UTILISING ADAPATIVE INTEGRATED WATER RESOURCES MANAGEMENT STRATEGIES IN MINING ENVIRONMENTS TO BETTER DEAL WITH CUMULATIVE IMPACTS

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ABSTRACT

Globally, freshwater scarcity is increasing and this, coupled with variability in supply, is leading to conflict among different sectors of society having economic, social and environmental consequences. To deal with this dynamic situation, the minerals industry needs new adaptive water management strategies to meet production requirements and contribute to the socio-economic development of communities in environments where water supply and demand fluctuates. The interactions between water availability, water value, policies, regulatory processes, and a growing awareness of cumulative impacts on water quality and quantity drive how water should be allocated among different users. It will place increasing demands on managing future water supply and the ability of tools to forecast future water availability scenarios in regions where mine expansion occurs in the context of other economic and social sectors whose demand for water is increasing. This paper covers the governance, human and environmental dimensions involved with water availability, management and conflicts in both Australian and Brazilian mining regions demonstrating how Integrated Water Resources Management (IWRM) leads to better Sustainable Development (SD) outcomes for the mining industry.

Keywords: *Adaptive Management (AM), Integrated Water Resources Management (IWRM), Cumulative Impacts (CI), Sustainable Development (SD), Water Use, Mining.*

INTRODUCTION

The minerals industry is in need of new adaptive water management strategies to meet production requirements and contribute to improved environmental outcomes and the socio-economic development of communities in environments where water supply and demand fluctuates. The paper argues that an integrated management approach that accounts for the needs and impacts of all water users is required and investigates the extent to which adaptive integrated water resource management can assist the minerals industry to improve sustainable development outcomes. The paper first traverses an number of conceptual approaches to natural resource management and synthesises these into an integrated framework. Case studies from Australia and Brazil are then explored to demonstrate the importance of the framework.

Adaptive Management (AM) is a cyclical process, relying on the results of prior actions to inform future actions and is composed of four steps: learning, describing, predicting and doing (Argent, 2009). AM has previously been used for water and also management of other natural resources, whole ecosystems, interactions between the environment and society. Adaptive management has also contributed to policy development and application (Stankey and Allan, 2009) and to support decision making by Watershed Councils (Habron, 2003). Dealing with the multiple variables associated with each different applications of adaptive management is difficult due to large uncertainties attributable to the lack of available data and information on water supply and uses. Management in these situations requires flexibility (Eppink, 1978), adaptation and a complete overview of resource availability and utilisation across all sectors of society. Effective adaptive management relies on a comprehensive integrated management system for water resources and vice-versa.

Integrated Water Resources Management (IWRM) is a framework where AM is being proposed to be merged. To date, IWRM concept has many points of views and remains amorphous making it difficult to be implemented since there is no common consensus of its definition (Biswas, 2008a, Biswas, 2008b). Water is essential not only for the ecosystem maintenance, but also any human existence and any of the social-economic activities within river basins. Therefore, water management is intrinsically related to the management of a whole river basin. This is difficult due to the various actors and uncertainties. Typically flexibility is essential to deal with all kinds of human activities and to promote continuous progress towards harmonious relations between all sectors within the same basin. Sectors within a river basin can include the minerals industry, agriculture, public supply, animals supply, recreation, amongst other uses. This water allocation and distribution between a wide range of actors leads to different perspectives about water management. Mostert (1999) described six different perspectives for catchment management. These perspectives are: natural sciences, engineering, social optimization, law, decision making and ethics. Even though these multiple perspectives have been observed, River Basin Management (RBM) consists of considering all activities with the aim of improving the functioning of the river basin (Mostert, 1999), This conception is aligned with what is being proposed here with IWRM framework, integrating all actors/sectors, activities and planning, with a AM support to better deal with different sectoral views on water allocation and Cumulative Impacts (CI) with the aim to achieve Sustainable outcomes.

