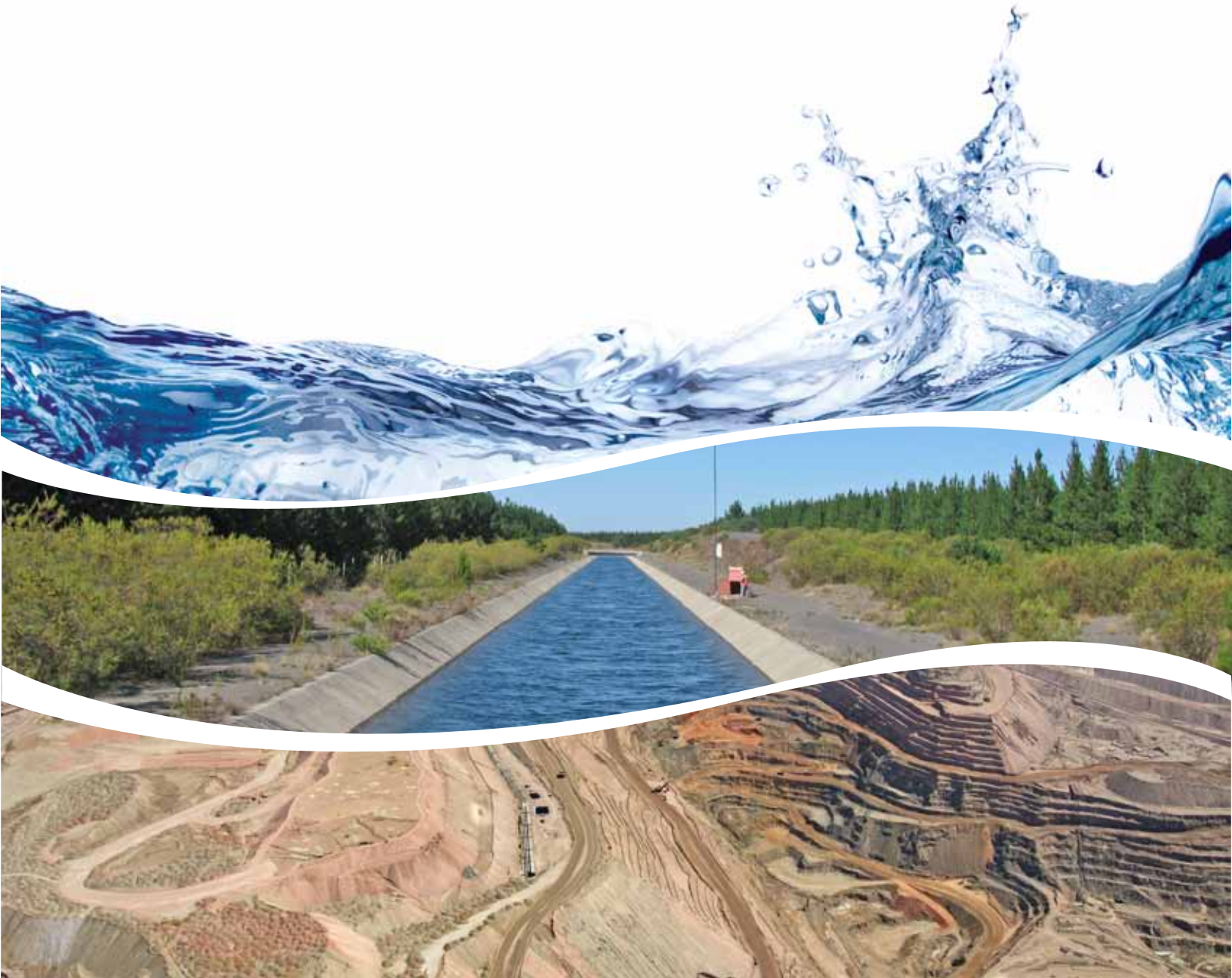
CRHIAM

CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

ANNUAL REPORT 2013 - 2014

WATER RESEARCH CENTER FOR AGRICULTURE AND MINING

CONICYT / FONDAP PROJECT 15130015




Universidad de Concepción
Universidad del Desarrollo
Universidad de Excelencia

CONTENTS

DIRECTOR'S REPORT

Availability and quality of water are two of the main limitations to economic growth and development in Chile. Geographically, the regions from Arica to Coquimbo is considered arid and the region from Valparaiso to the Biobío is considered semi-arid. The fact that 78% of the Chilean population lives in these areas (13.5 million inhabitants) shows the importance of the issue.

Chile is an agricultural and mining country. Agricultural activities are concentrated between Coquimbo and Los Lagos, covering the majority of the national territory, where more than 270,000 farmers work 30.5 million hectares, 40 % of the continental surface of the country. Chile has declared its intention to strengthen its agricultural sector and increase its economic competitiveness in order to become an international food provider. In addition, sustainable agriculture is important due to the fact that natural resources are finite and industrial and food exports will eventually be a major source of income for the country.

Meanwhile, mines are located in the northern part of Chile, from the provinces of Arica to O'Higgins. Although water consumption is lower in mining than in agriculture, 4% against 78%, a problem is posed by water scarcity and the great size of the mining industry and the central role it has in the Chilean economy, providing 60% of exports, 12% of the GDP and 21% of fiscal income. Recently the Chilean government declared that water resources are a priority for the mining industry.

Water in Chile is unequally distributed due to several factors, including the length of the country and its varied geography and climatic conditions.

Taking into account the scarcity of fresh water in the north of Chile, seawater may be considered a possibility to solve problems related to expansion and creation of new plants by mining companies. Nevertheless, seawater presents great problems which must be studied and solved before it becomes a general solution for use in the mining industry

Another source of water for the mining industry is recycled mineral processing water. The copper mining industry has been forced to improve its water recovery rates from thickener and tailing ponds, to the present level of 70%; with the development new technologies, rates should reach 80% in the near future.

Water quality is a key issue in agriculture, mining and human consumption, so great effort is needed in studying the treatment of acid drainage from mining and residual water from agriculture and livestock businesses as well as the sewage of rural villages and towns.

A final issue of interest related to water in the agriculture and mining industries is the analysis and promotion of regulations to improve the relationship between the industry and the public.

On December 9, 2013 CONICYT approved a FONDAP program to establish a Water Resource Center for Agriculture and Mining (CRHIAM) at the University of Concepción. CRHIAM is an interdisciplinary and collaborative research institution in the areas of agriculture and mining, which integrates the efforts of academic staff from the University of Concepción, the University of La Frontera and the University of El Desarrollo, with water as one of its main areas of research. Thus, 9 faculties of these universities became members of the center, with 30 researchers, 66 professionals and 4 administrative officials.

The mission of CRHIAM is to contribute to the solution of problems related to water resources in agriculture and mining, promoting the harmonic extraction of natural resources and optimizing

their use, leading to sustainable development in each of these economic sectors.

CRHIAM has three main objectives:

- To promote research, create knowledge and develop technologies in water resources, optimize their management and consumption, find new water resources and provide norms to regulate the interaction between the productive sector and society.
- To train researchers at the undergraduate and especially graduate and postdoctoral levels, to address the need for advanced human resources in the country.
- To create links with other national and international research institutions and public or private sectors to benefit from common research and technology transfer.

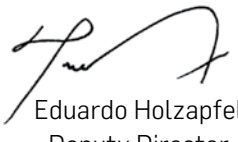
In its first year of work, 125 students took part in training courses on water-related subjects under the auspices of CRHIAM, 57 at the undergraduate level, 19 at the master's level, 39 at the PhD level and 10 at the postdoctoral level. CRHIAM's academics published 2 books, 3 book chapters, 23 ISI and 6 non-ISI research articles, gave presentations at 45 conventions and organized 48 extension courses, conventions, workshops and seminars.

The total budget of CRHIAM for the first year was US$3.93 million, of which US$1.4 came from Conicyt/Fondap Programs.

The most significant achievement during this first year of work was to assemble a tight group of interdisciplinary researchers from nine different faculties working together in research on water, leading to results for the agriculture and mining sectors. These researchers were working on water subjects without each other's knowledge and without a common objective, resulting in very wide-ranging topics. Now that knowledge is being better shared among researchers, the topics will be more effectively prioritized during the second year.

We would like to congratulate and thank the CRHIAM team for its commitment and dedication that resulted in a successful performance in 2014. Although this is our first year of work, we have fulfilled most of our goals.

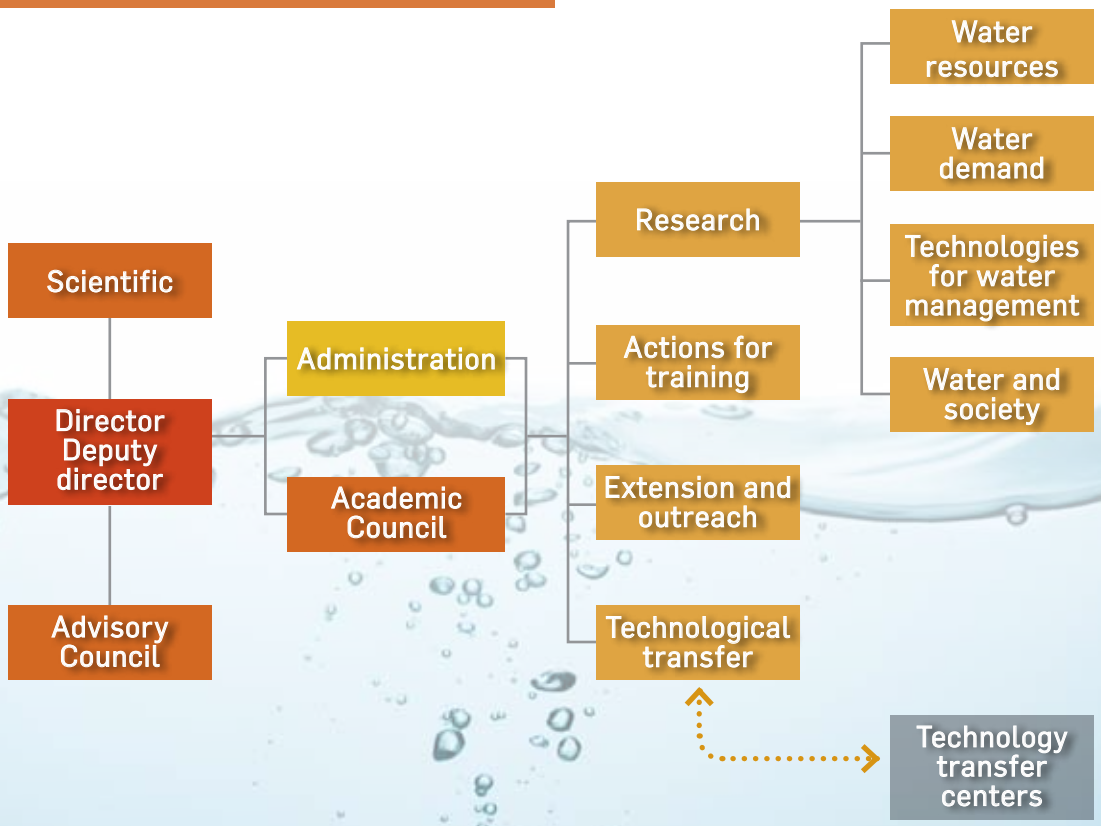
Fernando Concha
Director



Eduardo Holzapfel
Deputy Director

CRHIAM ORGANIZATION

ORGANIZATIONAL CHART



SCIENTIFIC COUNCIL

The Scientific Council is in charge of recommending general research guidelines and the evaluation of the advances of actual research performed at the center and suggestion of new lines when necessary. The council includes the director, deputy director and seven members from prestigious international Universities:

- Elías Ferere, Universidad de Córdoba, España.
- Jan Hopman, University of California, Davis, USA.
- Janusz Laskowski, University of British Columbia, Canada.
- Mark Servos, University of Waterloo, Canada.
- Niel McIntire, University of Queensland, Australia.
- Peter Scale, University of Melbourne, Australia.
- Reyes Sierra-Álvarez, University of Arizona, USA.

