Updated Integrated Environmental Recovery Plan

PRAI

November 2016

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1.0 SUMMARY

After the failure of the Fundão dam, two main work groups were formed – one focused on socioeconomic issues and the other on socioenvironmental ones. The actions to mitigate the environmental damage along an extension of 650 km are part of the Integrated Environmental Recovery Plan – PRAI. The PRAI report shows that the activities already concluded, those in progress and those that are still being planned are interconnected and converge on the reclamation of the rivers and the environment. The file is aligned with the TTAC – Framework Agreement signed in March 2016 between Samarco and its shareholders VALE and BHP Billion – and the federal government and the state governments of Minas Gerais and Espírito Santo.

On an emergency basis, Samarco carried out initiatives relative to the **safety of the remaining structures of the Company –** located within the Germano complex in Mariana, which had been impacted by the Fundão dam failure. Also a priority was to focus on two other issues – **the expansion of the tailings storage capacity and the containment and control of erosion in the impacted areas along the river banks.**

In parallel with the initial efforts, two central themes of PRAI were implemented, conducted by Fundação Renova, an entity established pursuant to the requirements of the TTAC to conduct the recovery measures of the impacts caused by the dam event. The first is the development of a scientific basis for risk analysis and the reclamation process, consisting of a series of scientific and social evaluations which have the objective of guiding the decision-making relative to the medium and long term remediation. The second is related to the actions which will promote the reclamation of the rivers, always with the contribution and approval of the competent environmental entities. These two work fronts are active and involve actions of short, medium and long range.

The integrated recovery plan follows a phased risk-based, including impact analyses and execution of environmental recovery works over the next two to three years, followed by monitoring, maintenance and assisted reclamation of the environment. The objective of the plan is to reclaim the area impacted by the failure of the Fundão dam, along the rivers Gualaxo do Norte, Carmo, Doce and their tributaries, as well as implement actions of a compensatory nature which are going to contribute to the restoration of the environment in the basin of the river Doce. The plan is based on a series of integrated activities and according to the priorities based on science, knowledge and the needs of the communities. Although scientific evaluations still need to be concluded before serving as a basis for the ultimate recovery (with regard to the handling of the tailings) and conservation of the fauna and flora impacted by the event, there is a series of activities developed of an emergency character or which advance on the basis of the studies already carried out.

The focus of the present document is to describe, in an integrated form, the actions of environmental recovery, as well as compensatory actions which are being developed by the Fundação Renova. Among them the guidelines for the handling of tailings; environmental recovery of the area where there was deposition of tailings in the channels and banks of the rivers; compensatory actions of recovery of springs and APP's degraded in the river Doce basin; diagnostic of impacts to the aquatic and land-based fauna and conservation units, which will direct the actions of reparation; improvements in the systems of water treatment and monitoring of water quality in the river Doce basin and in the sea. The document also will present, in a summarized form, actions which were performed or are currently in progress on the part of Samarco with focus on the guarantee of the safety of the remaining structures and increase in the retention capacity of tailings in the area of the mining complex, avoiding new contributions of tailings to the environment.

As shown in Figure 1, the areas of primary focus for execution in the rainy season and in the short term are:

Focus on Safety – Assuring that the existing structures in the area of the dams keep a global safety factor higher than 1.5 and guarantee the safety of the barrier of the Candonga reservoir, by means of dredging of the sediments deposited in its reservoir..

Creation of storage capacity – Create additional storage capacity within the mine area and surroundings, through the construction of certain structures and the application of dredging methods to collect sediments. The local water discharge flow rate will be regulated through an operational spillway (variable) to help reduce turbidity downstream.

Erosion stabilization and control – Stabilization of sediments deposited along the banks of the rivers mentioned above, especially as preparation for the rainy season, but also with the objective of preventing long term erosion, and the start of development of vegetation and soil profiles. These actions initiated in an emergency character are the first steps for the environmental recovery of the stretch between Samarco and the Risoleta Neves hydro-electric power station.

Using science as a basis for evaluation of risk and remediation – Conclusion of a series of scientific and social evaluations to provide input for the risk assessments and guide the decision making relative to remediation.

River reclamation activities – Design, definition of priorities and conclusion of the remediation activities and restoration in a sequence focused on reaching the agreed objectives.

The approach is based on an adaptive methodology which seeks to test alternatives for recovery and analyze the monitoring so as to provide input for future developments and assure the efficiency of the project.

Figure 1 presents the integrated activities required over the short and medium range in order to reduce the risks and impacts of the coming rainy season and conclude the technical and scientific evaluations necessary to provide a basis for the full and integrated approach to river reclamation.

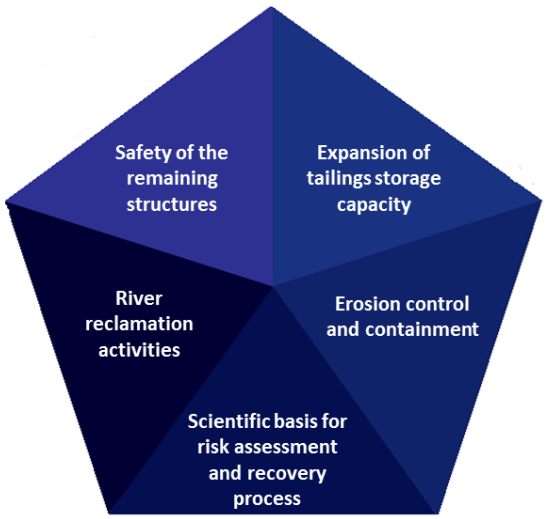

Figure 1: Consolidated view of the strategy adopted by Samarco for environmental recovery.

As this is an integrated environmental recovery plan, the approach has the broad objective of:

- Preventing any input of sediments or increase of turbidity in the impacted waterways;
- Recovery of the riparian forest and the river ecosystem;
- Recovery of the social and economic infrastructure of the affected communities in the shortest time possible.

Reclamation management in this timeframe allows the river system to readjust naturally, with the assistance of regenerative techniques and practical and monitored recovery. However, it is of the utmost importance that the intervention takes place in the short term (over the next two to three years) to stabilize and prevent the additional erosion of the tailings sediments along the banks of the rivers, and improve water quality.

2.0 INTRODUCTION

Based on the context presented in Section 1.0, this document has the objective of presenting the integrated methodology adopted by the Fundação Renova in the planning of the recovery actions. It will show that, in the months that followed the rupture of the Fundão dam, in November 2015, due to the emergency situation, several individual plans were developed based on technical studies at varying degrees of detailing, and, to lend sequence, others are being or will be developed in the future. It will also be demonstrated that the plans, albeit individual, follow a logical sequence which seeks to reconcile the urgent actions in the short term with the need to develop a broad ranging integrated recovery project in the long range.

In this regard, this report describes in detail the actions currently proposed and has the objective of describing the goals, restrictions and context of the previous, current and future planning in order to go beyond an isolated, out of context understanding about the strategy adopted and for the dialogue with several interested external players.

2.1 Summary of the Integrated Environmental Recovery Plan

The chart below (Figure 2) shows the process adopted initially by Samarco and the continuity of the same which is being conducted by the Fundação Renova in the planning of the recovery actions, in the form of a timetable. It is important to observe the separation that exists between the actions:

a) Emergency reinforcement of the structures and recovery of the infrastructure;

b) Containment of sediments and clarification of the water, and

c) Environmental, social evaluations and environmental reclamation of the rivers.

The reason for this grouping and its effects on the planning of the recovery actions will be addressed in greater detail in the following sections.

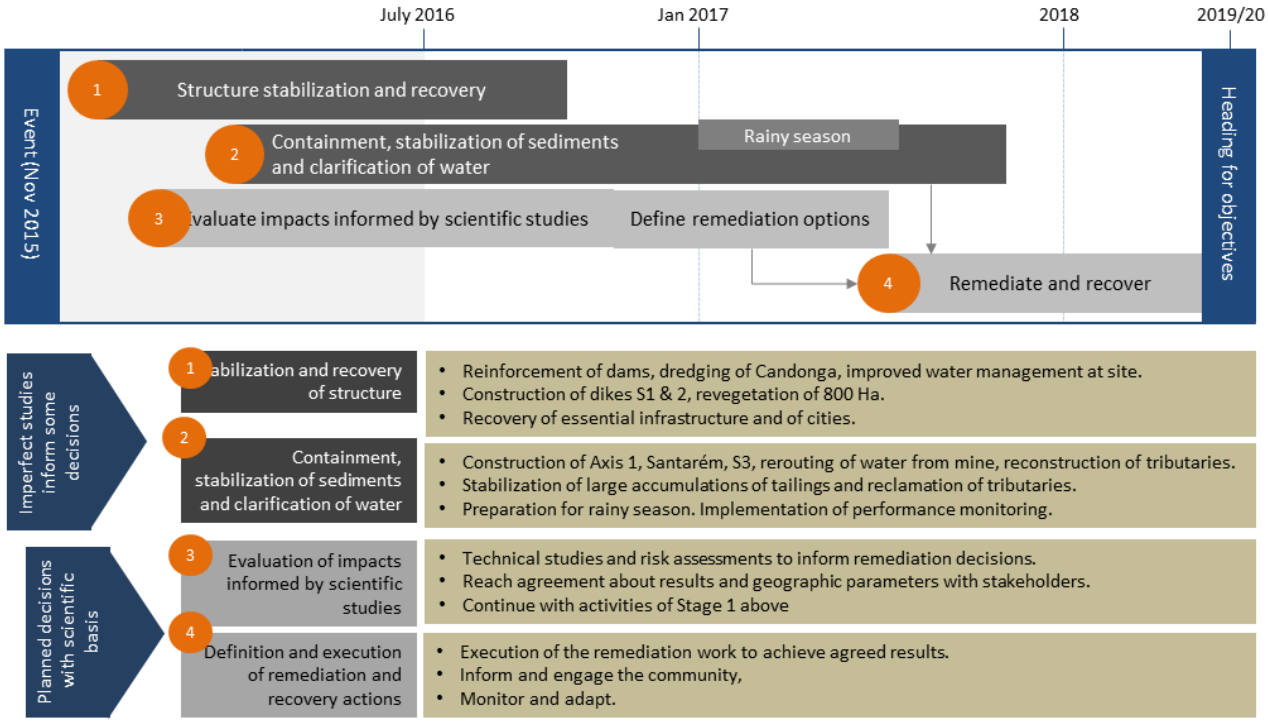

Figure 2: Timeline of the strategy adopted by Samarco and Fundação Renova for environmental recovery.

3.0 OBJECTIVES, RESTRAINTS AND ASSESSMENT FACTORS

This section presents the perspective of the Fundação Renova regarding the objectives of the recovery actions, the critical restraints and the assessment factors.

The planning of the recovery actions of the Fundação Renova has as its major objective the promotion of the recovery of the communities, the environment and the economic activities of the affected communities to return to the condition existing prior to the event. This overall objective may be divided into three sub-objectives with different timelines, defined in **Section 9.8**.

- Prevent entrainment of sediments and increase of turbidity during rainy seasons;
- Regeneration of the riparian forest and the river ecosystem in the long run;
- Recovery of the social and economic infrastructure of the affected communities in the shortest time possible.

The first two sub-objectives have as their main restraints time and natural processes. It is improbable that the actions that seek to avoid the entrainment of sediments and increase of turbidity during rainy seasons be effective in the first year. It is more probable that a term of 2 to 3 years will permit the execution of adjustments and improvements required. The rehabilitation of the riparian forest and the river ecosystem is, by definition, a natural process which, even though it can be initiated and facilitated by specific actions, it will follow its course over a longer period of time.

Main restraint on implementation in reclamation areas:

So far, the main restraint to the planning and execution of recovery alternatives has been time. We list below the main time restraint which has affected the fulfillment of the recovery objectives from the time of the accident:

In the first months after the accident, priority was given by Samarco to the emergency work on reinforcing the remaining containment structures and the recovery of critical infrastructure. In the actions to assure the structural safety and recovery of infrastructure – short term objectives – the time limitations implied in the need to abbreviate the planning process, since the postponement of these actions would generate even greater risks.

The second major time restraint is the upcoming rainy season. The dry season of 2016 allowed the development of supporting studies and discussions with stakeholders. In view of the number of players involved, the technical complexity, and the need to implement emergency actions, the time was not sufficient for a full and overall analysis of all of the possible alternatives, yet the postponement of the proposed actions would bring even greater risks.

The long term environmental recovery plans, however, will be less affected by temporal restraints. In fact, longer timelines will allow a better understanding of the results of the initial recovery actions. It will also be possible to hold deeper discussions with the interested publics about alternatives, benefits, risks and opportunities and a more iterative analysis of the results of the engineering studies and design.

Scientific basis of decisions: Another restraint to be taken into account is the limited scientific knowledge about the river, estuarine and coastal processes. For a full understanding of all of the underlying processes or those which may influence the decisions about the recovery actions, it is necessary to invest years of study. In other regions of the world, such as the Columbia river in the US, where studies have been ongoing for several years about impacts on the rivers, till today there is a debate about some of the conclusions generated.

Magnitude and Complexity of Recovery Actions: The complexity of some of the actions represents an additional restraint. The construction of dikes, the rerouting of waterways and the containment work on the river banks are complex actions which must be supported by proper engineering evaluations and studies. Whenever time permits, the best is to perform iterative cycles of investigation, engineering, execution and retrospective analysis. In complex works, another restraint is the pace of work. For example, the increase in the equipment fleet may accelerate the construction of the dikes, **yet the limitations of space, difficult access and properties of the materials make it impossible to work above a given construction speed without impairing safety and quality.**

Interaction with a natural system; /the projects for recovery of the rivers suffer another restraint due to the association of engineering with natural processes. The knowledge accumulated in the reclamation of a given river system may not be valid for other rivers or for other sections of the same river, making the initial stages of the recovery process at least partially experimental. In practice, this restraint implies that even the reclamation projects planned with the best expertise may not present the expected results, possibly requiring several years of adjustment until the projects attain full maturity.

Assessment of alternatives: The main assessment factors adopted initially by Samarco and, starting in August of 2016, by Fundação Renova are risks (considering the limits acceptable, support of the public or stakeholders (considering the minimum levels acceptable), and the feasibility of the recovery alternative. Experience from other projects indicates that these groups contemplate the interests of most of the stakeholders. However, the definition of what should be included in the group “support of stakeholders” , for example, may vary from one decision to another. The Fundação Renova recognizes that the complexity of the task assigned to each group may vary, depending on who is doing the evaluation.

Risk assessment: Three levels of risk are considered in the remediation process, which help to guide the prioritization of the activities and the focus of the work.

At the first level, the reduction of environmental, health and socioeconomic risks represents an essential part of the overall objective of the recovery actions. These risk assessments are being conducted in the field of

scientific studies, serving as a basis for definitions of the areas from which tailings are to be removed or the need for stabilizing given tailings deposits, definitions which are strongly influenced by the existence of risk to health or the environment.

The second level refers to the proposed actions and if they will achieve the expected results or, in the worst case, if they will be completely ineffective. These so-called “performance risks” are considered in the emergency and rainy season actions, being one of the fundamental aspects to be considered in the analyses of monitoring of the recovery projects. In the emergency works this type of assessment allows one to define whether the risk with a given recovery solution (such as Dike S3) will be lower than if no measure is taken at all.

The third level refers to the *residual risks*, in other words, the risks which remain even when the recovery actions are duly planned, executed, monitored and, if necessary, adjusted. These risks are inherent to river reclamation projects and may extend over time. This reasons, in and of itself, makes it important for these risks to be openly discussed and considered in the evaluation of the recovery alternatives. The knowledge of these risks is one of the factors which reinforces the need to manage the tailings based on a robust scientific foundation, mitigating the risk of having the movement of the sediments generate greater impacts than those which would be generated if no interventions were made, in addition to extending over time the solution which is being sought for society and the environment. In Section 8.0 we present the results available from the analysis of the impacts caused by the Fundão dam break on the environment. The information presented in this chapter and the reference documents show that the risks of leaving the tailings where they are, until the conclusion of the studies required to determine their definitive disposal, is low when compared to the residual risk of moving the tailings without sufficient scientific basis (definition of the real need for removal of the tailings from the environmental and social standpoints, definition of the site of disposal, and proper handling methodology).

4.0 PLANNING METHODOLOGY ADOPTED

This section describes the general methodology adopted by the Fundação Renova in the planning of the recovery actions.

4.1 Alternatives, decisions and time factor

The planning of the recovery actions consists basically of a series of decisions about the recovery alternatives, taking into account factors such as risks, time, restraints and feasibility. Ideally, each decision should be based on a complete analysis of all the possible alternatives considering the objectives, restraints and evaluation factors.

In view of the large number of possible alternatives to address the risks and deadlines in question, the planning of the actions for recovery from the impacts requires adopting a hierarchy of assessment of alternatives. First, one studies a broad range of alternatives with major differences amongst them, and then, the more subtle details and differences among the alternatives. The sequence of the studies regarding scope, pre-feasibility, feasibility and detailed design are an example of the planning hierarchy normally used I the mining industry.

Options and decisions in the emergency period: As noted in the section above, the Fundão recovery projects are subject to different time restraints. The emergency nature of the initial measures to reinforce the structures, and the current urgency in starting to prepare for the rainy season, curtailed the planning cycle. Even though Samarco has not failed to evaluate alternatives in all cases, the time restraints have prevented a complete and iterative assessment. Priority was given, therefore, to the identification of feasible alternatives and the minimization of potential risks associated with these alternatives, assuring that they are always lower than those that would result from not implementing any measures. In some cases, the processes, having been compacted due to time restraints, may be subject to future revisions. However, it is

possible to affirm that if one were to await the conclusion of more detailed studies, the risks would be unacceptable for all parties concerned.

Longer term decisions: as the projects progresses to the environmental recovery actions covering a longer timeframe, attention will once more be given to a more detailed analysis of alternatives. Particularly, there will be sufficient time to obtain more input for Fundação Renova to evaluate with greater certainty, including other perspectives about alternatives, objectives, restraints and risks. There will also be more time for scientific and engineering studies and for the performance of analysis by the competent authorities of the final planning proposed by the Fundação Renova without compromising the safety of the communities.

4.2 Scientific basis for decision making

The decisions about recovery actions should be supported by scientific studies in various disciplines, considering the time available and the urgency in implement the measures, including:

- Geochemical studies to evaluate if the tailings are toxic or could compromise the quality of the water
- Geomorphologic studies to identify the mechanisms of mobilization, transport and deposition of the tailings
- Ecological studies to evaluate the effects of the tailings on the habitat and aquatic fauna of the rivers, tributaries and adjacent marine areas
- Studies for adjusting the soil to evaluate if the distribution of sediments along the banks and flood plains will inhibit the reconfiguration of the topography and the vegetation
- Social and economic studies for diagnosis of the main impacts of the tailings and the recovery works on the industries, rural producers and infrastructure.

Some of these studies have already been developed and delivered to the competent entities. In any case, the expression “as time permits” is an important reservation. The studies above follow a logical sequence. For example, the geochemical studies identify the overall potential for toxic effects and, therefore, generally precede the ecological studies of the soil adjustment studies. As in all scientific fields, it is important for the studies described above to be the subject of iterative analyses and in-depth reviews.

In some cases certain decisions need to be made before it is possible to consolidate the scientific knowledge due to the emergency of the situation, although nothing is to be done without reasonable technical substantiation. This was exactly the case with the actions of structural reinforcement and recovery of infrastructure, where the emergency works started immediately after the accident, still in the rainy period, as well as the activities in preparation for the rainy season of 2016/2017, related to the containment of sediments and clarification of water. The decisions about the long term recovery actions have more scientific support, but it is probably and technically acceptable that some occasional uncertainties will remain. In this regard, it is essential that in all of the planning phases of the recovery actions, consideration be given to all the available scientific evidence, including any remaining uncertainties. Yet it is equally important that the recovery plans of an urgent nature do not become hostages to the need for a *perfect scientific basis*, under the penalty of impeding the execution of measures which are necessary and urgent, and creating other risks arising from lack of action. The reports and studies which support the decisions and the development of alternatives are detailed in **Section 8.0** of this report.

4.3 Technical support for recovery alternatives

As seen in Section 2.0, many of the recovery actions proposed consist of complex projects which require the development of engineering studies and design before their execution. These actions are subject to temporal restraints similar to those mentioned above with regard to the scientific studies.

In order for planning to take place within the established timeframe and meet the emergency needs of the situation, it is also important for the decisions to be based on reasonable considerations, as opposed to expectations of a *perfect technical basis*. In general, the level of engineering detail increases as the number of available alternatives goes down.

The initial selection of alternatives in the first six months after the event was based largely on experience and on engineering knowledge already acquired, and not only on specific scientific studies, in view of the urgency of the circumstances. In the subsequent phases of recovery action planning, where the number of possibly alternatives is reduced, one expects that the differences among the various alternatives can be clearly defined with little engineering effort. But, in some cases, more intensive engineering studies may be required to understand the subtle differences in the levels of technical risk. An open dialogue from the very beginning about the uncertainties associated with each decision may help The Fundação Renova and the regulatory bodies to define by mutual agreement the suitable levels of engineering efforts.

The engineering reports or studies which are or soon will be submitted are described in **Section 9.0** of the report.

4.4 Risks and uncertainties

The various types of risks involved in the planning of the recovery actions were described in Section 3.0. The risks, and, more broadly, the uncertainties, have a great influence on the planning of the actions. The assessment of risks and uncertainties will seek to:

- Understand risks to the environment, to human health, and the socioeconomic aspects in the current situation, and define, by mutual agreement, the objectives of reduction of these risks
- Evaluate the uncertainties associated with the success of each alternative, and consider them in the selection of the alternatives.
- Understand and communicate the residual risks which remain after the conclusion of the recovery action.

4.5 Monitoring and adaptive management

The Fundação Renova is aware of the limitations of the current status of scientific and engineering knowledge of river reclamation actions and the restraints impacting the planning of these options. Monitoring and adaptive management are, therefore, important strategies to manage these restraints.

Monitoring allows the evaluation of the effectiveness of the recovery actions. The assessments made by IBAMA in the phases Hélios – the Argos of the Augias operation (see Attachments of the Section 4.0) brought some good examples of monitoring techniques which can be employed in the evaluation of the performance of recovery actions, such as the reclamation of tributaries. The recommendations presented in the report of the Hélios phase were discussed in specific forums with IBAMA and are being considered in the actions of recovery of the area impacted. The Fundação Renova had access recently to the report of the Argos Phase and is working on a plan of action to comply with the recommendations of IBAMA.

Adaptive management is a process whereby the performance aspects are formalized in the form of scientific hypotheses, allowing the conception of monitoring programs to definitively address these issues.

Thus, the inclusion of an adaptive management process creates a feedback cycle to improve the remediation techniques over time.

The monitoring of the performance during the upcoming rainy season will be essential to serve as input to the development of projects to achieve the desired results, such as the reduction of turbidity and the transport of sediments from large deposits along the Gualaxo do Norte river. Thus, the fact that it is necessary to carry out actions of containment of sediments and clarification of water in the short range brings a positive aspect – there will be a set of recovery actions in full scale to be evaluated in the next rainy season.

4.6 Reference documents of Section 4.0 (See Attachment Section 4.0)

DOCUMENT	DOCUMENT TITLE	COMPANY	DATE
relatorio_fase_hélios_ operacao_augias	Relatório Fase Hélios - Operação Áugias (NAP DOCE)	IBAMA	Jul/16
relatorio_fase_argos _operacao_augias	Relatório Fase Argos - Operação Áugias (NAP DOCE)	IBAMA	Out/16

5.0 DEVELOPMENT OF RECOVERY PLAN USING CURRENT INFORMATION

Figure 2 shows the timetable of the Fundação Renova and of Samarco for the main actions related to the three main axes:

- Emergency reinforcement of the structures and recovery of infrastructure
- Containment of sediments and clarification of water and
- Environmental reclamation of the rivers.

This chapters summarizes the actions proposed for groups 1 and 2. It is important to remember that the lower level of detailing is intentional, since the focus is on the planning methodology.

Section 2.0 of this report presents a complete summary of the activities.

Figure 2 presented the process of execution of these phases and shows the connections among the various actions in the initial stage, which are thoroughly detailed in this report, as well as the assessment of impacts and proposal of guidelines for the handling of the tailings described in the document nº RT-023_159-515-2282 (see **Attachment Section 5.0**).

