B.1 Objective

The purpose of this study is to evaluate environmental functions of forests in economic terms. Decisions for forest conservation or development, which means cutting down trees, require reliable information for supporting the decision-making, however, the value of forests has not been estimated quantitatively. This paper presents the results of analyzing the relation between forest and water quality.

B.2 Economic evaluation methods for forests

We can discuss quite a lot about the value of forest. Timber and mushrooms are traded in markets, while prevention of flood recreation and beautiful scenery are also important values that are not easily evaluated by monetary terms. In this paper, we apply the substitution method for this problem with evaluating the function that forests play in reducing nutrients in water. The method evaluates the value of nutrients removal by forests with the same amount of nutrients reduction cost on the assumption that the same amount of the nutrients was supposed to be removed by the advanced waste treatment systems.

B.3 Functions of forests

As discussed in section B.2 the functions of forests play various roles as follows:

1. To prevent disasters in mountain regions,
2. To maintain water volume,
3. To provide a place for recreation,
4. To preserve natural environment and wildlife.

The second function means the forest soils, which act like a sponge, absorbing rainfall quickly and let the water flow slowly. Nutrients are also removed in this process.

B.4 Water quality index

We chose nitrogen as an index of water quality in this paper. The eutrophication is the most serious problem of the lakes in the world and that the main cause of the eutrophication is nutrients inflows. Phosphorous is also an important factor as eutrophication cause and that needs further study. We selected total-nitrogen discharge for simplicity in this paper.

B.5 Estimation of nitrogen removal by forests

As is shown in Fig. 3, nitrogen is carried by rainfall, and it falls into forests. Some of it is absorbed by the soil, and the remainder, not utilized by plants and soil microorganisms, runs off into rivers. The amount of nitrogen removed in forests is estimated by the difference between the amount of inflowing nitrogen with rainfall and the outflow of nitrogen from the forest.

In the first place, the concentration of nitrogen in rainfall is estimated. Second, the mean volume of rainfall mm /year is multiplied by the concentration of nitrogen gives the amount of inflow of nitrogen from rainfall annually. Third, the inflow of nitrogen by rainfall multiplied by forest area gives the volume of nitrogen by rainfall entering forests in the watersheds of Lake Biwa. Fourth, the reduction rate of forests is calculated from actual measurements (Tsutsumi, 1987; Kunimatsu, 1997). Finally, we estimate the amount of removed nitrogen by forests by multiplying the reduction rate and the volume of nitrogen inflow into forests.

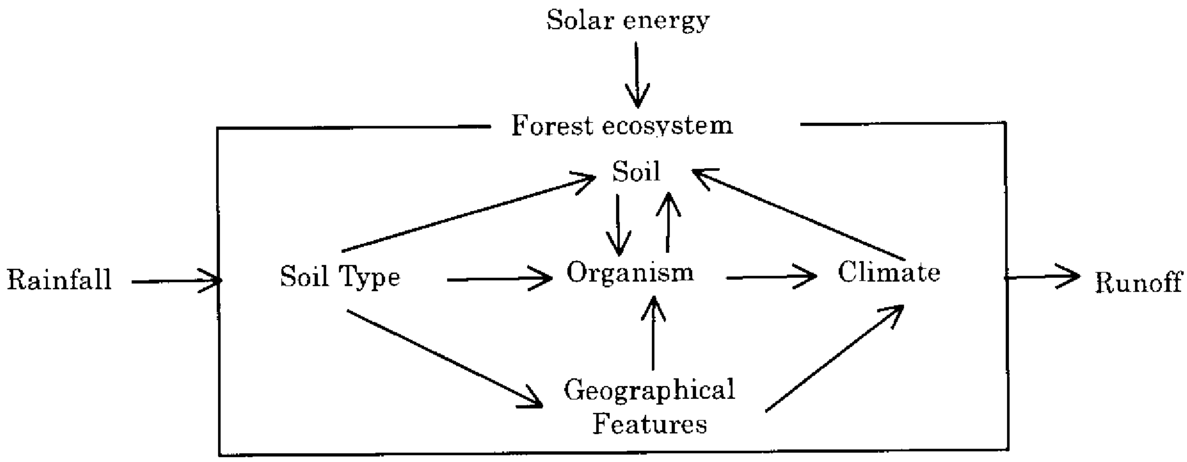

Fig. 3 Relation between forest ecosystem and runoff water quality.
Source: Kunimatsu, and Sudo (1997, p.7)

B.6 The amount of nitrogen loads from rainfall around Lake Biwa watershed

First of all, we have to estimate the concentrations of nitrogen in rainfall. In this section, we take a look at the relationship between the quantity and features of nitrogen existing in rainfall. It is known that the volume of rainfall affects nitrogen concentration. Strictly speaking, as the volume of rainfall increases, the concentration of nitrogen decreases, and also the nitrogen concentration becomes high after several fine days. For these reasons, it would be misleading to estimate the amount of actual nitrogen in the rainfall by multiplying the measured mean nitrogen concentrations (Table. 1) by annual precipitation. Tabuchi (1985) found that the way to estimate the amount of nitrogen loads by using a weight for the measured concentrations to get more accurate values. The concentrations of nitrogen could be 0.8 multiplied by measured concentrations. Using this ratio, we estimate the amount of nitrogen to be 0.74mg/l (1). The annual precipitation in Shiga prefecture amounts to 1,900 millimeters. In consequence the amount of nitrogen inflow from rainfall results in 14.06kg/ha/yr (2). Next, forest area in Shiga Prefecture is 204,693ha (Shiga prefecture forestry statistics, 1997). Then, it is concluded that 2877 tonnes of nitrogen flow in Shiga Prefecture forest from rainfall (3).