ADVISORY COMMITTEE

The Advisory Committee connects the center with the country's public and private sectors, and society in general, to lead the center's activity in benefit of the country. The advisory committee members are:

- María Eugenia Camelio, Director FONDAP.
- Reinaldo Ruiz, Chilean Presidential Delegate for Water Resources.
- Fernando Concha, CRHIAM Director
- Eduardo Holzapfel, CRHIAM Deputy Director
- IP Resources.
- IP Demand.
- IP Technology.
- IP Water and Society.
- Alexander Chechilnizky, President AIDIS.
- Álvaro Hernández, Director of Water Management, Codelco, Chile.
- Alvaro Prieto, General Manager, Iansa
- Carlos Estévez, General Chilean Water Director.
- Gustavo Tapia, General Manager of Technology and Innovation, Antofagasta Minerals.
- Ferruccio Medici M. Water end Energy Manager for Anglo American, Chile.
- José Luis Soler, Copefrut S.A President.
- Nelson Muñoz, General Manager of the O'Higgins province Development Corporation.
- Patricio Crespo, President of the National Agriculture Society.
- Patricio Grez, Executive Secretary of the National Commission of Irrigation.

ACADEMIC COMMITTEE

The Academic Committee is responsible for the operation and research progress of the center. The center is composed of eight principal researchers and is chaired by its director, Emeritus Professor Fernando Concha.

FERNANDO CONCHA
Met. Engineering

EDUARDO HOLZAPFEL
Agr. Engineering

ROBERTO URRUTIA
Envir. Science

PEDRO TOLEDO
Chem. Engineering

GLADYS VIDAL
Envir. Eng.

ALEX SCHWARZ
Civil Engineering

JOSÉ ARUMI
Agr. Engineering

RICARDO BARRA
Envir. Science

ADMINISTRATION

VALENTINA MUÑOZ
Project Engineer

SONIA AGUILERA
Administrative Officer

MARÍA IGNACIA CARRILLO
Journalist

CARLA INZUNZA
Secretary

INTERNATIONAL AND NATIONAL ASSOCIATION

1. Colorado School of Mines.
2. Institute of Environmental and Water Studies, IDAEA, Spain.
3. Lund University, Sweden.
4. New Mexico Water Resource Research Institute, USA.
5. Sustainable Minerals Institute SMI, University of Queensland, Australia.
6. University of Arizona, USA.
7. University of Melbourne, Australia.
8. University of California, Davis, USA.
9. University of Ghent, Belgium.
10. Universidad Politécnica de Madrid, Spain.
11. Leibnitz University, Hannover, Germany.
12. University of Waterloo, Canada.
13. University of York, Canada.

NATIONAL ASOCIATION

CRHIAM is also associated with two Chilean Universities: Universidad de la Frontera (UFRO) and Universidad Del Desarrollo (UDD).

RESEARCHER

Principal Researchers

1. Fernando Concha, Metallurgical Engineering.
2. Eduardo Holzapfel, Agricultural Engineering.
3. Roberto Urrutia, Environmental Science.
4. Pedro Toledo, Chemical Engineering.
5. Gladys Vidal, Environmental Engineering.
6. Alex Schwarz, Civil Engineering.
7. José Arumí, Agricultural Engineering.
8. Ricardo Barra, Environmental Science.

Associate Researchers

1. Aldo Montecino, Mathematical Engineering.
2. Alejandra Stehr, Environmental Sciences.
3. Alex Godoy, Engineering UDD.
4. Amaya Alvez, Legal and Social Sciences.
5. Christian Goñi, Metallurgical Engineering.
6. Daniel Sbárbaro, Electrical Engineering.
7. David Jeison, Environmental Engineering UFRO.
8. Diego Rivera, Agricultural Engineering.
9. Fernando Betancourt, Metallurgical Engineering.
10. Gonzalo Montalva, Civil Engineering.
11. Jorge Jara, Agricultural Engineering.
12. Jorge Rojas, Social Sciences.
13. José Vargas, Civil Engineering.
14. Juan Figueroa, Environmental Sciences.
15. Leopoldo Gutiérrez, Metallurgical Engineering.
16. Luis Lagos, Agricultural Engineering.
17. María Cristina Diez, Environmental Engineering UFRO.
18. Mario Lillo, Agricultural Engineering.
19. Raimund Bürger, Mathematical Engineering.
20. Jorge Figueroa, Environmental Engineering.
21. Sergio Acuña, Engineering, Bio-Bio.
22. Verónica Delgado, Legal and Social Sciences.

SUPORTING STAFF

1. Alejandra Fajardo
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4. Douglas Aitken
5. Felipe de La Hoz
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7. Leonora Hidalgo
8. María Ignacia Carrillo
9. María José Ortega
10. Marianela Carreño
11. Matías Vejar
12. Pamela Sanhueza
13. Patricio Leonelli
14. René Iribarren
15. Ricardo Pradenas
16. Ronald Burgos

FUNDING SOURCES, 2013-2014
TOTAL AMOUNT (US$3.93 million)

	ANNUAL FUNDING SOURCES	MCh$ 2014
1	Fondecyt 1140451 The sulfide diffusive exchange technology applied to wetlands for treatment of toxic acid mine drainage	51,456
2	Fondecyt 1120664 "Monitoring and fate determination of the biological activity of micropollutants contained in pulp and paper mill effluent treated by an aerobic bio-reactor".	46,835
3	Fondecyt Postdoctorado 3120216, "Evaluación de la eliminación del potencial biológico presente en aguas residuales urbanas y efluentes de celulosa Kraft a través de sistemas biológicos convencionales y no convencionales detectado con S. cerevisiae recombinante y Daphnia magna"	24,802
4	Fondecyt Postdoctorado 3140162 "Evaluation of organic micropollutants, nutrients and organic matter removal contained on domestic wastewater treated by constructed wetlands".	22,933
5	Fondo de Innovación Tecnológica de la Región del Bío-Bío, Corfo- INNOVA BIO BIO. Proyecto N° 13.3327-IN.IIP "Recuperación de agua mediante jardines depuradores a partir de aguas servidas rurales: Aplicaciones innovadoras con impacto para la comunidad rural", Línea de Innovación de Interés Público. Duración 2014-2016.	54,872
6	AQUASAT: Un servicio integrado para el manejo sitio-específico del agua de riego. FONDEF IT13I20002.	110,000
7	Sistema de Soporte de Decisión para el manejo espacial del riego en Pivotes Centrales. FONDEF CA13I10129.	57,500
8	Agua y Energía. Una integración interdisciplinaria para el fortalecimiento del Programa de Doctorado en Ingeniería Agrícola. Programas PM Ministerio de Educación.	84,000
9	Desarrollo de un Modelo de Transferencia Tecnológica Y Conocimiento FIC	130,000
10	Fondecyt 11130397.	16,973
11	Fondecyt 1130154.	18,711
12	Anillo ACT 1118.	112,500
13	Basal PFB 03.	120,000
14	Minera Centinela, Estudio CFD de feedwell.	18,000
15	Minera Candelaria.	7,000
16	Establecimiento de Red de Estaciones nivo-glaciales de Cordillera para la gestión integrada de los recursos hídricos de la cuenca del río Rapel. (FIC O'Higgins)	158,500
17	Developing a quantitative high-resolution temperature reconstruction for the last thousand years in South Central Chile using a calibration-in-time approach (Fondecyt N° 1120807)	56,000
18	Proyecto Fondecyt 1140466	56,333

19	Proyecto VRID UdeC 213.051.004-1AP, “Regulación y estímulos al aprovechamiento de los servicios ambientales existentes en las áreas protegidas de la región de Aysén”, Investigadora Principal Verónica Delgado. (3 años, ultimo año 2015)	2,500
20	Proyecto Fondecyt iniciación N° 11121371 “Teoría y práctica del Derecho Comparado por parte del Tribunal Constitucional Chileno 2006 – 2012: análisis crítico”, lo que permitirá elaborar una base de datos y una propuesta metodológica que pueda servir de m	14,500
21	Proyecto VRID-Asociativo “Los conocimientos y actitudes respecto a la democracia y la ciudadanía que poseen los estudiantes que ingresan a la Universidad de Concepción“. Como miembro del Grupo Interdisciplinario de Investigación en Derechos Humanos y Dem.	2,000
22	Fondecyt Postdoctorado 3140161 “Water available, water use, and water quality evaluation in rural Chilean watersheds, through community participation and field research”. Liderado por Dr Y Rivas y Patrocinado por Dr D Rivera.	6,750
23	Proyecto Fondecyt 1110298. Water availability in a stressed Andean watershed in Central Chile: Vulnerability under climate variability	5,000
24	Proyecto Conicyt-BMBF, PCCI1-2031. Modelación a multi-escala de sistemas complejos de suelo y rocas fracturadas para el manejo sustentable de recursos hídricos en cuencas andinas.	1,900
	TOTAL EXTERNAL FUNDING	1,179,065
	FONDAP 15130015	849,950
	Associate Universities (Udec, UFRO, UDD)	417,891
	TOTAL	2,446,906

RESEARCH

Research at CRHIAM is organized in four clusters: **Water Resources,** to search for new water sources from glaciers, surface water, groundwater and seawater for agriculture and mining, **Water Demand**, to optimize water usage for irrigation and recovery of water for reuse in mineral processing, **Technology for Water Management**, to treat residual water from different sources to be used as fertilizers and treat acid water from mines to purify it and recover metals, and **Water & Society** to contribute to improving the Chilean water law and analyze the relationship between mining companies, agriculture and society.

In the following pages the research performed during 2014 is presented.

WATER RESOURCES

I AVAILABILITY AND ANALYSIS OF GLACIER, GROUND WATER AND SURFACE WATER RESOURCES

1.1 Synergistic effect of climate change and land use on the hydrological regime and water quality.

The lack of high-quality data sets at an adequate spatial distribution in the Southern Hemisphere is recognized as the bottleneck in assessing and diagnosing forced or unforced climate variability during the last millennium. In this context, a high quantitative temperature reconstruction over the last millennium was made using calibration-in-time approach for Central Chile based on sedimentary pigments. The temperature reconstruction shows a warm period in 1020-1360, interrupted by short cold events. This period coincides with the Medieval Climatic Anomaly. Subsequently, a persistently cold period in 1370-1765 was identified, roughly coinciding with the Little Ice Age.

All available hydrological information for Chile from the DGA was collected and analyzed. This information will be used to develop statistical river flow forecast models for Central Chile.

1.2 Determination of the hydrological contribution of glaciers in the Central Chile Region under different climate conditions.

The mass balance is an indicator of the "health status" of the glacier and links the climate to the glacier. It seeks to understand the dynamic response of a glacier to climate conditions. The accumulation zone in a glacier gains mass, while the ablation zone loses more mass than what is gained in one year. The equilibrium line defines where the balance is zero. Between the upper and lower part, there is a gradient that generates a flow which compensates for the balance between both zones. In this context we are studying a glaciological and geodetic mass balance of "Glaciar Universidad" for the hydrological periods of 2013-2014.

This research will answer questions such as: (i) What is the hydrological contribution of "Glaciar Universidad" to the Tinguiririca River Basin? (ii) Is the glacier in equilibrium with the current climate? (iii) How important is albedo to the glacier's mass balance, and how can its modeling be improved within a mass-balance model? (iv) What is the most likely future scenario with respect to hydrological contributions of the basin's glaciers?

1.3 Improving our knowledge of groundwater recharge processes.

In volcanic Andean watersheds located in Central Chile, groundwater processes of recharge, storage and release play an important role as resilience mechanics for the effects of climate change and variability on water resources during low-flow conditions. Following up on a previous project we are developing studies to better understand: 1) the behavior of the volcanic aquifer formed by the Chillán volcano that delivers more water to some rivers than others and 2) the groundwater surface water connections at the lower part of the Renegado.

In a parallel study, we are developing a detailed study of the infiltration and exfiltration process along the Renegado River using stream flow measurement, geochemistry analysis and modeling. We are also starting a study of the vulnerability of drinking water sources to land use changes at the Renegado Valley.

1.4 Establishment of nivo-glacial stations in the Andes region of the O´Higgins province and development of a model for an integrated management of the water resources of the Cachapoal river.

Arauco Project: Instrument-selected watersheds. We operate an intensive monitoring network and community activities to assess

the link between rural communities and water availability at a watershed located in the area of Arauco. By means of long-term collaboration with Dr. Jonh Selker of Oregon State University, we continue the monitoring of a small watershed in the coastal mountains. The instrumentations are related to moisture measurements and flow in an intermittent creek. These data will be used for the implementation of a hydrological model in 2015.

2 SEAWATER IN MINERAL PROCESSING

2.1 Reagent to depress pyrite.

The floatability of pyrite particles is depressed during froth flotation using seawater, even in the absence of pyrite depressants such as lime or sodium meta-bisulfite. These results suggest that the ions present in seawater such as $Ca2^{+}$, $Mg2^{+}$, Na^{+} and K^{+} may affect the action of xanthate collectors on the flotation of pyrite. We want to identify the independent effects of each of these ions on pyrite floatability.