The recovery and stabilization methods adopted so far are based on:

- Our understanding of the mechanisms of sediment transport and distribution
- The time needed to implement any specific solution
- The feasibility and effectiveness of the solution (safe and practical).

As knowledge increases and the information about the performance of the initial solutions is evaluated, future solutions should have a wider scope, and be more and more effective and adequate. Due to time restraints, technical assessments still exist to be concluded to provide input, in a more complete form, for the evaluation of the options. Consideration has not yet been given to the use of emerging technologies, except on an experimental basis, since the primary focus is on adopting safe, well known and practical solutions. The methods adopted are concentrated in the following broad categories of recovery efforts.

5.1 Reinforcement of structures and recovery of infrastructure

The containment and recovery of the infrastructure of existing tailings have been, without a doubt, the most important activity conducted by Samarco in the first months which followed the event occurred at the Fundão dam.. The work concluded so far assures the stability of the existing structures through the execution of recovery works and minimization of erosion (rerouting of the water). On the other hand, new structures have been conceived, some of them already being built, and they all together represent an integrated solution for the containment of sediments. The techniques adopted for the recovery of structures reflect best engineering practices, with exclusive application of alternatives which have already proven to be effective in other locations.

5.2 Sediment containment and water clarification

Physical structures in the river are considered to be the most appropriate measure to minimize, quickly and effectively, the discharge of sediments during events of mass movement or the continuity of erosion after rains. Samarco has made and continues to make a major effort for the installation of these structures. The containment solutions developed for the emergency and for the initial rainy period sought to install proven and simple alternatives, with criteria of known performance, effectiveness and risk management control. Essentially, the concept consists of a series of dams and dikes.

5.3 Environmental reclamation of the rivers

Figure 2 also presents the environmental recovery actions along the Gualaxo do Norte, Carmo and Doce rivers. The priority actions for the next rainy season are in progress or in an advance stage of planning. The integrated medium and long term planning for all of the affected areas is in the initial phase of development.

5.3.1 Stability of tailings and environmental recovery

Large deposits of sediments resulting from the tailings are found along the first 75 km of the river banks. These deposits will continue to generate turbidity and a sediment load in the river during the rainy periods. Therefore, the stability of this material is an important control tool in the short and medium term. The alternative to the stability is the removal of the sediment (described in **Section 5.3.2**). Evaluations, including t IBAMA reports (Report Phase Helios and Argos, see **Attachment Section 4.0**), were / are being analyzed and, when applicable, considered by the Fundação Renova as points of improvement, identifying priority areas and activities and establishing success factors that are feasible and realistic (**Section 7.0**). Although most of the studies are wide ranging, there is still uncertainly as to the most effective and sustainable

environmental controls and stability measures, thus requiring adaptive management over many years. The current controls are based on the best geomorphologic and hydrological information available, as well as on the accumulated experience in other part of Brazil and around the world. Monitoring will continue to be an important activity in the optimization of the performance and design. The stability activities in execution are described in **Section 7.3**, including the drainage control and the configuration of the contour of the flood plains, the recovery of tributaries, revegetation and armoring of the main channel.

5.3.2 Removal of tailings

The two main methods of removal of sediments are being applied – namely, excavation and dredging. Excavation and removal of tailings along the banks of the rivers are currently limited to the cities and the infrastructure area. The removal of sediments will be considered more broadly as part of the planning of environmental and social impact as described in **Section 9.1** (document nº RT-023_159-515-2282, see **Attachment Section 5.0**) and will require a series of integrated social and scientific studies to serve as a basis for the definition of priorities and the areas for removal, disposal and recovery. The attempt to remove sediments along the river should be based on considerations which require more thorough technical analysis and understanding of the potential risks. Tailings were removed from the river and cities, with the excavation/dredging up to this time approximately 680 thousand m³ (150,000 m³ in Barra Longa and 530.000 m³ in the reservoir of the Risoleta Neves Power Plant), which were taken to a disposal area as part of the efforts of recovery of the cities and maintenance of the stability of the Risoleta Neves Power Plant. In addition, some 2.3 Mm³ of tailings were incorporated into the topsoil, in a provisory and emergency manner, as part of the works of reconfiguration of the terrain and preparation for planting – both for emergency revegetation of 800 ha (shown in detail in **Section 7.3.3**) and economic recovery of rural properties. The definitive destination of this volume of tailings already handled will be defined after the conclusion of the evaluations described in the flowsheet “decision making process on tailings management” presented as one of the Attachments of **Section 9.1,** which is being made in conjunction with the responsible environmental agencies.

5.3.3 High priority areas

The geomorphology study and the associated investigations pointed to 16 areas of tailings disposal as being prioritary for the containment actions for the next rainy season. The recommended actions have the objective of preventing the erosion of large accumulations of sediments on the banks and floodplains of the rivers and their tributaries, through measures of topographic reconfiguration and drainage control, armoring and bioengineering.

Various containment techniques were evaluated in the development of plans for the priority areas, generally based on the experience acquired in other regions. Some of these techniques have already been or will be implemented before the next rainy season. Their effectiveness will be assessed by means of an adaptive management program and monitoring in the rainy period, contributing to future planning.

Over the next two years, continuity will be given to the dredging of the Candonga dam and the modernization of the water treatment plants and supply systems to prevent impacts on industries and on human health, and to mitigate the risk to the stability of the dam.

5.4 Integrated Environmental Recovery Plan of the Affected Areas

The environmental recovery of the areas impacted by the tailings of the Fundão dam includes the recovery of the physical environment (in the area where there was deposition of tailings within and outside the

channels of the rivers, identified as Environmental Area 1), diagnostic of impacts to the fauna as much as aquatic as land-based and actions of conservation for reparation of the impacts mapped out.

The recovery of the Environmental Area 1 involves 8 (eight) principal steps as indicated below:

1. Creation / recovery of accesses (completed);
2. Initial ground cover with grasses (complete, currently receiving maintenance);
3. Recovery of the tributaries (in progress – 58 recovered of 92 mapped out);
4. Reconfiguration and control of erosion of the plains (in progress);
5. Regularization of the river banks (in progress);
6. Revegetation of the river banks and plains (to be performed after the execution of items 4 and 5);
7. Planting of agriculture (to be performed after the execution of item 4);
8. Planting of riparian forest (to be performed after the execution of item 6).

The eight steps listed are presented in a schematic form in the following figures:

Figure 3 – Schematic representation of the steps 1 to 3 of the environmental recovery.

Figure 4 – Schematic representation of the steps 4 and 5 of the environmental recovery.

Figure 5 – Schematic representation of the steps 6 and 7 of the environmental recovery.

Figure 6 – Schematic representation of step 8 of the environmental recovery.

The processes of identification and evaluation of alternatives and the full planning of the environmental recovery actions will continue through to 2017. The extension of the timeline is necessary for the conclusion of the scientific studies and for the execution of the prioritary actins in the rainy season of 2016/2017. The proposed schedule has the further advantage of allowing a greater participation by the inspection entitles and other stakeholders involved in the selection and analysis of alternatives.

The integrated plan will be largely based on the results of these evaluations, but will also have sections dedicated to the residual risks associated with the stability of the structures, the containment of sediments, the clarification of water and the prioritary areas.

5.5 Performance criteria of environmental recovery actions

The performance criteria for the environmental recovery actions in the rainy season include specific objectives for the areas which are deemed prioritary, including:

- Revegetation of 800 ha in impacted areas;
- Development and implementation of a monitoring plan for the performance of the containment

measures, based on the principles of adaptive management.

The performance criteria for the integrated plan are yet to be defined, but in the TTAC (the Framework Agreement) signed on 02 March 2016, some examples of possible criteria were put forth:

- Reduction of turbidity to <100 NTU in the Gualaxo do Norte by the dry season of 2019;
- fulfillment of the commitments related to water supply by mid 2018;
- management of the accumulated sediments in the Candonga dam by the end of 2016;
- Rehabilitation of 2,000 ha by March 2020;
- Reclamation of 5000 springs, at the rate of 500 per year over ten years.

The expectation is that some of the criteria above will be replaced by other broader ones. For example, the objective of 100 NTU is actually the reflection of a wider ranging action of recovery of water quality and of water resources. The final definition of the performance criteria must be based on scientific studies and by performance monitoring, being a core element of integrated planning.

Operação Áugias of IBAMA provides a solid basis for the definition of the performance criteria and the Fundação Renova has been considering these performance criteria, both for the rainy period and for the long term, be developed jointly with the main stakeholders.

In addition to technical criteria, it is also important to define criteria related with processes for integrated planning. The Agreement brings an example upon referring to the recovery plans, taking into account the local socioeconomic benefits. Another possible criterion related to processes would be for the process of identification and evaluation of alternatives to be totally transparent, assuring the time and opportunities needed for the participation of the stakeholders, for the scientific and technical bases to be duly detailed, for the results and residual risks to be discussed with transparency and defined by mutual agreement among all parties, and for there to be an adequate provision for monitoring and adaptive management. In short, one must make the best use of the time available to assure that all the issues raised in Section 2.0 are dealt with properly.

5.6 Reference documents for Section 5.0

DOCUMENT	DOCUMENT TITLE	COMPANY	DATE
RT-023_159-515-2282	*Avaliação dos Impactos Físicos Associados ao Rompimento da Barragem de Fundão - Relatório Técnico*	Golder	July/16
RT 003-159-515-2282 02-B PT	*Relatório do Plano de Amostragem e Análises (SAP) que descreve as investigações de campo e de laboratório planejadas como parte do estudo de caracterização geoquímica de rejeitos, solos e sedimentos.*	Golder	**August/16**
RT 008-159-515-2282 02-B	*Relatório de Trabalho de Campo que descreve as atividades dos trabalhos de campo conduzidos pela Golder Associates Brasil Consultoria e Projetos Ltda (Golder) entre os dias 23 de Janeiro e 12 de Abril de 2016 como parte do Programa de Caracterização Geoquímica de Rejeitos, Solos e Sedimentos (Golder, 2015).*	Golder	**August/16**

Anexo A	*Lista de amostras coletadas*	Golder	**August/16**
ART Golder	*ART da Empresa Golder Associates*	Golder	**May/16**

6.0 TECHNICAL ASSUMPTION UNDERPINNING CURRENT RECOVERY ACTIVITIES

This Section sums up the overall understanding of the distribution of tailings along the path from the mine to the Candonga dam. These estimates varied over the past nine months, as more data became available. The decisions on emergency works and infrastructure had to take into account the information available at the time.

6.1 Distribution and Volume of Tailings

Table 1 and **Figure 7** present a summary of the estimated tailings volume between the mine and the Candonga dam in July 2016.

Table 1: Summary of the estimated volume of deposited tailings all the way to the Candonga dam.

Component	Volumes (Mm^3)			Description	Source of information
	Nov/2015 (before break)	Jul/ 2016	Difference (discharged or accumulated)		
Fundão dam	56,4	12,8	-43,8	Material lost by rupture and subsequent losses	Samarco (topography)
Santarém dam	7,8	9,8	2,0	Deposition	Samarco (topography)
Deposition in Santarém upstream of S2A	0,0	0,3	0,3	Deposition	Samarco (topography)
Deposition in Santarém upstream of S3	0,0	1,3	1,3	Deposition	Samarco (bathymetrics)
Bento Rodrigues area	0,0	1,2	1,2	Deposition	Golder (drilling)
Flood plains of Gualaxo do Norte as far as Rio Doce	0,0	11,2	11,2	Deposition in flood plains	Golder (drilling)
Channels of Rio Gualaxo do Norte as far as Rio Doce	0,0	2,8	2,8	Deposition in channel	Golder (drilling)
Candonga dam	0,0	10,5	10,5	Deposition behind dam	Samarco (bathymetrics)

Fundão – The volume of tailings remaining within the Fundão structure is estimated at approximately 12.8 Mm³. Section 8.2 describes the study which details the methods used to estimate the numbers and the changes in the volumes from 5 November 2015 on, due to erosion and instability.

Santarém to Bento Rodrigues – A large volume of sediments discharged during the event was deposited in Santarém and along the banks of the upper Gualaxo do Norte river as far as Bento Rodrigues. The estimated volume is 12.6 Mm³, of which 9.8 Mm³ are deposited in the Santarém dam and a total of 1.6 Mm³ is deposited in the areas of Dikes S1A, S2A and S3. The rest (1.2 Mm³) is deposited in the valleys, tributaries and banks of the river system.

Bento Rodrigues to Candonga – The volume of sediment deposited downstream as far as Candonga is estimated at 14.0 Mm³, of which approximately 4 Mm³ are considered as movable and subject to re-entrainment and transport. Large deposits of sediments are found in the flood plains. Golder identified the main points of deposition (document nº RT-023_159-515-2282, See Attachment **Section 5.0**).

Candonga – The Candonga dam served as an important containment barrier, retaining a large quantity of the sediments flowing downstream. After the event, the volume of tailings is now 10.5 Mm³ (document nº RT-023_159-515-2282, See Attachment **Section 5.0**).

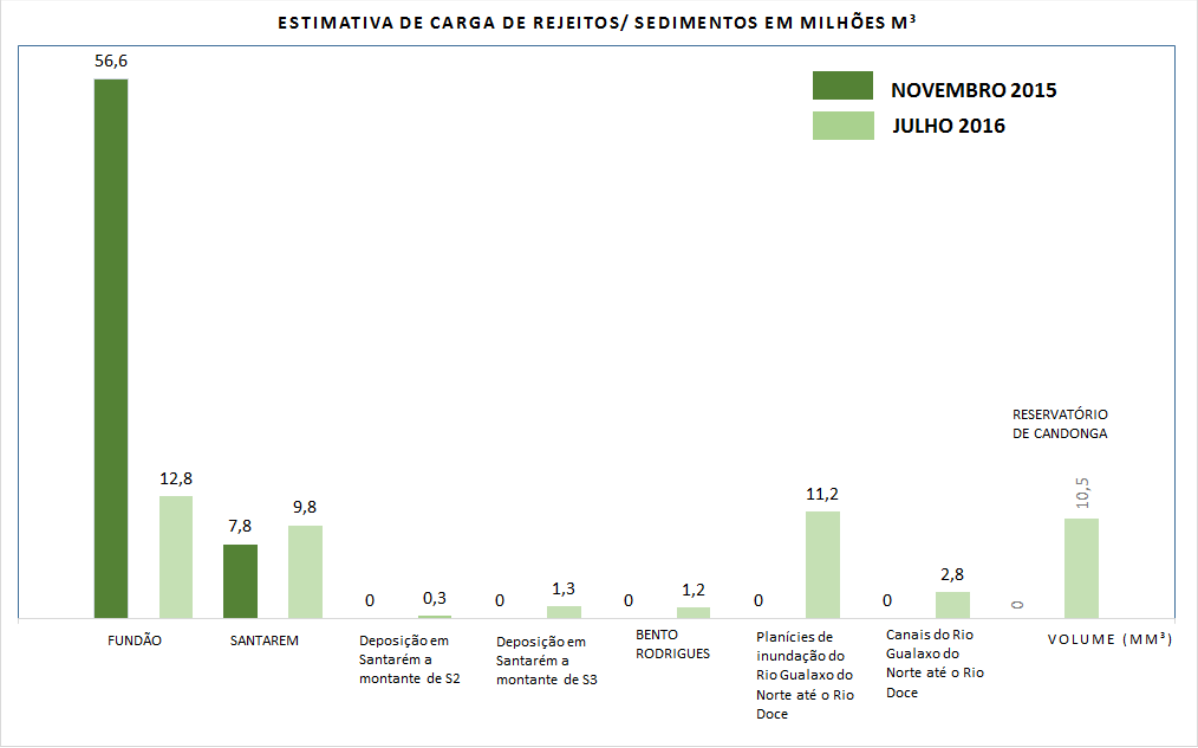

Figure 7 – Estimate of tailings/sediment load in millions of m³ (Source: Golder, RT-023_159-515-2282, Attachment Section 5.0).

The Foundation Renova recognizes that part of the sediment passed through Candonga because of the event and later in the form of finer suspended loads. The definition of sediment volumes deposited along the river Doce but downstream of Candonga and the ocean was not considered in this document.

7.0 IMMEDIATE PRIORITY ACTIONS

7.1 Safety Focus

Immediately after the incident with the Fundão dam, Samarco began the mapping of the impacts in the remaining structures of the Germano Complex, having in sight that five structures suffered impacts (Dikes of Sela, Tulipa and Selinha and the dams of Germano and Santarém). Faced with this, design companies, and external consultants made many inspections of the site and mapped the actions necessary for execution of the emergency reinforcement of said structures, making it possible that these same structures may be rebuilt to support the loadings of their previous conditions and to the parameters established in the Brazilian technical standards. The construction works were begun immediately.

Looking to reduce the impacts of the rains, Samarco began in December/15 the installation of the system of pumping of the existing superficial waters in the Germano dam, whose spillway operates through the Tulipa Dike and the discharge occurs within the Fundão valley. The pumping was implemented, the works concluded in February/16 and the current installed capacity is approximately 5.780m³/h. Of this volume, 1700m³/h are destined to Concentrator II, where the volume is treated and discarded in the valley of the Piracicaba river. The rest is discharged downstream of the Germano Dam, so as not to flow through the Fundão Valley.

Figure 8 presents a summarized form of the status of the works of reinforcement executed on the remaining structures of the Germano complex.

Estrutura	Obra	Status
Selinha	Implantação de berma de reforço na sua porção inferior	28/12/2015
Sela/ Tulipa	Reforço na ombreira comum e reforço nas seções críticas de Tulipa	Setembro 2016
Tulipa	Readequação do sistema extravasor ao lado do atual	Março 2016
Germano	Implantação de berma de reforço para recompor erosões e recomposição da drenagem superficial	18/06/2016
Santarém	Prolongamento da drenagem interna, construção de aterro de reforço e recomposição da crista	19/02/2016

Figure 8 : Emergency works of containment and stabilization executed during the rainy period 2015/2016

All of the structures already have global (overall) safety factors above 1.5; as indicated in **Table 2**.

The operational conditions of the structures are assessed monthly by the companies BVP Engenharia and Norwest, such that the data is presented with the same frequency to the DNPM – Departamento Nacional de Pesquisa Mineral [National Department of Mineral Resources].

In addition to this, the companies Norwest and DAM perform independent audits assessing the operational conditions of the structures.

A fourth company – AECOM – analyzes independently the operational conditions of the remaining structures and reports the results directly to the Public Prosecution Office of the State of Minas Gerais.

Table 2: Overall Safety Factors of the remaining structures.

STRUCTURES		Oct/16
SANTARÉM		2.87
GERMANO		1.98
SELA/TULIPA	SELA	1.54
	TULIPA	1.65
	COMMON ABUTMENT	1.58
SELINHA		1.86

7.1.1 Handling of Superficial waters

As a way of increasing the control of the contribution of water from the hydrologic basins in the valley of the Germano, Santarém and Fundão dams resulting from the drainage (perennial or intermittent) and from the regional rains, Samarco is re-designing the handling system of superficial waters. The general concept of the system, objectives and capacities are presented in a summary form in this chapter. More detailed information about this activity can be found on the page of the company in the internet www.samarco.com.

The main objectives of this system are:

- Deviation of water to facilitate the execution of the infra-structure works;
- Reduction of the entrainment of solids downstream; and
- Contribute to the safety of the remaining structures.

The measures already implemented are listed in Figure 9. Figure 10 illustrates the flows pumped at each structure.

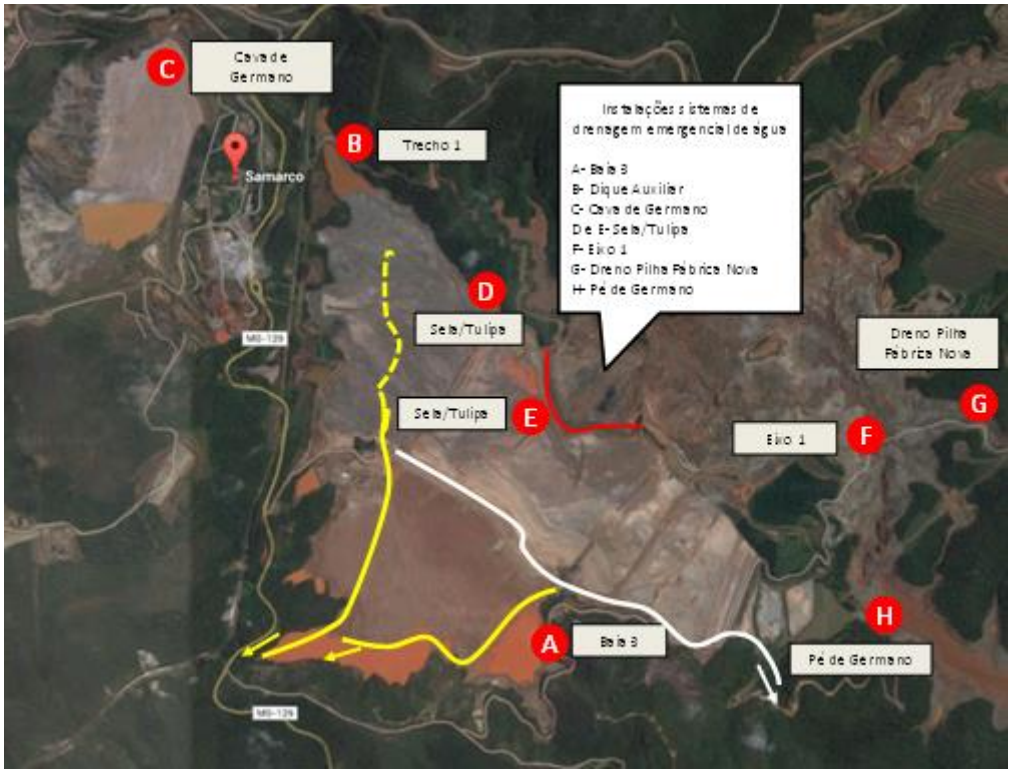

Figure 9: Location of the installed pumping systems – Red Points.

LOCAL	ATUAL (m³/h)	ADICIONAL (m³/h)	TOTAL (m³/h)
Cava de Germano	1.070	0	1.070
Barragem Germano:			
Dique Auxiliar	1.170	0	1.170
Sela/Tulipa	1.920	0	1.920
Baia 3	1.620	22.000	23.620
Total Barragem Germano	4.710	22.000	26.710
Sub-total do desvio de fluxo água superficiais	**5.780**	**22.000**	**27.780**
Eixo 1 (Fundão):			
Bombeamento	6.000		6.000
Dragagem	400		400
Sub-total do desvio do Eixo 1	**6.400**		**6.400**
Dreno da Pilha de Fábrica Nova	240		240

Figure 10: Summary of Flow Rates Pumped.

7.1.2 Emergency Systems

7.1.2.1 Emergency Warning Systems

Immediately after the accident with the Fundão dam, Samarco started the implementation of the Emergency System for the area of self rescue and throughout the coverage area resulting from studies of the " DAM BREAK" between Germano unit and the city of Barra Longa - MG.

The system was specified with long-range sirens (Pavian model) meeting the requirements FEMA (Federal Emergency Management Agency) as described below:

• Sound power to range up to 2,000 meters;

• 70dB minimum acoustic power at the edge of the coverage area;

• Possibility of emitting beep tones and loudspeaker;

• Communication with control unit by two or more media;

• Control unit with drive data log (Vektra); and

• Self testing of multiple siren System.

Figure 11: Long Range Sirens.

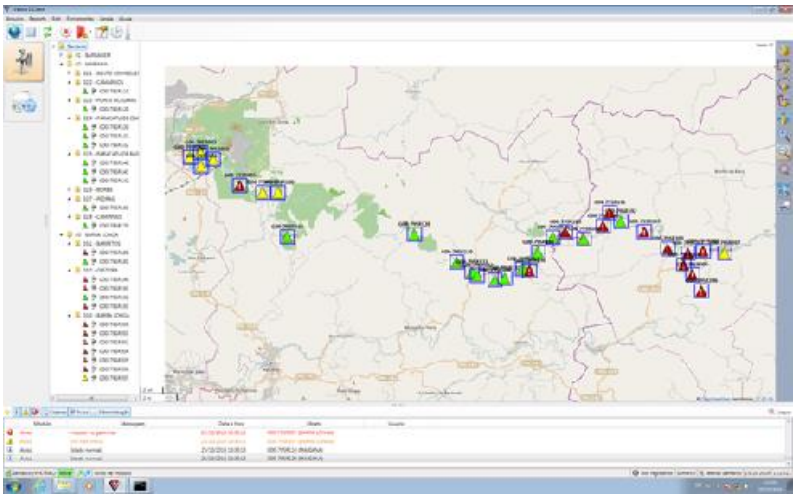

Figure 12: Command center with activation data log (Vektra).