Sustainable Development (SD) has many different concepts from different perspectives as well. This variety of SD concepts have been very well reviewed and published within "A New Conceptual Framework for Sustainable Development" by Jabareen (2008) where seven different conceptual perspectives were used to describe SD. These are: "natural capital stock", "equity", "eco-form", "integrative management", "utopianism", "political global agenda" and finally the "ethical paradox" which is the heart of this framework as an interwoven result of the other six concepts. Jabaren (2008) describes that "*The paradox between 'sustainability' and 'development' is articulated in terms of ethics. In other words, the epistemological foundation of the theoretical framework of sustainable development is based on the unresolved and fluid paradox of sustainability, which as such can simultaneously inhabit different and contradictory environmental ideologies and practices. Consequently, SD tolerates diverse interpretations and practices that range between 'light ecology', which allows intensive interventions, and 'deep ecology', which allows minor interventions in nature*.".

SD can be regarded as composed of three pillars or dimensions. These are: Environment, Social and Economical sustainability. These dimensions are usually mentioned, described and cited with different hierarchical approaches (Giddings et al., 2002) who concluded that these dimensions are partially connected and do not produce an integrated approach. This is understandable once SD can also be seen as an endless journey where there is always a need for continuity as "development" can be infinite. However, here is proposed that IWRM is an integrated variable of SD that need a continuous adaptive management process to solidify integration and continue to improve in the same pace as sustainability. This is such a strategic tool that can certainly be applied to support decision making, minimizing negative CI and maximizing positive CI (Figure 1).

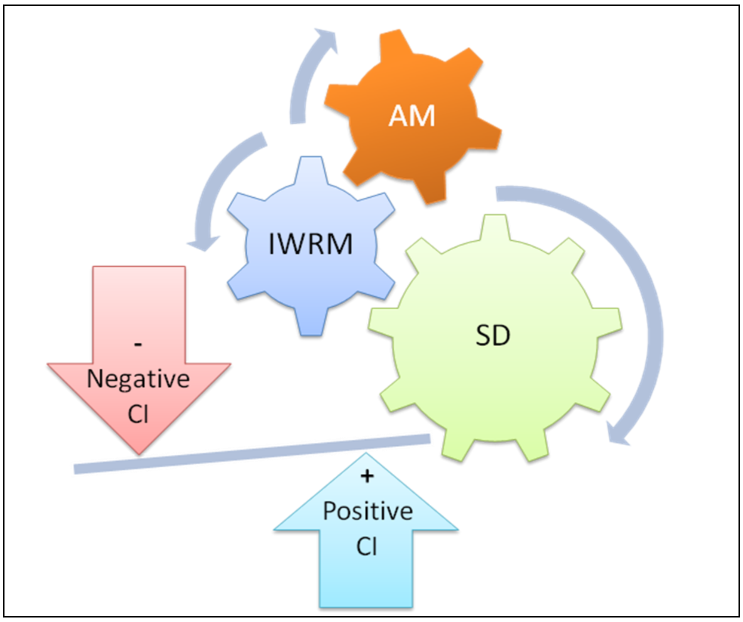

Figure 1: Sequencial process of the application of the macro components of the framework proposed.

Franks et al. (2010b) describes CI as the successive, incremental and combined impacts of one or more activities on society, economy and the environment. CI can be positive or negative and vary in intensity, spatial and temporal extent. They can aggregate and interact such that they trigger other impacts causing multiple effects. The framework for dealing with CI (Franks et al., 2010b, Franks et al., 2010a) is very much aligned with AM frameworks; it is a closed cycle where the decision making process is reviewed through analysis of new information. To manage these impacts, it is crucial to understand the causes that unpin them in order to ensure sustainable outcomes for the management of the River Basin.

METHODS

Now that different tools have been defined and integrated, this section inserts the main components of the proposed framework for Adaptive Integrated Water Resources Management (A-IRWM) as a proposition to better understand and deal with water management systems and its components. In the next section case studies will be described in a succinct form, enough to illustrate in practice the appliance of this framework when mining coexists with other sectors in the same region or river basin. Both regions, in Australia and Brazil, have advanced in water management in the past decades. Although, IWRM do not have yet a unique precise definition that is applicable to any region or nation, as physical, social and political realities may interfere. Due to various scenarios and situations, uncertainties are the most certain fact, thus flexibility and adaptation becomes necessary.

To integrate all components of this framework it is important to map how the system works, its interconnections and variables. At the macro scale, the framework has been divided into 3 dimensions and 3 sequential paths that lead to the understanding each dimension: Physical Dimension/Technical Path, Human Dimension/Social Path, and Governance Dimension/Governmental Path (Figure 2).

