Final, 6 Dec. 2023

BRC Research Program 2024–2028

1. Introduction

Human activity is the largest driver of nature loss in land-use change and conversion of natural habitat. This is a global problem, as nature underpins healthy society and robust global economy. Land-use change, and specifically the loss of natural intact habitat, has both impacts on the loss of local biodiversity and the global climate.

The world's biodiversity is at risk and steeply declining (Cardoso et al. 2020). Humans and their activities are responsible for nature loss but are also negatively affected by it (Arneth et al. 2020; Scherer et al. 2020). In response to this crisis, the United Nations Convention on Biological Diversity has established a Global Biodiversity Framework that aims to halt and reverse biodiversity loss, by 2030, and to put nature on a path to recovery, by 2050, for the benefit of people and the planet (CBD 2022).

The Amazon rainforest is one of the most biodiverse places on earth, supporting over 3 million species, including over 2,500 tree species. It also has a significant role in regional climate regulation and atmospheric carbon concentrations, influencing rainfall and weather patterns. The rainforest is also important for socio-economic development in the region and for the indigenous and traditional communities.

It is predicted that half of the Brazilian Amazon is either already deforested or projected to be by 2050 (Carvalho et al. 2023). Recent studies have shown that even if mining is not the major driver of deforestation, it has important environmental consequences and is causing extensive deforestation of the Amazon rainforest. Therefore, the impacts of mining on biodiversity are a major concern and an important topic for restoration and conservation actions in those areas. The operational mining leases in the Brazilian Amazon occupy a relatively small part of the total forested area. However, it is important to recognize that mining drives deforestation and environmental impact far beyond the areas of operations, including changes in land use, infrastructure, urban expansion, effects on indigenous territories, waste disposal, and pollution (Sonter et al. 2017).

The mining industry is a key player in the global economy and an important economic activity in the Amazon region. However, the mining industry also has ambitious commitments to biodiversity conservation and rainforest restoration. To apply best practices, the industry needs to support studies aimed at evaluating and developing recovery techniques for impacted areas, in addition to contributing to the development of rainforest restoration ecology research and promoting the monitoring and conservation of biota. The knowledge of the physical environment and ecological relationships established in a natural environment, whether in areas that are not heavily impacted or in areas undergoing processes of ecological succession, such as former abandoned pasture areas transitioning into forests, can provide valuable insights into the path to follow. This knowledge serves as a basis for comparisons to assess the success or failure of restoring areas impacted by mining. Therefore, it is essential to precisely know how mining activities impact the physical environment and biodiversity and, more importantly, which aspects of biodiversity are most vulnerable to these impacts. This understanding is fundamental to manage these impacts responsibly and to take accurate and effective action to mitigate them in the future.

2. Ecologically responsible mining

Hydro, one of the main bauxite mining companies in the Amazon region, operates to minimize environmental impacts and promote sustainable land use. The company recognizes that the activities may affect biodiversity values within terrestrial and freshwater ecosystems, as well as ecosystem services. Ecologically responsible mining, during all stages of the mining operations lifecycle, should be anchored in the biodiversity Impact Mitigation Hierarchy (IMH) with its four pillars of (1) avoiding, (2) minimizing, (3) repairing or remedying, and (4) offsetting impacts on biodiversity. This provides a tool to connect economic and social development with the demands of protecting natural heritage for future generations (Sonter et al. 2017). To apply this hierarchy effectively, Hydro needs to first understand the biodiversity and ecosystems present and how these can be affected by their operation (directly and indirectly).

Where impacts do ultimately occur, Hydro is responsible for restoring and rehabilitating those impacts. Primary research can inform on the most appropriate ways to undertake these processes such that the outcomes provide ecological value as quickly and effectively as possible.

Beyond the mining operation, it is also important to understand the consequence of the cumulative impacts of anthropogenic activities on the wider ecological landscape and how Hydro can contribute to effective conservation management of the region.

It is important to emphasize that scientific investigation is the “cornerstone” of this effort. Mining companies cooperating with academic and research institutions in this process provide credibility, impartiality, and objectivity in producing results. The research generated may support decision-making processes and serve as a solid foundation for the mining industry to build more sustainable practices to ensure biodiversity conservation for future generations.