To meet the needs of the areas of self rescue as well as the communities of Mariana and Barra Longa, the following sirens will be required: 31 (thirty-one) sirens distributed as follows, 5 in Dams areas, 2 in Bento Rodrigues, 1 in Camargos, 1 in Ponte do Gama, 3 in Paracatu de Cima, 3 in Paracatu de Baixo 1 in Borba, 1 in Pedras, 1 in Campinas, 2 in Barretos, 4 in Gesteira and 7 in Barra Longa.

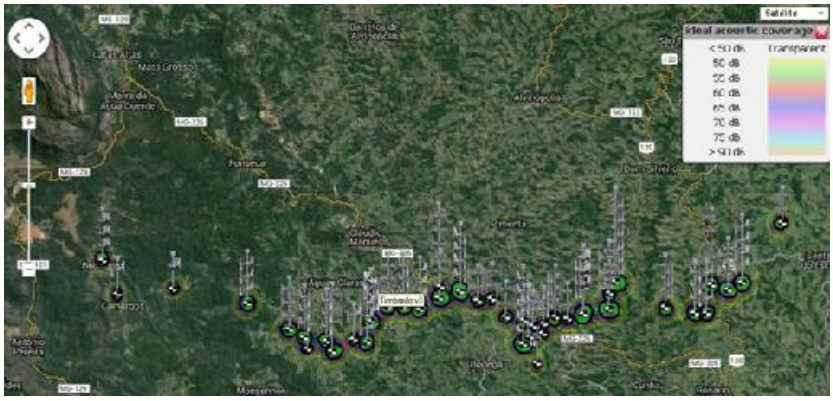

Figure 13: Overview of all Sirens

Figure 14: Sirens of the Germano and Santarém dams .

Figure 15: Sirens of the Communities of Mariana

Figure 16: Sirens of the Barra Longa communities.

7.1.2.2 Warning System against Floods

Renova Foundation is implementing the warning system against floods in the basin of the Carmo river, specifically for the riverside towns of the Gualaxo do Norte river and the urban area of the city of Barra Longa - MG, which is based on prior knowledge of the occurrence of precipitation events, in terms of intensity and spatial and temporal distribution, as well as the likely response of the basin to these events, in terms of generating flows and possible floods in river stretches of interest.

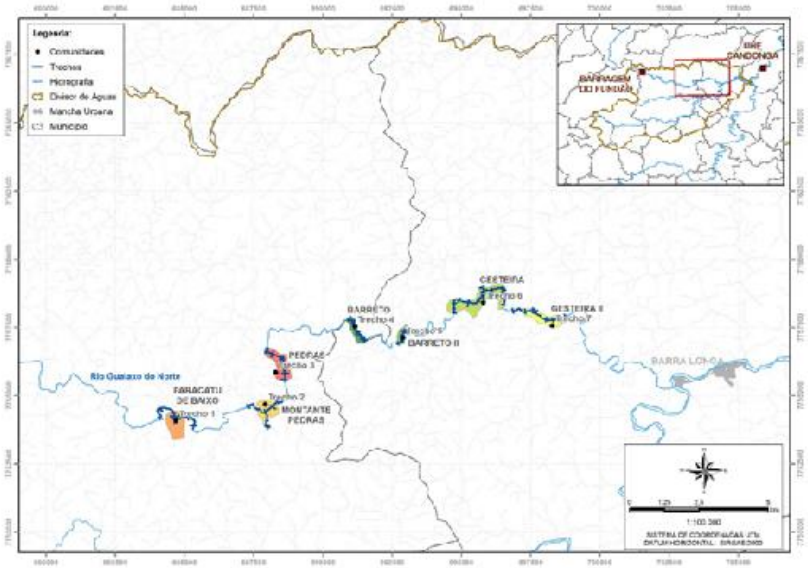

Figure 17: Areas and stretches of Rivers for the warning system against floods.

The system will be based on qualitative assessments, considering the weather forecasts of precipitation events provided by INPE - National Institute for Space Research. Based on these forecasts, the possibility of establishing its correlation with stream flow data from existing stations for preliminary stream flow forecasting will be evaluated.

The system also includes an assessment of the representativeness of the hydro-meteorological monitoring network, implemented and operated by Samarco in the area of Germano mine, to support not only the flood forecasting, but also the future development of studies related to the recharge potential areas of interest to

the hydro-geological and hydrological models as well as rain transformation into flow in the region of interest of the Renova Foundation.

The existing network in the area of Germano Mine consists of 5 automatic weather stations of the type “Weather-Hawk”, 2 rain gauges of the type “Ville de Paris” and 3 gauged stations on the river Piracicaba.

The information obtained, both in existing stations (SAMARCO and hydro-meteorological network of official bodies) and the stations to be installed, will be compiled and handled through an easy application tool that incorporates viewing weather forecasts on the Internet, viewing phenomena of precipitation and stream flow in transit along the basin in real time, allowing system operators to correlate a particular state of current flow the storms that may induce the formation of floods, so it is possible to issue alerts to population about the risk of flooding. Regarding the weather forecasts in the first stage, it is estimated that advance achieved for storm warning is about 12-24 hours. For flows, it is estimated that the advance can be achieved between 3 to 5 hours.

The hydro-meteorological network to be deployed will initially be comprised of five (5) Automatic linigraphic stations and eight (8) Automatic pluviograph stations with real-time data transmission, distributed along the Carmo river basin, as well as installing conventional linimetric sections along the Gualaxo do Norte river basin, in the passages of interest shown in the Figure above. As far as possible, existing installations of the official network of the National Water Agency will be used - ANA - optimization services.

Figure 18: Pluviographic station and data logger

Figure 19: Linimetric Section and automatic level sensor

7.1.3 Candonga Dredging

The dredging of sediments deposited in HPP (Hydro-electric Power Plant) Risoleta Neves reservoir will be performed in two phases. The first is being conducted by Samarco and have its goals and planning as presented in summary form in this chapter. More information about this activity can be found on the company's website at www.samarco.com internet.

The completed Phase 1 is to reestablish the operating conditions of hydroelectric power, ensure the structural safety of the dam itself and contribute to the improvement of water quality. The sediments deposited Will be dredged in the first 400 m upstream of the dam operation, which will be performed in 6 steps, expected to remove 1.3 Mm³ of sediment by July / 17, as indicated below:

• Step 1 - Cutting 30m distance from the main dam, starting from EL.312 to EL.308, with resulting cut slope of 1V: 15H – resulting in an estimated volume of 70,000 m3;

• Step 2 - Cut to 415m distant from the main dam, maintaining the EL.308 where the slope is 1V: 15H – resulting in an estimated volume of 442,000 m3;

• Step 3 - cutting up to 30m distance from the main dam, starting from EL.308 to EL.302 where is slope 1V: 15H - estimated volume 110,000 m³;

• Step 4 - cutting up to 325 m distance from the main dam, starting from EL.308 to EL.302 and slope 1V: 15H - volume estimated 403,000 cubic meters;

• Step 5 - Cut up to 30m distance from the main dam, starting from EL.302 to EL.297 where is slope 1V: 15H - estimated volume 64,000 m³; and

• Step 6 - cutting up to 250 m distance from the main dam, starting at EL.302 to EL.297 and slope 1V: 15H - estimated volume of 209,000 m³.

The second phase of dredging will be conducted by Renova Foundation, covering periodic maintenance dredging of the reservoir operating conditions. The planning activities of Phase 2 should be completed in March / 17, including dredging strategies in other areas of the reservoir, as well as their destinations to be studied and defined. In all, it is planned to remove approximately 10 Mm³ of sediment through dredging of HPP Risoleta Neves reservoir over 5 years of activity.

7.1.4 Reference Documents of Section 7.1

DOCUMENT	NAME OF THE DOCUMENT	COMPANY	DATE
G017860-Y-100012	Arquitetura do Sistema	ECM	Dec/15
G017800-Y-1ET002	Especificação técnica – sistema de comunicação satélite e rádio	ECM	Dec/15
G007900-N-2MD001	Memorial descritivo do Sistema de Alerta de Emergência	Samarco	Oct/16
G007900-N-2MD002	Áreas de instalação das Sirenes – Fase 01	Samarco	Aug/16

7.2 Creation of storage capacity

For containment of the remaining tailings in the area of the Samarco dams, the company installed and is installing structures from the Fundão valley to the confluence between the Santarém creek and the Gaulaxo do Norte river. In a summarized form, these structures Will be identified and Will have their objectives and installation status presented in this chapter. More information about this activity may be found on the page of the company in internet, www.samarco.com.

Axis 1

Axis 1 was conceptualized to contain the sediments deposited in the Fundão valley, with a predicted location near the old axis of the Fundão dam.

The project for the first phase of dam implementation was conceptually planned to be deployed up to 830 m elevation in 2016. In March 2016, work began on the removal of tailings at the dam's site. Due to the short period for execution of Phase I of this Dam, considering the restrictions of the rainy season, it was defined to start the foundation cleaning without all the information of the geotechnical survey campaign. Based on the initial survey results, a foundation cleaning volume of 250,000 m³ was estimated. With the advancement of the surveys and observation of local soil conditions, the following problems and their consequences were detected:

- Foundation cleaning volume: as the foundation cleaning progressed and the drilling was completed, a revision of the project was necessary, which raised the expected excavation volume from 250,000 m³ to over 700,000 m³. As a consequence of this significant increase in the volume of foundation cleaning, there was a delay in the schedule of about 45 days;

- Identification of cracks in the shoulders and ground: near the end of the foundation cleaning, cracks were identified on the ground and on the left abutment at the site planned for the construction of the dam. This was only possible after cleaning, ie removal of the mud. In this way, it would be necessary to treat the foundation and the left abutment, before starting the construction of the dam. The deadlines for carrying out this treatment were very large, rendering the construction work unfeasible this year. In this way, it was defined as the best technical alternative to move the axis of the Dam by approximately 50 m upstream of the initial position. In this new position, the volume of landfill required to build the dam increased by 44.5%, or 246,000 m³ more than initially planned. As a consequence of this increase, it became impracticable to complete Axis I at elevation 830 m in 2016, thus re-defining its construction at elevation 820 m;

- Low availability of clay material: with the increase of the landfill volume of Axis I, it was necessary to obtain a greater amount of clay material. Due to the simultaneous construction of Axis I and the New Santarém Dam, both in compressed soil, it became difficult to feed the two works with clay material at the necessary rhythm, considering the quantity and quality restrictions of the available clay deposits;

In view of the facts described above, it was defined as the best solution to halt the construction of Axis I at elevation 789 m, in order to prioritize the use of the clay available for construction of the Nova Dam of Santarém, since this structure has a greater containment capacity of tailings in the short term, thus becoming a priority in Fundão valley retention / containment strategy.

In any case, the construction of Axis 1 Dike in the next dry period becomes relevant, especially for the medium and long term, mitigating definitively the possibility of mud / tailings descent in the Fundão valley. With this in mind, a protection of the dam and of the cofferdam is being built to avoid the possible overtopping and consequent damage to the structures. The first phase of the installation of the structure is forecast to be concluded in 2017. Still in 2016, four barriers upstream of the cofferdam of Axis 1 will be installed, which will act as devices to dissipate the energy of the materials coming from the potential displacements in the Fundão valley. These structures, referred to as barrier sections 1, 2, 3, and 4, will be installed in arms of the Fundão valley, with a limited storage capacity and expectations are that they may be silted up over time, until they become totally covered by the tailings and/or submerged by the reservoir of Axis 1.

The barrier section 2 had the installation concluded in October / 2012. The rest of the structures have their conclusion foreseen for December/2016.

Nova Santarém Dam

Planned to be constructed downstream of the old Santarém dam, it Will have a capacity to retain 7 Mm^3 (upon reaching the elevation of 770 m).

The new Santarém dam will afford the total containment of the remaining sediments in the Santarém valley and the clarification of the water which will overflow downstream.

The installation works of the new Santarém dam are currently in progress, with their conclusion scheduled for December, 2016.

Second Raising of the S3 Dike

The S3 dike was installed in February/ 2016 downstream of the Santarém dam and upstream of the community of Bento Rodrigues. The second raising of the S3 dike is planned to increase the total retention capacity to 2.9 million m^3.

Conceived to minimize the entrainment of sediments of the area of the dams to the environment and improve the quality of the water which overflows to the Gualaxo do Norte river, o dike S3 permits that Samarco can manage the effluents coming from the Fundão valley in relation to the standard allowable indices of turbidity and also contain the solids deposited upstream of this structure.

The raising of Dike S3 is in progress with its conclusion set for November/ 2016.

Dike S4

The S4 Dike is being installed next to the confluence of the Santarém creek and the Gualaxo do Norte river, downstream of Bento Rodrigues. The structure which will have a retention capacity of 1.05 Mm^3, had its height planned in order to avoid the inundation of the ruins of the community of Cento Rodrigues, which will be preserved.

The main objective of Dike S4 is to avoid the entrainment of sediments deposited on the plain of Bento Rodrigues to the Gualaxo do Norte river. The structure also will act as a last barrier for sediment containment in the event of an entrainment of tailings from the valleys of Fundão and Santarém to downstream of the S3 Dike in the rainy period.

The works for installation of Dike S4 are in progress, with conclusion set for January/2017. After the fulfillment of the expected objectives for the S4 Dike, it will be de commissioned, permitting the environmental recovery of the area surrounding the ruins of Bento Rodrigues.

7.3 Emergency Actions for Stabilization and Control of Erosion

With the objective of stabilizing the deposited sediments in the river channels impacted by the event occurred at the Fundão dam, Samarco, under the direction of the specialized consulting companies, such as GOLDER Associates, executed and has been executing several actions which are presented in detail in the following chapters.

7.3.1 Tributaries

In December of 2015, Golder Associates performed an initial assessment of the scenario resulting from the collapse and developed a adaptive plan of recovery. This plan, which is currently being carried out by Samarco, identified the initial actions to mitigate the impacts identified and one of these initial actions is the recovery of the channels of the tributary creeks impacted by the event.

The environmental recovery of the tributary creeks involves basically: the cleaning of the tributaries, including the removal of the tailings present in the channel of these water courses; and the reconstruction of a proper flow section, based on solid methods of bioengineering suitable for each tributary, including the protection of the banks to avoid new contributions of sediments and tailings in the water courses.

It is important to point out that all of the interventions made in the tributaries up to this moment have been limited to phase 1 of the environmental recovery process, which is the physical stabilization of the area. The questions related to the biological component such as biodiversity, reforestation and return of the fauna will be addressed in the next step of the program of environmental recovery.

All of the sediments deposited in the channels and banks of the tributary creeks, if not removed or stabilized, tend to return to the main water courses, thus contributing to the elevation of the level of turbidity of the water and entrainment of solids into the course of the main rivers. Therefore, it is necessary to perform interventions with the objective of cleaning the channels of these tributaries or stabilize the tailings deposited there, preventing them from being entrained into the water ways.

7.3.1.1 Trade-off Study

Before assessing the recovery options, it was necessary to know the extent of the area and characterization of the impact of the collapse of the dam. The tributary streams affected were mapped using GIS with a basis on the images of the aerial survey made after the collapse, as supplied by Samarco. In the total, 73 areas were mapped and of these 55 were selected as priority sites for short range recovery programs. Currently, Samarco has mapped a total of 101 tributaries, of which 9 do not have access, and if considered that, in relation to the need of creating accesses, the impact of the intervention would be greater than the benefits and defects of recovering these inaccessible tributaries, presented in the Attachments of Section 7.3.1.

The tributary streams impacted which were selected as priority for the immediate work of development of recovery and construction projects are located along the Santarém creek, Gualaxo do Norte river and Rio do Carmo.

The types of recovery assessed are methods which may be combined with the base case, or, if feasible, may be alternatives to the base case. Each local has an impact characterization which is "*sui generis*". Therefore, during the construction, each location will be assessed case-by-case and an adaptation will be made in the field, applying an adequate recovery method.

For assessment, the environmental recovery alternatives of the tributaries were considered the objectives of the environmental recovery plan, which include:

- **Objective 1**, minimize the volume of tailings deposited which tend to migrate to the main rivers, and
- **Objective 2**, restore the values of the habitat to a condition comparable with that which existed before the collapse of the dam.

Golder studied 21 alternatives of lining/armouring or protection of the tributary channels. The alternatives assessed are listed below and include a combination of traditional engineering methods (ex.: rock facing), bio-engineering (ex.: re-vegetation), and geo-synthetic materials (ex.: geo-grids).

The types of recovery assessed are listed below and include a combination of the proven methods and the alternative methods of bio-engineering, according to Li & Eddlemen (2002). With this, 12 typical sections were defined to be adopted in the recovery of the tributaries. **Figures 20 and 21** illustrate the schematic drawings of each typical section.

- **Type A**: Rock Armouring/ rock facing — The use of rocks for the protection and stabilization of banks is a solutions with proven results, widely used in Brazil (Brighetti 2001) and around the world (USACE 1994; Baird & Fotherby 2015). This option is based on successful experience by Golder, principally for environmental recovery after the collapse of the Mount Polley tailings dam in August of 2014, in Canada.
- **Type B**: Live Stakes — This option involves the placement of live stakes with roots or branches on the banks of the water course. The erosion of the bank will diminish thanks to the growth of the roots which consolidate the soils of the embankments and the vegetation established on the surface which will reduce the energy of the flow.
- **Type C**: Live Fascines — This option involves live stakes with roots or cut branches which are tied in cylindrical bales and inserted into the banks of the water course in shallow trenches, which are installed perpendicular to the slope of the bank, and act as retention dams reducing the flow velocity on the slope to laminar.
- **Type D**: Brush Layering — This option involves live stakes of bushy species tied together, installed in a configuration partially superimposed between layers of soil. This superimposed placement of branches and soil runs perpendicularly to the slope of the bank. The branches which stick out from the surface of the embankment increase the roughness and reduce the flow velocity.
- **Type E**: Branchpacking — This option utilizes a combination of brushlayering affixed to the banks of the water course with wooden stakes, placed between layers of compacted fill. These layers of branches/brush and compacted fill run perpendicularly to the embankment. This option is more indicated for direct areas of depressions in the banks of the water course.
- **Type F**: Vegetated Geogrid — This option involves the creation of layers of live stakes interspersed with layers of earth covered with natural or synthetic geo-textile. Multiple layers are placed perpendicular to the embankment.
- **Type G:** Live Cribwall — This option involves the placement of logs/posts without treatment in interlocking structures forming boxes, along the foot of the bank of the water course. The structures do a box-type are filled with layers of adequate earthen material together with live stakes with roots, extending into the embankment.

- **Type H**: Joint Planting — This option is a combination of rock lining with live stakes placed at the joints or openings to permit the re-establishment of vegetation.
- **Type I**: Brushmattress — This option involves live stakes and branches installed parallel to the direction of the inclination of the slope of the bank, to form a mattress. This mattress may be affixed with anchors or clips. The live stakes and branches are keyed into the foot of the embankment of the river bank in shallow trenches lined with stones.
- **Type J**: Tree Revetment — This option involves tying whole dead trees and anchoring them in the foot of the bank.
- **Type K**: Log and Rootwad Revetment— This option promotes the establishment of habitats for wild animals and fish through the anchoring of logs and rootwads at the foot of the embankment of the river bank.
- **Type L**: Dorman Post Plantings This option involves the placement of live sleepers on the embankment of the river bank in an organized configuration, covering the entire surface.
- **Type M**: Coconut Fiber Rolls — This option involves the use of natural fibers of coconut bark tied with a string made of coconut fiber to form a cylindrical object. The rolls are anchored or staked to the internal foot of the bank of the water course.
- **Type N**: Coconut Matting — This option involves the use of biodegradable organic materials and help the establishment of vegetation on the embankments of the river banks or in the bed of the streams. The blanket is made of sown coconut fiber with a poly-propylene netting.
- **Type O**: Geotextile Tubes (Geotubes) – This option involves tubes made of geotextile material filled with sediments. The tubes are placed in parallel to the direction of the flow along the water course, which may be at the top of the bank or at the foot of the embankment of the river bank. The tubes may be piled to supply greater depth of protection against erosion or covered with earth to allow the establishment of vegetation.
- **Type P**: Soil Cement Bags — This option involves a combination of a mixture of dry earth (or deposited tailings) with cement, placed in a geotextile Polyester sack with UV protection, or similar solution. The sacks with soil-cement will be cured and become practically the same as rock. The sacks are placed manually and piled on the embankments of the river banks to protect against erosion.
- **Type Q**: Gabions— This option involves the use of wire cages of steel filled with stones and placed one next to another to create a mattress covering large areas of the embankment of the river banks which need protection against erosion. The gabions are a robust option for erosion protection and tolerate differential settlement.
- **Type R**: Geocell — This option is versatile and offers several configurations for erosion protection. One configuration uses geotextile fiber of polypropylene molded into a honeycomb format, creating a system of cellular confinement which has conditions to cover all of a surface of an embankment. The filler material may vary, from gravel to native soil.
- **Type S**: Elastomeric Polymer Spray — This solution involves a mixture of a pre-determined proportion of polymer components and hardener. The solution is applied by jet-spray upon within a surface of an open excavation, comparable to a surface of a water course, and creates a

consolidated and impermeable surface.

- **Type T**: Planting — This option involves the planting of grass or other vegetation to stabilize the soil of the banks. The use of Vetiver grass was considered, because of being a perennial grass type with a deep root system which helps to stabilize the banks. The grass may be planted in windrows along the embankment of the banks, which restrict the movement of soil and refuse on the embankments, and little by little create an earthen barrier.
- **Type U**: Subaqueous Caps — This option supplies a composite barrier of earth or other specified material placed over the residues or tailings, thus impeding that they spread to a greater part of the environment nearby.

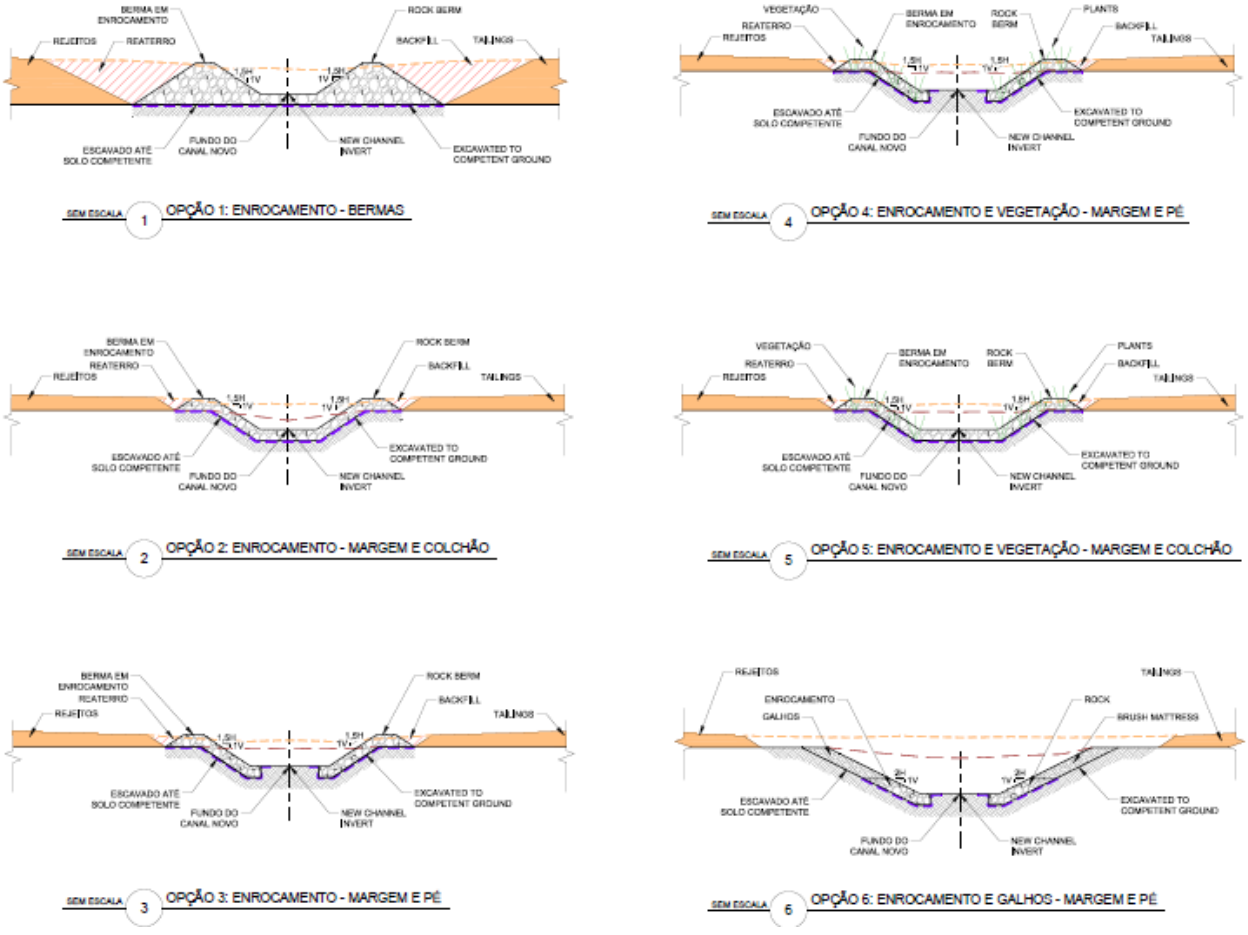

Figure 20: Typical Options of bio-engineering – Options 1 to 6 (Golder Associates - G006900-C-100024_R-01, see Attachment Section 7.3).