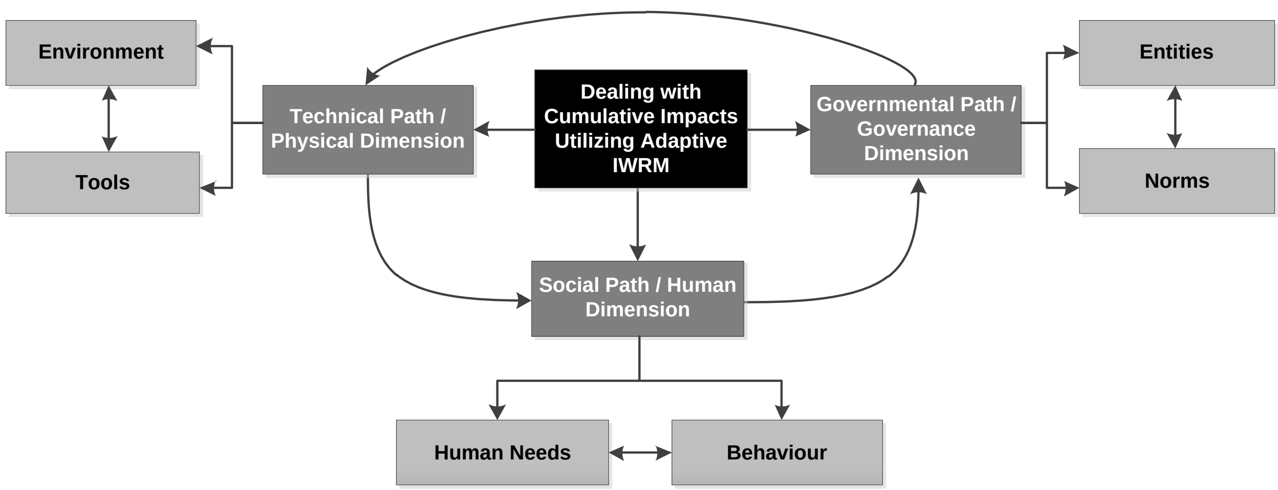

Figure 2: Conceptual framework for dealing with Cumulative Impacts in an Adaptive IWRM approach.

The physical dimension of the model is composed of the environment and its variables and the tools available collecting information and understanding the ecosystem and its interrelations. Its components, for the purpose of this work, only water is directly considered, in quantity and quality, amongst the other natural resources. To follow this path tools are necessary, such as wireless flow meters and water level meters as well as computer systems such as GIS that combined with Remote Sensing techniques can support research studies to better understand environmental dynamics and assess and monitor cumulative impacts. The main objective here is to understand the water cycle and water accountings within the area of study.

The Human Dimension path consists of individuals and communities. To understand this branch of the model it is necessary to understand that the environment is habited by humans who organize in groups, but can also have influence in the system as an individual. Either individuals or groups have needs that in this case will be individual or collective needs. However, Individual needs can be aligned with collective needs since man while living in communities have an interdependent relationship with one or more groups. Once the needs are known, the next step is to understand the drivers for conquering the needs and also understand the means that are available to achieve their goals.

The Governance Dimension is composed by governmental and non-governmental entities creating norms to be followed. Everyone’s goals can be limited by externalities or other external factors that directly affect not only the Human Dimension but also how it interacts with the Physical World. The responsibility for this is through governance procedures instituted by local, state and federal governments, private companies and another category in between nominated as multi-stakeholders and Natural Resources Management (NRM) Bodies/Groups or its equivalent in Brazil known as Hydrographic Basin Committees. These entities participate directly and indirectly in the development of norms, such as legislation, regulations, policies and river basin plans and programs.

The three paths are connected by water which links a mine site to its surrounding environment and community. The integrative nature of water means that decisions made about water consumption at almost any point in the supply - use - treat - output cycle affects other users and the environment. It also necessitates collecting, analysing and using information about water at a hierarchy of scales and in a coordinated manner. Operational monitoring of water use is needed to understand local demand and use for day-to-day decision making. Water use data within individual industries or by stakeholders is required to ensure best practice and most efficient use of water is achieved when benchmarked against other similar users. Regional and long term water information is required to understand cross-sector competition and demand for the resource. The complex interplay between multiple and interacting users, the value obtained from those uses and their impact on the long term sustainability of the resource is needed to establish policy and governance procedures for compliance.