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Landscape changes directly influence global climate changes and accelerate the loss of biodiversity. Biodiversity loss is a major concern associated with mining and restoration in the Amazon rainforest and is an important topic for conservationist actions in those areas. However, it is a complex and challenging endeavour to choose the suitable approaches to monitoring biodiversity changes in these areas, as well as optimize the management of rainforest restoration, which is both economically feasible and will ultimately result in a forest structure and biodiversity comparable to the old primary forest of the area. Similarly, it is scientifically challenging to choose the right methods for assessing restoration success by proper monitoring.

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3. Status of rainforest restoration ecology

The Amazon stands out with mineral abundance and diversity, contributing to the local and national economies in Brazil (Martins et al. 2022). The mining activity in Pará state follows the Normative Instruction n° 07 (Secretaria do Estado de Meio Ambiente e Sustentabilidade 2015), which describes forest suppression as the first step, followed by removal of the organic soil and soil sterile layers to reach the mineral. The total removal of vegetation disturbs the flora and fauna and the ecological relations of the landscape.

Soil removal is an inevitable factor in open-pit bauxite mining and is a cause for concern. It involves not only the mobilization of enormous masses of earth in the pre- and post-mining processes but also leads to drastic changes in the soil, resulting in the loss of important functions for the maintenance and stability of environmental services. Soil is considered a non-renewable resource (FAO 2015), as its formation and/or regeneration process is very slow. The good news is that man can act as an accelerating agent in these processes. Technosols correspond to soils whose origin is strongly related to human action (World Reference Base for Soil Resources 2022). In the Paragominas mine, the technosols are generally constructed using a layer of topsoil over the overburden layer, and many important properties for initial plant establishment are lost in the pitting process, land relocation, and mine soil construction operations. Even so, Brasil Neto (2017) and Souza (2018) report improvements in physical-chemical attributes in the surface layer of the soil, mainly in older Natural Regeneration areas. However, Brasil Neto et al. (2021), warn about the depression of tree components in Natural Regeneration areas due to the low diversity and high dominance of a few pioneer species, which could compromise the successional trajectory of the area. The death of trees and the lack of continuity in the successional trajectory, with the formation of gaps, can, in turn, hinder the advancement of pedogenic processes and even lead to losses in soil quality. Chan Chen et al. (2020) demonstrated that soil and vegetation influence each other, characterizing the existence of a co-evolution between them. In this relationship, a progressive successional trajectory is related to the formation and maintenance of soil physicochemical properties through mutual feedback. In this way, understanding soil-vegetation co-evolution feedback provides an additional tool to support predictions and mitigations of the impacts of human actions on global changes and the provision of ecosystem services (van der Putten et al. 2013). Ecological restoration is a multi-task field involving concepts of disturbance events, genetic adaptation, succession after a disturbance, population ecology, community assembly theory, and landscape ecology. It aims to restore the health, integrity, and sustainability of ecosystems that have been degraded by human activities (Smithsonian Environmental Research Center 2023).

Different strategies for promoting the restoration of forest landscapes vary in cost and benefits (Alliance for Restoration in the Amazon 2020). In mining areas, it starts with soil recovery, followed by vegetal restoration that consequently provides wild ecosystem restoration (Macdonald et al. 2015). Restoration may be achieved through many techniques and their combinations (Catterall and Kanowski 2010). A recent overview of the ecology restoration in the Amazon highlighted seedling planting, natural regeneration, hydroseeding, and nucleation as the main methods (Martins et al. 2022). The restoration initiatives must also consider the proximity to remnant rainforest, which affects biodiversity outcomes (Catterall and Kanowski 2010). Finally, monitoring restoration is critical to its success (Alliance for Restoration in the Amazon 2020). The goal is that reforestation projects provide areas consisting of varied species and physical structures and complexity resembling the primary rainforest biota (Catterall and Kanowski 2010).