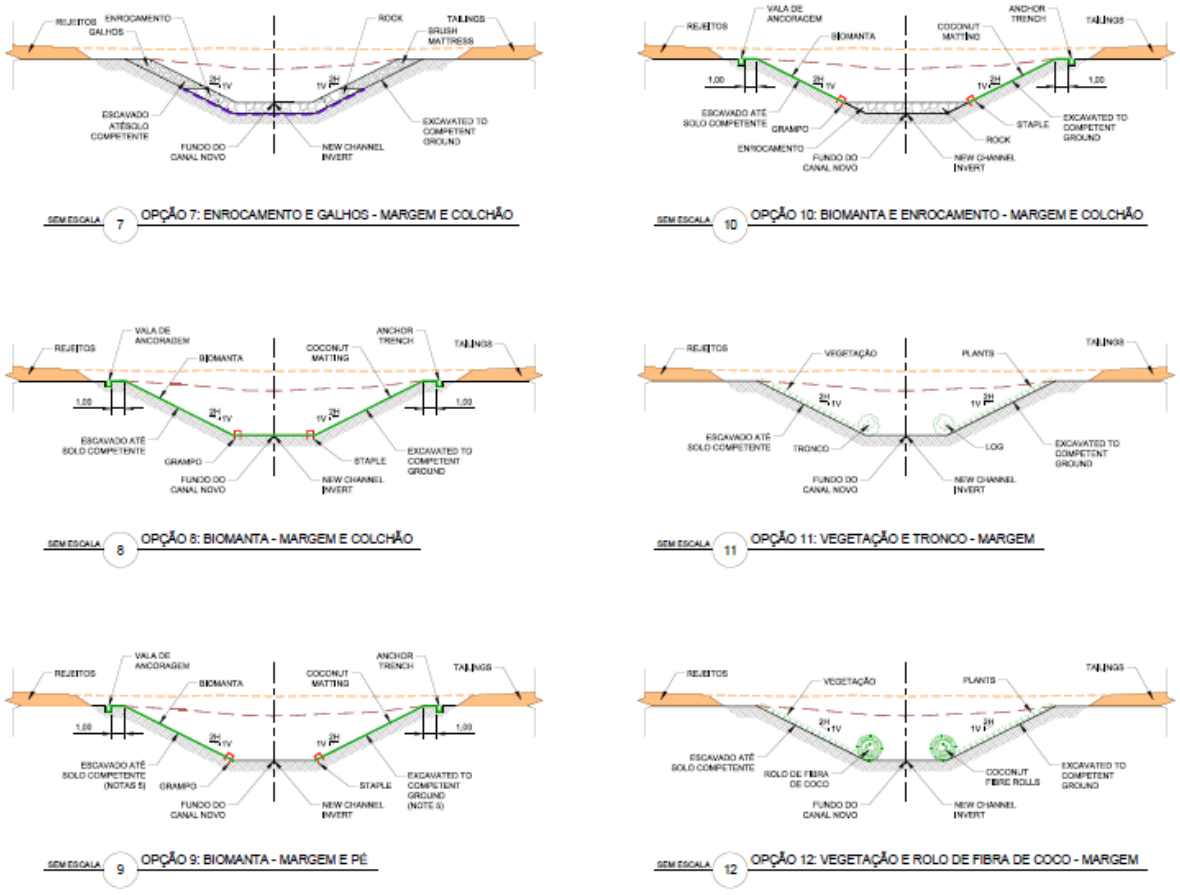

Figure 21: Typical Options of bio-engineering – Options 7 to 12 (Golder Associates - G006900-C-100025_R-01, seer Attachment Section 7.3).

The advantages and disadvantages of each type are compared with the criteria adopted in the decision making, including the two main objectives of the environmental recovery plan, as well as the constructability. The assessment is presented in the following form:

- Green indicates that the type of recovery is preferred for a given criterion, or that the advantages are greater than the disadvantages.
- Orange indicates that the type of recovery is acceptable and/or feasible, but is not the most recommendable for the given criterion, or that the disadvantages and advantages do not supply a decisive comparison.
- Red indicates that the type of recovery is not acceptable or feasible for a given criterion, or that the disadvantages of the option are greater than the advantages.

Each type of recovery is assessed in **Table 3**. Since all of the types of recovery were assessed applying the method above, the types preferred were compared with a general adequacy to the environmental recovery plan.

Table 3: Assessment of Recovery Options

Criteria	Recovery of the fish habitat	Protection against Erosion	Constructability
Type A: Rock facing armouring	Supplies a solid foundation for the construction of the components favoring the habitat of fish in the bed of the channel.	Solution of widely proven efficiency globally for protection against erosion of water courses	Rapid and easy placement with construction equipment.
Type B: Live stakes	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the vegetation established on the banks of the river.	Adequate protection against erosion when the vegetation has established itself. However, it does not supply any protection against erosion until the vegetation does establish itself.	Easy installation with manual labor
Type C: Lives Fascines	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the vegetation established on the banks of the river.	Adequate protection against erosion once the vegetation has established itself on the slope of the banks. The rolls of branches act as small containment dams and interrupt the surfaces of the slope, reducing the velocity of the laminar flow .However, it does not supply any protection against erosion until the vegetation has been established.	Causes a minimum of disruption on site when installed correctly no the embankment of the banks, since the trenches are shallow.
Type D: Brush Layering/ layers of branches	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the vegetation established on the banks of the river.	Supplies protection against erosion immediately after installation, since the live stakes stick out of the slope of the bank. The velocity of the laminar flow is reduced by the increased roughness of the slope.	More adequate for filling in embankments . If constructed on an embankment in cut, the degree of disruption may be severe. Layers multiples of live stakes and layers of earth . can demand intensive manpower.
Type E: Branchpacking/	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the established vegetation in localized areas where installed. However, the installation aims at the recovery of existing depressions, and would not be a continuous solution along the entire	Good method for reinforcing the soil only in localized areas (existing holes and depressions, for example). It is not used directly for protection against erosion as a proactive approach, by being more of a reactive nature.	Reasonably simple installation. The equipment for earth moving needs to be constantly in motion due to areas selected for construction.

Criteria	Recovery of the fish habitat	Protection against Erosion	Constructability
	water course.		
Type F: Vegetated geogrid	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the vegetation established on the banks of the river.	Supplies protection against erosion immediately after installation, supplying long range stability. Adequate for protection of the foot of the slope and for external curves where high flow velocities are expected..	Accessibility of construction equipment for earth moving may be limited. Multiple layers of vegetated geogrids require intensive manpower..
Type G: Live Cribwall	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and offers sufficient space for hiding places of fish due to the interlocking arrangement of the box type.	Supplies protection against erosion immediately after installation, supplying long range stability. Adequate for protection of the foot of the slope and for external curves where high flow velocities are expected..	The construction may be complex, requiring intensive manpower for the interlocking arrangement.
Type H: Joint Planting	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the vegetation established on the banks of the river.	Good protection against erosion immediately after installation, increasing with the establishment of the vegetation.	Easy and fast placement with construction equipment (rock) and manual labor (planting).
Type I: Brushmattress	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the vegetation established on the banks of the river.	Good protection against erosion immediately after installation. Efficient on 2H:1V slopes or less, and captures sediments on the slopes of the banks during rains.	Easy and fast placement with manual labor and small size construction equipment
Type J: Tree Revetment	Supplies good conditions for the restoration of the habitat of the fish due to the natural material in the foot of the channel.	Protects the foot of the channel, and supplies good protection against erosion immediately after installation. The lining with trees will have a limited useful life, and may become degrade over time.	Easy and fast placement with manual labor and small size construction equipment
Type K: Log and Rootwad Revetment	Supplies good conditions for the restoration of the habitat of the fish due to the natural material in the channel.	Installation in steps, in a way that the protection of the channel is not continuous. The logs and rootwads have a limited, and may become degraded over time..	Easy and fast placement with manual labor and small size construction equipment

Criteria	Recovery of the fish habitat	Protection against Erosion	Constructability
Type L: Sleeper-Post Plantings	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the vegetation established on the banks of the river.	Adequate protection against erosion once the vegetation is established. However, supplies very little protection against erosion before the vegetation actually becomes established.	Easy installation with manual labor
Type M: Coconut fiber rolls	Supplies good conditions for the restoration of the habitat of the fish due to the natural material in the lower part of the lowland. The sediment that descends the slope of the banks is captured and allows the vegetation to establish itself.	Protects the foot of the channel, ands captures deposited tailings and sediments which come down the slope with rain and help in the establishment of the vegetation..	Easy installation , and causes very little disturbance to the local
Type N: Coconut matting	Supplies good conditions for the restoration of the habitat of the fish due to the natural material in the lower part of the lowland. The sediment that descends the slope of the banks is captured and allows the vegetation to establish itself.	Captures tailings and sediments which come down the slope with the rains and help in the establishment of the vegetation.	Easy installation , and causes very little disturbance to the local
Type O: Geotextile tubes (Geotubes)	It is not sufficient as an isolated model for establishing vegetation in the area of the foot of the embankment for recovery of the habitat of fish. It needs to be combined with another method for meeting the objectives established of habitat recovery.	Supplies good protection against erosion and acts as a good physical barrier to the transport of deposited tailings and sediments which come down the embankment.	Requires heavy equipment for making the culverts and backfill and placement of the tubes filled at the base of the culvert. The hydraulic backfill of the tubes increases the construction time. Access and mobility of the equipment may be restricted.
Type P: Soil-cement sacks	The synthetic characteristics off the cement may potentially alter the pH of the water course, which may result in the loss of aquatic life. The smooth surface does not offer adequate conditions for the establishment of the growth of vegetation. The sacks also will suffer erosion over time and pollute the water course. Greater details may	Once cured, supplies a technically robust and structurally stable for protection against erosion. However, the stacked sacks of soil-cement have little flexibility and low tensile strength.	In spite of easy installation, once the sacks are filled and closed requires intensive manpower to sow the sacks in place if necessary, fill the sacks with tailings and cement, and sow the sacks closed , in addition to stacking them. In the foot area.

Criteria	Recovery of the fish habitat	Protection against Erosion	Constructability
	be found in the *Soil Cement Technical Memorandum* (Golder 2016C).		
Type Q: Gabions	Supplies marginal conditions for the recovery of the habitat of fish. However, the use of smaller stones reduces the voids used as hiding places for fish, and frequently does not allow the establishment of vegetation.	Supplies robust protection and structurally stable against erosion immediately after their installation, principally around external curves of the water course. However, the durability of the wire cages is questionable during storms of greater intensity and with the passage of time.	Requires construction equipment for installation (for ex. Mechanical hoisting, placing of fill material with rocks. The question of access may be a problem,. Requires very intensive manpower
Type R: Geocells	Supplies good conditions for the restoration of the habitat of the fish when the vegetation establishes itself in the filler material of earth inside the cells. It needs to be extended to a part below the inundated area..	Supply adequate protection against erosion immediately after installation for the embankments. The protection increases as a function of the development of vegetation ..	Requires heavy construction equipment (for ex. Mechanical hoisting, trenches for anchoring,). The access may be a problem.. Labor intensive for mobilization and anchoring along the embankment of the banks.
Type S: Elastomeric Polymer Spray (Diamondguard)	The smooth surface does not supply adequate conditions for the establishment of the growth of vegetation.	It is comparable with a geo-membrane since it acts as an impermeable layer with good stretching and high tensile strength properties. Highly efficient in the protection against erosion.	Construction would have to be made by trained technicians. Potential problems with the application depending on the climatic conditions (for ex.: rains, wind storms,).
Type T: Planting (e.g., grass Vetiver)	Supplies good conditions for the restoration of the habitat of the fish due to the natural material and the vegetation established on the banks of the river.	Once the roots are good and deep and live fences are formed, it is a good form of protection against erosion. The tailings deposited and the movement of sediments coming down the slope are retained by the live fences and stop them from entering the water course.	Easy placement with manual labor
Type U: Subaqueous Caps	Supplies ideal conditions for the recovery of the habitat of the fish since the upper layer provides natural material to promote bioturbation. However, the bioturbation (of the layer of vegetation) in the submerged cover is above the lined layer. Consequently,	An efficient form to contain tailings deposited and the sediments, since it offers a physical isolation.	The construction schedule can be long with the placement and management of the sequential layers .Requires a system of management of water. . More

Criteria	Recovery of the fish habitat	Protection against Erosion	Constructability
	the risk of washing/removal of the bioturbation is probable during more significant events due to the limitation of the establishment of deep roots. This may destroy a fish habitat which had already formed.		applicable for large open areas. Accessibility to water courses may be complicated.

The mapped tributaries and the defined recovery alternatives, for each tributary was delimited to the contributing basin and the design flow rates were calculated. The method of calculation of the design flow rates varied depending on the area of contribution of the following form: rationale (A [area] < 1 km²), modified rationale *1 km², A < 10 km²), HEC-HMS ((10 km² < A < 70 km²) and regionalization of flow rates (A > 70 km²)). Based on the design flow rates and on the field surveys made for each tributary, the dimensioning of the hydraulic section of the tributary was made.

The calculation takes into account the size and shape of the section, the slope of the channel and the roughness. The projects of recovery were developed for each tributary which consisted of plan and profile drawings and typical sections. These projects were filed by Samarco with the competent organs for obtaining authorization for the execution of their construction. Once the work has begun, in case of change in the field conditions resulting from the works of clearing the channel, for example, the technical accompaniment of the work (ATO) will suggest optimizations in the design sections. Such optimizations are verified (the calculations are redone) and, if still feasible, will be implemented.

7.3.1.2 Results Expected / Obtained

The tributary reclamation works were initiated in January, 2016. Up to the present moment, 101 tributaries affected by the collapse of the Fundão dam have been mapped, resulting in recovery works forecast in 92 locations, some of these tributaries do not have access and there would be greater environmental impact for opening of the access than benefit in its recovery. This was the conclusion of the technical analysis performed by Golder Associates and presented in the documents of reference of this section. **Table 4**, which follows, shows the progress of the works developed up to this moment.

Table 4: Status of the recovery work of the Tributaries.

Situation	Quantity of Tributaries
In progress	8
Concluded	58
To be executed	26
Total	**92**

The weekly reports of accompaniment of the activities of recovery of the tributaries are presented in the reference documents of this section.

As an example, the following photographic record presents some of the tributaries where recovery works have been carried out. The photos illustrate the situation before, during and after the intervention. Visually it is possible to note that the water of the tributaries is clear, that is, with a low turbidity. The river bed was clean and the banks and slopes do not present erosive processes.

On 26 July 16, a daily monitoring of water quality of the tributaries was initiated, with focus on the turbidity, in such a way to form a data base which proves numerically the efficiency of the works performed. Currently, the monitoring of turbidity and suspended solids is being carried out on 12 tributaries, of which some are in construction and other where work has not started yet. The referred monitoring and maintenance of the works are being developed with special focus on the next rainy season. The monitoring report of the month of October is presented in the reference documents of this section.

The works developed on the tributaries up to this moment are aimed at the mitigation of the environmental impacts on the water quality of these water courses. Visually, one may infer that the intended objective was reached. Additional turbidity monitoring will be implemented to confirm this perception.

Tributary 5 of the Gualaxo do Norte River (TG05)

Figure 22: Environmental recovery of the tributary TG05.

Tributary 49 of the Gualaxo do Norte River (TG49)

Figure 23: Environmental recovery of the tributary TG49.

Tributary 51 of the Gualaxo do Norte River (TG51)

Figure 24: Environmental recovery of tributary TG51.

7.3.1.3 Monitoring and Control

Environmental monitoring and control is forecast in the whole recovery program of the tributaries relative to the evolution and effectiveness of each solution implemented in the field before, during and after the rainy periods. This action has the objective of assuring the recovery of all the area degraded in accordance with the Integrated Plan of Environmental Recovery proposed.

7.3.1.4 Reference Documents of Section 7.3.1

DOCUMENT	NAME OF DOCUMENT	COMPANY	DATE
Relatórios de Obra	Relatórios de acompanhamento do avanço das atividades de recuperação de trubutários	H3M	
Documentação de engenharia	Book de documentos de engenharia da recuperação dos tributários impactados	Golder	

7.3.2 Reconfiguration of the Channels of the Main Rivers and Control of Erosion

The company Golder Associates is responsible for the development of the engineering designs of reconfiguration of the channels of the main rivers and of the control of erosion in the areas impacted. For emergency response for the next rainy season, 14 areas contemplated in the geo-morphologic study were defined as priority. The next figure presents the areas to be prioritized. The areas 12 and 16 are not included in the scope of this work since the S4 Dike is being installed in area 12 (plain area located near Bento Rodrigues), which will have its environmental recovery concluded after the decommissioning of the dike and the area 16 (Candonga) is being dredged for removal of the deposited sediments.

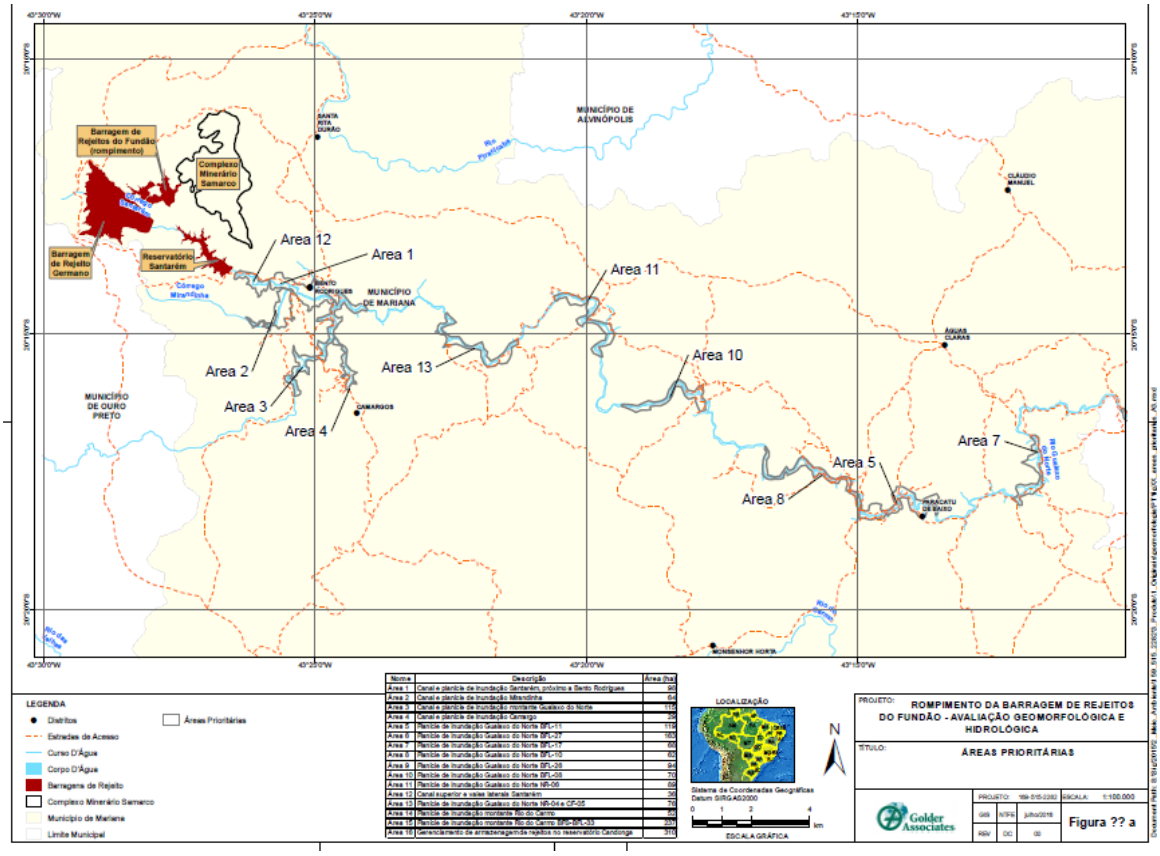

Figure 25: Priority Areas – Part 1.

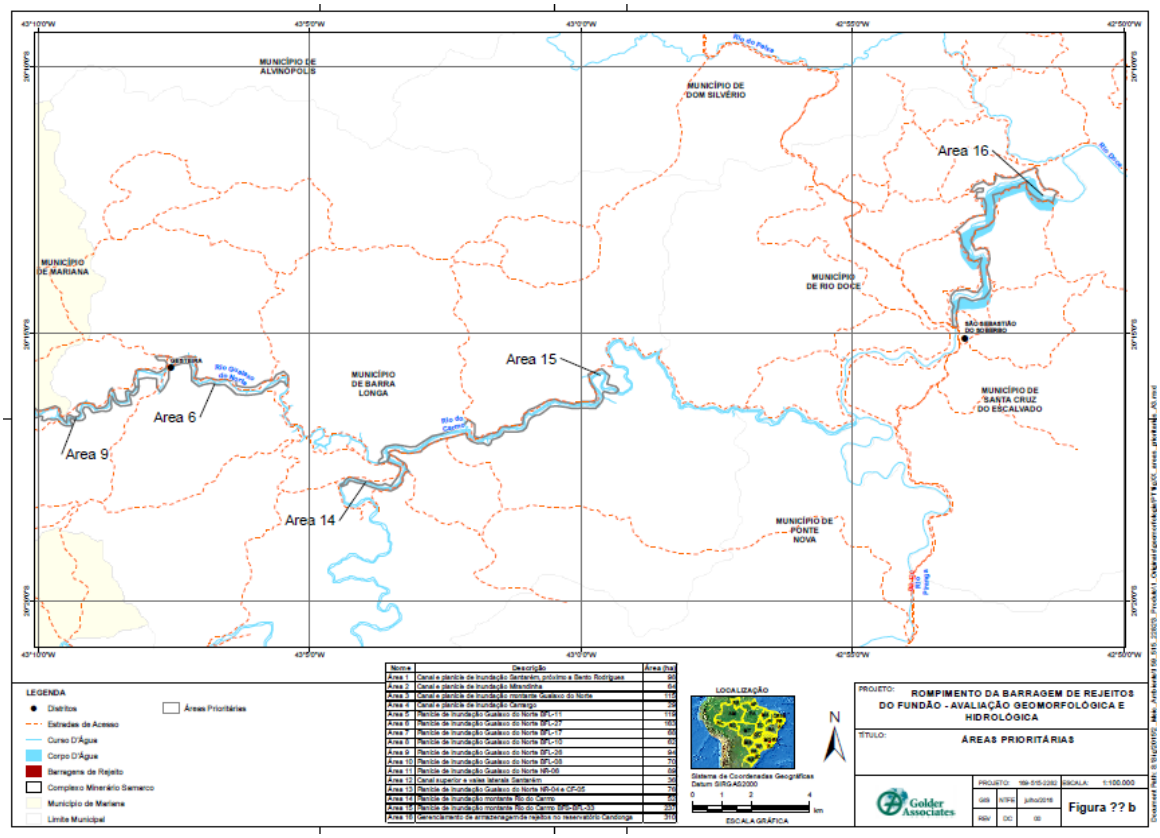

Figure 26: Priority Areas – Part 2.