It is well known that using conventional water copper ions activates the surfaces of pyrite particles during the process of froth flotation. However, the experimental evidence obtained so far indicates that the effect of copper ions in the froth flotation process using seawater is different, resulting in lower pyrite recovery. The study to correlate the chemistry of copper ions in seawater with the process of activation/depression of pyrite is analyzed.

Sodium meta-bisulfite (SMB) is used in the mining industry to depress pyrite in the process of flotation using seawater. However, the mechanism of action is still unknown. Results so far indicate that one important aspect is the order of addition of this reagent. The depressant effect of SMB is stronger when it is added before the collectors.
Studies to evaluate Dextrin as reagent for pyrite depression using real ores are also carried out.

2.2 Electrolytes in Seawater: effect on the rheological properties of mineral suspensions

It is known that the high ionic content of industrial water, especially if it is seawater, disrupts the normal functioning of the polyelectrolytes present in the solution. The aim of this study is to evaluate the effects of the presence of different types of salts, classified according to their maker or breaker condition, on the viscous behavior of solutions of polyelectrolytes.

We studied the impact of several electrolytes present in seawater on the rheological properties of flocculated alumina suspensions assessed using creep testing at pH conditions both above and below the isoelectric point. A high salt concentration of 0.5 M was used to approach the ionic strength of seawater. For both pHs studied, the sediments demonstrated viscoelastic non-linear behavior observed as a non-linear relationship between yield strain and applied stress. In the presence of flocculants, new results were found.

A new empirical three-parameter visco-elastic model for describing the rheological behavior of linear and nonlinear materials was postulated. In particular, the model successfully reproduced experimental creep curves at various constant stresses for flocculated suspensions of alumina in the presence of different types of seawater salts.

2.3 Maker/breaker electrolytes: effect on frothers and collectors

We measured surface tension of aqueous solutions of metyl isobutyl carbinol (MIBC), a widely used frother, in the presence of different salt electrolytes, NaCl, KCl, $MgCl_2$ and KI. While MIBC decreases surface tension compared to pure water, salt electrolytes increase it. For low concentrations of MIBC the effect of the salt dominates but for higher concentrations of MIBC and salt the surface tension decreases even below the surface tension of MIBC in water without salt. For concentrations under 2 M of electrolytes the change in surface tension occurs independently of the concentration and kind

of electrolyte. Surface excess curves reveal that adsorption of MIBC in the air-solution interface increases with salt concentration.

To better understand the macroscopic results we are currently observing the behavior of ions, frothers and water from the bulk to the air-liquid interface, through molecular dynamics simulations. To study the surface activity of MIBC in the presence of NaCl and water, we used the GROMACS simulation package. The effect of NaCl was quantified through the density profile of MIBC along the gas-liquid interface, the surface tension, and the mobility of MIBC with its mean square displacement. These results will help to explain our experimental results with several frothers in aqueous solutions with various electrolytes.

2.4 Population balance model for flocculation

A population balance model was used to describe the time evolution of aggregate size distribution in turbulent shear flow during flocculation. The fractal nature and the permeability of the aggregates and its evolution over time are also part of the model. The model showed excellent agreement with experimental flocculation kinetics and for aggregate size distributions. When the aggregates underwent restructuring, properties such as permeability, breakage rate and collision rate changed considerably over time. When the aggregates were permeable, the collision frequency was significantly smaller than when they were impervious.

2.5 Nano-scale adhesive forces in colloidal systems

The effects of different salts on the efficiency of flocculants are well known, although their mechanism action is not clear. A good way to understand these effects is to use Atomic Force Microscopy (AFM).

Using AFM, we measured the nano-scale adhesive forces between a colloidal silica probe and a flat silica substrate in a range of aqueous NaCl, $CaCl_2$, and $AlCl_3$ solutions, with concentrations ranging from 10^{-6} to 10^{-2} M at pH ~5.1. Notably, the measured force curves reveal large pull-off forces in water which increase in electrolyte solutions, with jump-off-contact occurring as a gradual detachment of the probe from the flat substrate rather than as a sharp discontinuous jump.

An additional tool to interpret results is in development: a molecular model of water (based on the rigid water model TIP4P / 2005) which, implemented as molecular simulations, can go through all the aggregation states of water.

The growth of a solid on a liquid observed in molecular dynamics simulation of water according to the TIP4P/2005 potential was analyzed in light of the averaged local bond order parameter. The location of each interface was determined from the average position of the respective cluster molecules, with the thickness of the interfaces also obtained. This analysis was compared with analysis of profiles of local order and H-bonding in the direction of growth. Once combined, the methods are complementary. A quantitative correlation was observed in simulation snapshots of the system between thickness and position of the interface in time.

Here we also analyzed molecular dynamics simulations to study capillary liquid bridges between two planar substrates and the origin, strength and range of the resulting force between them. The force between the substrates due to a bridge of liquid argon is estimated by different methods including non-equilibrium simulations of moving substrates connected by liquid bridges and macroscopic balance of forces.

We recently designed an innovative computer experiment that allows direct calculation of the capillary force exerted by a liquid water bridge between two flat substrates from molecular dynamics simulations without any arbitrariness regarding the geometry and location of the free surface of the bridge.

Issues we want to answer include: (1) molecular water ordering in the presence of maker and breaker ions, (2) spatial distribution of ions in solution, (3) structure of polyelectrolytes in water and in the presence of ions, (4) assessing the salting-out effect of polyelectrolytes in the presence of ions.

Because the system is complex and there are so many components, the approach to improve the understanding of flocculation mechanisms was to involve coarse-grained Monte Carlo simulations. The main components are flocculants or polyelectrolyte (PE), solid particles (mainly colloidal silica particles) and saline solution (Na^+, Ca^{2+}, Cl^-).

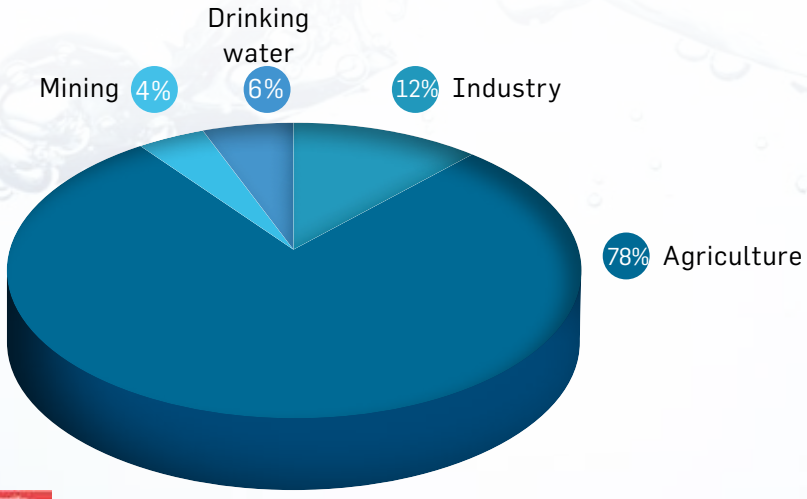
2.6 Scaling and anti-scaling of inverse osmosis membrane

Reverse osmosis is the preferred method to obtain processed water from seawater to process copper ores by flotation in the mining industry. One of the problems with membrane processes is scaling with calcium and magnesium ions.

The objective of this study is threefold: measuring the induction period for scale layers to begin to grow, determining the scaling kinetics and evaluating the effects of a range and dosages of commercial anti-scalants.

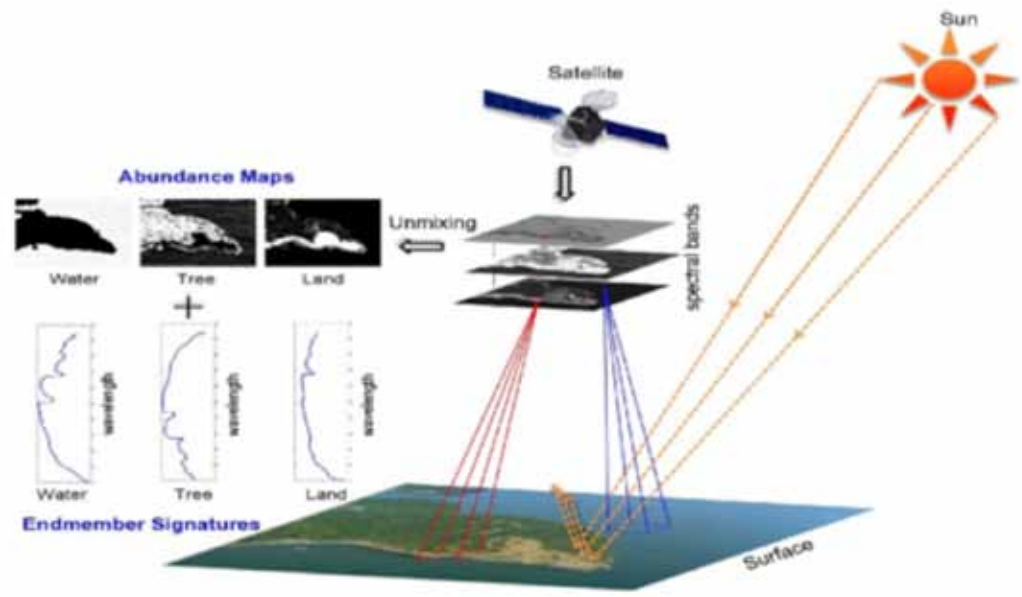
WATER DEMAND

CONSUMPTIVE WATER USE



Fuente :Dirección General de Aguas - Ministerio de Obras Públicas - Gobierno de Chile
http://wwwdga.cl/eventos/agua%20estamos%20adonde%20vamos_matias%20desmadryl.pdf

OPTIMIZATION OF WATER USED FOR IRRIGATION



1.1 Evapotranspiration of partial covered crops

Evapotranspiration (ET) was measured and modeled for partially covered surfaces. The model can estimate both Transpiration (T) from the canopy and Evaporation (E) from the soil. Soil evaporation on partially vegetated surfaces over natural vegetation and orchards includes not only the soil under the canopy but also areas of bare soil between vegetation contributing to total ET. Soil evaporation can account for 2545% of annual ET in agricultural systems such as partially vegetated surfaces like fruit orchards (i.e. apples, oranges, vineyards, avocados, blueberries and lemons among others) that cover a significant surface of the total area under irrigation.

1.2 Image processing to determine water demand.

Satellite images are the main data input to estimate spatial crop water demand. In order to have high quality data it is necessary to include radiometric and geometric correction of images in addition to the graphic co-register of each image. After this process, the improvement of the satellite image resolution is performed with the fusion technique, using the WATFRAC model developed in our research group. Two products were obtained: satellite images of Landasat 7 and 8 with resolution of 15 meters and another obtained from high-resolution sensors (e.g. QuickBird, WordView, Pleiades, SPOT) with sub-metric resolution.

1.3 Decision Support System AQUASAT

AQUASAT is a Computational Dynamic Decision Support System platform able to make irrigation decisions by combining satellite and meteorological information as well as field data. It offers detailed information for water management in spatially distributed irrigation. AQUASAT permits, given historical information, the estimation of water demand and selection of areas recommended for water management and support for irrigation analysis.

AQUASAT uses satellite images as an information source allowing specific information from ground cover, especially crops, to be extracted. The image information is processed and stored as input data for the model that determines evapotranspiration with the surface energy balance, validating field information determined through the Eddy Covariance and Surface Renewal technique.

AQUASAT was validated with historical data in two cases: i) a Blueberry field with partial cover under drip irrigation and ii) a Sugar Beet field with full cover under a pivot system. In both conditions, the support system exhibits adequate performance, and may help farmers make decisions related to irrigation time and frequency, taking into account the spatial variability of the demand. The system requires a significant upgrade to allow for better interaction with stakeholders and the step up of the data management with new technologies.

For this purpose, we developed a database with spatial characteristics and the ability to store the entirety of the baseline data of each farm, as well as to register the processes required for the management and operation of irrigation. In addition, it has the capacity to incorporate a “field book,” that is, the record of activities carried out for each crop. This information will support the AQUASAT platform for the adequate estimation of water demand.

1.4Decision support system for spatial irrigation management of central pivots.