Poorter et al. (2021) have pointed out the importance of chronosequence studies to infer trends in forest recovery. They reported that studies on the recovery of single attributes have shown that ecosystem functioning, such as nitrogen fixation, recovers fast (in about three decades Gei et al. 2018), whereas aboveground biomass and species richness recover more slowly (three to seven decades) (Poorter et al. 2016, Rozendaal et al. 2019) and species composition recovers slowest, and might take centuries (Rozendaal et al. 2019). They concluded that we lack a comprehensive understanding of how multiple attributes differ in recovery rates and how recovery of these attributes is interrelated. Despite the recent advances, the studies in mining areas must continue, including the capacity of the recovering forests to remove carbon dioxide from the environment, rescue and conserve the biodiversity and their ecological relations, improvements for forest natural regrowth and planting, availability of supplies, and monitoring (Martins et al. 2022).

Stream restoration is also critical to maintaining the health of aquatic and terrestrial ecosystems. Monitoring and restoring streams in mined areas can be part of broader landscape restoration efforts to return the condition of the area to a more natural state. Stream restoration should focus primarily on surrounding vegetation (riparian forests) and physical habitats (e.g., channel structure and biodiversity refugia), while stream monitoring will allow researchers and policymakers to understand better biodiversity status and trends (Dixon 1996). Restoration may support the ecosystem functions of these waters, including the maintenance of water quality, benefiting aquatic biodiversity, and providing drinking water for people. Other benefits include the maintenance of biodiversity, flood protection, prevention of soil erosion, maintenance of nutrient cycling and transporting, and increased microclimate resilience since healthy streams can better keep stable water temperatures and provide shelter for species that need to move in response to changing climate conditions.

The success of such studies depends on partnerships between the private sector, which must ensure compliance with Brazilian laws throughout its production, and the research institutions to fill the knowledge gaps and develop technologies in the recovery and conservation maintenance of the areas (Alliance for Restoration in the Amazon 2020).

4. Why a BRC Research Program?

BRC needs a research program that makes clear priorities of relevant research questions, which will act as a guide for the consortium participants to design research projects and strengthen the university-industry partnerships.

According to the Consortium Agreement, “the main aim of the cooperation is to develop research activities, both applied and basic, and build a strong base of outputs in biodiversity and climate knowledge.” Within this broad frame, BRC is currently focusing on research with a bearing on the environmental issues of strip mining activities in the Eastern Brazilian Amazon, especially at Mineração Paragominas S.A. (MPSA).

BRC was constituted in November 2013, and the first projects were presented to the scientific committee in March 2014. At that time, the consortium had limited knowledge of the MPSA and little knowledge of the biodiversity reports commissioned by Vale and Hydro. The first projects proposed covered some key topics related to forest restoration and were the results of what was possible to present straight away without the ideal development of a larger, coherent research program with links between the individual projects. Subsequently, the Research Program documents of November 2015 and September 2018 were used as a guide for research priorities, calls for proposals, and evaluation of proposals.

After 10 years of studying biodiversity and restoration, building a stronger background and knowledge of the biodiversity in strip mining areas in Eastern Amazonia, the consortium can rethink and propose new directions taking advantage of the newest and emerging technology to improve sampling, surveying, and monitoring in order to contribute the conservation of Amazon biodiversity.

5. Objective

The overarching objective of this Research Program is to direct, promote, and implement collaborative research projects related to the assessment and monitoring of anthropogenic actions, conservation of biodiversity, and ecosystem restoration as a result of mining activities in the Eastern Brazilian Amazon, in this way seeking to inform science-based management strategies in these areas.

6. Baseline and previous research in the MPSA

Hydro produced a comprehensive report (Salomão et al. 2012). This report concluded that Hydro should aim at establishing a model for forest restoration that is research-based and that can be applied to other damaged areas of the Amazon under similar conditions. Hydro should develop innovative holistic monitoring approaches that include all activities of the processor components of forest restoration that must be carefully observed both in the early (deforestation) phase and the later phases (induction of reforestation and natural regeneration).

The owners of the bauxite mine in Paragominas, Vale, and later Hydro, have used consultancy companies to fulfil the legal requirements related to the environmental regulations regarding mapping and monitoring biodiversity in the MPSA. More than 40 reports from the first years of these projects were summarized by BRC in 2015 in two *Synthesis reports* (Ferreira 2015, Juen and Sena 2015). These reports highlighted knowledge gaps that needed to be addressed in future research. The reports also proposed that BRC should establish an overarching research program to address the knowledge gaps.