For the execution of the activities, the following methodology was adopted

- Field survey;
- Definition of the assumptions of the design;
- Definition of the typical sections;
- Development of the hydro-dynamic modeling (HEC-RAS);
- Dimensioning of the sections;
- Development of the special designs.

7.3.2.1 Field Survey

The field survey had as its objective to assess all of the areas contained in the scope of work, collecting photos and information relevant to the development of the initial designs of the priority areas. This survey permitted the identification of typical engineering solutions, or that is to say solutions which may be applied commonly for the majority of the areas visited. See below some photos of the field work done by the Golder team.

Figure 27 Field Survey executed by the Golder team.

7.3.2.2 Definition of the assumptions and criteria of the design

With the intent of making clearer the assumptions and criteria of the designs, these were divided into 2 groups, those being: (i) reconfiguration of the channels of the fivers and (ii) control of the erosion processes.

The assumptions of the reconfiguration of the river channels group are:

Assumptions:

- Minimize the re-mobilization of tailings and sediments deposited on the Banks;
- Minimize the movement of the tailings and sediments deposited in the bed to avoid increase of turbidity in the water and de-stabilization of the Banks;
- Avoid the reconfiguration of areas where the natural vegetation has already re-established itself for stabilization of the Banks;
- Avoid the reconfiguration of the areas where the remaining riparian vegetation (ex.: root system) remain acting in the stabilization of the Banks;
- Minimize the use of “heavy” engineering solutions;
- Adopt techniques of bio-engineering where possible, utilizing natural solutions which are going the contribute to the local bio-diversity;
- Monitor the works performed and repair the defective points until stability and integration is reached with the surrounding environment;

Design criteria

- Stabilization works will be designed for the larger bed – return period of 10 years.

The assumptions which should be adopted by the group of control of erosion processes are:

Assumptions:

- Minimize the erosion produced by the superficial flow in the areas impacted;
- Deviate the superficial flow to avoid the contact with areas impacted by tailings;
- Minimize or limit new movement of earth in natural areas;
- Install adequate superficial drainage in the impacted areas;
- Revegetate all of the impacted areas;
- Monitor the works performed and correct the defective points until stabilization and integration are reached with the surrounding environment;

Design Criteria:

- The drainage deviations, such as crest gutters, shall be designed for an event with a period of return of 25 years;
- The measures of control of erosion and sedimentation shall be designed for conducting rainfall with a 25 year return period:
- The measures of control of erosion and sedimentation should permit a minimum efficiency of 80 % for a rainfall with a return period of 5 years;

7.3.2.3 Definition of the Typical sections

After the field survey, it was verified that there exist three typical sections which repeat themselves in the majority of the areas visited, being:

Typical Sections:

- TYPE A: Bank exposed with the presence of beach (**Figure 28**);
- TYPE B: Bank exposed without the presence of a beach (**Figure 29**);
- TYPE C: Bank exposed with high embankment and intermediate bench (**Figure 30**);
- TYPE D: Stabilized bank where the need will be assessed of the application of specific measures for the containment of erosion and reinforcement of vegetation (**Figure 31**); and
- TYPE E: Exposed bank, situation in which the sections type above are not applicable , thus requiring a specific design (**Figure 32**).

In the stretches whose characteristics of the channel do not permit the application of the typical sections, special designs will be developed.

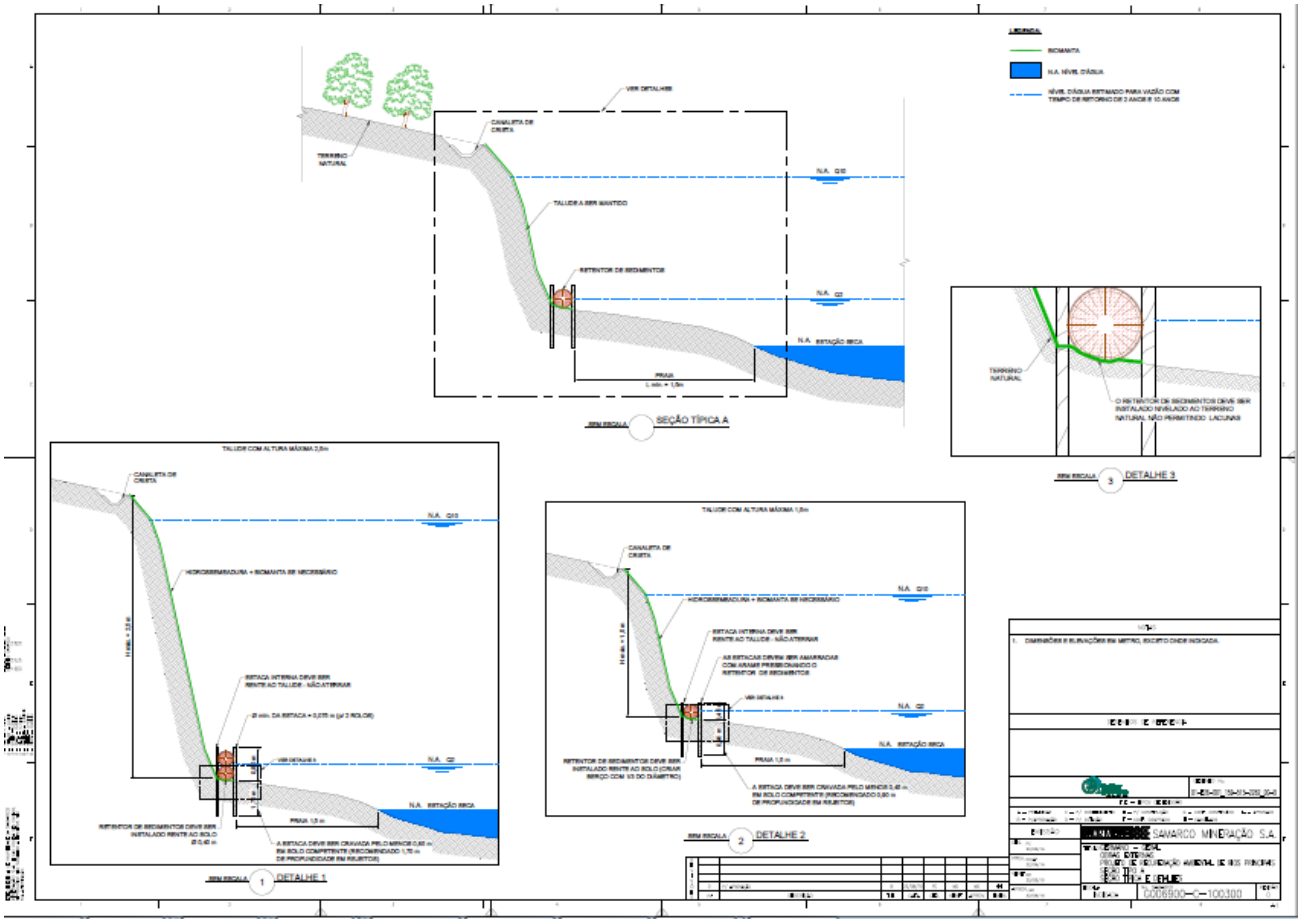

Figure 28: Section TYPE A schematic.

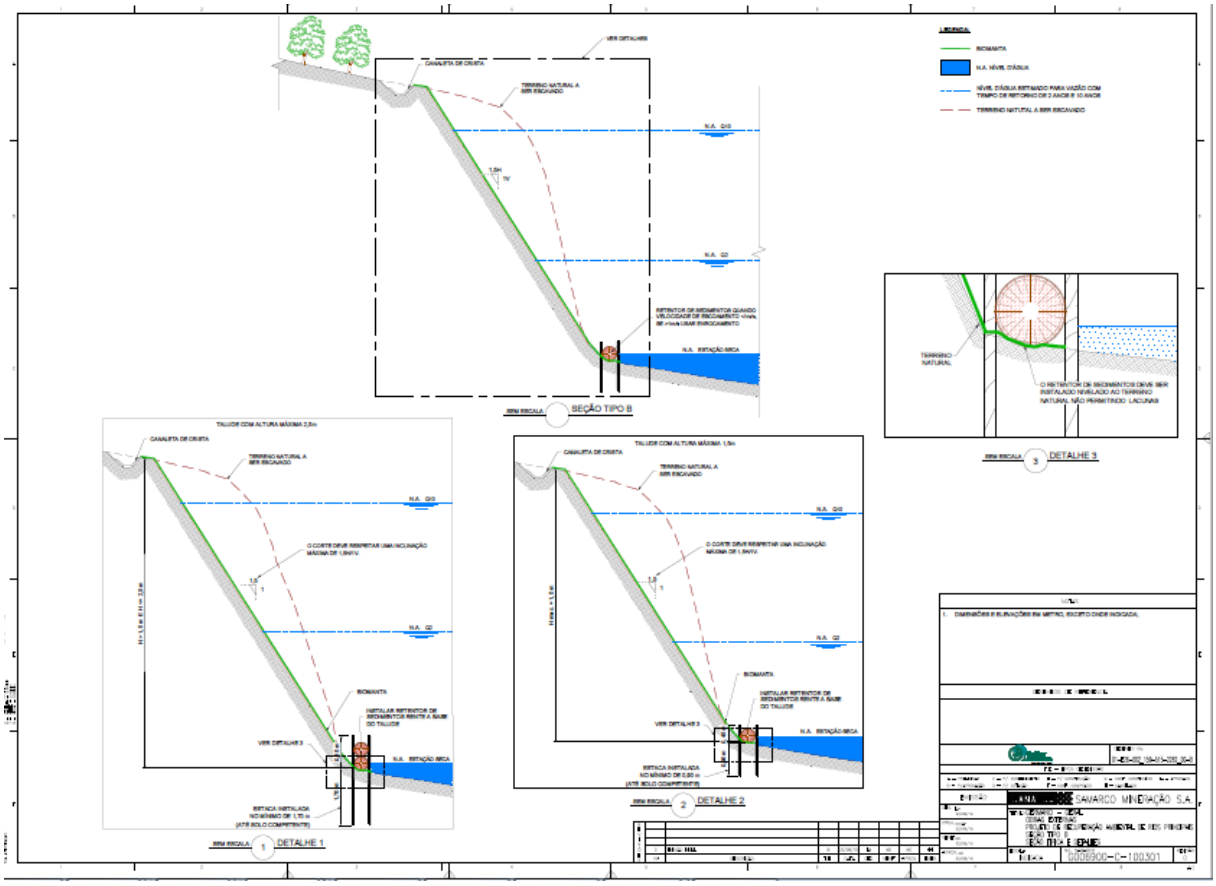

Figure 29: Section TYPE B schematic.

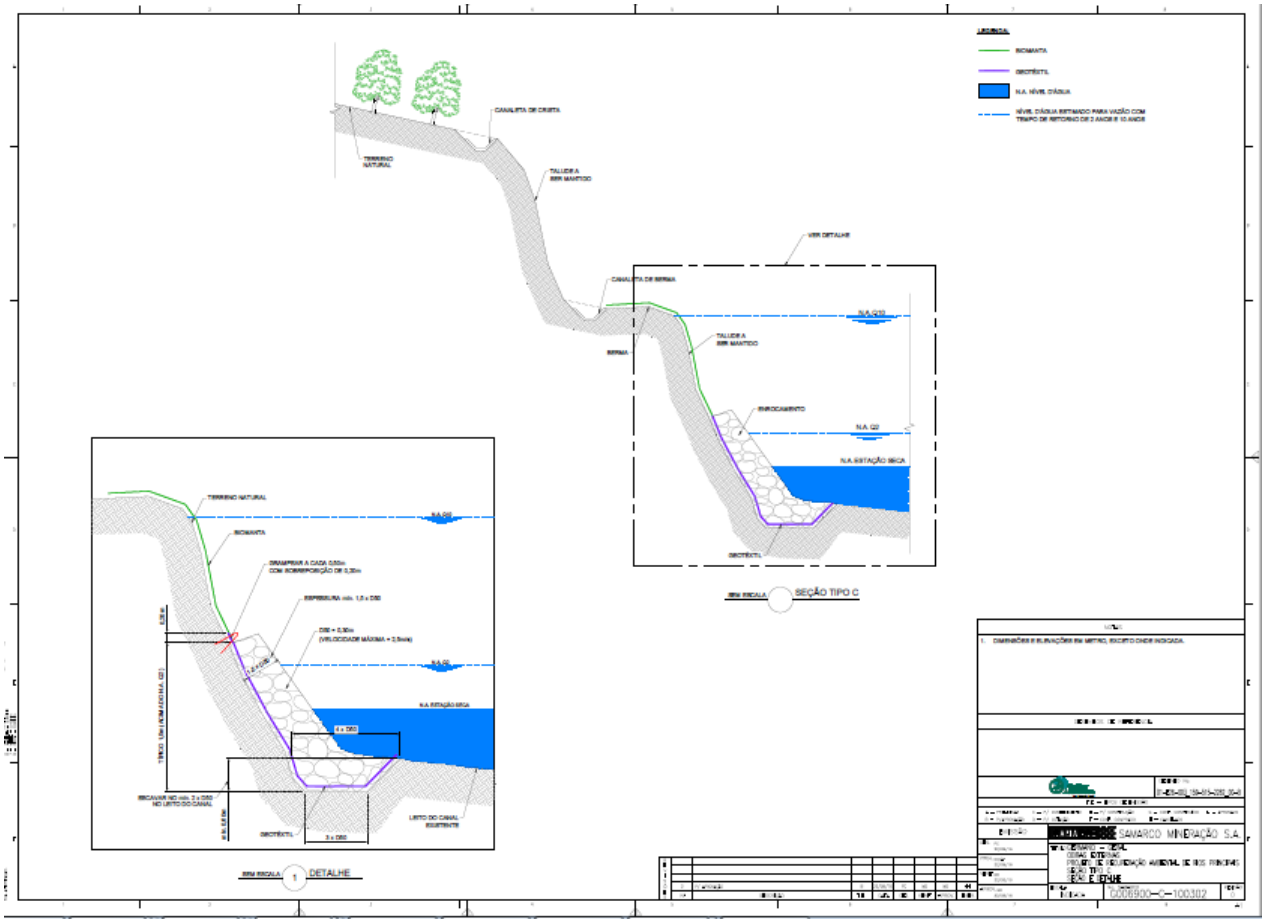

Figure 30: Section TYPE C schematic.

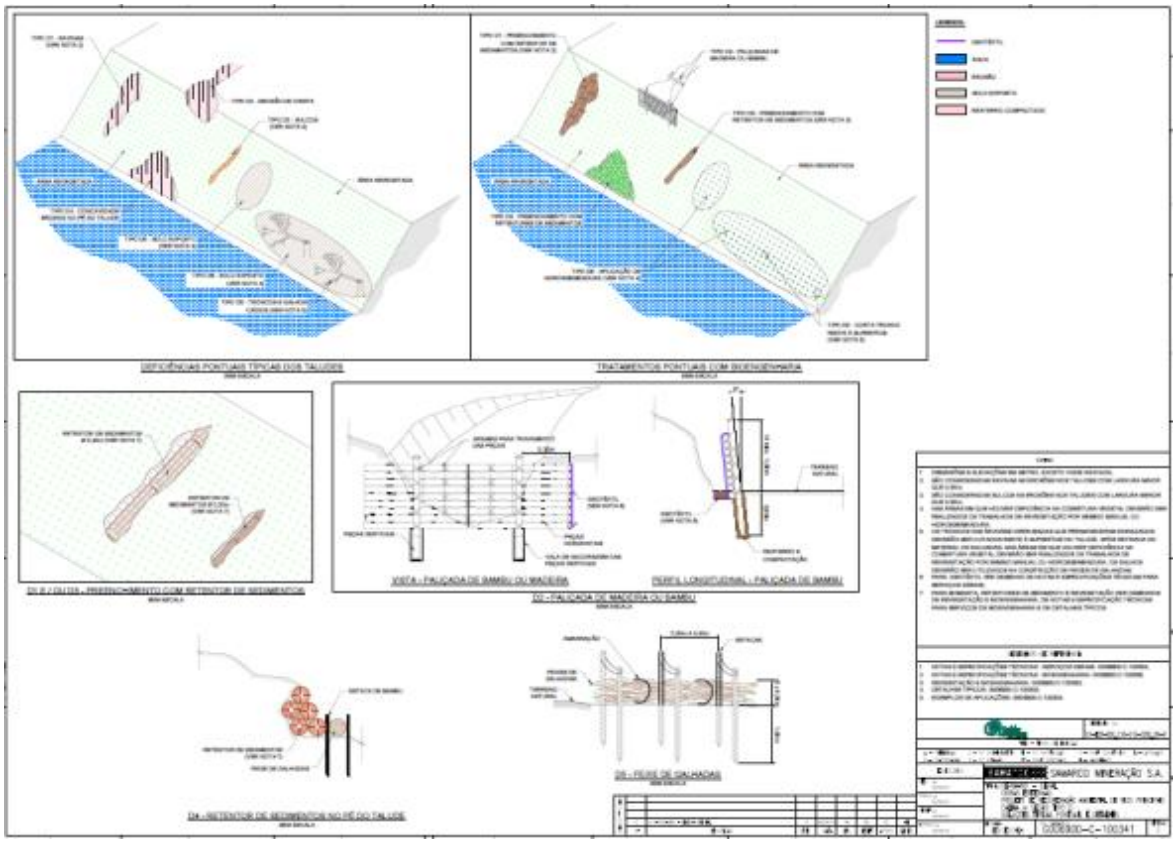

Figure 31: Section TYPE D Schematic

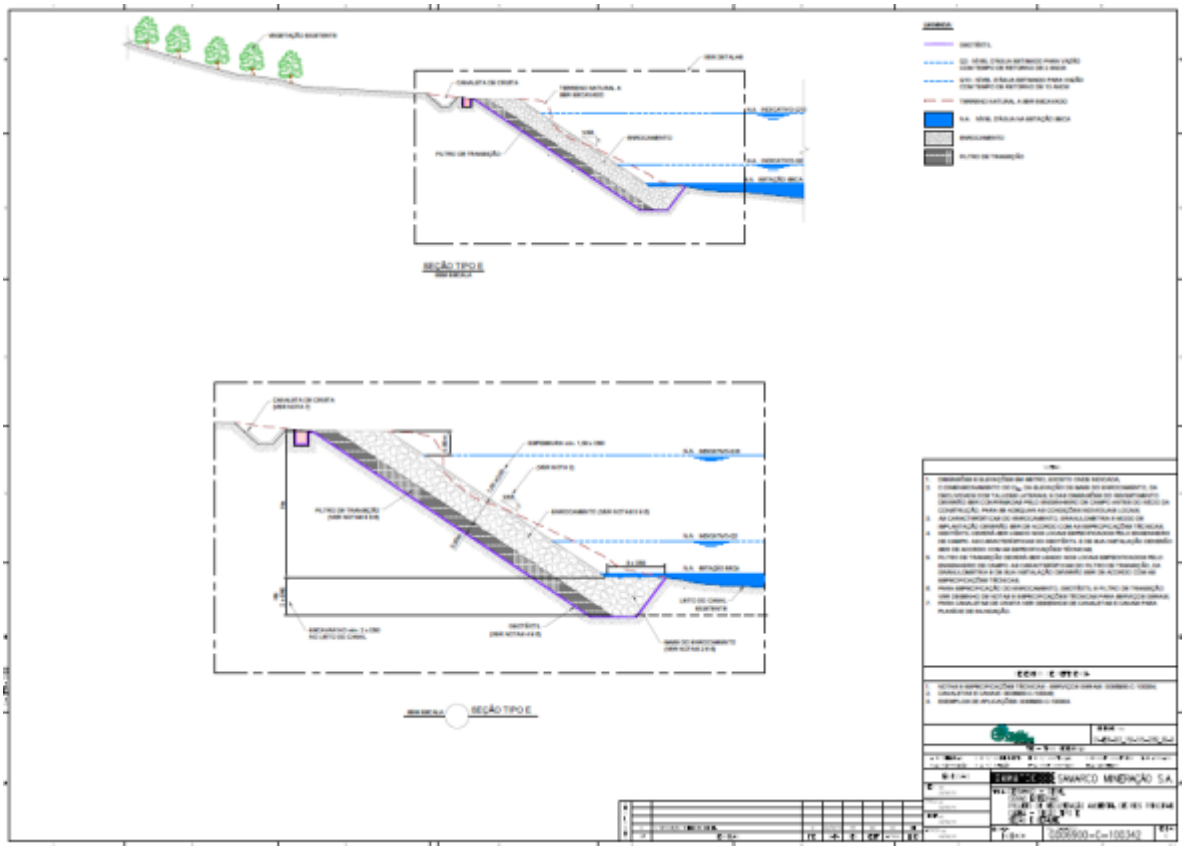

Figure 32: Section TYPE E Schematic.

7.3.2.4 Flood Plains

With a basis on the Field surveys and on analyzes of the topographical data and GIS models drainage structures and erosion and sediment control structures Will be proposed for the flood plains. Such structures have the objective of disciplining the rain Waters and those coming from superficial flows of areas upstream, permitting their infiltration and conducting them in a clean and disciplined form to safe points for dissipation.

Among these structures we may highlight:

- Rain gutters with triangular and trapezoidal cross-sections in earth or lined with anti-erosive bio-blankets;
- Trapezoidal channels with dikes and sediment retainers;
- Windrows of protection in level;
- Contour ridges with sediment retainers, strips of branches and/or Vetiver Grass;
- Wooden or bamboo live crib-wall;
- Embankments with rock armouring;
- Energy dissipaters.

It is important to point out that all these structures offer a perfect synergy with the activities of subsequent re-forestation which are detailed in specific designs. Typical drawings follow below for erosion control.