In Chile, irrigation by center pivots has recently increased significantly. The center pivot allows the irrigation of large areas that are destined mainly for intensive production of annual crops and/or vegetables. The system has the advantage of applying water with high uniformity and high application efficiency. However, not all the areas under this irrigation system are irrigated adequately. Despite the fact that along the equipment the water application is uniform, under the pivot it is common to find great spatial variability of soils, crops and conditions. Today, the only way that producers can compensate for some of these problems is by controlling the rotational speed of the equipment. Applying just the right amount of irrigation water to each zone according to the soil characteristics and water demand of the crops requires especially precise irrigation.

There are technological alternatives that allow the control of the depth and/or variable rates of water applied in the sprinkler package of the center pivot (precision irrigation). These technologies are based on wireless communication with control nodes that can handle one sprinkler or a group of sprinklers using solenoid valves. This alternative, associated with a global positioning system (GPS), allows the depth of water applied in any section and position of the equipment to be controlled. Information obtained from remote sensors (images captured by satellite or other airborne vehicles) can be used to estimate the spatial variability of the crops present in a farm.

We are developing and evaluating a support system that allows real-time spatial management of irrigation for center pivots that will allow a reduction in water losses due to surface runoff and deep percolation resulting from excessive or inadequate irrigation rates. An increase in water use efficiency and a significant reduction in the energy associated with irrigation are projected. A center pivot with a precision irrigation system will allow producers to have multiple crops under the pivot, with areas defined by the farmer and not by the irrigation equipment, which will optimize water use and increase production in areas where problems are currently expected.

1.5 Effect of wetted area in orchards under drip irrigation

Analysis of wetted area in blueberry irrigation, where the number of laterals drip per row and the total berry yield affects production in sandy soil, shows the greatest effect is obtained when plants are irrigated with four laterals drip per row. The two irrigation frequencies evaluated did not affect blueberry production under drip irrigation, although a barely noticeable trend of greater yield was observed under the irrigation treatments of six days per week, compared with those that were irrigated only four days per week. An interaction effect was observed between irrigation frequency and number of lateral drips on the percentage of exportable fruit (caliber 10 mm). Plants irrigated four days per week produced a significantly larger percentage of exportable fruit, compared with those irrigated six days per week. Nevertheless, when plants were irrigated six days per week the increase in number of laterals drip per row increased the percentage of exportable fruit. Therefore, the recommendation is to use four laterals drip per row for commercial production of high-bush blueberry in sandy soils.

A new study on the effect of wetted area in apples orchards under drip irrigation was initiated in September 2014. The objective of this study is to evaluate the effect in the localization and percentage of wetted area, in yield and biophysical parameters in Brookfield apple orchards. Brookfield is a new apple variety which is expected to be the most-exported in the near future.

1.6 Soil description methodologies for irrigation management and design.

Soil description is a basic datum for irrigation management and the design of irrigation systems. The factors that affect variation in soil characteristics are soil slope, soil parental material and the use of soil and its management. However, the most important parameter for design and management of irrigation systems is soil physics, important characteristics that relate water-holding capacity to infiltration rate, which is usually related to texture.

Several methodologies are used to determine soil characteristics. ESRI shapes from CIREN can be used to delimit the soils as a basic

analysis of soil maps and its characteristics, although it is not a precise method, and presents significant variations, especially in the boundary zone.

The methodology based on soil texture characteristics, developed as a low-cost method by Saxton and Rawls, was used, but didn't prove to be reliable for determining the characteristics for water management and irrigation system design.

The best description of soil characteristics was provided by the most reliable method, in situ methodology. The number of points tested is highly correlated with the variability of the soil, which can be analyzed initially with the CIREN soil map and satellite images. However, in situ methodology has by far the highest cost, and therefore, the determination of the optimum number of points is an important issue.

WATER RECOVERY FROM MINING OPERATIONS

2.1 Settling velocities of particles in non-Newtonian fluids.

The various operations of a mineral processing plant require the transport of suspensions of small particles at high concentrations. These suspensions behave as non-Newtonian fluids, that is, they have non-linear relationships between shear stress and shear rate.

The parameters in a boundary layer on a sphere are a function of the rheology of the fluid. Using the power index and the consistency index as parameters of the sphere, an explicit equation for the drag coefficient and the settling velocity of spherical particles in mineral pulps was developed.

2.2 Development of new instruments to determine thickening parameters

Two new instruments to measure thickening parameters were designed: a laboratory instrument, based on differential pressure, to measure the solid concentration profile in a suspension's sediment and a new method to estimate the flux density function of non-flocculated suspensions. Preliminary experiments reveal acceptable results for both instruments.

2.3 Ultra-flocculation reactors

Previous research demonstrated that for a given physicochemical state ultra-flocculation is a function of the following three variables: suspension concentration, flocculant dosage and intensity of solid-flocculant mixing, measured as shear rate.

Unfortunately thickeners are unable to control these three variables during operation and therefore to optimize flocculation in a thickener it is necessary to perform flocculation in a special ultra-flocculation reactor before the feed enters the thickener. These types of reactors have not yet been designed.

Using computational fluid dynamics (CFD) and Population Balance Models (PBM), the performance of cylindrical and classical baffled ultra-flocculator reactors were studied. The cylindrical reactor permitted controlled shear rates from 200 to 5000 s-1 for few seconds. The results indicate an advantage of cylindrical devices which exhibited smaller sizes for the same task. Pilot-scale tests are in progress.

2.4 New thickening model

A one-dimensional model of continuous sedimentation with time-varying feed properties was proposed for a clarifier-thickener. The governing equations are two nonlinear partial differential equations for the solid fraction and the floc size as functions of depth in the thickener and time. A numerical scheme and a simple regulator were proposed and numerical simulations were performed.

2.5 Control strategies

Using the phenomenological clarifier-thickener model, we studied the current control strategies (PID, MPC and Fuzzy), applied to thickening in the mining industry. The results hint at how to improve their performance by using the insights offered by simulations.

2.6 Monitoring and modeling to support tailings dam operations

Key aspects in understanding transport phenomena associated with ponds are the physics of fluid for both tailings and water released from the pond. These ponds are used to deposit flotation tailings, from which water can be recovered. Unfortunately, a great deal of this water is lost by evaporation and water infiltration. From an operational point of view, to make a water balance in a tailing dam, it is of interest to know how much water is lost by infiltration.

In this work an online measurement system for water infiltration in a column filled with flotation copper tailings was implemented. The testing methods show improvements for testing different types of soils.

TECHNOLOGY FOR WATER MANAGEMENT

ACID MINE DRAINAGE TRATMENT

1.1 Problems of water quality and quantity in several locations

We visited several mining operations, small and large, to get a better understanding of the critical water scarcity and contamination issues that require technological solutions. We visited the large copper mining operations Carmen de Andacollo of Teck, Andina of Codelco and Los Bronces of Anglo American, located in the 4th, 5th and Metropolitan Regions, respectively. Additionally, we visited several small-scale gold/copper mining operations around Andacollo. The problems related to water resources and mining are diverse, in some cases water-quality driven and in others water-quantity driven.

The city of Andacollo (pop. approx. 12,000) has a legacy of groundwater contamination due to mining. Water for human consumption is pumped from far away and distributed by truck to rural inhabitants due to a persistent drought and groundwater contamination. The owner of the recently expanded Carmen de Andacollo project, Teck, is looking for alternative water sources such as seawater. The city is located approximately 30 km from the coast, and hence seawater is an option, as is solar-driven local treatment of water impacted by mining. Pre-treatment, Nano-filtration and reverse osmosis are candidate technologies we plan to evaluate.

Codelco Andina, a large copper mining operation, has historically contaminated the Aconcagua River. This is a key watershed for the 5th Region, where significant agricultural activity takes place. Copper levels in the river have historically been above irrigation water standards, affecting a large area of irrigated land. The source of contamination has been mainly acid mine drainage (AMD) discharged by the Andina operation in the high Andes (up to 500 L/s), characterized by very high copper and sulfate concentrations and extreme acidities. Because this is a long-term problem, passive solutions ought to be explored.

1.2 Diffusive exchange reactor with internal sedimentation for copper recovery from acid mine drainage

Our passive treatment solution for surface waters contaminated with Acid Mine Drainage(AMD) are wetlands based on fine organic substrate beds, crossed by vertical screened tubes that convey the water through the beds, and allow lateral exchange of solutes. Influent sulfate diffuses through the screen into the bed, where it is converted into sulfide, which diffuses back to the tube, where it forms sparingly soluble precipitates with metals. The precipitates, in turn, sediment out within the tubes, accumulating at the bottom, from where they can be removed. This work studied the performance of one 2-m long vertical diffusive exchange column with internal precipitation, allowing the simultaneous removal and recovery of copper from AMD. Detailed insight was gained into reactions and transport processes within the tubular screen by the use of several sampling points along the column. High sulfate reduction rates of 0.2-0.6 moles/m3-day were achieved and CuS precipitates were harvested.

1.3 Diffusive bench scale exchange reactor study for evaluation of four prototypes.

Based on our successful results with the diffusive-exchange column reactor, we started experiments with four bench-scale prototypes (200 L tanks) and so far have successfully treated AMD rich in copper. Thus, this technology holds promise for the long-term solution of AMD contamination, and we plan to continue experimentation to obtain information on the key design parameters, such as bed depth, tube diameter and tube coverage. Diffusive exchange sulfidogenic permeable reactive barrier for the remediation of groundwater contaminated with AMD.

1.4 Effect of drainage composition, membrane type, pressure, pH and temperature on sulfate and metal rejection, flux and fouling in Nano-filtration of amd.

We are treating the AMD of Andina by nano-filtration using an NF/RO pilot unit. Sulphates and metal rejections were 96% for copper and 90% for sulphates. We determined the flow and pressure ranges for optimal flux and rejection, and corresponding energy consumption for two commercial membranes. Next, we plan to optimize the operation for volumetric water recovery and concentrate minimization, which involves testing of anti-scalants, and coupling treatment with metal recovery technologies, such as ionic exchange or solvent extraction and electro-winning.

1.5 Isolation of halotolerant bacterial communities for bioleaching operations with seawater.

Bio-mining uses less water than conventional technologies such as copper flotation, and is becoming more cost competitive. Using sediment and AMD samples from Andina and Andacollo as a source of microorganisms, we developed iron and sulfur oxidizing communities that could be used in bioleaching operations. Considering that seawater use will increase in the near future, we plan to develop halo-tolerant bioleaching communities. We expect to use these cultures not only in bio-mining to reduce water usage, but also as a means to accelerate AMD generation from waste dumps such as those of Andina, decreasing lifetime costs of AMD management.

1.6 Entrapment of water in pores of tailing dums

During our visit to the Las Tórtolas operation of Anglo American in the Metropolitan Region, we learned that water management was critical there. The main water sink in their operation is entrapment in tailing pores. Hence, we obtained tailing samples to study tailing consolidation behavior in our lab.

There are more than 600 tailing dams in the country, and most of them are abandoned. The seismic failure of dams due to liquefaction is another aspect that we are pursuing to improve designs and mitigate risks. We found that all tailing dams we visited have seepage problems, thus contaminating groundwater resources. In the Huechún Dam of Codelco Andina, a hydraulic barrier pumps 200 L/s contaminated groundwater back into the dam without treatment. The high sulfate water could be treated and reused in agriculture. Existing technologies and practices need to be evaluated or new technologies could be developed in order to avoid new seepage or detect existing seepage points to optimize seepage recovery and reuse.

1.7 Consolidation and water recovery.

Tailing consolidation behavior has a strong impact on the storage capacity and water recovery of a given tailing disposal facility. Land availability, and to a greater extent water availability, are the primary factors driving the study of the consolidation behavior of tailings under realistic operational conditions in the case of Chile. To estimate the rate of volume change of tailing deposits over time, one must not only consider large deformations, but also self-weight consolidation and permanent recharge. We developed a one-dimensional model that shows significant improvements in the volume change predictions over conventional methods. To continue model refinement and achieve better parameter estimates, we set up a column experiment to monitor tailing consolidation from Las Tórtolas under different operational conditions.

1.8 Seismic safety.

This project studies the effect of spatial variability of geotechnical properties

on seismic vulnerability of tailing dams. Preliminary modeling shows that spatial variability of geotechnical properties of tailing (deposit) and sand (dam) conditions the seismic response of the system. We now plan to obtain continuous records of tailing properties in situ, and thus characterize spatial variability. Because tailings are saturated, the dynamic solicitations can generate liquefaction, which along with dam-tailing interactions will be considered in the modeling.