Over the last 10 years, the BRC consortium has approved 26 research projects. The projects involved researchers who are members of the BRC, partner researchers from other institutions, and undergraduate and postgraduate students. The consortium has supported wide knowledge generation and people training while contributing to the sustainable development of the Amazon. Projects were carried out on recovery techniques for degraded areas after bauxite mining, soil quality, biodegradation process of stored wood, preliminary assessment of aquatic and terrestrial biodiversity in the area, and its relationships with environmental conditions. In the last call for project proposals, projects involving new ways of evaluating biodiversity with a genetic approach, mechanisms to measure dispersion, involving the association of fauna with humans, and even projects in the mining pipeline areas were also considered.

In the context of the projects, more than 35 dissertations and theses from postgraduate programs at partner institutions were developed, and around 60 articles were published in important scientific journals such as Environmental Pollution, Ecological Indicators, Journal of Animal Ecology, and others. Furthermore, a book compiling the results of 10 years of studying biodiversity and restoration in mining areas is in an advanced phase of publishing. Also, the BRC researchers have participated in many national and international conferences and organized internal scientific symposia to discuss the relevance and applications of the data obtained up to the moment, besides the gaps that remained for future research guidelines.

As part of exchange activities, the BRC held three editions of the International Field Ecology Course in Tropical Ecology and Biodiversity, offered annually to postgraduate students from partner institutions with activities in Brazil and Norway, allowing the exchange of information and providing opportunities for consolidation of knowledge among students and teachers. As a result of this activity, 48 students had the opportunity to travel abroad (for most of the participating Brazilian students, it was the first time that they travelled to another country), and three articles were published based on the results. Such results and activities are indicators of the internationalisation of Brazilian science on Amazon’s demands towards a sustainable development.

7. Thematic areas and priorities

For Hydro to effectively manage the risks and impacts on the biodiversity and ecosystems affected by its bauxite mine, there are several specific research needs that can be addressed by the BRC's research program.

For Hydro to make informed decisions, the company must have a good understanding of the biodiversity and ecosystems present at their site and how they are affected by the mining activity. Suitable methodologies are needed for establishing baseline conditions for these features and monitoring changes in the baseline in response to the impacts and rehabilitation efforts.

To be able to account for impacts on biodiversity and ecosystems of the mining operations and disclose these transparently, a practical accounting framework is needed for measuring the ecological condition of local biomes at varying levels of human disturbance. This framework would then allow Hydro to characterize the habitat conditions of an area before mining but also track progress in areas under rehabilitation. Trialled and tested monitoring frameworks should also be applicable to areas under restoration and conservation beyond this specific mining site.

Hydro's current rehabilitation techniques have already been improved by input from the BRC, but the company must explore ways to increase the rate of recovery in areas under rehabilitation and ensure the long-term success of the rehabilitation efforts into the future.

Tailings storage facilities presents a unique challenge in this context. It will not be as easy to rehabilitate as mined areas due to the nature of the substrate and the lack of topsoil. Technical solutions are needed, which can be a combination of technology and nature-based solutions.

Finally, whilst managing the direct impacts of the mine should be Hydro´s priority, it is well known that the mining sector can contribute to numerous indirect impacts due to opening areas previously inaccessible to the human population and economically driven in-migration of people. The scale and type of indirect impacts will be context-specific, related to the geographic location, history of human presence, socio-economic factors, etc. A better understanding of the indirect impacts caused by Hydro’s bauxite mine in Paragominas would also inform more effective landscape-wide conservation measures and a better understanding of the cumulative effects of human activity on biodiversity and ecosystems in the region.