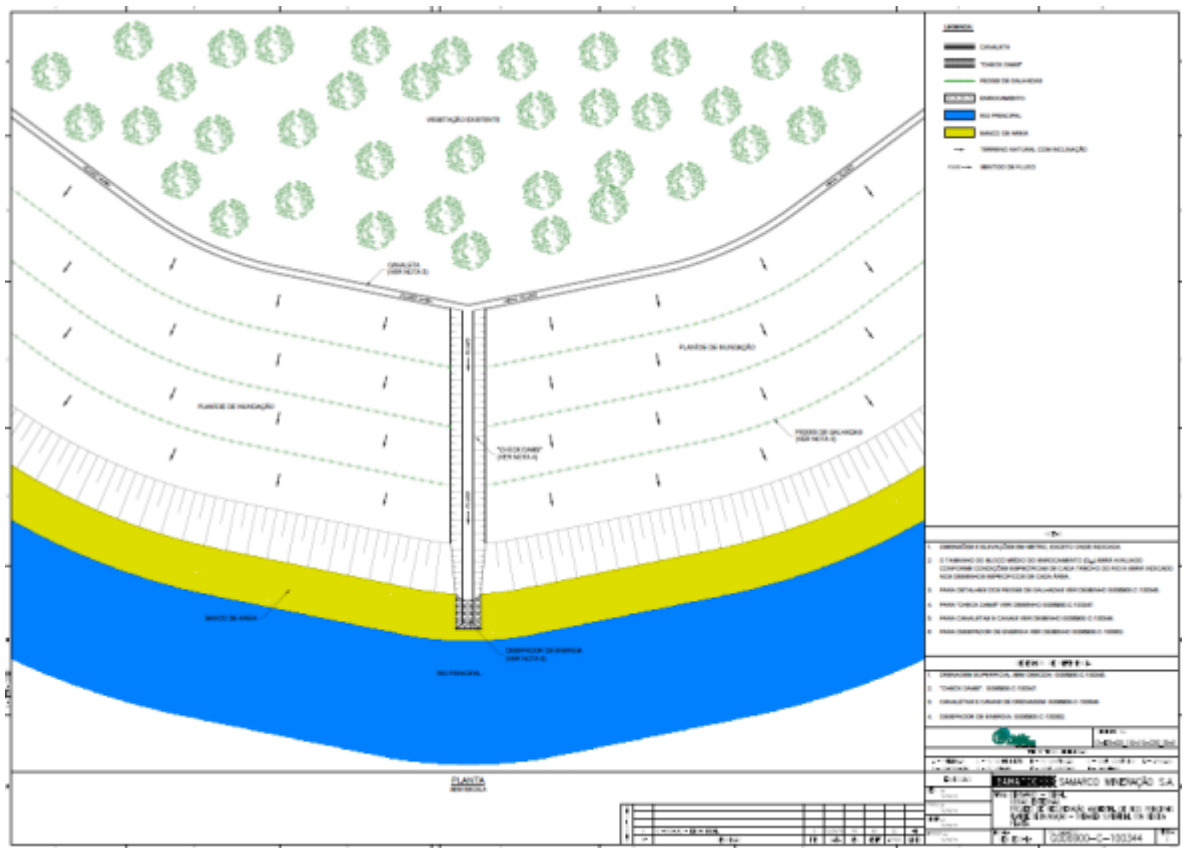

Figure 33: Typical drawings of erosion control (1)

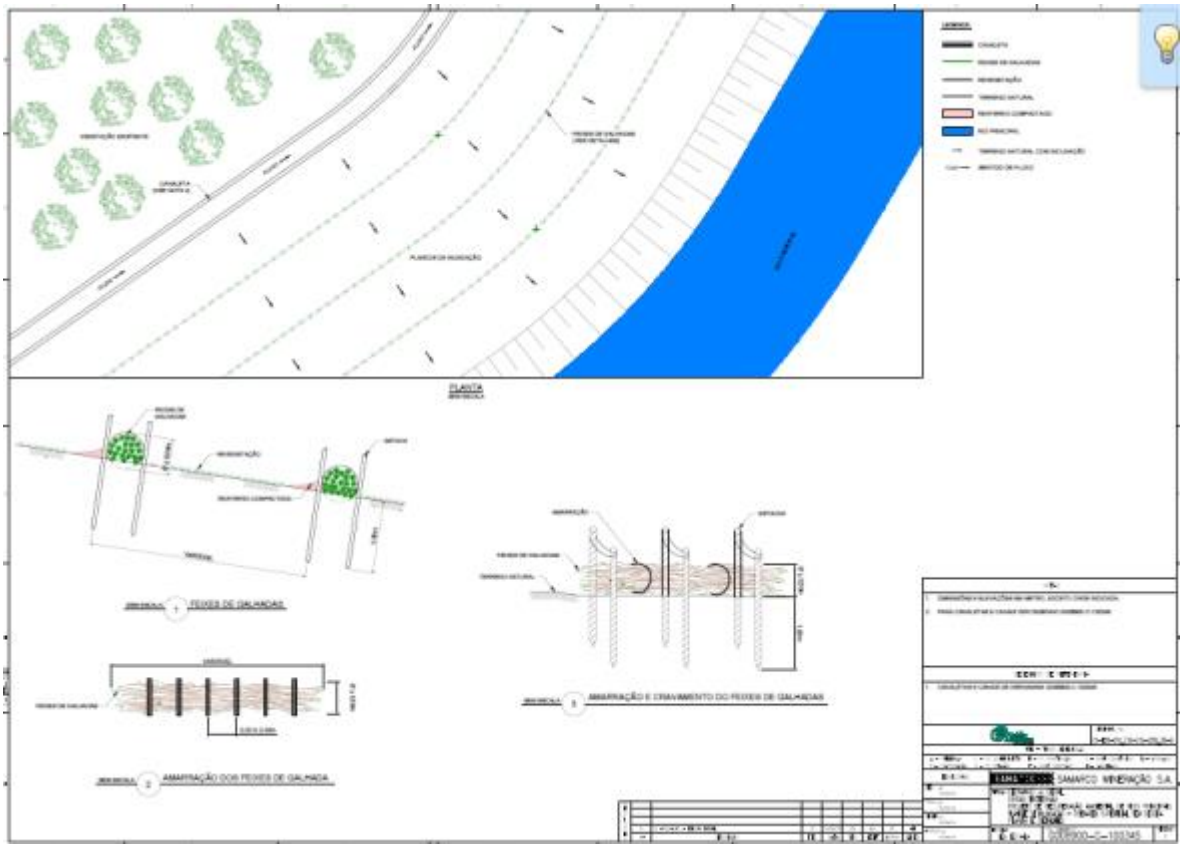

Figure 34: Typical drawings for erosion control (2)

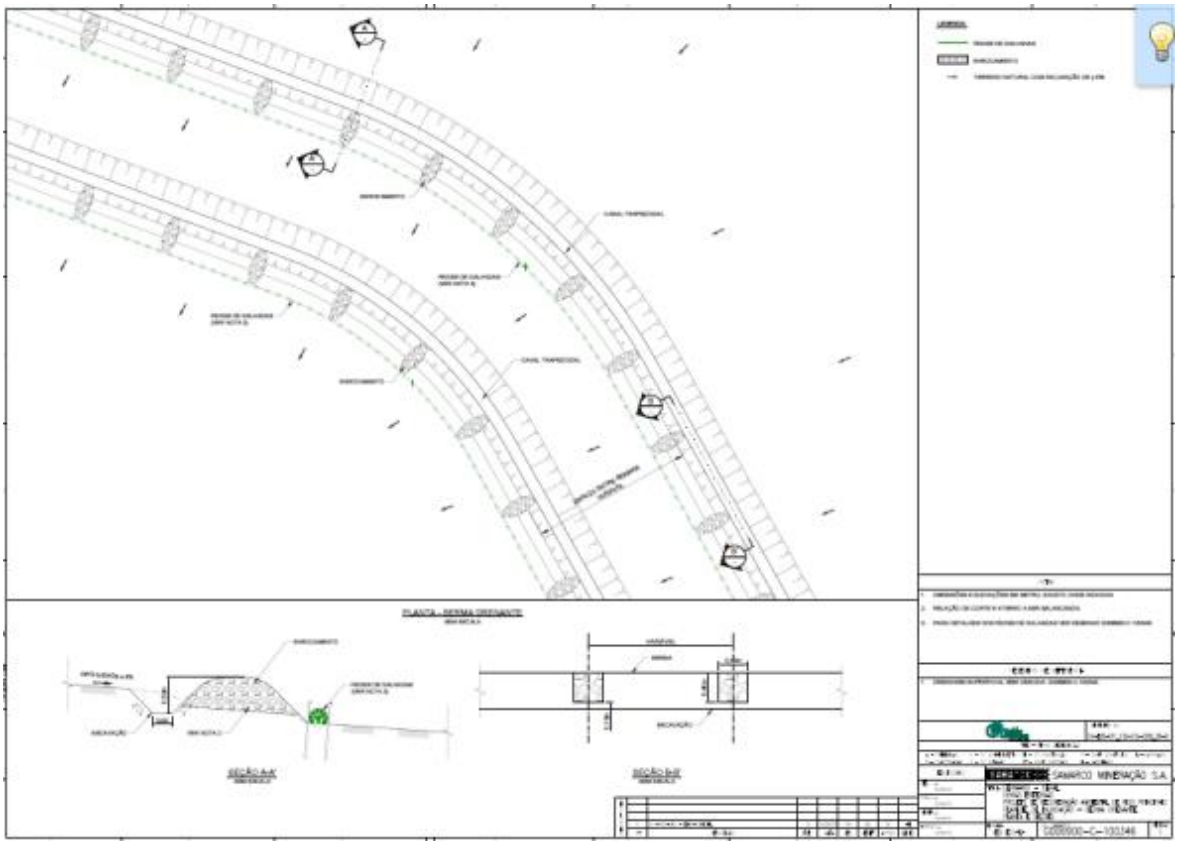

Figure 35: Typical drawing for erosion control (3)

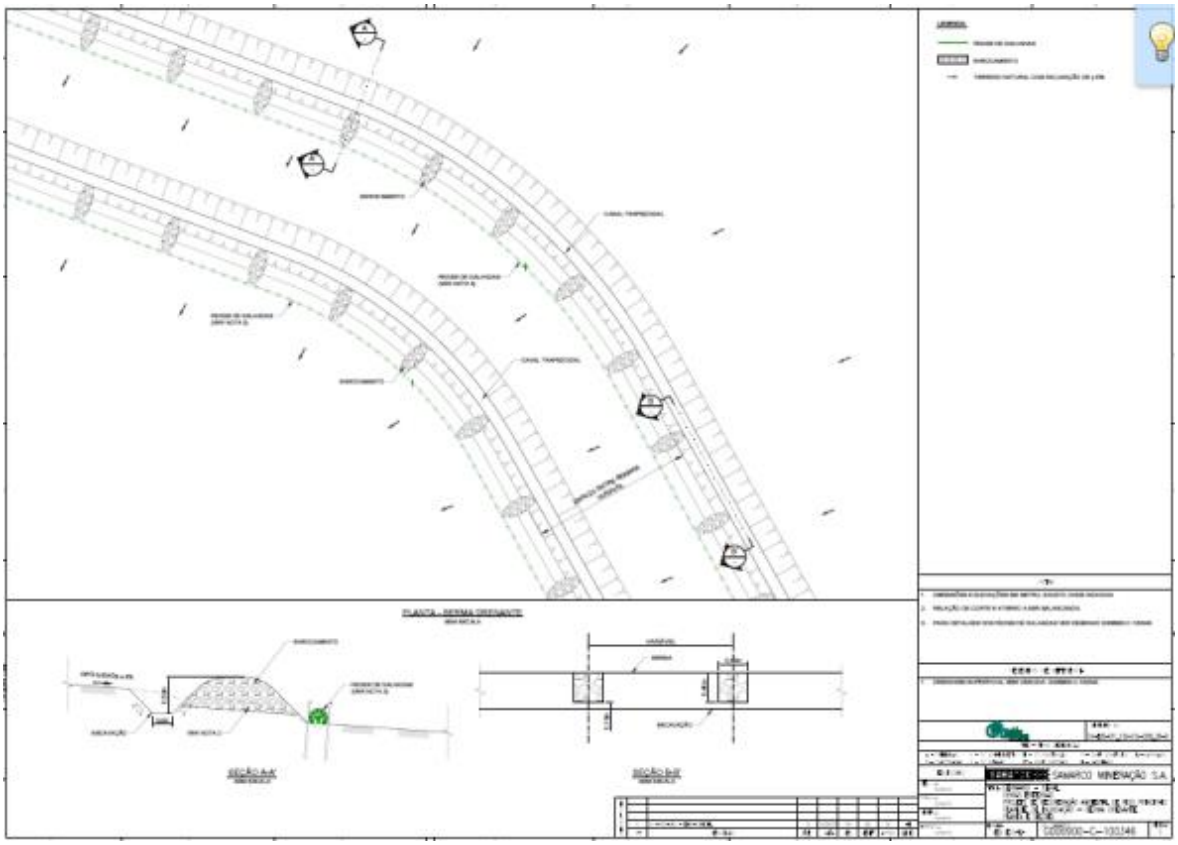

Figure 36: Typical drawing for erosion control (4)

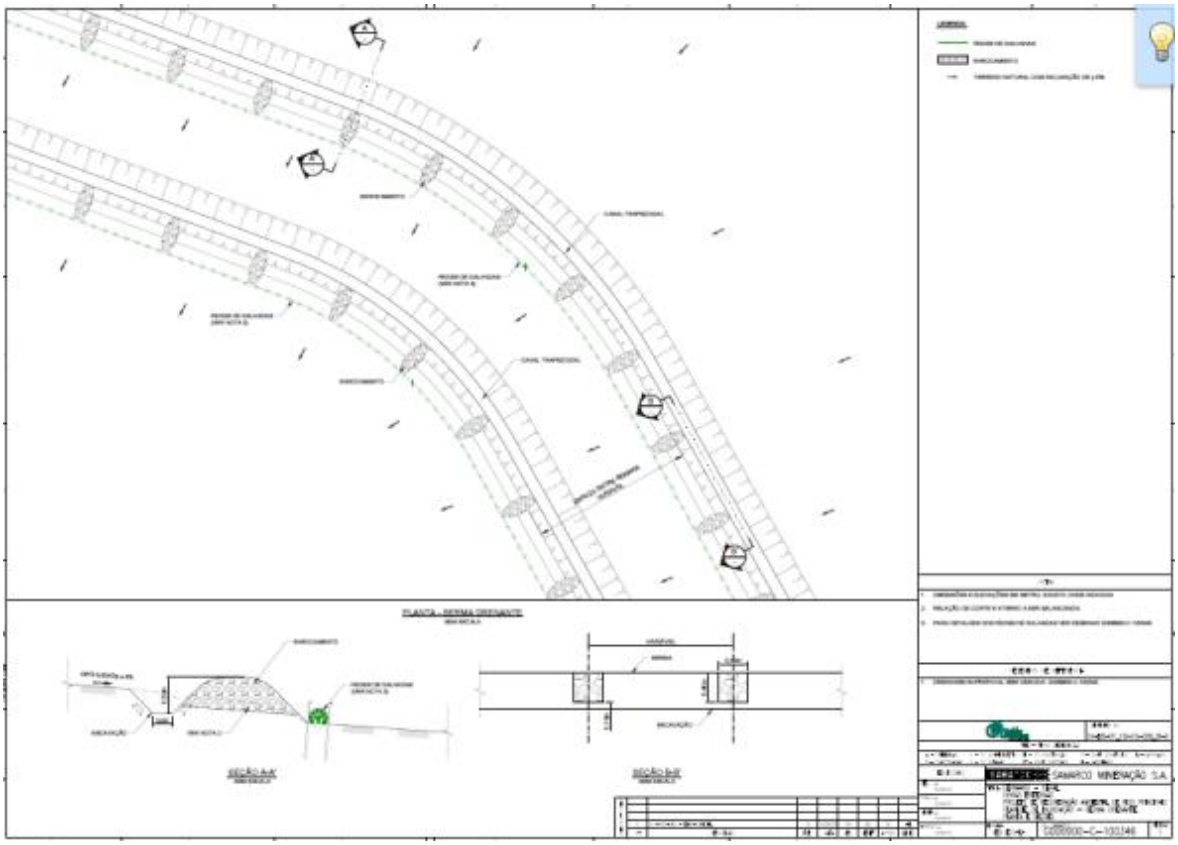

Figure 37: Typical drawing for erosion control (5)

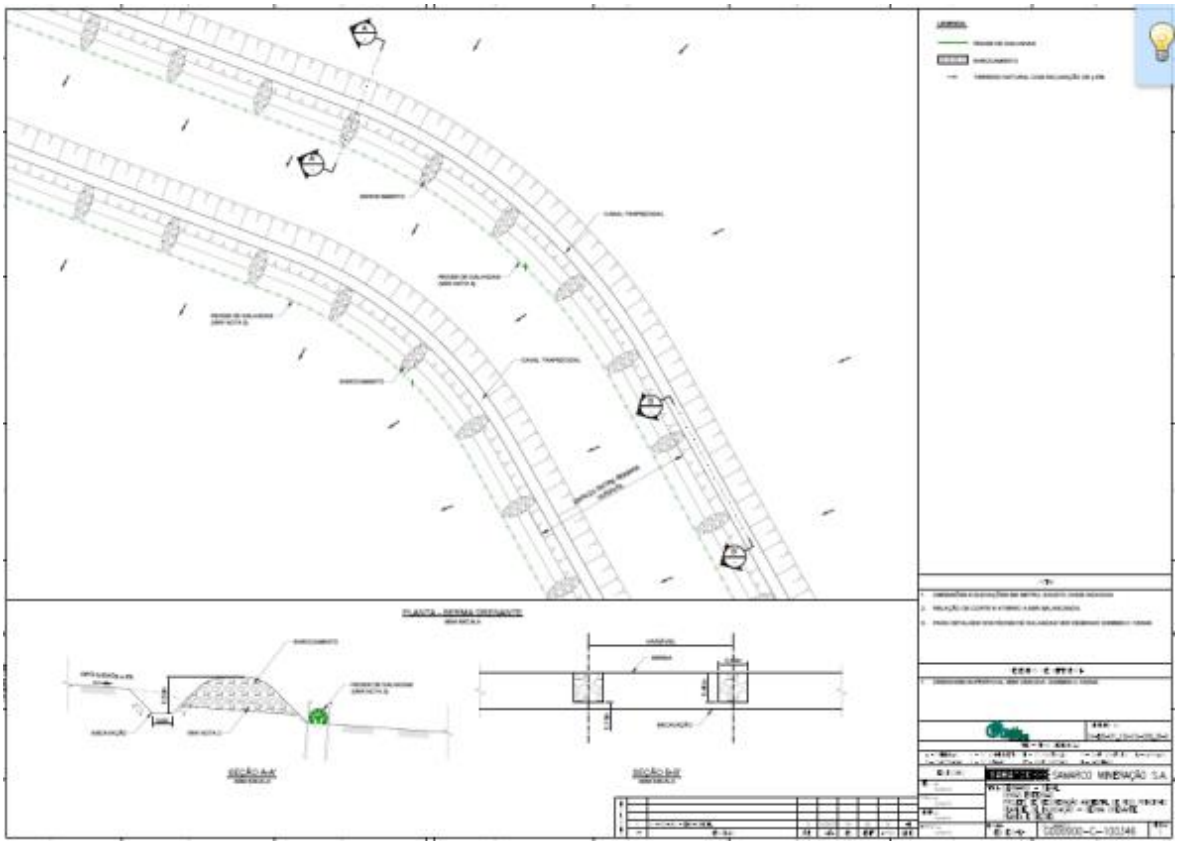

Figure 38: Typical drawing for erosion control (6)

7.3.2.5 Construction Steps

The process of construction of the interventions follows the standard shown below:

- Clean up upstream and configuration of the impacted area;
- Routing of the superficial drainage flow and installation of the erosion control measures;
- Conformation of channel embankments;;
- Application of channel lining – typical section;
- Revegetation;
- Monitoring and maintenance.

The steps of clean-up upstream, removal of tailings and conformation of embankments can be executed.

After the survey of the pertinent data, a document was developed named Report of General Project Guidelines - *Relatório de Diretrizes Gerais do Projeto* (**Atttachment G006900-G-1RT102_R-01**), which presents in detail the information related to this chapter.

Presented below is a Schedule of execution of the activities of reconfiguration of the channels and erosion control.

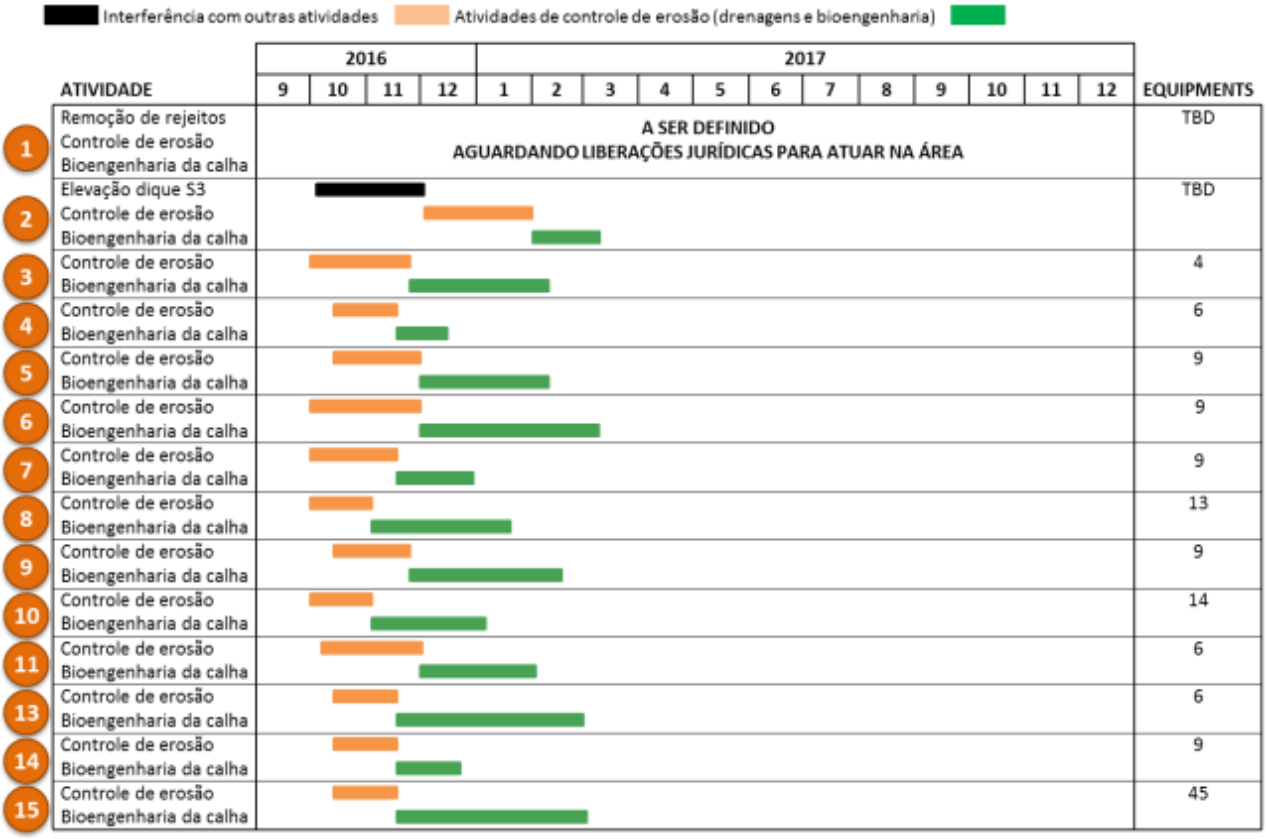

Figure 39: Schedule of activities of reconfiguration of the river channels and erosion control

The average quantities of equipment and labor are also shown below for activities of bio-engineering to meet the program needs.

Quantidade de equipamentos estimados = 138

AREA	01	02	03	04	05	06	07	08	09	10	11	13	14	15
Equipamento	Em definição	Em definição	04	06	09	09	09	13	09	14	06	05	09	45

Pessoas para atividades de bioengenharia = 531

- **Samarco = 28**
- **Golder = 23**
- **Locação de equipamentos = 138**
- **Bioengenharia = 480**

Figure 40: Quantity take-off of equipment by area and labor for bio-engineering

7.3.2.6 Reference Documents of the Section 7.3.2 (See Attachment Section 7.3.2)

DOCUMENT	NAME OF THE DOCUMENT	COMPANY	DATE
Documentação de Engenharia	Book de documentos de engenharia da reconformação das calhas principais	Golder	

7.3.3 Emergency Planting

With a goal to reduce the entrainment of solid particles into the water courses by surface erosion or into the air by wind erosion, measures of erosion control were taken by means of implanting a vegetation cover with rapid growth over the deposited mine tailings on the banks of the water courses impacted. Large exposed surfaces were prioritized in the proximities of the affected communities and the Areas of Permanent Preservation (APP).

As the scientific studies which will support the decision making about the need or not of tailings removal, as well as the extent of this possible removal, are still being evaluated by the competent entities, the program of revegetation was adopted as a temporary measure.

For the seeding, species of rapid germination and growth are being selected in a mix of grassy species (for the generation of biomass) and legumes (for the fixation of nitrogen) herbaceous and shrubby (document Nº RT-002_159-515-2282, **Attachment Section 7.3.5**). The species were selected in such a way to allow the establishment of a future of ecological succession of riparian vegetation. Additional measures for the establishment of the ecologic succession are planned within environmental recovery phase. However, one must highlight that specific decisions are subject to the approval of the environmental organs and need the consultation of the landowners of the properties affected. The combined strategy of utilization of the species of grasses and legumes of rapid growth for generation of biomass and fixation of nitrogen, followed by a strategy of ecological succession is amply used in environmental recovery in Brazil.

7.3.3.1 Trade-off Study

The selection of the alternatives of the initial emergency program took into account the objective of the program, which is to promote a rapid ground cover to minimize laminar erosion, with consequent entrainment of particles to the water courses and reduced of water quality, during the rainy season and to minimize the wind drag, with consequent drag of particles to the atmosphere and reduction of air quality, during the dry season.