It is true that behind all this dimensions economical aspects are involved. Even though economical impacts can happen due to the use of water and although Barrett (2009) says that “*strategic view can only be achieved by access to and interpretation of the best available scientific and economic data on water*”*,* in this framework, which is a preliminary synthetised conceptual model for a PhD research project, economy is not present at this level of the framework as it is considered consequence of the first dimensional level described so far. As concluded by Moran (2006), “*value is intrinsically subjective; ‘value is in the relative desires of the user’.*”, it becomes clear that the value of water is not only related to economy, there are also different types of value: environmental, social and economic, who are the actual users of water, or the primary values. Therefore, economical impacts and values, again, are a consequence and thus, can be called secondary value as well as cultural value which is related to the Social Dimension. Nevertheless, considering the proposed model , in the following topic will be highlighted aspects of the physical world, human and governance dimensions involved with the natural and actual water availability (Rocci et al., 2011 "in this proceedings"), and conflicts in two countries (Australia and Brazil) where adaptive management can be applied since mining generates considerable external revenue as it interacts with the whole river basin. This permits a comparative case study of mine water management in two regions drawn from multiple publically available sources and triangulated to ensure data accuracy and these countries’ approach towards AM, IWRM, SD and CI regarding the minerals industry in the context of the proposed framework.

FINDINGS AND DISCUSSION

Australia and Brazil are located in the South Hemisphere along equivalent latitudes and with similar climate throughout their territories but with a great divergence regarding predictability of rainfall periods and droughts. While in Brazil rainfall is relatively easy to predict, the Australian continent shows that rainfall has a high level of spatial, temporal and quantity uncertainty (Pigram, 2007, Letcher and Powel, 2011, Quiggin, 2011) which makes it harder to manage water resources. Besides, due to a high evaporation index, Australia has the lowest run-off in the world while the South American continent shows the largest. These statistics affect directly the amount of physical water available. Brazil holds approximately 12% of the worlds freshwater resources (ANA and UNEP, 2007) while Australia holds only 1%, although, the only state considered to have poor water per capta is South Australia (Pigram, 2007). But on the other hand water availability in Brazil is higher in the North region where there is less demand for usage and smaller towards the Southern regions where the demand for water is much higher (ANA and UNEP, 2007) including great consumptive and non-consumptive uses by the minerals industries.

These countries are both producers of a great diversity of ore. Mining industrial process demand great amount of fresh water such as 20GL/year in only one mine site. This is a critical quantitative aspect of concern of water allocation. In the case of other types of mining, such as gold, water quantity shares its concern with the quality aspects, due to the chemicals used to segregate the ore from the rest of the source rocks. Mining activities are responsible for generating cumulative impacts, but can also receive them when generated by other actors such as communities and governmental and non-governmental entities through all sorts of existent norms, but also on going norms being elaborated that will eventually become future current norms. We are not referring to natural impacts, but anthropologic impacts, therefore after understanding the environment, it is essential to understand the human dimension, which is directly linked with the Physical World and Governmental Dimensions. Thus, mining activities is one of the many anthropogenic activities which is the example given in this paper and the focus of this framework that can actually be applicable to any other scenario.

THE MINERALS INDUSTRY AND THE BOWEN BASIN / QUEENSLAND / AUSTRALIA

The Bowen Basin is a geological basin outcropping approximately 60,000km² in Central Queensland, Australia (Figure 2). No different than other mining regions, cumulative impacts is a fact in the Bowen Basin region such as the increasing areas of voids, increasing disposal of wet tailings, disruption of regional aquifers, continuous import of water from adjacent hydrological basins, cumulative run-off and stream/creek flows, downstream accumulation of salt and sediment and final landform hydrology (Moran et al., 2005). These examples can be consequence of sequence of events which starts with the mining extraction itself creating voids that disrupt aquifers and become exposed to the environment. Voids capture rainfalls and accumulate water that can overflow downstream carrying sediments and water altering stream geochemistry. Discharges can also be directed to storages and overland flow across worked areas, such as spoil and tailings, which will flow to dams with a risk of breaching them and reach the environment. This situation has not impeded the need to import water from other catchments that after being used is also added to the volume cumulated in voids and storages to manage worked water.