The short-term industry needs for research related to the conservation of biodiversity in connection with the direct and indirect impacts of mining operations include:

- Methodologies and accounting frameworks for measuring the ecological condition of a local biome. - Pre-mine areas, mined areas under rehabilitation, and areas used as compensatory offsets
- Identification of prioritized biodiversity impacted by mining, and find suitable methodologies for establishing baseline knowledge, and monitoring impacts of mining and gains for rehabilitation (e.g., remote sensing, eDNA, etc.)
- Techniques and protocols for increasing rehabilitation rates of areas impacted by mining
- Technical solutions for rehabilitating bauxite tailings, maximizing biodiversity gains without compromising safety
- Characterizing and measuring the indirect impacts of the mining and human activity in the broader landscape on biodiversity

Considering the objectives of the Research Program, according to the themes outlined above and in section 5, researchers can work at different levels of investigation:

1) Studies of organisms, populations, and their biotic and abiotic interactions with the physical environment, including behavioural studies, ecological characteristics, occurrence, abundance, distribution, delimitation, dynamics, intraspecific interactions, and temporal and spatial variability

2) Studies of biological communities and their interactions with the physical environment, including studies of structure, distribution, dynamics, variability, and interspecific interactions

3) Studies of ecosystems, including biotic and abiotic compartments, focusing on nutrient cycling and energy flow, temporal evolution of soils, microhabitats, habitats, and landscapes

In addition to applying methodologies already recognized in the literature, BRC encourages the use of new and emerging technology to improve sampling, surveying, and monitoring biodiversity in BRC projects, including Artificial Intelligence technology, molecular tools (DNA-barcoding, environmental DNA, etc), and other environmental technologies. BRC aims to be at the forefront in applying the newest technologies and research methods and collaborating with research groups who are developing such technologies. State-of-the-art technology may simplify or reduce the costs of expensive and comprehensive sampling in the field and may benefit both basic biodiversity research and monitoring programs. To solve some of the research questions, BRC projects might benefit from being multidisciplinary, and in some cases include elements of both natural sciences and social sciences.

It is essential to highlight that projects conducted by the BRC must prioritize biodiversity conservation in the context of mining and its surroundings. Therefore, projects that value the generation of information that can be used in the planning of more efficient solutions for biodiversity conservation and the sustainable use of tropical forests and aquatic systems are welcome.

8. Actors/partners

BRC consists of five members: MPEG, UFRA, UFPA, UiO, and Hydro. The Consortium Agreement between these institutions has been extended for a third five-year period (November 2023 – November 2028). BRC cooperates with other partners, mainly with Brazilian institutions.

BRC will prioritize research projects that are based on joint research, including at least two consortium partners. At the same time, we encourage our researchers to cooperate with external actors to improve the quality, the scope, and the dissemination of the research.

9. Time frame

We propose this Research Program to follow the Consortium Agreement timeline and have a five-year horizon (2024 – 2028). We propose that the Program be revised after three years based on new assessments of research theme priorities. The program needs to be in line with the long-term strategy of BRC, which will be developed at the start of the new five-year period.

10. Reporting and assessments of project results

- Each project should produce a written progress report every half year that will be presented to the Scientific Committee (SC) meetings. The report should follow a format provided by the BRC Secretariat. An annual seminar where all project leaders, Hydro, and the Scientific Committee discuss progress reports and project results should be organised. The outcome of the seminar should be summarised and presented at the next SC meeting.
- A final report should be submitted by the end of the project period. The report should follow a format provided by the BRC Secretariat.

BRC should improve procedures to communicate new results from BRC projects to Hydro managers so that these results can be used in improving Hydro´s restoration program, biodiversity monitoring, etc. The BRC Scientific Committee and the Secretariat may assist Hydro in organising general seminars, thematic seminars, internal seminars, and workshops, where representatives from BRC projects meet representatives from Hydro and discuss project results and propose how the results can be implemented by Hydro. Synthesis reports of project results should be produced at certain intervals, preferably every 2–3 years. Larger meetings (conferences) should be organised or supported by the consortium every 2–3 years with representation from BRC projects together with other research groups working on rainforest biodiversity and restoration.

Additionally, an outreach program is encouraged to strengthen the connection between the partners (industry and researchers) and the society (general public, municipality, etc.). These activities should focus on teaching the public about the importance of mining activities in the region and biodiversity and conservation in the Amazon forest in general.