Four alternatives were considered for the initial emergency program of vegetation:

- Seeding of *brachiaria*: this is a grass of African origin which was introduced into Brazil and currently is broadly utilized for the formation of pasture areas for cattle. The species of brachiaria, are perennial, have a good plasticity supporting different soil conditions and climates, have a rapid growth and a good vegetation cover. However, they are aggressive species, normally dominating the environment and making recolonization of the area difficult for native species or the actions of planting, because the demand a large maintenance effort;

- Seeding of the mix of grasses and legumes: in the strategy, species of grasses and legumes are selected which have rapid growth and a short cycle. The grasses have the role of

producing biomass and increasing the organic material in the substrate and the legumes have association with nitrifying bacteria and, therefore, help in the fixation of the nitrogen. The combined strategy of the utilization of species of grasses and legumes of rapid growth for the generation of biomass and fixation of nitrogen, followed by the development of the strategy of ecological succession is amply utilized in environmental recovery in Brazil, as demonstrated in academic articles presented in the attachments of the **Section 7.3.3**;

- Management of the natural regeneration: The administration of the natural regeneration is a technique which normally leads to reforestation with the greater diversity of the natural environments. It is recommended when there are some remaining forests in the surrounding area. The administration of the natural regeneration is foreseen in the standing legislation. However, its implementation and the growth of the vegetation are slower;

- Planting of seedling trees: the planting of seedlings of native tree species is one of the techniques of environmental recovery most employed currently. This methodology, even while employing a smaller diversity of species considered high, still presents a smaller diversity than that associated with the administration of the natural regeneration. However, with a faster cover of vegetation than with the former method.

The criteria considered for the definition of the alternatives were:

- Implementation time: refers to the time necessary for the implantation of the actions of soil covering. For example: time necessary for preparing the soil, seeding, planting, or implementing the actions of the administration of the natural regeneration. The time of implementation was classified as Low when less than 1 year; Medium when requiring between 1 and 3 years; High between 03 and 5 years e very high when more than 5 years;

- Time for soil covering: refers to the time necessary between the implementation of the actions and the growth of the vegetation to the point of promoting a covering of the soil capable of minimizing the laminar erosion and wind drag. As with the time of implementation , the time of soil covering was classified as Low when less than 1 year; Medium when requiring between 1 and 3 years; High between 03 and 5 years e very high when more than 5 years;

- Effectiveness of the control of laminar erosion and wind erosion: refers to the effectiveness of the measures adopted in the minimization of the laminar erosion during the rainy season and of wind erosion during the dry season. The effectiveness of the control of laminar erosion and of wind erosion was considered after the growth of vegetation and was classified as High when the land has herbaceous/ brush cover and Very High when covered with forest. The items “high” and “very high “ are in relation to the land exposed of naked substrate, according to the universal formula of soil loss;

- Biodiversity of the flora and of the fauna: refers to the biological diversity which will be present after the growth of the vegetation, considering floristic aspects, by means of the species implanted and of the allowance of egress of other species of natural regeneration, and faunistic ally by means of the attraction of the wild fauna, be it for utilization of the floral resources (pollen and / or nectar), be it for shelter;

- Acceptance on the part of the landowners: refers to the acceptance on the part of the landowners of the measures proposed for initial emergency revegetation. Having in view that a good part of the landowners had pasture or agricultural land before the accident, the wish of the majority of them is the re-establishment of their pre-existing productive activity. The acceptance on the parte of the landowners was classified as Low when the final result of the actions leads to a forest-type vegetation, Medium when a herbaceous/brush vegetation is established which permits its substitution [to other cultures] and High when seeded with brachiaria, species more commonly utilized for pasture;

- Acceptance on the parte of the regulating organs: refers to the acceptance on the part of the regulating organs of the measures proposed for the initial emergency revegetation. The regulating organs tend to accept better the plan when the actions of revegetation lead to a rapid ground cover and not retard the re-establishment of the Atlantic Forest (Mata Atlântica). The acceptance on the part of the regulating organs was considered Low for the utilization of aggressive species which make the ecological succession difficult, Medium for the actions which lead to the re-establishment of the Mata Atlântica, however, have a long implementation time and for the establishment of the ground cover, since the minimization of the laminar erosion and wind erosion would be delayed, and High for the utilization of herbaceous/brush species of rapid growth and short life cycle which promote a rapid ground cover and do not impede the future re-establishment of forest land;

- Compatibility with the legislation and good practices: refers to the fulfillment of the environmental legislation in force in Brazil and in the State of Minas Gerais and with the good practices which foresee the reforestation of the native vegetation in the Areas of Preservation Permanent (APP) and, also, of the protection of the native vegetation of the Atlantic Forest Biome. The compatibility with the legislation and good practices was considered High for actions which promote the reforestation of the vegetation of the Mata Atlântica, mainly the APP; Medium for the actions which do not make the reforestation of the areas difficult; and Low for the actions which make the future reforestation difficult.

Table 5, which follows**,** presents the results of the assessment of the alternatives of the Program of Initial Emergency Revegetation.

Table 5: Assessment of the alternatives of the Program of Initial Emergency Revegetation.

Criteria Considered	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
	Seeding with Brachiaria		**Seeding of Mix of Grasses and Legumes**		**Administration of Natural Revegetation**		**Planting of tree seedlings**	
Implementation time [1]	Low	20	Low	20	Very High	5	High	10
Time for ground cover[1]	Low	20	Low	20	Very High	5	High	10
Effectiveness of laminar erosion & wind erosion control[2]	High	15	High	15	Very High	20	Very High	20
Biodiversity of flora and fauna[2]	Low	5	Medium	10	Very High	20	High	15
Acceptance on part of Landowners[2]	High	15	Medium	10	Low	5	Low	5
Acceptance on part of regulating organs[2]	Low	5	High	15	Medium	10	Medium	10
Compatibility with legislation & good practices[2]	Low	5	Medium	10	High	15	High	15
Score	2º Place	85	**1º Place**	**100**	3º Place	80	2º Place	85

Scoring: Items [1] – Low = 20; Medium = 15; High = 10; Very High = 05 points;
Items [2] – Low = 05; Medium = 10; High = 15; Very High = 20 points

The results expected of the Program of Initial Emergency Revegetation are:

- Rapid coverage of the areas with herbaceous and brush species;
- Reduction of the load of solid particles entering the creeks and rivers;

- Reduction of the emission of particulate material; and,
- Improvements in the water quality of the substrate.

Currently, the step of implementation of the Program of Initial Emergency Revegetation was concluded in July 2016, proceeding with the step of maintenance of the areas revegetated.

In the following are presented some results reached according to the report MT-008_159-515-2282_01-B developed by Golder Associates.

For the Program of Initial Emergency Revegetation, two subcontracted companies were utilized by Samarco: Agroflor and RG Bioengenharia. The first was signed with Agroflor and the areas were prioritized around the communities and rural properties affected, those being: Bento Rodrigues, Ponte do Gama, Paracatu de Cima e de Baixo, Pedras, Barretos, Gesteira e Barra Longa. This contract was aimed at the revegetation of 200 hectares and was extended for an additional 50 hectares. The second contract, celebrated with RG Bioengenharia and Samarco prioritized the revegetation in the proximities of the water courses affected and aimed at the revegetation 600 hectares. Additionally, Samarco is performing the reconfiguration of the main rivers and respective tributaries, also in accordance with the description in the present report. After the works of reconfiguration are executed actions of revegetation utilizing, also, grasses and leguminous species. These works were directed and accompanied by Golder Associates.

7.3.3.2 Methodology

The methodology of the Program of Initial Emergency Revegetation was presented in the Plan of Environmental Recovery (document º RT-002_159-515-2282, **Attachment Section 7.3.3)**.

Preparation of the mix of seeds

The compilation of seeds which was used for the seeding was developed by the specialist in environmental recovery, Professor Doutor Ademir Reis (from the company Restauração Ambiental Sistêmica – RAS). The mix was composed of herbaceous and brush species of legumes (Fabaceae), grasses (Poaceae) and one species from another family (Brassicaceae), which are available commercially. The mix was prepared in such a way as to not include species which might impede the future succession development of the tree colonies, or of invasive species such as brachiaria (*Brachiaria* spp) or “capim gordura” (Melinis minutiflora).

The compilation of the species acceptable for being utilized and available in the market are presented in the **Tables 6** (legumes), 7 (gramineae) and **8** (other family). The composition of the mix was utilized for seeding in the different areas depending on the commercial availability of same at the moment of purchase.

Table 6: List of the species of legumes (Fabaceae) non-invasive acceptable for use in the Program of Initial Establishment of the Vegetation cover.

Scientific Name	Popular Name	Size	Life Cycle	Ecological Function
Calopogonium mucunoides	Calopogônio	Vine - herbaceous	Annual	Fixation of Nitrogen
Crotalaria spp.	Chocalho de cascavel	Shrubby	Annual	
Canavalia ensiformis	Feijão de porco	Herbaceous	Annual	
Cajanus cajan	Feijão Guandu	Shrubby	Annual	
Mucuna aterrina	Mucuna preta	Liana	Annual	
Mucuna pruriens	Mucuna cinza	Liana	Annual	

Scientific Name	Popular Name	Size	Life Cycle	Ecological Function
Pueraria phaseoloides	Pueraria	Liana	Perennial	
Glycine wightii	Soja-perene	Liana	Perennial	
Stylosanthes spp.	Estilosante	Shrubby	Perennial	
Canavalia ensiformis	Feijão-de-porco	Shrubby	Annual	
Lupinus albus	Tremoço branco	Shrubby	Annual	
Vicia sativa	Ervilhaca	Liana	Annual	
Arachis pintoi	Amendoim-forrageiro	Shrubby	Perennial	
Desmodium spp.	Pega-pega	Shrubby	Perennial	
Vigna ungiculata	Feijão-miudo	Shrubby	Annual	

Table 7: List of grass species (Poaceae) non invasive acceptable for use in the Program of Initial Establishment of the vegetation cover.

Scientific Name	Popular Name	Size	Life Cycle	Ecological Function
Sorghum bicolor	Sorgo-forrageiro	Herbaceous	Annual	Generation of biomass
Avena spp.	Aveia-amarela, aveia-preta	Herbaceous	Annual	
Cynodon dactylum	Capim-vaqueiro	Herbaceous	Perennial	
Lolium multiflorum	Azevém	Herbaceous	Perennial	
Paspalum notatum	Batatais, pensacola	Herbaceous	Perennial	
Axonopus spp.	Sempre-verde	Herbaceous	Perennial	

Table 8: Species of another family (Brassicaceae) non invasive acceptable for use in the Program of Initial Establishment of the Vegetation cover.

Famíly	Scientific Name	Popular Name	Size	Life Cycle	Ecological Function
Brassicaceae (Cruciferae)	*Raphanus sativus*	Nabo-forrageiro	Herbaceous	Perennial	Generation of biomass

In addition to these species available in the market, the enrichment of the above mix was also recommended with seeds of ruderal species (those that are first to colonize disturbed land) observed in the field in December of 2015 with seeds available for collection on the banks of the tributaries upstream of the areas affected by the collapse of the Fundão dam. These seeds were used for in the area of greatest physical impact on the banks of the water courses observed between the Bento Rodrigues district and the Candonga Reservoir (Risoleta Neves) in Minas Gerais.

Table 9 presents a list of native ruderal species whose seeds were available for collection and should be collected and utilized for the enrichment of the mix of commercial seeds.

Table 9: List of native ruderal species whose seeds are available for collection and can be utilized for the enrichment of the mix of commercial seeds of the Program of Initial Establishment of the ground cover.

Family	Scientific Name	Popular Name	Size	Cycle	Function
Fabaceae	*Mimosa pigra*	Mimosa-de-espinho	Shrub	perennial	
Fabaceae	*Mimosa pudica*	sensitiva	Shrub	perennial	

Family	Scientific Name	Popular Name	Size	Cycle	Function
Fabaceae	*Indigofera* spp.	Anis-selvagem	Shrub	perennial	Fixation of nitrogen
Fabaceae	*Sesbania punicea*	Flamboiant-mirim	Shrub	perennial	
Fabaceae	*Desmodium* spp.	Pega-pega	vine	perennial	
Boraginaceae	*Varronia curassavica*	balieira	Shrub	perennial	Generation of biomass
Verbenaceae	*Lantana* sp.	Lantana	Shrub	perennial	
Poaceae	*Gynerium sagittatum*	Cana-do-rio	Shrub	perennial	
Solanaceae	*Solanum spp.*		Shrub	perennial	
Convolvulaceae	*Ipomoea cairica*	Corriola	liana	perennial	

Preparation of the Substrate and Seeding

Prior to the seeding, several experiments were performed in small areas to assess the need of soil preparation and the best method to prepare the soil. These experiments demonstrated that there are low germination and ground cover in the sites where no previous preparation of the substrate was made by means of scarification of the surface. Therefore, the experiments performed demonstrated the necessity of executing the preparation of the soil to provide fixation indices, germination and ground cover within the conditions encountered.

The methods of scarification selected included the manual opening of micro planting holes with the use of small hoes or, where the substrate may be flat and firm, utilization of motor-cultivators (**Figures 41, 42, 43 and 44**).

Figure 41: Manual micro planting holes of the soil using small hoes near Barra Longa.

Figure 42: Semi-mechanized preparation of the substrate using a motor-cultivator near Barra Longa.

Figure 43: Preparation of the soil utilizing manual and semi-mechanized methods of scarification of the substrate, seeding and fertilization being executed near Paracatu de Baixo

After the scarification of the substrate, the seeds are applied casting (hand sowing). During the experimental phase of the Program of Initial Establishment of the Vegetation Cover an application rate of seeding above the normal was used (400 Kg/ha). This high rate was utilized due to the uncertainties regarding the indices of germination. However, as the germination has been high, the utilization of seeds will be reduced to 300 Kg/ha during thee revegetation phase in APPs. This quantity of seeds per hectare is still considered conservative.

Figure 44: Seeding by casting performed by local workers.

As the substrate has few nutrients, fertilization was utilized so that the recently germinated seeds could form roots and develop. For the mulching of the planting, inorganic fertilizer was used with Nitrogen (N), Phosphorus (P), and Potassium (K) – (NPK 8-28-16) at the rate of 400 Kg/ha. The phosphorus (P) stimulates the formation and initial development of the roots, however, for the later development of the plants, the utilization of smaller quantities of this nutrient is advisable. Therefore, for the fertilizing of the cover when the leaves and roots are already in development, NPK (20-05-20) was used at the rate 200 Kg/ha for the phase of the experimental seeding. Then for the seeding phase this rate was divided in two applications of 100 Kg/ha to allow that the plants to absorb the nutrients for a greater period along its development.

7.3.3.3 Results Obtained

The principal results obtained until this moment were:

- The mix of seeds used had a good germination and the initial growth had indicated positive results for the initial control of the laminar erosion;
- At least part of the kinetic energy of the rain drops is being reduced by the foliage of the plants which have reached a reasonable size and a good rate of ground cover has been achieved;
- The roots and rootlets of the plants in development over the tailings promote an adhesion of the soil, even though only sub-superficial;
- The contact with the tailings does not inhibit the germination of the seeds (multiple species), their subsequent growth, or the development of the rootlet structures up to the stages observed, which indicate that the tailings probably are not toxic for land-based plants. A chemical study of the vegetation tissues is in the phase of contracting to assess other and future aspects of the vegetation growth in the tailings;

- A preparation of the soil by means of superficial scarification of same if it proves to be necessary. The seeding in spoils where there was no scarification of the land did not show to be effective;
- The addition of fertilizers to the areas seeded presented better results, presumably due to the low nutrient loading of the materials deposited;
- Some areas, particularly in those whose seedlings are small, present a formation of erosive furrows; in some cases, the seeds deposited in these furrows by the rains germinated and are growing;
- Some cows, horses, pigs, and capybaras were observed eating the seedlings in development thus damaging their opportunity for full growth;
- Also there was some loss to birds and ants (ant-killer was used, but, due to the extent of the area seeded, in some locations insects were still observed consuming the seeds and new leaves;
- The majority of the areas seeded are flat and, in some cases, wide. This fact can result in drought and reduction in the development of microclimates and in the riparian areas, in the development of micro-habitats;
- The quantity of the mix of seeds utilized per hectare proved to be adequate;
- In some locations there was excellent ground cover, in others the indices were not so good and a program of maintenance will be initiated soon.

In summary, the actions of emergency planting were executed, up to 21 July 2016, by the companies contracted by Samarco, with revegetation of a total of 808.49 hectares considering spatial areas. Initially an extension of 835.22 hectares re-vegetated was reported, however a topographical error was identified on one of the areas re-vegetated of Bento Rodrigues, with this the final expanse already rectified by Samarco in conjunction with the proper authorities was corrected to 808.49 hectares. The documentation which proves the conclusion of this measurement was revised and is presented in **Section 7.3.4**. In the same section is presented a letter from ERG explaining the error of topographical measurement.

Additionally, the process of maintenance of the revegetated area will be initiated, with the objective of maintaining the planted ground cover until the beginning of the final vegetation recovery, which will be executed with native tree species. In this service, items such as irrigation, ant control, fertilization are to be included, in addition to planting new impacted areas.

Immediately below, please refer to examples of maps with the areas re-vegetated (**Figures 45 and 46**). This information was obtained from topographical data by ERG

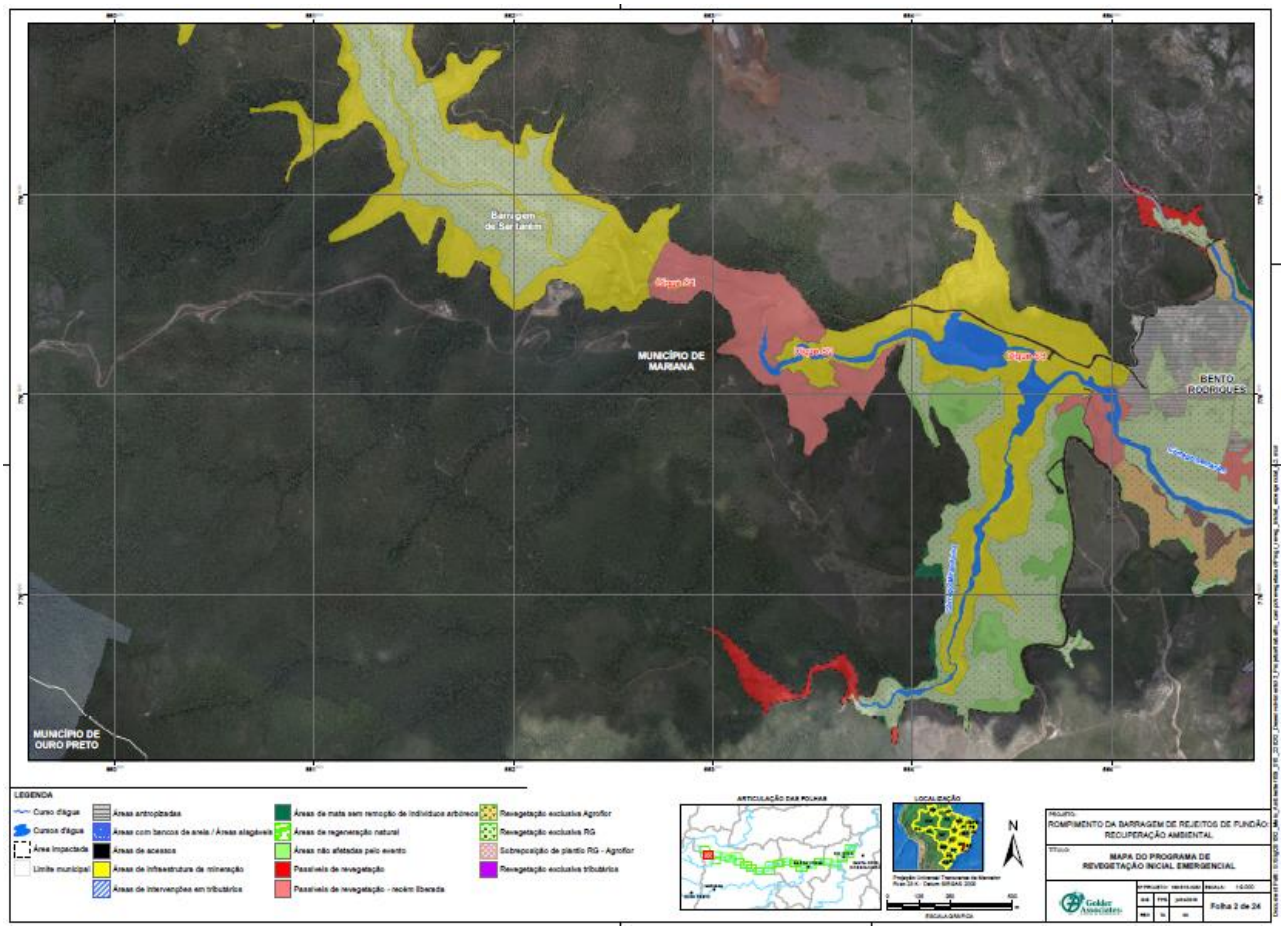

Figure 45: Map of the program of initial emergency revegetation. (Source: Golder Associates).

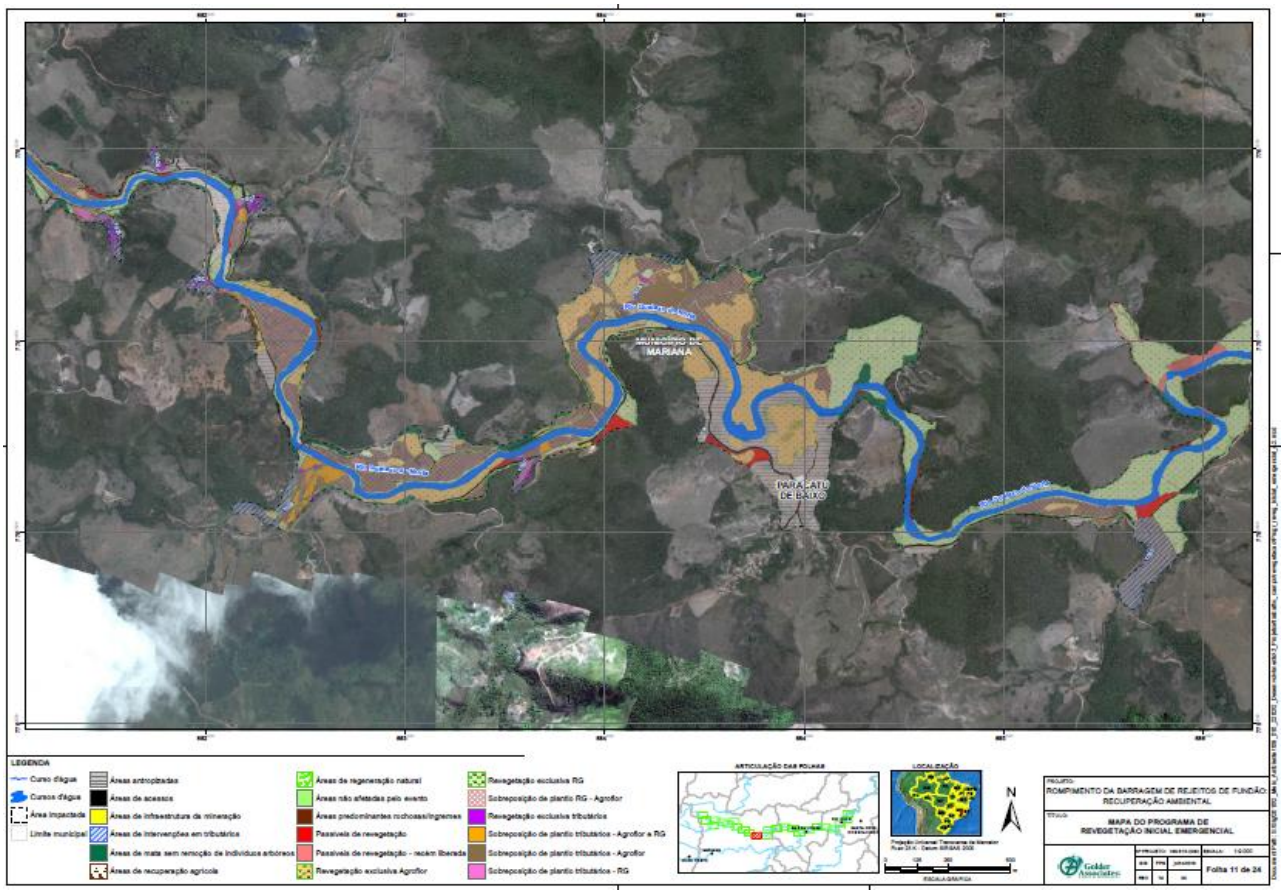

Figure 46: Map of the program of the Initial Emergency revegetation . (source: Golder Associates).