0.93mg/l * 0.80 = 0.74mg/l--- (1)
0.74mg/l * 1,900mm = 14.06kg/ha/yr------------------------------ (2)
14.06kg/ha/yr * 204,693ha = 2,877 tonnes/yr----------------------(3)
2,877 tonnes / year * 0.736 = 2118 tonnes / year------------------ (4)

Table 1 Nitrogen concentrations in rainfall

Monitoring point	Year	T-N (mg/l)
Shiga Prefecture, Otsu north	1974-75	0.72
Shiga Prefecture, Otsu south	1974-75	1.15
Shiga Prefecture, Kusatsu	1974-76	0.88
Shiga Prefecture, Hikone	1976-78	0.98
Mean		0.93

Source: Tabuchi (1985, p.19)

Table 2 The balance of nitrogen in forests, inflow and outflow

Monitoring point	Inflow (kg/ha/yr)	Outflow (kg/ha/yr)	Removing Ratio	Note
Shiga, Wakame	6.92	1.83	73.5%	Tsutsumi, 1987 p.55
Shiga, Somegaya	9.09	2.66	70.7%	Tsutsumi, 1987 p.55
Shiga, Ryuosan	11.9	4.2	64.7%	Tsutsumi, 1987 p.55
Shiga, Aburahidake N	12.8	5.62	56.0%	Kunimatsu, 1997 p.12
Shiga, Aburahidake S	20.8	4.59	77.9%	Kunimatsu, 1997 p.12
Shiga, Myokojisan	13.3	2.65	80.0%	Kunimatsu, 1997 p.12
Shiga, Kutsuki R	16.8	1.22	92.7%	Kunimatsu, 1997 p.12
	7.18	1.70	76.3%	Forestry Agency, 1999 p.5

Next step is to estimate the amount of reduced nitrogen by forests. From the monitoring results (Table 2) the nitrogen reduction of forests has very wide range (56.0%-92.7%). The reason is the differences in soil type, climate, geographical features and so on (Fig.3) The arithmetical mean of removed ratio is 73.6%, in Shiga Prefecture. The forestry agency of Japan estimated the removed ratio to be 76.3%. Therefore, we use the value, 73.6%, as the nitrogen reduction rate by forests in the Lake Biwa watershed. From the estimation above, the forest in the Lake Biwa watershed removes 2,118 tonnes of the nitrogen load every year (4).

Surely there are many factors that change the removal ratio (Fig. 3). What seems to be lacking is relation between nitrogen removal ratio and other factors. However, in this paper, we use 2,118 tonnes of nitrogen reduction annually (4).

B.7 Economic Evaluation

We estimated in the previous section that 2,118 tonnes of the nitrogen load are removed annually. How much does it cost, if we assume that the same reduction of the nitrogen load is carried by the advanced waste treatment system? Lake Biwa is suffering from eutrophication since nitrogen and phosphorus concentrations have reached high levels. Therefore, Shiga Prefecture installed an advanced treatment plant in 1980, which could remove nitrogen and phosphorus effectively. The capacity and performances of this treatment plant is as in the following.

1998

Treatment capacity	158,800m^3/day
Actually treated volume	122,822m^3/day
The amount of nitrogen flown in the treatment plant	352499.14 kg/day
The amount of nitrogen discharged by the treatment plant	70008.54 kg/day

From these data, this advanced treatment plant removes approximately 103,109 tonnes of nitrogen annually. The construction cost and operation cost, of the plant are respectively 19 billion yen and 220 million yen[1]. If we regard the lifetime of the plant as 20 years, and the interest as 5 %, the annual cost of the plant is estimated to be 764 million yen. The problem

[1] The exchange rate is approximately ¥120 for $1.0 US$ (March, 2001)

is that the advanced treatment plant removes mainly phosphorus and nitrogen. In other words, annual plant cost contains both treatment costs. It was clarified through the interview (Shiga Prefectural government, Sewer program section, 1999) that 36% of whole cost could be regarded as the nitrogen removal cost. Therefore, nitrogen removal cost is estimated to be 275 million yen annually, and 2,670 yen per tonne.

C Results and concluding remarks

Through the estimation procedures executed in this study it is concluded that the amount of nitrogen reduction by the forest is about 2,118 tonnes, and that the nitrogen reduction function of the forests around Lake Biwa is equivalent to 5.65 million yen. It should be noted that the advanced waste treatment system cannot treat storm runoff, because watershed area is too vast to gather the storm run-off by using a pipeline network. Another important point is the fact that the estimation is based only on a function of nitrogen reduction. Forests have a lot of benefits for human and nature, as already mentioned before; therefore, we should keep in mind that this result is the underestimates of the value of forests. We can analysis quantitatively only limited value of forests and more detailed study is essential in near future.

D Acknowledgements

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