Franks et al. (2010a) Also mentions about this situation as an example of environmental cumulative impacts in this same region. Mainly from the mining operations vulnerable to major flooding, saline water discharges are being introduced into the Fitzroy catchment. This situation is extremely concerning due to the cumulative impact of mines on water downstream of the catchment area affecting ecosystems as well as compromising public water supply. This is a cumulative scenario full of uncertainties that needs to be predicted in the most realistic way in Environmental Impact Statement (EIS) approval processes where planning water management needs to be shown.

Rolfe et al. (2007), even though focusing on the social cumulative impacts, has detected that in Central Queensland, the EIS process has focussed on single projects and therefore does not adequately represent or predict cumulative impacts due to simultaneous multiple projects being developed in the same region. Uncertainties are inevitable in water management, consequently, the creations of norms to manage water is a difficult task and needs to be always going through adjustments as the knowledge on the water system evolves as well as new demands and concerns about water flows (Quiggin, 2011) and water availability.

THE MINERALS INDUSTRY AND THE PARAOPEBA BASIN / MINAS GERAIS / BRAZIL

The Paraopeba and Das Velhas River Basins are the main sources of freshwater for Belo Horizonte (Capital of State of Minas Gerais, Brazil) and the western and southern municipalities of its metropolitan region. Even though the average annual rainfall in Paraopeba Basin is 1,403.6 mm per annum, water availability in Paraopeba Basin is becoming an issue of concern to all water users within the Basin (Belo Horizonte) (CIBAPAR and HOLOS, 2009). There are many different sectors demanding water in Paraopeba Basin and the search for more water is increasing each day, especially with the development of new mining projects that “competes” with other industrial sectors, pisciculture/aquaculture, agriculture and mainly public water supply, besides the environment which is legally protected by the governments. The legislation in Minas Gerais sets that 70% of the minimum flow of 7 consecutive days in 10 years of recurrence ($Q_{7/10}$) needs to be preserved within the rivers for ecological maintenance.

With the latest Brazilian Constitution (Senado Federal, 1998), the Water Management System started to gain new perspectives by the improvement of how it has been developed along the past several decades since the 1934 National Water Code. Contrariwise Water Code, after the 1998 Federal Constitution, water resources became property of the Union or the States. Since then, whoever needs access to water resources requests it through a water grant to the State Water Management Department, in the case of Minas Gerais, IGAM, or the National Water Agency (ANA). Water Grants for private use expires every five years and need to be renewed. When renewal time comes there is no guarantee that the water grant will remain the same, it will depend on the current River Basin water availability and its existing allocation. However, in scenarios of scarcity human and animal supply have priority of water access (CNRH, 2011, Minas Gerais, 1999) and other users can have their allocation reduced after reallocation analysis. Although, so far, reallocation of great amount of water has never happened in Paraopeba Basin, but it can certainly be a concern for industries, especially from the mining sector since new projects and expansion projects are becoming reality in this basin concurring with other sectors to access water.

The highest amount of accessible water in the Paraopeba Basin is allocated for human supply. Knowing that, legally, human consumption has priority in case of scarcity, one of the alternatives that are being considered by the industries is to have, as a backup plan, dams for water supply to increase the availability of water for off-take by regulating river flows in order to keep the business running in case of a critical scenario of reallocation of existent water grants for industrial use to human consumption.