ANAEROBIC TREATMENT OF RESIDUAL WATER FROM DIFFERENT SOURCES TO BE USED AS FERTILIZERS

2.1 Nutrient and resource recovery from rural agro-industries.

Climate change caused by greenhouse gas (GHG) emissions is one of the major challenges facing mankind today. In Chile, most of the agro-industrial and livestock sectors, among others, have a responsibility to mitigate methane. One way to reduce GHG is to treat agro-industrial waste.

In order to reduce the impacts on the environment and biogas production, various technologies exist for the abatement of organic matter. Anaerobic digestion is the main technology used for the treatment of organic matter removal in swine wastewater.

2.2 Combined conventional and non-conventional technology applied to agro-industries

Anaerobic digestion is the main technology for organic matter removal. However, a subsequent system is generally required to remove nutrient and recalcitrant organic matter, among others. Constructed wetlands are described as a passive and cost-effective alternative for nutrient removal. This technology uses different configurations in order to evaluate the nitrogen removal efficiency. The main processes involved in nitrogen removal in constructed wetlands include the processes of nitrification/denitrification, ammonia volatilization, plant uptake and sedimentation.

2.3 Toxicity evaluation of the treated effluent

The effluent treated by anaerobic digestion contains high levels of nutrient that could be considered for biofertirrigation of crops. The risks of this substrate are the high concentrations of ammonia, pathogens and micropollutants (like metals) as well as the pH. All of these compounds can be expressed in the acute toxicity of this effluent. Due to the high values of the acute toxicity effluents, they cannot be discharged directly into the aquatic ecosystem. However, it has excellent characteristics as fertilizer due to its high content of ammonium and the low toxicity effects for the plants evaluated by Rapahnus sativus.

Other pollutants contained in this treated effluent are copper and zinc used in animal production on pig farms. Metals from swine slurries average 11 mg Cu/L and 75 mg Zn/L. The aim of this work was to evaluate the distribution and bioavailibity of copper and zinc from a constructed wetland as a distribution model of the metal discharged.

2.4 Bio-fertirrigation by treated effluent

Considering fecal coliform as the main indicator of pathogens or fecal contamination, the evaluation of the influence of anaerobic technology on bio-fertirrigation was studied. The problem is related to the excess of land-spread slurry given both the increasing number of intensive farms showing an increase of 2.6% and the nonexistence of regulations. Biofertirrigation could potentially contribute to air pollution by generating greenhouse gases such as methane and carbon dioxide as well as ammonia as a product of organic matter decomposition. In addition, groundwater is polluted mainly by the transport of nitrate and pathogens through the soil and the eutrophication of water bodies due to the excess of nutrients.

According to the results of this study, proper irrigation management is indispensable to achieving a considerable bacterial retention in soils when using anaerobically treated swine slurry as biofertilizer.

2.4 Characterization of the sewage coming from rural areas as a potential for their reuse

In Chile, preliminary estimates indicate an average production of urban wastewater in the range of 84-120 L/(hab·d) (SISS, 2012). Work in our research group has estimated a

production per inhabitant of around 170 L/hab d and for sewage from rural type a value of 160 L/hab·d. Sewage is characterized by nutrient, organic matter and solids. The phosphorus content in sewage consists mainly of phosphates, polyphosphates and organic phosphorous (basically phosphate incorporated in organic forms). Of these compounds, phosphate is more than 60% of the phosphorus present in sewage. Phosphorus is a limiting macronutrient in agriculture, so it's recovery from sewage or directly reuse, could be significant for the economy. Also, micropollutant pathogens are very important for studying certain types of wastewater. In order to understand the physical-chemical characterization and risk to the rural community posed by wastewater, this year we edited the book *Sewage and Its Treatment in Rural Areas: The Current Situation and Challenges* by Vidal, G. and Araya F. UdeC ISBN 978-956-227-378-7; Register PI 242.970, 113 pp, 2014.

2.5 Green technologies: constructed wetlands for sewage treatment with wide applications in rural areas in terms of their performance for water reuse.

Constructed Wetlands (CW) have been defined as engineering systems constructed to treat sewage under different design and operating conditions, taking advantage of natural processes involving vegetation, soil and bacteria). This technology may reduce energy and chemical compounds in the treatment. Moreover, the evaluation of the green technologies regarding biodiversity and the landscape environment is very important. The sewage treated in rural areas can be reused in agriculture due to of the nutrients it contains.

2.6 Nutrient recovery from sewage

Phosphate and nitrogen are the main nutrients in sewage. Phosphorus contained in sewage may be removed by mesocosm-scale constructed wetlands, although removal efficiency is between just 20 and 60%. Phosphate removal can be enhanced by increasing wetland adsorption capacity using special media, such as natural zeolite, operating under aerobic conditions. The objective of this study was to evaluate phosphate removal in sewage treated by constructed wetlands (CW) with artificial aeration and natural zeolite as a support medium for the plants. The study compared two parallel lines of CW: gravel and zeolite. Each line consisted of 2 CW in series, where the first CW of each line has artificial aeration. The results showed that phosphate removal efficiency was 70% in the zeolite medium, presenting significant differences with the results obtained by the gravel medium. Additionally, aeration was found to have a significant effect only in the gravel medium with an increase of up to 30% for phosphate removal. Thus, *Schoenoplectus californicus* contributed to 10-20% of the phosphorus removal efficiency.

WATER AND SOCIETY

1 CONTRIBUTION TO WATER LAW AND ANALYSIS OF THE RELATIONSHIP BETWEEN MINING COMPANIES, AGRICULTURE AND SOCIETY.

1.1 Mapping for integration of social linkages.

Mapping water conflicts: the quest of socio-hydrological patterns in current status of water management is prone to conflicts among stakeholders. As a cluster, we decided to analyze legal records as a proxy for conflict intensity. We developed an information tool to map legal disputes through the automatic extraction of relevant information.

In doing so, we completed the following tasks: definition of a database architecture; definition of the contract for the design and implementation of a data mining tool; population of the database; analysis of an intermediate results meeting for feedback. We plan to build a nation-wide policy analysis on these results.

1.2 Sustainability Assessment of Water Public Policy: Prioritizing actions.

Water demand is increasing due to expanding industrial operations. Therefore, a need has arisen to increase the infrastructure for water supply, storage and distribution as a strategy to improve water availability as well as improvement in water efficiency and water allocation. In 2011, the National Commission for Irrigation issued the National Irrigation Strategy (NIS) as a blueprint of actions necessary to deploy an effective nationwide irrigation policy. We analyzed the NIS using a sustainability assessment approach that prioritizes and defines the scope to ensure the sustainability of water resources.

We completed the following tasks: (1) definition of a framework where water resources are the keystone for the new irrigation policy, (2) proposition of three main scopes: to increase availability of water resources, improve water use efficiency, and improve water allocation based on information systems and water markets. All proposed actions are based on (1) the relationship between increasing water availability and its efficient use to alleviate water scarcity and improve food security, (2) environmental sustainability and (3) the role of users to promote a fair distribution of resource into water markets.

1.3 Survey of information relevant to use of water in Chile and Water User Organizations (WUO)

Preparation of sociological investigation: "Perception and civil practices of the value of water as a natural and social good: the human, agricultural and mining consumption in Chile in times of climate change" to be carried out in four regions of the country. This investigation should provide a significant quantity of hard information to the center, which will allow us to know what the population and users of the water resource think.

The group is supporting the doctoral thesis of Robinson Torres, sociologist and PhD candidate at the University of Arizona, USA. This doctoral thesis will compare the practices of water use in two basins. A major part of the thesis is being developed in the Biobío Region, especially the river Ñuble.

1.4 Water as a judicial issues in Chile

The legal working group aimed in 2013 to study every single case decided during that year by a Chilean tribunal. (1,009 first instance cases, 42 Court of Appeal cases, 19 Supreme Court cases). Every case has been examined and translated into a chart designed to obtain relevant legal information. The idea is to provide technical judicial input necessary to understand the reasons for conflicts on water rights and be able to provide valuable empirical information to the legal community and public policy makers.

2 IDENTIFICATION AND CATEGORIZATION OF ECOSYSTEM SERVICES

2.1 Mountain watershed hydrology and the vulnerability for water provision as ecosystem services

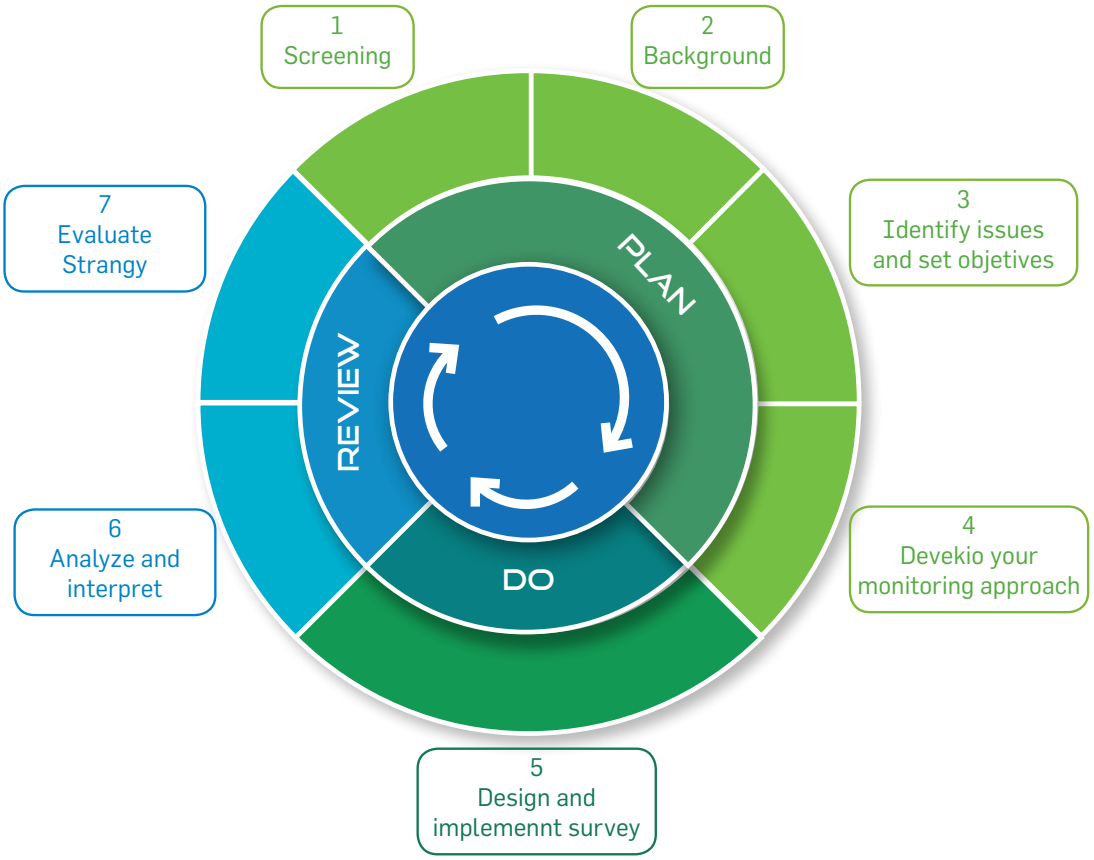
The Laja Project is being developed in collaboration with the University of Leibniz, Hannover, through the bilateral Conicyt Project BMBF PCCI1-2031 "Multi scale modeling of complex hydrological system for the sustainable management of water resources on Andean watersheds". As a future line of research, we will submit an international proposal regarding water resources management and conflict resolution.

2.2 Identification and quantification of ecosystem services.

Ecosystem services (ES) are being identified on a basin scale. As a first step we are working on case studies in the Biobio Basin in South Central Chile. The idea is to select methodologies for assessment and validation of the important issues addressed by the Fondap cluster.

The group has already identified the methodology proposed by the Millenium Ecosystems Assessment Program (UN) as suitable for our purposes. We have collected relevant information on the main indicators which will allow the validation and quantification of services. For this purpose, we have an ongoing cooperation with colleagues from the University of Murcia who carried out this work for Anadalucía in Spain.

3 DEVELOPMENT OF MONITORING STRATEGIES



3.1 A socio-hydrological approach for water sustainability

Leading hydrologists and earth sciences researchers advocate for a shift in hydrological sciences, evolving to more integrative approaches with social and natural sciences. We operate an intensive monitoring network and community activities to assess the link between rural communities and water availability.