11. Scientific publication of results from BRC projects

- The BRC secretariat will provide a BRC Contribution number for each new BRC scientific publication. This contribution number should be included in the publication.
- A draft manuscript of a new publication should be sent to Hydro for comments on technical issues related to their mining operations. The content of the published paper will be the full responsibility of the authors, but Hydro has the possibility to comment on the various aspects of the paper. However, comments made on the scientific content will be assessed at the discretion of the authors. To avoid delaying the publication process, Hydro will have two weeks to comment on manuscripts. Preferably, the authors should inform Hydro at an earlier stage so that they can allocate time to do their review.

12. Procedures for calls and evaluation of proposals

The Research Program includes projects financed (partly or fully) by Hydro and by other sources. However, the procedures for calls and evaluation of new projects presented here only relate to projects financed by Hydro.

The Research Program opens for two different streams (A and B) for calls for project proposals and evaluation of these.

A) The regular stream will be by open calls on pre-defined priority research themes listed in the Research Program. The BRC Scientific Committee will lead the process before each call to select the research themes that will be covered by the call. This selection will be based on identified knowledge gaps needed to be given high priority in new projects.

B) Given the specificity of mining operations, another stream will be applied for calls for proposals induced for solving specific needs for Hydro's operations.

A. Bidding process – stream 1

The BRC Secretariat will coordinate the bidding processes on behalf of the Scientific Committee. The secretariat will provide instructions about the format and requirements needed to be included in the project proposals. This also includes information about the medical exams, safety courses, and other relevant courses that Hydro requires by research groups before being allowed to enter the company's area. For each call, the Scientific Committee may consider restricting the number of proposals that can be submitted by a single research group. The calls will be announced on the BRC website. Efforts should be made to inform all relevant research groups in the BRC academic institutions about calls for new projects.

The aim is to apply evaluation procedures that are not too time-consuming, expensive, and bureaucratic. At the same time, the procedures should be transparent, and impartiality issues should be avoided.

An evaluation and selection committee comprised of members from outside the BRC-community will be appointed by the BRC Scientific Committee based on recommendations from the Secretariat. The committee will carry out a scientific and technical assessment of the proposals, following a pre-defined ranking system. The committee will also assess the proposal's potential to contribute to the generation of new knowledge that promotes the conservation of Amazonian biodiversity and/or assists in forest restoration, as well as mitigating impacts on the environment and biodiversity.

In principle, the evaluation of proposals will follow two steps:

1. *Technical quality*

A pre-selection of the proposals will be made that eliminates proposals that do not qualify for funding. This technical evaluation includes assessing the relevance to the call and the Research Program, the feasibility of logistics, and that the guidelines given in the call have been fully followed. This assessment will also include potential scientific overlap with other ongoing or completed BRC-projects. Those proposals that pass the technical assessment will be assessed according to scientific quality.

2. *Scientific quality*

The evaluation and selection committee will rank the project proposals according to the following assessment criteria:

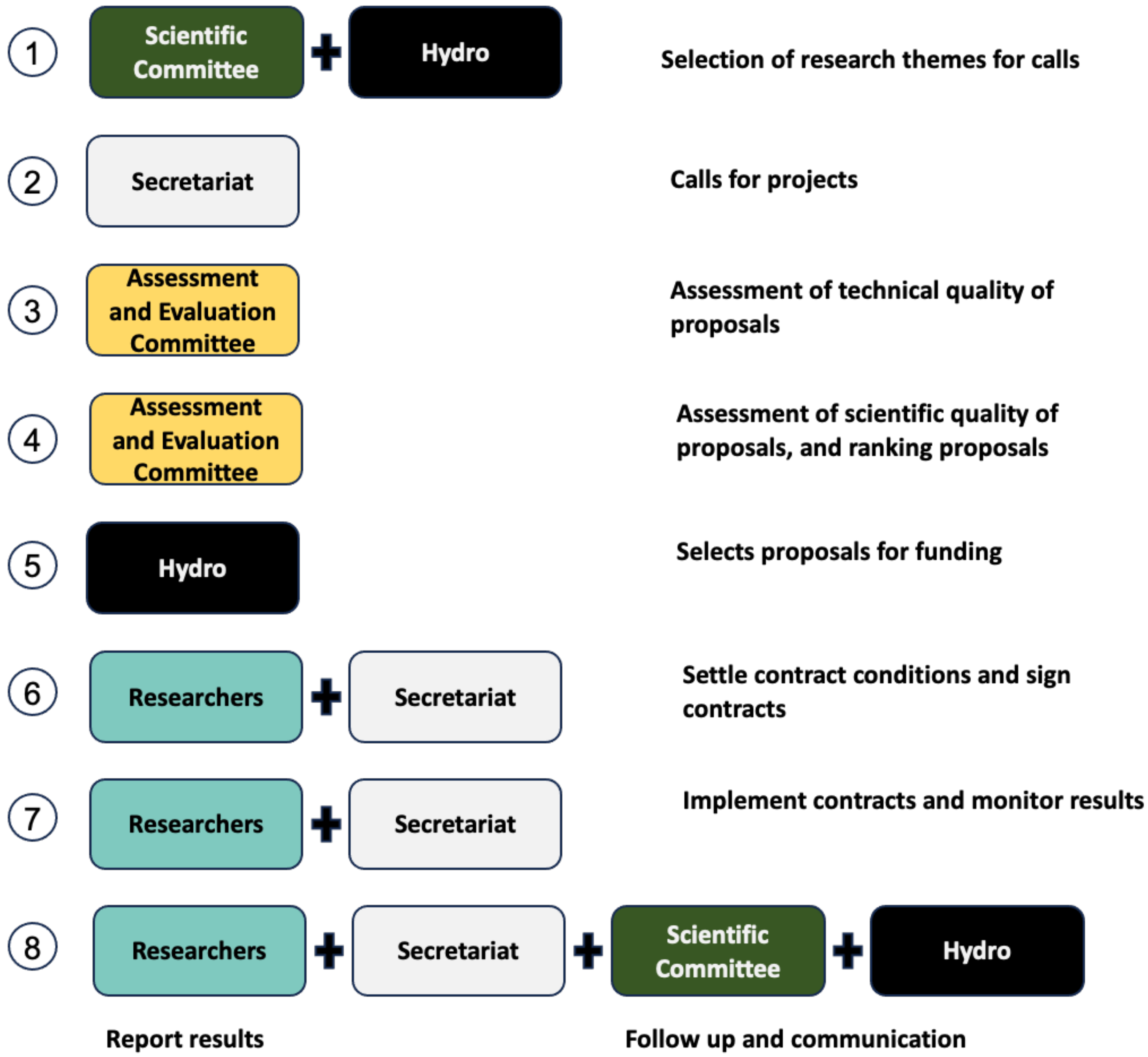
- Addressing important gaps identified in existing knowledge, not covered by current projects.
- Scientific quality, including innovativeness, clear objectives and research questions, and proper data collection methods and statistical analysis to obtain reliable results.
- Projects with a high academic impact, both in terms of scientific publications and increased qualification of students and researchers.
- Feasibility of proposed activities and deliverables.
- Adequacy of deliverables/products.
- Budget plan (Budget should be compatible with activities and deliverables).
- In-kind budget contributions from BRC partners and/or partial external funding.

The evaluation and selection committee will propose a ranked list based on the overall quality and relevance of the proposals. Before the evaluations, the BRC Scientific Committee will determine a threshold for the ranking of each proposal, below which proposals are not eligible for funding.

To assure that all the consortium partners are represented as project coordinators among the proposals to be funded, the following selection procedure should be followed:

- Of the proposals with ranks above the given threshold, the highest ranked proposal coordinated by each of the four scientific consortium institutions will constitute the four proposals of highest priority for funding.
- If funds are available to fund more than 10 proposals, the two highest ranked proposals coordinated by each of the four scientific consortium institutions will be given the highest priority.
- Other proposals classified above the threshold may be approved if they are in the BRC's interest and have the financial availability to do so, following the ranking list.