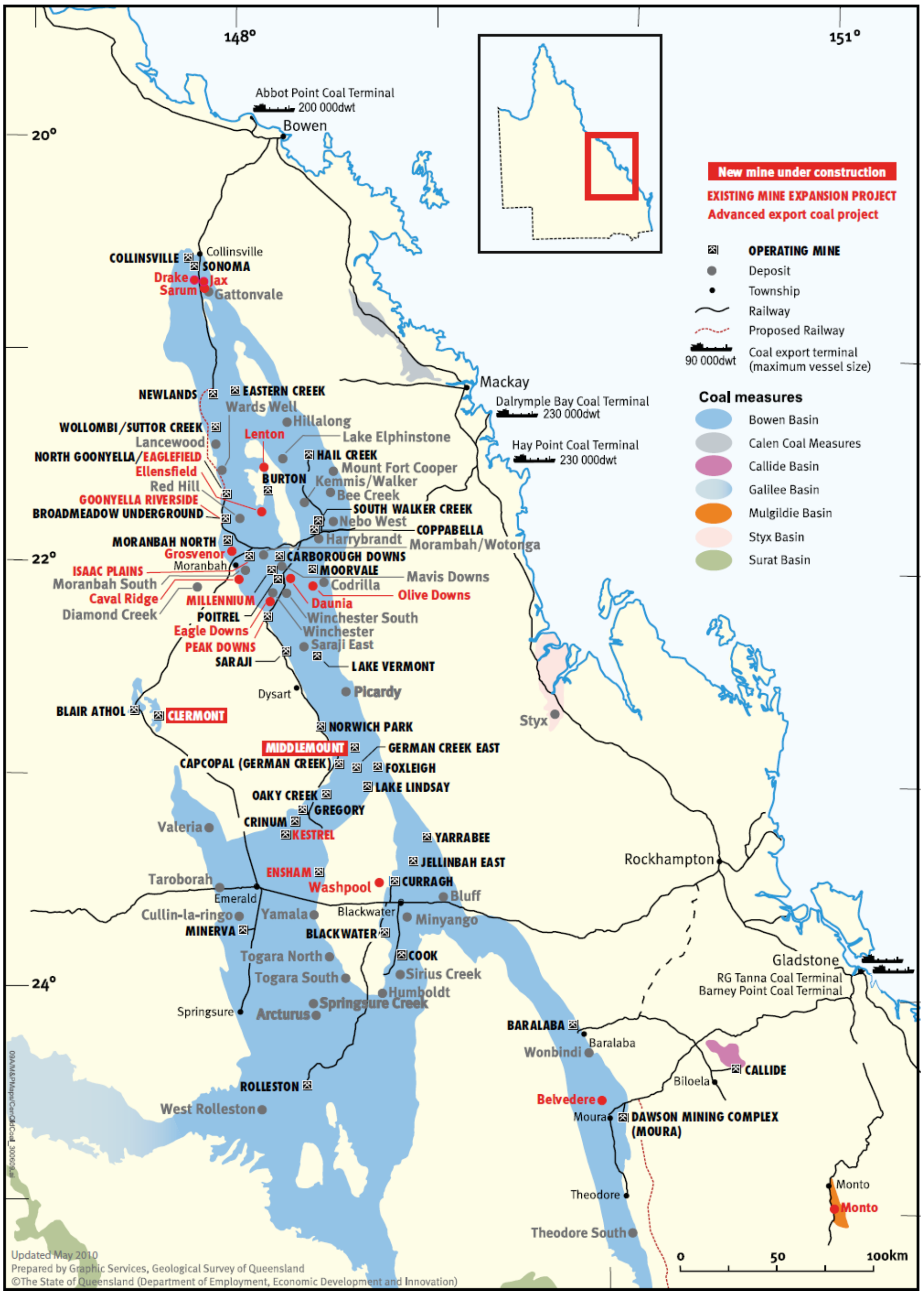

Figure 3: The Bowen Geological Basin, Central Queensland, Australia (QDEEDI, 2010).