We completed the following tasks: operation of a hydrological monitoring network in the Coastal Range; outreach activities to rural schools; hydrological and biological monitoring and modeling; biodiversity assessment. Recently, we calibrated a simple rainfall-runoff model for groundwater recharge estimations, and a climate perception survey. As of now, two undergraduate students are working on their bachelor's theses.

3.2 Building monitoring capacities at community level

Small local communities are facing large problems in generating or accessing information relevant to the decision-making process and planning. We are working on developing easy-to-use and affordable kits to improve data generation and community empowerment. These smart devices are under development using open software and hardware tools.

We completed the following tasks: testing and operation of an Arduino-based soil water content sensor; testing and operation of control systems based on Littlebits; assessment of water quality kits for citizen monitoring; design and testing of a water quality buoy. A prototype of the buoy will be deployed during the first semester of 2015 under field conditions. Additionally, two R+D projects are under negotiation to test new monitoring systems in the private sector.

3.3 New developments in the water quality monitoring:

group is also developing new strategies for monitoring pollutants in surface waters based in passive samplers, a time weighted approach for measuring pollutants in surface waters with potential application in monitoring strategies. This is based on passive diffusion of pollutants from water to a polymer or another suitable matrix sampler, which will capture pollutants from the water. The system has been assayed in laboratory settings and now a field study is planned.

ADVANCED HUMAN RESOURCES TRAINING

One of the main objectives of the center is to train researchers at the undergraduate and especially graduate and postdoctoral levels to address the lack of advanced human resources in the country.

GRADUATE PROGRAMS

1. Doctorate in Agriculture Engineering, Water Resources, UdeC.
2. Doctorate in Environmental Sciences, Aquatic Systems, UdeC.
3. Doctorate in Electrical Engineering, UdeC.
4. Doctorate in Chemical Engineering, UdeC.
5. Doctorate in Metallurgical Engineering, UdeC.
6. Doctorate in Engineering Mathematics, UdeC.
7. Doctorate in Natural Resources, UFRO.
8. Doctorate in Food Engineering, UBB.
9. Master of Agricultural Engineering, Industries, Mechanization and Energy in water resourced.UdeC
10. Master in Environmental, Labor risks and Bu siness Social Responsibility. UDD.
11. Master of Science in Electrical Engineering, UdeC.
12. Master en Ingeniería Metalúrgica. UdeC.
13. Master in Natural Resources Economy and evironment. UdeC
14. Master of Science in Chemical Engineering, UdeC.
15. Master of Science in Civil Engineering, UdeC.
16. Master in Sustainability Management, UDD.
17. Master of Science in Biotechnology, UFRO.
18. Master of Science in Food Engineering, UBB.

UNDERGRADUATE PROGRAMS

1. Electrical, Chemical, Metallurgical, Civil and Mathematical Engineering, UdeC.
2. Agricultural Engineering, UdeC.
3. Environmental Engineering, UdeC.
4. Legal and Social Science. UdeC.
5. Environmental Engineering, UFRO.
6. Food Engineering, UBB.

STUDENTS

Postdoctoral

1. Carolina Reyes Contreras, University of Concepción. Previous affiliation: CSIC, Spain.

2. Heidi Schälchli,University of LaFrontera. Previous affiliation: Universidad Estatal de Campinas (Unicamp), Brazil.
3. Jorge Saavedra M., University of Concepción. Previous affiliation: Universidad de Concepcion, Chile.
4. Javiera Cardenas, University of Concepción. Previous affiliation: Universidad de Concepción, Chile.
5. Jorge Alvez, University of Concepción. Previous affiliation: Universidad de Campina Grande, Brazil.
6. María del Carmen Martí Raga, University of Concepción, Previousaffiliation: Universidad de Valencia, Spain.
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9. Sudarshan Kumar Kenettinkara, University of Concepción, previous affiliation: Tata Institute of Fundamental Research Centre for Applicable Mathematics Bangalore, India
10. Yessica Rivas, University of Concepción, Previous: affiliation: Universidad Austral de Chile

Postgraduate

Doctoral

1. Alejandra Galvez. Regulatory aspects of ind genous consultation in Chile.
2. Alejandra Villamar. Effect of anaerobic treatment on the efficiency of removing nutrients and metals in pig manure in constructed wetlands.
3. Alejandro Pannunzio. Design criteria and operation of irrigation systems and their effect on productivity of irrigation water, sustainability and environmental effects produced.
4. Ana Araneda. Using the earthworm as an indicator organism impact of agrochemicals in an agricultural watershed.
5. Andiranel Banegas: Studies of hyporheos communities in an intermittent river basin Itata, Bio Bio region
6. Angel Pedrero. Automatic detection and analysis of anomalies based on irrigation objects using multimodal images
7. Carlos González. Precision Irrigation Management in Kingpins.
8. Daniela López. Green Technology for sewage treatment: Evaluation of water reuse.
9. David Fonseca. Characterization of object oriented agricultural covers for detecting changes.
10. Denisse Alvarez. Recognition of changes in temperature over the past 1000 years in northern Patagonia, through the application of stable isotopes and other proxies.
11. Elvis Gavilán. Mathematical Modeling and Numerical Simulation of Spatial-Temporal Models of Vector-Transmitted Diseases.
12. Francisco Cabrera. Startegies for the enrichment of PHA accumulating microorganisms in mixed cultures.
13. Francisco Zambrano. Risk maps at regional agricultural drought.
14. Gabriel Abogasi. Regulation of the Seaboard.
15. Gerson Valenzuela, Analysis of the anisotropic growth of ice crystals by computer simulation.
16. Gonzalo Quezada. Simulation polyelectrolyte adsorption on solid surfaces and particle aggregation in saline media.
17. Haydee Osorio. Synthesis of the hydrological system of the Chagres river in Panama.
18. Hernán Aguilera. Watering specific site on grapes tables.
19. Javier Camaño. Flood management.
20. Javier Peñaloza Gómez. Challenging the Chi lean Water Model under the human rights threshold.
21. Jessica Cabezas. Regulating the minimum ecological flow calculation.

22. Jorge Rodríguez Urrutia. The Citizen participation in the process of establishing water rights in Chile: Analysis and proposals.
23. Juan Carlos Ortega. Direct Osmosis: an alternative to the concentration of urban wastewater
24. Juan Pablo Asenjo. Bases for regulating the mechanism of biodiversity Compensation Banks.
25. Katherine Brintrup: Hydrological control on the dynamics of bioavailable nitrogen in an intermittent river basin Itata, Bio Bio region.
26. Leopoldo Carrasco. Regulation for an integrated system of watersheds.
27. Leslie Meier. Biogas upgrading using microalgae.
28. Lihki Rubio. High Resolution Methods with Polynomial Viscosity Matrices and Adaptive Mesh Refinement for Multi-Species Kinematic Flow Models.
29. Lina Uribe. Mechanisms involved in depression of pyrite during flotation of copper sulfide minerals in seawater.
30. Maria Elisa Diaz: "Determination of ecosystem services Biobío River Basin.
31. María Fernanda Saavedra. Evaluation of the effects of effluents from sewage treatment plants on Oncorhynchus mykiss using laboratory and field experiments: use of biomarkers such as assessment tools for the biochemical, reproductive and hematologic responses.
32. Meyer Guevara: Effects on macroinvertebrate communities for agriculture water extraction.
33. Norma Pérez. Optimization of the treatment of acid drainage containing arsenic in anaerobic reactors with active diffusion.
34. Pablo Pedreros. M Benthic macro-invertebrates in rivers header: potential implications of the current global warming.
35. Patricio Neumann. Advanced anaerobic-digestion of biosolids: energetic and environmental implications.
36. Ricardo Jeldres. Experimental study of flocculation of mineral suspensions and modeling based on population balance.
37. Vanessa Novoa. Accounting water footprint of Cachapoal River basin for the evaluation of Sustainability.

Master's

1. Carolina Morales. Determination base flow behavior and its relationship to the hydrological variables of Diguillín river basin, Biobío Region.
2. Cristian Romero. Flocculation mechanism.
3. Denisse Duhalde. Analysis of environmental risk associated with changes in land use in the basin of Renegade.
4. Edgard Faúndez. Ultra-flocculation in cylindrical reactors.
5. Francisco Flores. Test station of antifouling for calcite and gypsum.
6. Francisco Lecaros. Effect of wetted area in the production of Apple vary Brookfield.
7. Gonzalo Valenzuela. Effect of spatial variability in seismic vulnerability of tailings dams.
8. Gustavo Chaparro. Diffusive exchange system for treating acid mine drainage with high concentrations of copper.
9. Julio Mendoza. Validation System Support for Decision AQUASAT.
10. Lama, Waldo. Deficit irrigation in kiwi.
11. Marco Salazar. Experimental study of ultra-flocculation reactors.
12. María Elisa Neubauer. Organic matter from Kraft mill process valorization: Mitigation of the overall change.
13. María José Pérez. Life Cycle Assessment in Chilean Premium Wine Industry.
14. Mariela Guajardo. Feasibility Study Technical-Economic of Environmental Monitoring Networking, Autonomous and inexpensively applied in Chile Water System
15. Michael Araneda. Bio-flocculation in primary sedimentation as a strategy to increase the production of biogas plants wastewater treatment.

16. Nicole Alavania. Proposal of an Integrated Management System in a pilot plant Egg Production.
17. Tania Mundaca. Development of a model of systemic approach to analyze environmental conflicts in the basins of Maule and Itata.
18. Victoria López. Occupational Risk Prevention and Corporate Social Responsibility.
19. Walter Valdivia. Soil classification for designing irrigation systems.

Undergraduate

1. Andrés Agurto. Precision Irrigation kingpins.
2. Alejandra Lavados. Evaluation of the interaction of surface and ground water in the estuary Renegade.
3. Alvaro Conejeros. Conceptual study of leaks in the Lake Laja.
4. Andrés Altamirano: Oxytetracycline behaviors in purines produced by cattle in a dairy.
5. Camila Bustos. Acid drainage treatment using nano-filtration
6. Camila Matta. Water balance of Laguna Santa Elena.
7. Camilo Mejías. Identification of the flux density function by measurement of settling curves and numerical simulation in continuous sedimentation.
8. Camilo Souto,. Precision ferti-irrigation.
9. Cristian Benaprés. Comparison of pyrite flotation in fresh and seawater.
10. Cristian Romero, Effect of different salts on the rheological behavior of flocculated silica slurries as a function of pH.
11. Cristina Oblitas. Depression pyrite flotation through the use of polymers.
12. Dalton Anziani. Installation of an experimen tal column for the characterization of copper tailings consolidation.
13. Danissa Valdivia. Preliminary evaluation of the degree of contamination of a site with forestry residues.
14. David Mellado. Development of an Automatic Downloads Manager of Satellite Images.
15. Eduardo Lados. Hydrological monitoring in coastal basins: relationships precipitation of runoff and recharge estimation.
16. Francisco Faúndez. Evapo-transpiration in Arándanos.
17. Fernando Cortez. Institutional groundwater.
18. Fernando Matus. Experimental study of the effect of coagulation additives in thickening process.
19. Francisco Flores. Study of salt encrustation on solid surfaces: Design and implementation of experimental system.
20. Gabriela Morales. Evaluation of the stability of an activated sludge system by physicochemical and biological indicators.
21. Gonzalo Rebolledo. Determination of nutrients in watersheads of the range of Nahuelbuta with forest plantations and native forests.
22. Gustavo Chaparro. Development of a batch sulfate bioreactor system with a diffusive exchange.
23. Honorio Latin. Water analysis Ñuble's river hydrological regime and the impact of the construction of the Punilla dam.
24. Javiera Torrijos. Effect of seawater salts on the wettability of particulate solids.
25. Jerónimo Ferrer. Mechanisms of flow and transport of saline solutions in porous rock.
26. Jonathan Labrin. Batch Methodology for Georeferencing of Satellite Images coming from different sources.
27. Jonathan Ortega. Study pyrite flotation in seawater using different types of collectors.
28. José Muñoz Cáceres: Implementation of ISO 6878: 2004 E, for the determination of Total Phosphorus in Wastewater".
29. Julio Careaga. Mathematical Modelling and Numerical Simulation of secondary settling tanks with variable cross-sectional area in wastewater treatment plants.
30. Karen Ambiado. Treatment of brackish acid water using nano-filtration.