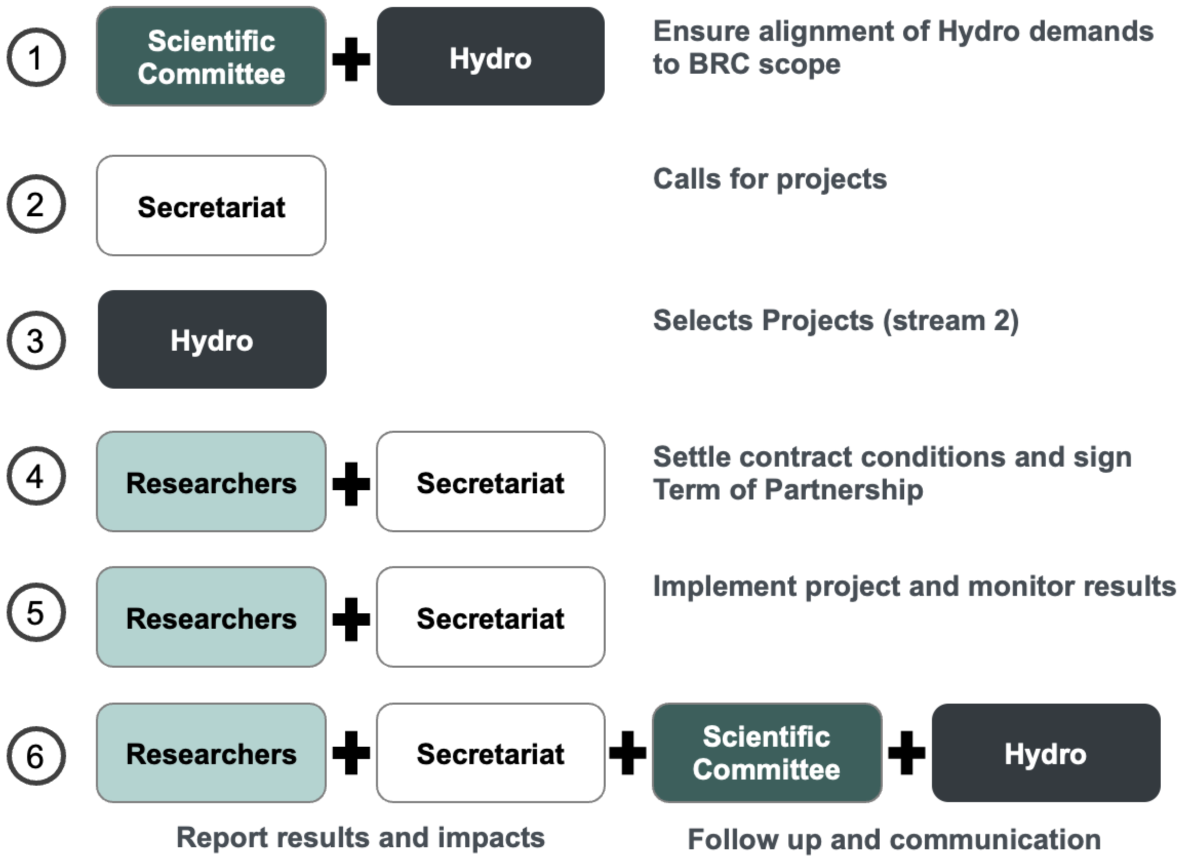
The ranked list of prioritized proposals with ranks above the threshold will be presented to Hydro and recommended to be funded.



B. Bidding Process –stream 2

The second stream starts with a request from Hydro to BRC to open a call for one or more project proposals with research theme or themes of high priority for the needs of Hydro´s operations. Before the call is announced, the BRC Scientific Committee will consult with the Research Programme and ensure that the research theme/themes is/are within the scope of the BRC scope.

The received proposals will be evaluated by Hydro, who also select the proposal/proposals that will be funded. The secretariat and each project owner will settle contract conditions and sign the Terms of Partnership. The project owner is responsible for implementing the project, including reporting of the progress of the project to Hydro and the BRC Scientific Committee. The SC will monitor the progress of the project. The results and impact of the project should be communicated in the project final report. The BRC Scientific Committee and the Secretariat may assist Hydro and discuss project results and propose how the results can be implemented by Hydro.



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