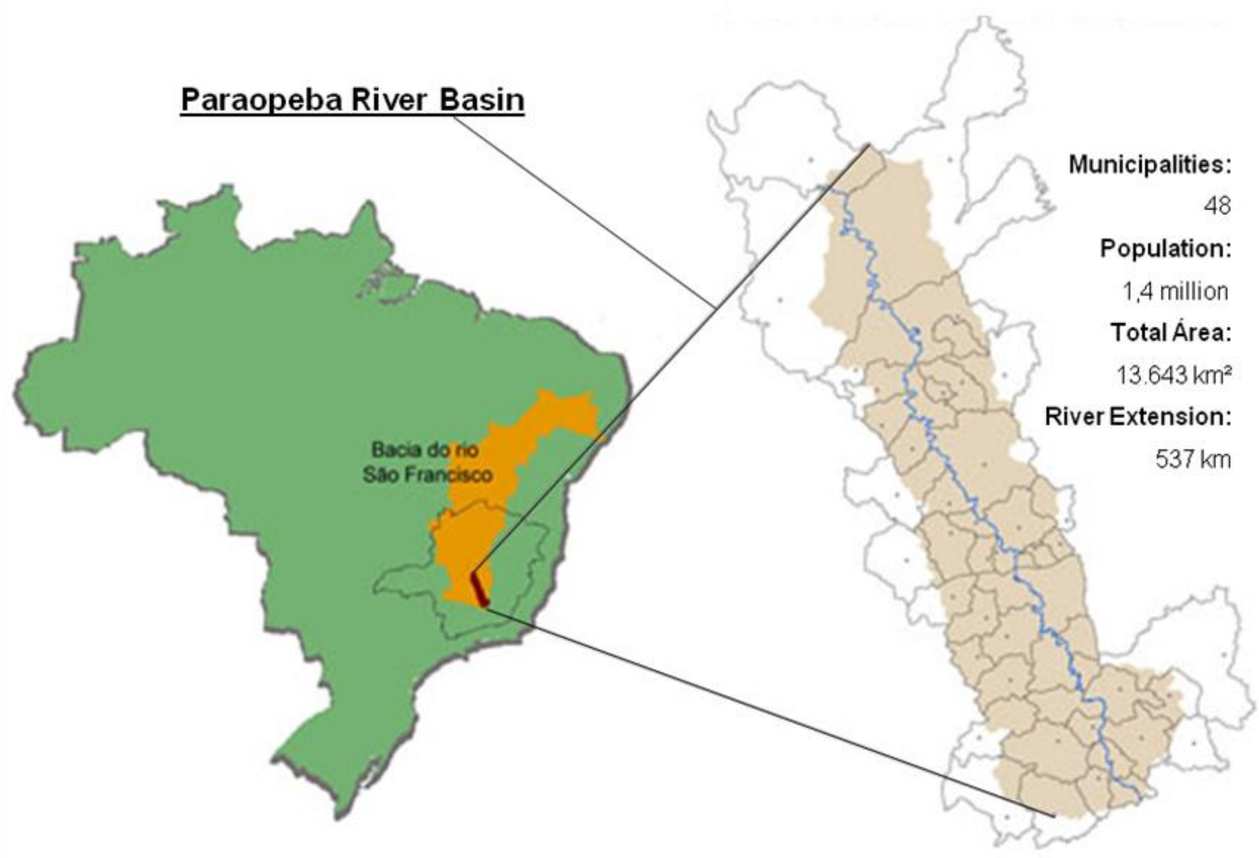

Figure 4: Paraopeba River Basin - Location and brief information (CBH-Paraopeba, 2011).

STATUS OF MINING AND ADAPTIVE IWRM CONTEXT

While adaptive management is not a panacea it is a strategic tool for assisting decision making with flexibility. Adaptive management provides a framework for improved ecosystem management (Argent, 2009). However, in face of such potential and ongoing cumulative impacts related to the use of water and the mining industry, either as source or receptor, the active mining industry in this regions who are engaged with water management issues already have an Adaptive IWRM Plan or is currently working to have one. Those who are still not engaged with IWRM will have to recover the time lost so far and catch up to this type of integrated framework in order to keep their business alive, profitable and keeping or searching leaderships in the sector.

The mining industry interacts with all dimensions of the framework: Environmental, Society and Governance. These components make up the structure of the system which has evolved on a temporal scale; thus, it is called here the Structural Hierarchical Sequence (Figure 5). In practice, each of these components have their own different needs and requirements to access water resources, therefore water has different values that need to be identified and understood. Sustainability needs to be addressed with the focus directed at sectors' demands and flexible management of conservation and allocation of water given that sectors' demands are variable. Finally, tradeoffs may be necessary in scenarios of scarcity considering that human consumption has priority over all other users for maintenance of human life. This sequence of consequences related to the use of water and its interaction with the Structural Sequence, can be named as Practical Hierarchical Sequence (Figure 5). Cycling through this Adaptive Integrated Water Resources Management (A-IWRM) framework can assist mining sector to better plan and predict outcomes lowering uncertainties after each time a new information or outcomes become facts. These sequences show the general components that are necessary to consider when planning and managing the use of water which is shared with other sectors.