31. Laura López Sotelo. Nitrogen removal by vertical flow constructed wetlands.
32. Loreto Acevedo. Disinfection processes (chlorine and UV) for a decentralized wastewater treatment (constructed wetlands).
33. Luciano Matus. Historiographical analysis of heavy rainfall in early twentieth century.
34. Manuel Silva. Technical Evaluation of ultra-flocculator reactors by using CFD
35. Marcelo Soto. Design of a database with spacial characterıstics to Support Agricultural Management in Santa Monica´s Farm.
36. María Ignacia Sandoval. Problems in the rules for granting water rights.
38. María Paz Rojas. Trends in the precipitation and flow of the basin of Itata.
37. Mauricio Keller. Effect of ions present in seawater in the flotation of pyrite.
38. Natalia Campos. Copper leaching from the gangue mineral composite PV-M103050 as a function of acidity.
39. Natalia Sepúlveda. Low frequency variability of the 0°C isotherm (freezing, Ho) level in Chile.
40. Nathaly Yañez. Surface tension of frothers in saline waters: effect of electrolytes.
41. Nicolás Yung. Rheology study of alumina suspensions in the presence of flocculating salts and seawater.
42. Niela Araneda. Application of ELCOM-CAEDYM water quality models for developing a plan to restore the Three Pascualas, lagoon in the commune of Concepcion
43. Paola Urquijo. Improved effluent treatment system Kraft pulp by adding a tertiary technology for removing recalcitrant organic matter.
44. Patricio Muñoz. Generating a distributed model for modeling the accumulation and melting of snow cover in the upper basin of the river Malleco.
45. Paulo Alarcón. Evaluation of the effects of forest plantations on the flows in micro-watersheds of Nahuelbuta.
46. Rodolfo Bascur. Modeling precision irrigation in Central Pivots.
47. Rodrigo Carvajal. Numerical Simulation of Sedimentation Processes Using Stochastic Differential Equations
48. Rodríguez, Gastón. Estimation of evaporation in water bodies.
49. Rossana Fuentes Aranda: Mites fresh water in the region of Biobío.
50. Sebastián Lara. Rheology of a particulate system: Impact of pH in the presence of flocculants.
51. Sebastían Lucares. Design of a database as a tool to support agricultural production management in the Los Abedules.
52. Silvana Pesante. Application of ozone in origin biosolids reduction in activated sludge plant for wastewater treatment.
53. Víctor Osores. Mathematical Modeling and Numerical Simulation of a Multilayer Shallow Water System with Polydisperse Sedimentation in Two Horizontal Dimensions.
54. Viviana Contreras. Effect of maker-breaker salts on the wettability of silica surfaces.
55. Viviana Gavilan,. Determination of Central Pivot systems using satellite imagery.
56. Yaritza Burgos "Influence of temperature on body size Diamphipnoidae (Plecoptera) family."

CRHIAM was active in extension and outreach during 2014 through books, scientific publications, conferences, workshops, panels and press releases.

OUTREACH

Books

1. Vidal, G. y Araya F. Las Aguas Servidas y su depuración en zonas rurales: Situación actual y desafíos. 113 páginas, Ed. UdeC, ISBN 978-956-227-378-7; Registro PI 242.970, 2014.
2. Concha F. Solid-Liquid Separation in the Mining Industry, Fluid Mechanics and its Applications, Volume 105, 429 p.,2014, Springer Verlag, Heidelberg, ISBN 978-3-319-02483-7.

Book Chapters

1, Holzapfel, E., Pannunzio, A., Lorite, I., Silva de Oliveira, A., Farkas, I. Sustainable Micro Irrigation, chap. Design and management of irrigation systems: Chile. 10p., 2014, Apple Academic Press. ISSN0716-534X,
2. Delgado, V. Los servicios Ecosistémicos y ambientales en la legislación. Anales VII Jornadas de Derecho Ambiental de la Universidad de Chile, Centro de Derecho Ambiental, 2014
3. Godoy, A, Aitken, L., Bozo, RE. and Rivera, D. Environmental Microbial Biotechnology inside mining operations from an engineering viewpoint based on LCA, "Environmental Microbial Biotechnology" for the "Soil Biology" Series. 28 p. Springerlink, http://www.springer.com/series/5138?detailsPage=titles

■ JOURNALS

ISI Publications

1. Arumi[3], J.L., Maureira, H., Souvignet M., Perez, C. And Rivera, D. 2014. Where does the water go? Understanding geo-hydrological behaviors of Andean catchment in South-Central Chile, Hydrological Sciences J., DOI, 10 1080/02626667 2014 934250.
2. Arumí[3], J.L., Rivera, D., Oyarzún, R., Muñoz, E. y Aguirre, E. 2014, Caracterización de dos grupos de manantiales en el río Diguillín, Chile, WaterTechnology and Science, 5 (6) 2014.
3. Betancourt[3], F., Bürger, R, Diel, S. and Faras, S. 2014. Modeling and controlling clarifier-thickeners fed by suspension with time dependent properties. Minerals Engineering, 62, 91-101.

4. Carrasco-Benavides[1], M., Ortega-Farías, S., Lagos, O., Kleissel, J., Morales, L. and Kilic[2], A. 2014. Parametrization of the satellite based model (METRIC) for the estimation of instantaneous surface energy balance component overdript-irrigated vineyard. 2014. Remote Sensing. 6:11342-11371.
5. Chartier[1], C., López, D. and Vidal[2], G. 2013. Anaerobic Technology Influence on Pig slurry Biofertirigation: Evaluation of Enteric Bacteria. Water Air Soil Pollut. 225, 1790-1800.
6. Chamorro S, Vidal G. 2014. Determination of sub lethal effects of the Kraft pulp mill effluent over feeding behavior by Daphnia magna. Toxicology Letters. 2014;229:S58-S59.
<http://dx.doi.org/10.1016/j.toxlet.2014.06.237>
7. Garcia-Pedrero, A[3], Gonzalo-Martin, C, Fonseca-Luengo, D.and Lillo-Saavedra, M. 2015.,A GEOBIA Methodology for Fragmented Agricultural Landscapes. Remote Sensing. 7, 767-787; doi:10.3390/rs70100767
8. Correa-Araneda, F, M. E. Díaz, K. Ovalle, F. Encina-Montoya, R. Urrutia, R. Figueroa. 2014. Benthic macro invertebrate's community patterns of Mediterranean forested wetlands and their relation with changes in the hydro period. Limnetica.33 (2):361-374
9. Gutiérrez[3], L. and Pawlik M. 2014. Observations on the yielding behavior of oil sands slurries under vane and slump tests. Canadian Journal of Chemical Engineering. Mail of acceptance.
10. Holzapfel[3], E., J. Jara A.M Coronata. 2015. Number of drip laterals and irrigation frequency on yield exportable fruits of higher blueberry grown in sandy soil. Accepted in Agricultural Water Management. 148:207-212
11. Jeldres[1], R.I., Toledo[2], P.G., Concha, F., Stickland, A.D., Usher S.P. and Scales, P.J. 2014. Impact of sweater salts on the viscoelastic behavior of flocculated mineral suspensions. Colloids and Surfaces A: Physicochem. Eng. Aspects 461, 5–302.
12. Ortiz[1], G. Villamar C.A. and Vidal[2] G. 2014. Odor from anaerobic digestion of swein slurry; Influence of pH, temperature and organic content, Scientia Agricola, AS-2013-03.7214.-
13. Plaza de los Reyes[1], C., Pozo, G. and Vidal[2], G. 2014. Nitrogen behavior in a free water surface constructed wetland used as post-treatment for anaerobically treated swine wastewater effluent. Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering, 49(2), 218-227, DOI: 10.1080/10934529.2013.838925.
14. Pozo K., G. Perra, V. Gomez, R. Barra & R. Urrutia. 2014 Temporal trends of polycyclic aromatic hydrocarbons (PAHs) in a dated sediment core of a high altitude mountain lake: ChungaraLake, Northern Chile (18° s). J. Chil. Chem. Soc. 58(2):2248-2251
15. Rivera[3], D; Sandoval, M.; Godoy, A. 2014. Exploring soil databases: a self-organizing map approach. Soil Use and Management. DOI: 10.1111/sum.12169.
16. Rivera[3], D, Lillo, M. Granda, S. 2014. Representative locations from time series of soil-water content using time stability and wavelet analysis. Environ. Monit Assess. DOI 10.007/s10661-014-4067-0.
17. Rojas[1], K. Vera, I and Vidal[2], G. 2013. Influencia de la estación y de las especies Phragmitesaustralis y Schoenoplectuscalifornicus en la eliminación de materia orgánica y nutrientes contenidos en aguas servidas durante la operación de puesta en marcha de humedales construidos de flujo horizontal sub-superficial, 2013. Rev. Fac. Ing. Univ. Antioquia N. º69 pp. 289-299.
18. Saavedra[1], J.H., Rozas, R.E. and Toledo, P.G. 2014. Amolecular dynamics study of the force between planar substrates due to capillary bridges. J. Colloid and Interface Sciences. 426:145-151.

19. Troncoso[1], P., Saavedra, J.H., Acuña, S.M., Jeldres, R.I., Concha, F. and Toledo[2], P.G. 2014. Nanoscale adhesive forces between silica surfaces in aqueous solutions, J. Colloid and Interface Science, 424 2014, 56-61.
20. Valenzuela[1] G.E., Saavedra, J.H., Rozas, R.E. and Toledo[2], P.G. 2014. Analysis of energy and friction coefficient fluctuations of a Lennard Jones liquid coupled to the Nosé-Hoover thermostat, Molecular Simulation, DOI:10.1080/08927022.2014.895077.
21. Vera[1], I., Araya, F., Andrés, E., Sáez, K., and Vidal[2], G. 2014. Enhanced phosphorus removal from sewage in subsurface treatment wetland through zeolite as medium and artificial aeration. Environmental Technology 35(13), 1639-1649. DOI: 10.1080/09593330.2013.877984.
22. Villamar[1], C.A., Neubauer, M.E., Vidal[2], G. 2014. Distribution and availability of copper and zinc in a constructed wetland fed with treated swine slurry from an anaerobic lagoon. Wetlands 34(3), 583-591. DOI 10.1007/s13157-014-0527-0.
23. Villamar[1], C.A., Silva, J., Bay-Schmith, E., Vidal[2], G. 2014. Toxicity identification evaluation in anaerobically treated swine slurry: A comparison between Daphnia magna and Raphanussativus. Journalof Environmental Science and Health, Part B 49(11), 880-888.

Non-ISI Publications

1. Morales[3], G., López, D., Vera, I., y Vidal; G. Humedales construidos con plantas ornamentales para el tratamiento de materia orgánica y nutrientes contenidos en aguas servidas. Theoria 22(1) 33-46, 2014.
2. Holzapfel[3], E. David Bryla, Jorge Holzapfel, Ruperto Hepp Manejo de agua y riego en arándanos Frutícola 3, 43-49, 2013
3. Alvez[3], Amaya. ¿El Agua como parte de nuestro catálogo de Derechos Fundamentales? Compatibilidad del modelo, tensiones y alternativasCapítulo de libro, en Actas del IV Seminario de la Asociación Nacional de Profesoras de Derecho Constitucional cuya temática central fue La Constitución Económica; Universidad Católica del Norte, Sede Coquimbo, agosto, 2014, Legal Publishing (forthcoming, 2015).
4. Amaya Alvez[3] M. Algunos comentarios a la práctica del derecho comparado por parte del Tribunal Constitucional chileno 2006-2012. XLIII Jornadas de Derecho Público. Editorial Legal Publishing 2014.
5. Arumí[3], J.L.; Rivera, D.; Billib, M.: Oyarzún R.; Muñoz, E. y Osorio H. Hidrogeología de la cuenca del Diguillín en el complejo volcánico Nevados del Chillán. Revista de la Asociación Latinoamericana de Hidrología Subterránea. 2013
6. Osorio, H., Ugarte D., Rivera ,D., Arumi, J.L. 2014. Adaptación de un modelo hidrológico austero a una cuenca tropical en Panamá. Gestión Ambiental.