In both, Australian and Brazilian examples, A-IWRM can be useful. In the first example, the critical aspect regards the quality of water and the second on quantity. Avoiding undesired outcomes of overflows can be easily managed with projects refinements, where drainage systems can be planned to direct to bigger dams to hold and treat water and perhaps, as an integrated and flexible way, impound this water back to attend the mine site demands and/or provide it to another use less noble than human or animal consumption that do not demand high level quality of water. The Brazilian example is also related to the potential conflict between sectors but in a quantitative manner. In conclusion, fit-for-purpose is a critical component of the A-IWRM. It determines the value of water to different sectors and stakeholders in society. Water value in relation to demand determines how water resources should be allocated and strong governance provides the regulatory framework within which allocations can occur. However, where water supply is limited due to environmental constraints, trade-offs among different sectors and uses must occur. A-IWRM provides the context within which flexible decisions can be made that adapt to changing water availability from the environment and demand by society.

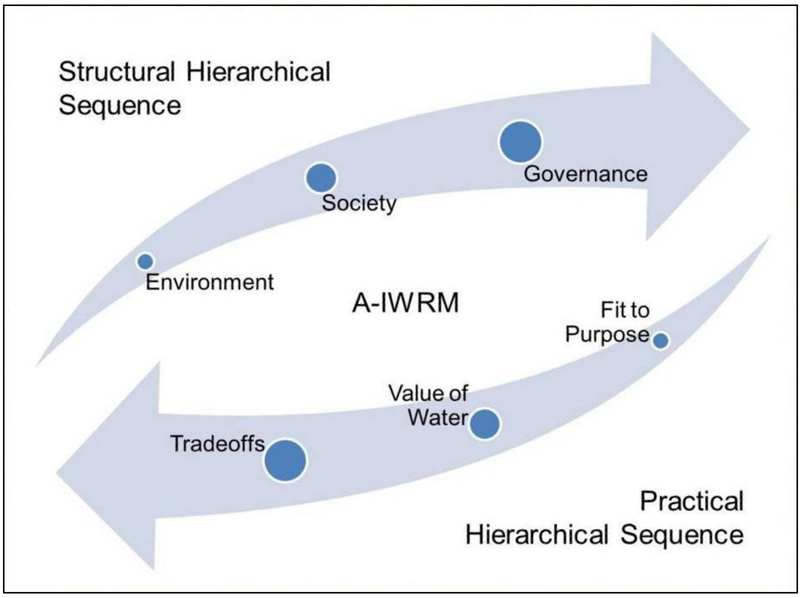

Figure 5: Schematic overview of the Sequential Hierarchy of IWRM.

CONCLUSION

The regulatory processes created to manage the water resources are currently not adequate to deal with uncertainties in water information and are not flexible enough to adjust decisions in response to variability in water supply and demand neither in quantity nor quality. An adaptive system is needed, that combines technical knowledge with environmental uncertainties to improve and apply the norms such as legislation, regulations, policies and river basin plans and programs. A river basin information system (data hub) is crucial for holding and controlling all information related to the use of water and planning needed to obtain water grants and environmental licences. This is essential for understanding and building scenarios for A-IWRM. Limits to the amount of water that can be derived or captured, in terms of percentage of characteristic flow of the regional regime, needs to be well defined considering the need of all sectors against the environmental needs to be sustained. Water quality needs to be known in its natural state and monitored to guarantee future supply aiming fit to purpose distribution with minimum cost as the main economical value of water can be considered indirect or the infrastructure needed to derive, treat and discharge. Economical aspects are located in sub-dimension(s) level(s) of the future and more advanced version of the present proposed conceptual framework.

Although governments are responsible for IWRM in their respective jurisdictions, sector should create their own management system as a way to make rational water management and to gather information for appropriate interactions with other sectors of users and the government. The mining sector only recently is starting to create its structure that is likely to be improving and gaining force and respect within the catchments where they are present as it can benefit other sectors as well. In summary, this integrated approach is about understanding the holistic scenario of a river basin composed by several different sectors, which have different values and needs for water resources, where tradeoffs within water allocation is the key adaptive component that ends a cycle of the A-IWRM framework giving flexibility to the system attending the needs of all and, consequently, permitting development within the journey of sustainable development.

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