EVENTS ORGANIZED

Type of event	N° Part	City	Dates
International Conventions			
XXVII IMPC-2014	1000	Santiago	20-10-2014
Joint Rough Set Symposium 2014	200	España	09-07-2014
National Conventions			
XIX Congreso Chileno de Ingeniería Química	300	Concepción	15-10-2014
Workshops			
Agua Potable y AguasServidasen el Sector Rural	78	Concepción	14-08-14
9th CI2MA Focus Seminar: Modelling and Numerical Simulation in Wastewater Treatment	25	Concepción,	22-04, 2014
Seminario “Gestión ambiental comunal: riesgos ambientales y acciones de la conservación del patrimonio natural en la comuna de San Pedro de la Paz” Seminario realizado por proyecto Fonis y CHRIAM	20	San Pedro de la Paz,	25-04-14
Seminario “Gestión ambiental comunal: riesgos ambientales y acciones de la conservación del patrimonio natural en la comuna de Concepción” Seminario realizado por proyecto Fonis y CHRIAM	20	Concepción	09-05-14
Seminario “Propuestas para la Gestión de Recursos Hídricos”. Gobernación Provincial de Ñuble	30	Chillán	07-14
Water resources in agriculture and minning	31	Concepción,	14-10-14
Día de campo eficiencia en riego	27	Curicó,	18-02-2014
Recursos hídricos y el desafío de una agricultura sustentable	80	San Fernando,	06-11-2014

Courses			
Curso Escuela de Verano: Conceptos básicos y nuevos enfoques para evaluar el desempeño ambiental y mitigación del cambio climático en la industria sanitaria	15	Concepción	13-01-2014
Microbiología avanzada para reuso de aguas servidas: Tecnologías verdes en el marco del cambio climático global	15	Concepción	31-08-2014
Escuela de verano 2014: Manejo Integrado de Ríos. 14 al 17 de Enero 2014. Este curso integra la experiencia alemana en el manejo de ríos, a la realidad chilena. El curso aborda aspectos teóricos sobre modelación del escurrimiento en ríos, incluyendo análisis de incerteza, manejo de embalses, protección frente a crecidas, aspecto sobre ecología fluvial, servicios ecosistémicos y toma de decisión basada en criterios múltiples.	20	Chillán	01-2014
Escuela de verano: "El recurso agua: un análisis comparativo e interdisciplinar de las cuencas hidrográficas de los ríos Iguazú (Brasil) y Biobío (Chile) bajo escenarios de alta demanda y cambio climático". Fac. Cs. Ambientales/Centro EULA: Curso internacional Chile-Brasil (Universidad de Concepción, Chile y Universidad Positivo, Curitiba, Brasil; 24 al 28 de Marzo de 2014).	14	Concepción	03-2014
Curso Internacional Gestión sostenible del agua: experiencias y perspectivas en España y Chile. Universidad de Córdoba. Expositor "Estrategia nacional de recursos hídricos en Chile (2012-2015). Un análisis crítico"		Huelva	18-7-2014
Curso de Verano: Universidad Internacional de Andalucía, "Gestión Sostenible del Agua: experiencias y perspectivas en España y Chile". 14 al 18 de julio Campus Santa María de la Rábida/Huelva.	15	España	14-07-2014
Diploma de especialización en sistemas de micro riego	27	San Fernando,	06-10-2014
Sistemas de micro riego: Manejo y evaluación	18	San Fernando,	08-01-2014
Método simplificado para la determinación de la demanda de agua de los cultivos	15	Chillán	31-01-2014
Diseño de sistemas de riego por goteo y pivote central	12	Punta Arenas,	20-01-2014
Energías renovables no convencionales: energía solar fotovoltaica y energía eólica	12	Punta Arenas,	20-01-015
Curso práctico de microriego	9	San Fernando,	14-04-2014
Agua, clima y gestión integrada del agua	40	Rancagua	08-05-2014
Hidrología de crecidas	20	Temuco	08-05-2014

Aguas superficiales y subterráneas	20	Temuco	09-05-2014
Aforo en canales	20	Temuco	09-05-2014
Relación suelo-agua-planta para la programación del riego	20	San Vivente de Tagua Tagua	12-06-2014
Relación suelo-agua-planta para la programación del riego	15	Santa Cruz	12-06-2014
Diplomado en riego avanzado	22	Chillán	12/04-1014
Innovaciones en riego presurizado	26	San Vicente de Tagua Tagua	07-08-2014
Innovaciones en riego presurizado	19	Santa Cruz	07-08-2014
Sistema de información meteorológica de California (CIMIS) y determinación de demanda de agua en frutales	10	Curicó	25-06-2014
Fundamentos en la medición y cuantificación de nieve	11	Rancagua	15-01-2014
Introducción a WEAP	10	Rancagua	26-11-2013
Modelación avanzada, estudios de caso e implementación de modelos WEAP	8	Rancagua	27-11-2013
Alternativas de reúso de aguas residuales en el norte de Chile -Experiencia en CIDERH	26	Concepcion	07-04-14
Conferences			
Microorganismos y el manejo sustentable del suelo	19	Concepcion	22-05-14
Sewermining: getting back resourcesfromsewage	21	Concepcion	29-jul-14
Biorefineria de microalgas: una alternativa para la obtención de bioenergia	27	Concepcion	18-11-14
Seguridad para Celadores	21	San Fernando	14-01-2014
Huella del agua y huella de carbono	16	Curicó	24-03-2014
Revestimiento de canales	12	Mostazal	12-04-2014
Fortalecimiento a las OUAs	25	Rauco	12-05-2014
Agua, clima y gestión integrada del agua	31	San Vicente	15-05-2014
Administración de las OUAs	23	Rauco	19-05-2014
Control de heladas	85	Rancagua	26-06-2014

Relación suelo-planta-agua y consideraciones en el diseño de un sistema de riego presurizado	11	San Fernando	07-11-2014
Métodos de riego presurizado; operación y evaluación de un sistema de riego presurizado	11	San Fernando	12-11-2014

TECHNOLOGY TRANSFER

CRHIAM organized its technology transfer in association with different centers operating under the University of Concepción such as IIT, the WaterCenter in San Fernando and EULA, and from independent centers such as CETTEM. During 2014 we can report the following activities:

Water Center of San Fernando:

- Fourteen national training courses with 268 participants.
- Four international training courses with 39 participants.
- One diploma in irrigation with 25 students.
- Twelve seminars with 676 participants.

CETTEM and IIT:

Efficiency of the feed well in a thickener for Centinela Mining of Antofagasta Minerals. The project consisted of a CFD modeling of the feed well to detect inefficiencies and make recommendation.

INTERNATIONAL COOPERATION

Visits of Center members to international institutions

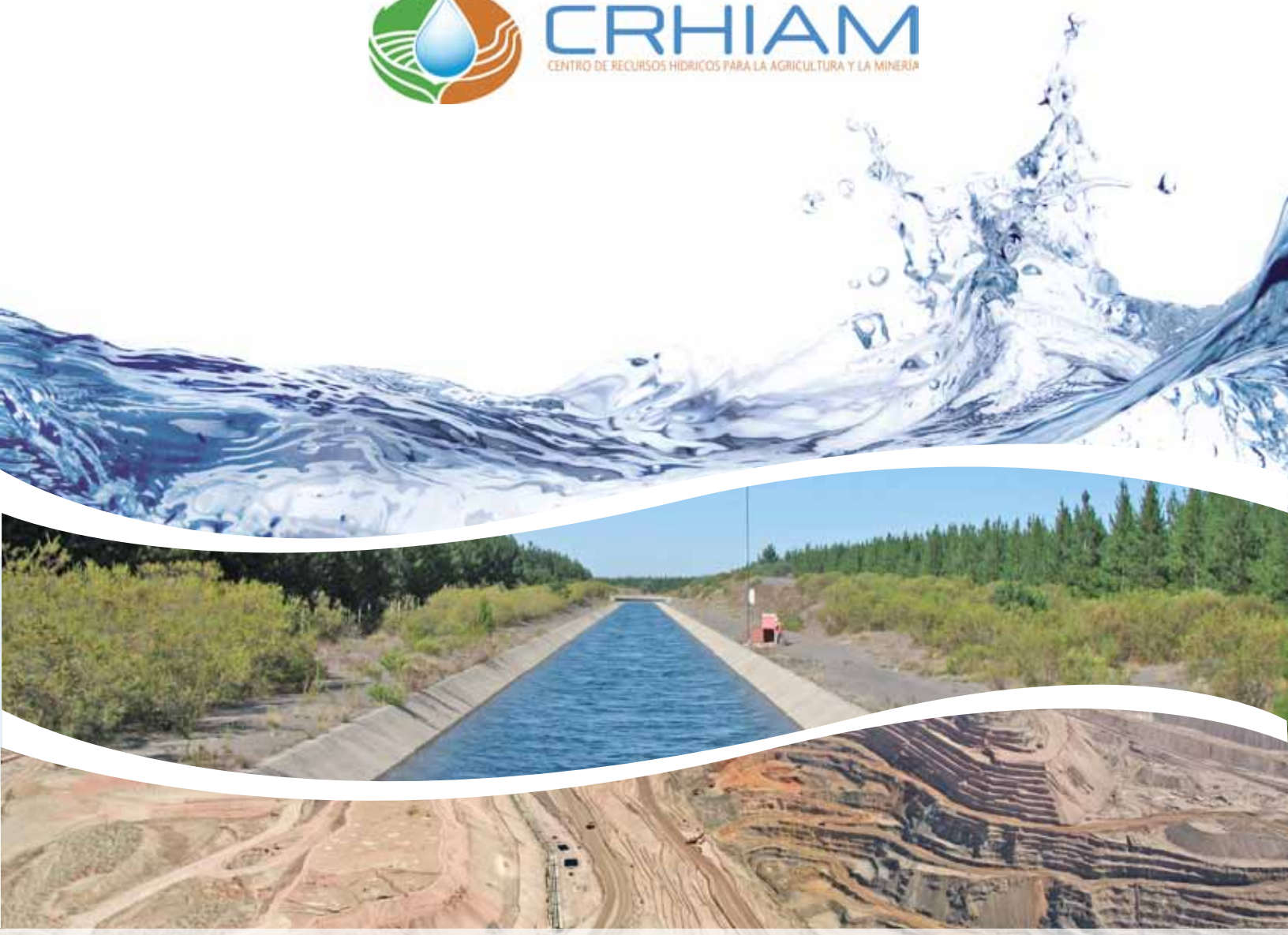
1. Mario Lillo; visit to: Universidad Politécnica de Madrid, Spain
2. Eduardo Holzapfel; visit to: University of Crandfield, England
3. Eduardo Holzapfel; visit to: INOVAGR, Ceara-Brazil
4. Eduardo Holzapfel; visit to: Universidad Federal de Reconcavo de Bahia, Brazil
5. Gladys Vidal; visit to: Water Center Monterrey, Mexico
6. Gladys Vidal; visit to: XI Symposium on Anerobic Digestion, La Habana, Cuba
7. Ricardo Jeldres; visit to: Norman B. Keevil Institute of Mining Engineering, UBC, Canada
8. Octavio Lagos; visit to: IFAPA, Spain
9. Raimund Bürger; visit to: Universität Stuttgart, Germany
10. RaimundBürger; visit to: Universitat de Valencia, Spain
11. RaimundBürger; visit to: Lund University, Sweden
12. RaimundBürger; visit to: Université de Versailles Saint-Quentin-en-Yvelines, France
13. Alex Godoy; visit to: Natural Applied Sciences Dept, University of Wisconsin - Green Bay, USA
14. Alex Godoy; visit to: Department of Civil, Environmental &Geomatic Engineering, Faculty of Engineering Science, University College London, England
15. Diego Rivera; visit to: Department of Civil, Environmental &Geomatic Engineering, Faculty of Engineering Science, University College London, England
16. Alex Godoy; visit to: Earth Institute, EarthEngineeringCenter and Columbia Water Center, USA.

Scientific visits of foreign researchers to CRHIAM.

1. JanuszLaskowski, University of British Columbia
2. Reyes Sierra, University of Arizona
3. ElíasFerere, University of Cordoba
4. Johannes Hopmans, University of California Davis
5. Mark Servos, University of Waterloo
6. Max Billib, LebnitzUniversity of Hannover
7. Consuelo Gonzalo, Universidad Politécnica de Madrid
8. Ernestina Menosalve, Universidad Politécnica de Madrid
9. Niel Mc Intyre, University of Queensland
10. Sara Pérez, España Universidad de Valladolid
11. Raúl Muñoz, España, Universidad de Valla dolid
12. Marek Pawlik, University of British Columbia
13. Carlos D. Acosta, Universidad Nacional de Colombia
14. Pep Mulet, Universitat de València
15. IgmarNopens, Gehnt University
16. Elena Torfs, Gehnt University

CRHIAM

CENTRO DE RECURSOS HIDRICOS PARA LA AGRICULTURA Y LA MINERÍA



Universidad de Concepción

Universidad del Desarrollo
Universidad de Excelencia