Some examples of the evolution of the initial emergency revegetation are presented in the **Figures 47 to 52**.

Figure 47: Revegetation in the region of Ponte do Gama.

Figure 48: Revegetation in the region of Barra Longa.

Figure 49: Revegetation in the region of Barra Longa.

Figure 50: Revegetation in the region of Paracatu de Cima.

Figure 51: Revegetation in the region of Paracatu de Baixo.

Figure 52: Revegetation in the region of Paracatu de Baixo.

7.3.3.4 Reference Documents of the Section 7.3.3

DOCUMENT	NAME OF DOCUMENT	COMPANY	DATE
RT_002-159-515-2282_02-J	Plano de Reabilitação Ambiental	Golder	Feb/16
Anexo I - Relatório Agroflor	Contenção de carreamento de sedimentos por meio de revegetação	Samarco / Agroflor	Mar/16
Anexo II - Relatório Geral Samarco 2016_R1	Serviços para contenção de sedimentos por meio de vegetação	RG Bioengenharia - Soluções Ambientais	Aug/16
Anexo III - Impeditivos-rev 00	-	Golder	Jul/16
Anexo IV - Progr_reveg_inicial_emergencial_A2	Mapa do programa de revegetação inicial emergencial - Folha 1 a 24	Golder	
Introdução_R5	-	Golder	Aug/16
Artigos acadêmicos revegetação	Artigos acadêmicos que demonstram ampla utilização do mix de gramíneas e leguminosas como parte da estratégia de recuperação ambiental		
Anexo V - ARTs	ART das empresas envolvidas na revegetação emergencial		

7.4 Additional Actions for Rainy Season

The Action Plan for the Rainy Season 2016/2017 is part of the integrated strategy with the objective of moving to the next rainy season with smallest possible generation of impacts to the society, to the environment and to the economic activities by the event of 5 November of 2015.

During the rainy period, which goes from October to March, the levels of precipitation present greater intensity, as per the example presented in **Figure 53**.

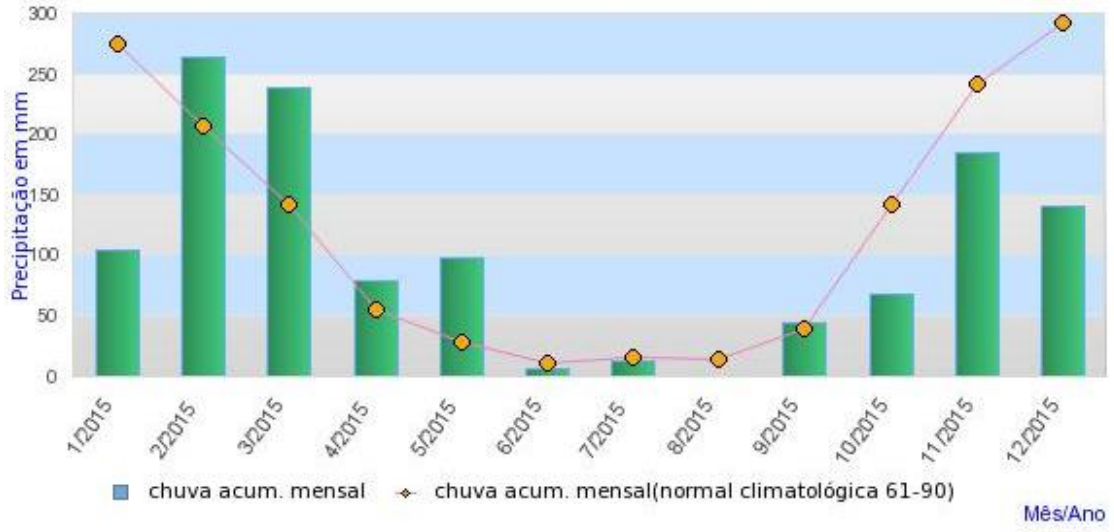

Figure 53: Accumulated monthly rainfall mensal in 2015 (Source: INMET)

Under natural conditions, such levels of volume of rain can cause an increase in the flow of the river, provoking possible entrainment of solids deposited on its banks and increase in the turbidity of the water. After the event of collapse of the Fundão dam on 5 November of 2015, part of the sediments remained

deposited in the channels of the rivers and could be returned to the watercourses with the occurrence of rains.

In that sense, several preventive actions are being taken with the objective of minimizing the impacts on the water quality for the next rainy period and, for this, an integrated strategy is being developed which is aimed at acting on the potential causes as well as on the consequences of a scenario with high turbidity in the next rainy periods.

The documents which integrate this strategy are:

1) Integrated Environmental Recovery Plan (PRAI)

- ✓ This plan presents the strategic pillars and unites the actions which are being performed for the environmental recovery. Here, one seeks to detail the action fronts established to avoid the availability of new sediment points in the water courses.

2) Plan of Monitoring and Control of the structures during the rainy period (PMC)

- ✓ Establishes the routine of operation for the rainy period aiming at mitigating the impacts of the rains on the interventions executed

3) Action Plan for the Rainy Season

- ✓ Establishes the preventive actions and contingencies with a view to possible scenarios of increased turbidity, aimed at mitigating the impacts on society and the environment, The document considers several situations, including the most critical.

Figure 54, which follows, presents schematically the logic strategy developed to meet this demand.

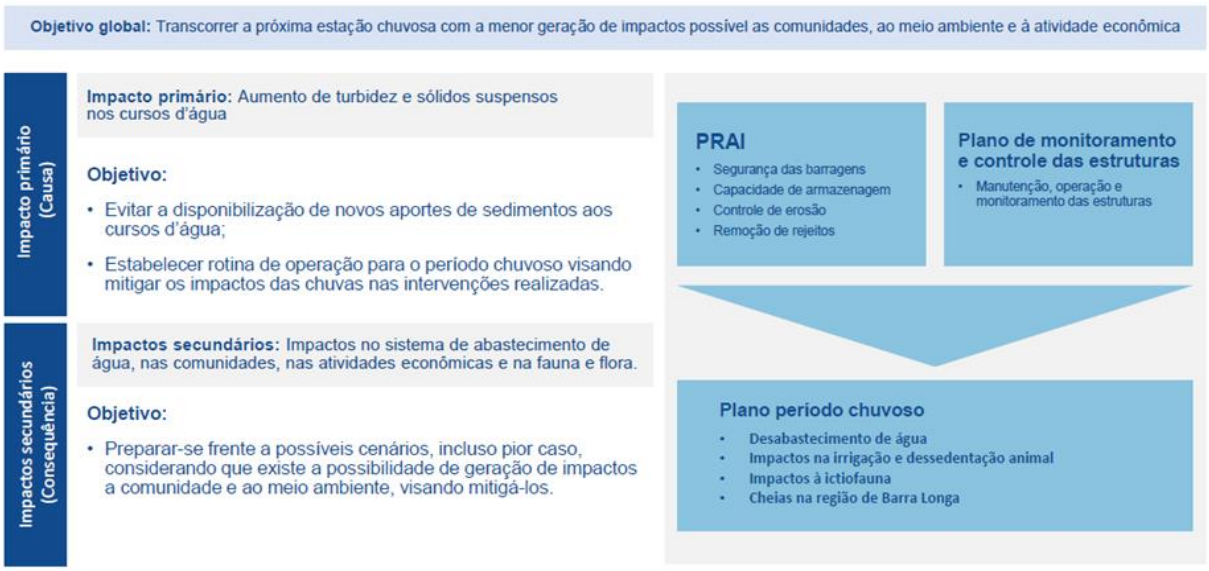

Figure 54: Integrated strategy for preparation of the next rainy period.

The risks identified are:

- Impacts on the supply of water of the municipalities;
- Impacts on the irrigation and watering of animals;

- Impacts to the ichthyofauna;
- Floods;

With a basis on the experience after the event of collapse of the dam in 2015, the Plan of Actions for the Rainy Period 2016/2017 presents the work fronts employed, aiming at the mitigation of the impacts identified resultant from the eventual increases in the levels of turbidity in the river.

8 SCIENTIFIC BASIS OF THE RISK ASSESSMENT AND RECOVERY PROCESS

8.1 Determination of the Volumes of Deposited Tailings

Based on the topographic surveys procured by Samarco from company HGT, there were in Fundão valley 56.4 Mm³ of tailings and sludge before the event. At the first moment of the accident, 32.2 Mm³ leaked to Fundão valley. Later on, in the wet season, additional 11.5 Mm³ were entrained; therefore, currently there are approximately 12.8 Mm³ of remaining tailings in the Fundão dam. According to the same topographic survey mentioned above, currently the Santarém dam has 9.8 Mm³ of settled tailings.

The incident involved significant erosion and/or subsequent disposal in sections of the upper Doce River basin, resulting in changes in the morphology of some river stretches. As indicated in this report, efforts are being made to stabilize the river banks, minimize erosion and remobilize deposited sediments, as well as understand the potential for flooding under these new conditions.

Moreover, Samarco started the monitoring and quantification of movement of solids along the affected area through topo-bathymetric surveys and flights over the entire area conducted immediately after the break..

8.1.1 Methodology Used for Calculation of Volumes

Initial calculations to estimate the volumes that supported the values described were carried out by company HGT (document no. G001600-O-1MC001, **Attachment Section 8.0**). Attachment Section 8.0 has the entire calculation log.

8.1.1.1 Methodology Used in the Area Upstream the Santarém Dam

The software Endurance (version 1.01) of HGT Geoprocessamento Ltda was used, with routines for calculation of Volume provided in the endurance/gis package.

The methodology is based on calculating the difference in volumes between two different surfaces. The surfaces were produced through the technique Post-signaling per Area, consisting of aero-photogrammetric process from images collected by an ARP (Remotely Piloted Aircraft).

Surface differences are calculated from a filter, which identifies the area of interest of the calculation. Two free volumes are calculated until an arbitrary elevation higher than the maximum existing in the study area, the difference between the volumes is the quantity of material moved in the period.

8.1.1.2 Methodology Used in the Area Downstream the Santarém Dam

The recovery software Endurance (version 1.01) of HGT Geoprocessamento Ltda was used, with routines for calculation of Volume provided in the endurance/GIS/stereo package.

The methodology is based on calculating the difference in volumes between two different surfaces. Two surfaces were used for calculation: the first one, or primitive, was a public global surface, a photogrammetric overflight made by the United States Air Force (USAF) in 1966, at scale 1:60,000, the second one, related to the surface after the break, was made through aerial photogrammetry using panoramic images collected on Nov 08, 2015.

Due to the scale and deteriorated quality of the images collected by the USAF in 1966 used as primitive, the volume of each area was calculated based on an average of altimetric difference as per points with marked elevations near the hydrographic courses in altimetric sections, measured in the stereographic replicator comparing the USAF model with the base generated by aerial photogrammetry.

The primitive obtained to carry out the calculation of volume for the stretch downstream of Santarém to PCH Candongas (USAF) was unsatisfactory due to low quality of conservation (Images printed in the collection), large difference of dates, and scale much lower than that of the aerial photogrammetry of Nov 08th, thus being data of quality lower than that required for volume calculation with satisfactory level of accuracy.

8.2 Geomorphology

The break of the Fundão dam involved significant erosion and/or subsequent deposition in stretches of the upper Doce river basin, resulting in changes to the morphology of some river stretches. Efforts are being made on an emergency basis to stabilize the river banks, minimize erosion and remobilize deposited sediments, and to understand the potential for flooding under these new conditions.

In order to provide scientific basis for erosion control and stabilization actions in the areas affected by the event occurred at Fundão dam, Samarco hired Golder Associates, which performed the geomorphology study of the impacted area.

This study consisted in a description of how the tailings were carried and their deposition along the river system, definition of the regime of sediment transportation on the rivers, identifying the main sources of sediments, and evaluation of sediment transport load in the river system for pre- and post- break conditions.

One of the main answers obtained from this study was the definition of priority areas where interventions must be undertaken to minimize the quantity of sediments in the river system during the next wet season.

These areas are listed below, including examples of potential engineering solutions which were assessed for containment and stabilization of sediments in each one. These examples were defined from preliminary data generated/analyzed in the geo-morphological study and do not necessarily represent what will be performed in each area. The engineering service for proposal of appropriate technical solutions for each area was carried out, the status of the recovery activities in progress, as presented in the **Section 7.3.2**.

- Channel and floodplain of Santarém Creek, near Bento Rodrigues
  - To restore the channel of the Santarém Creek, by removing tailings from the channel area and building a lined channel with adequate normal bed width and normal bed depth;
  - To reconfigure the outline of the floodplain, install surface erosion control and sedimentation basins in the floodplain to control runoff to the main river, and reforest the floodplain of the Santarém Creek;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.
- Channel and floodplain of Mirandinha River
  - To restore the Mirandinha River channel, by removing tailings from the channel area and building a lined channel with adequate normal bed width and normal bed depth;

- To reconfigure the outline of the floodplain, install surface erosion control and sedimentation basins in the floodplain to control runoff to the main river, and reforest the floodplain of the Mirandinha River;
- To restore tributaries and line tributary channels in floodplains affected by tailings.

- Channel and floodplain of upper Gualaxo do Norte River

  - To restore the channel of upper Gualaxo do Norte River, by removing tailings from the channel area and building a lined channel with adequate normal bed width and normal bed depth;
  - Stabilize the end of the tailings flow impact area upstream and connect the channel to the unaffected channel upstream;
  - To reconfigure the outline of the floodplain, install surface erosion control and sedimentation basins in the floodplain to control runoff to the main river, and reforest the floodplain of the Upper Gualaxo do Norte River;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.

- Channel and floodplain of Camargo River
  - To remove tailings from the river and floodplain, reconfigure the outline of the floodplain and reforest the floodplain and valley walls;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.

- Floodplain BFL-11 of Gualaxo do Norte River
  - To remove tailings from the river and floodplain, reconfigure the outline of the floodplain and reforest the floodplain;
  - To install surface erosion control and sedimentation basins in the floodplain to control runoff to the main river;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.

- Floodplain BFL-27 of Gualaxo do Norte River
  - To remove tailings from the river and floodplain, reconfigure the outline of the floodplain and reforest the floodplain;
  - To install surface erosion control and sedimentation basins in the floodplain to control runoff to the main river.
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.

- Floodplain BFL-17 of Gualaxo do Norte River
  - To remove tailings from the river and floodplain, reconfigure the outline of the floodplain and reforest the floodplain;

- To install surface erosion control and sedimentation basins in the floodplain to control runoff to the main river;
- To line the outer edges of meandering curves where erosion occurred;
- To restore tributaries and line tributary channels in floodplains affected by tailings.

- Floodplain BFS-10 of Gualaxo do Norte River
  - To remove tailings from the river and floodplain, reconfigure the outline of the floodplain and reforest the floodplain and valley walls;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.

- Floodplain BFS-26 of Gualaxo do Norte River
  - To remove tailings from the river and floodplain, reconfigure the outline of the floodplain and reforest the floodplain and valley walls;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.

- Floodplain BFS-08 of Gualaxo do Norte River
  - To remove tailings from the river and floodplain, reconfigure the outline of the floodplain and reforest the floodplain and valley walls;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.

- Floodplain NR-06 of Gualaxo do Norte River
  - To remove tailings from the river and floodplain, reconfigure the outline of the floodplain and reforest the floodplain and valley walls;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings.

- Channel and valley areas of upper Santarém Creek
  - To reforest exposed valley walls of upper Santarém Creek;
  - To restore the channel, where required.
- Floodplains NR-04 and CF-05 of Gualaxo do Norte River
  - To remove tailings from the river and reforest the floodplain and valley walls;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in areas affected by tailings, where required;

- To restore and line the channel at the affected hydroelectric power plant.

- Floodplain upstream Carmo River
  - To remove tailings from the river and the floodplain, reconfigure the outline of the floodplain and reforest the floodplain;
  - To install surface erosion control and sedimentation basins in the floodplain to control runoff to the main river;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings;
  - To stabilize the tailings flow impact end upstream, where required.

- Floodplain BFS-BFL-33 of Carmo River
  - To remove tailings from the river, reconfigure the outline of the floodplain and reforest the floodplain;
  - To install surface erosion control and sedimentation basins in the floodplain to control runoff to the main river;
  - To line the outer edges of meandering curves where erosion occurred;
  - To restore tributaries and line tributary channels in floodplains affected by tailings;
  - To remove tailings from the city and restore the city and floodplain surrounding Barra Longa.

- Candonga Reservoir
  - To manage the storage of tailings and create additional storage areas, where feasible, for sediments brought from areas upstream.

The geo-morphological study is presented in detail in document no. RT-023_159-515-2282 (**Attachment Section 5.0**), Section 3.0, including the analysis methodology, studied sites and indicative maps of priority areas for containment of sediments. Fundação Renova contracted Golder Associates to perform the engineering services necessary to define which actions must be taken in each one of the priority areas, in order to minimize the amount of sediments to the river system in the next wet seasons. After definition of the engineering projects, the field activities were initiated and are in progress, as presented in **Section 7.3** and has the execution timeframe indicated in **Section 9.8**.

8.3 Geochemical Characterization

With the collapse of the Fundão dam, part of the tailings which were contained in this structure moved downstream, changing the physical conditions of the environment. As part of the analysis of impacts of the event, the geochemical characterization of the tailings was necessary, as well as mixtures of soil and sediments deposited in the drainage system downstream the Fundão dam.

In order to provide scientific basis for the tailings management actions, Samarco hired Golder Associates which conducted the geochemical characterization of the area which had primary contact with the tailings and turbidity plume derived from the event occurred in the Fundão dam.

The analysis of 310 samples of tailings, soil, sediments and baseline collected from the region of the Samarco dams to the Atlantic Ocean was conducted. The samples were submitted to a test program divided into two phases:

1. Phase I – To know the composition of the materials: Analysis of the concentration of metals, acid generation potential, pH and conductivity of paste, mineralogical composition (X-Ray Fluorescence), species of carbon and nitrogen;
2. Phase II – To know the reactivity of the materials: Mineralogical characterization (X-Ray Diffraction and degree of release of particles), short-term leaching tests - ABNT 10,005/2004, ABNT 10,006/2004, leaching using water from the river and the sea, with pH variation, sequential extraction; and long-term analyses - column test and wet cell test (these tests together show the potential for mobilization of metals from the solid phase to the aqueous phase).

Among the key findings of this study, we highlight the following:

- Tailings are material with the lowest concentration of trace metals among all the materials analyzed at work and with less potential for release of metals to the environment;
- The baseline samples (samples collected in areas not affected by the deposition of tailings) registered the highest concentrations of trace metals among the group analyzed. Furthermore, these samples registered the highest potential for mobilization of metals;
- None of the materials tested, including tailings, mixtures of tailings with soil and sediment had the potential for generating acid;
- Among the 52 samples analyzed for waste classification, none was classified as hazardous waste;
- The results of the chemical composition and potential for mobilization of metals from tailings and mixtures of tailings with soil and sediments indicate that these criteria should not restrict any decision making related to waste management.

Further analyses from an environmental and social point of view which are being or will be conducted for decision-making regarding waste management are presented in chapter 9.1 hereof. The geochemical study is presented in detail in document no. RT-023_159-515-2282, (Attachment Section 5.0). Additionally, the report of the Plan of Sampling and Analysis (SAP) which describes the field and laboratory investigations planned as part of the study of the geo-chemical characterization of tailings, soils and sediments and the report of Field Work which describes the activities of the field works conducted by Golder Associates Brasil Consultoria and Projetos Ltda. (Golder) between the days of 23 January and 12 April of 2016 as part of the Program of Geo-chemical Characterization of Tailings, Soils, and Sediments (Golder, 2015) are presented in the Attachments of Section 5.0. These independent studies have already been provided to the competent agencies and are still under review by them and internally, so they can still be subject to adjustments and optimizations.

On 11 October 2016 the Technical Memorandum was officially filed, regarding the method of sequential extraction used in the geochemical study, called the Tessier Method. The memorandum describes the rational for the choice of the method, and also presents a general discussion about the existing methods of sequential extraction, with their pros and cons of each. We concluded that, although the Tessier method has some limitations in terms of selectiveness (just like all other methods of sequential extraction), its use in the program for the geochemical characterization at Samarco is considered appropriate. The results of the Tessier extractions may be used to produce reliable and defensible inferences with regard to the provenance of the trace metals, and the associated environmental availability. The Technical Memorandum is shown in the Attachments to Section 5.0.

The aforementioned studies have already been submitted to the competent entities and are being reviewed by them, so that there may still be some adjustments and optimizations to be made.

8.4 Air Quality

With the break of Fundão dam, tailings and other solid materials carried by runoff were deposited along the banks of rivers and affected surrounding areas. Tailings and most of the material entrained consist of granular material, which is susceptible to fugitive emissions of particulate matter caused by wind erosion if

this material is exposed without vegetation. These fugitive emissions can cause changes to air concentrations of particulate. Factors which contribute to these emissions include wind velocity on the exposed surface and content of moisture of the material, as well as the total area of exposed surface.

Another potential impact on air quality associated to the Fundão dam break is related to air emissions resulting from recovery actions taken by Samarco and its contractors.

Considering potential impacts to air quality resulting from the Fundão dam break, Samarco has established a monitoring program focused in the municipality of Barra Longa, where there is the largest number of people who could be exposed to emissions from the tailings and recovery activities. This program included the installation of a mobile automatic air quality and surface weather monitoring station in the urban complex of Barra Longa (installed by company EcoSoft Consultoria and Softwares Ambientais and monitoring was effectively started on Feb 18, 2016).

Among the main results of the monitoring of the automatic air quality station of Barra Longa, we highlight the following:

In the period analyzed (Feb 18, 2016 to Sep 30, 2016), there was no violation of the quality standards set forth by CONAMA Resolution no. 03/1990 for pollutants regulated by the Brazilian legislation (PM10 and PTS). For pollutant PM2,5, whose monitoring in Barra Longa-MG was started on May 16, 2016,

despite the absence of statutory limits nationwide and in the state of Minas Gerais, the averages of 24 hours of the PM2.5 registered in the period were at levels below the limit defined by State Decree no. 59113/2013 of São Paulo, by the air quality standard set out by the US Environmental Protection Agency (USEPA), and also remained at levels below the limit recommended by the World Health Organization.

In addition to the monitoring indicated above, a study using aerosol monitors to determine the concentration of particulate in the atmosphere at various points in Barra Longa was carried out by the company Newfields between June 23 and 28, 2016.

Among the main findings of the study conducted by NewFields, we highlight the following:

The average concentrations of particulate detected at all locations containing tailings were lower than the simultaneous measurement of particle concentrations at the quality monitoring station located outside the affected area. This shows that the locations with deposited tailings, the waste dump at the Exposition Park [or Fairgrounds] and the tailings excavation sites along the river, do not contribute to the concentrations of particulates measured by the air monitoring station in Barra Longa.

The detailed monitoring plan, analysis of results and conclusions are shown in detail in document no. RT-023_159-515-2282, **Section 6 (Attachment Section 5.0)**.

8.5 Reference Documents of Section 8.0

DOCUMENT	NAME OF THE DOCUMENT	COMPANY	DATE
G001600-O-1MC001	Germano Geral, Barragem de Fundão, Volume de rejeito movimentado Pós-Ruptura - Memória de Cálculo	HGT	
ART HGT	ART da empresa HGT		Jul/16

9 ENVIRONMENTAL RECOVERY AND COMPENSATION ACTIVITY

This section presents the ongoing studies focusing on mid- and long-term environmental recovery.

9.1 Tailings management guidelines

The main purpose of this Section is to define the guidelines for management of tailings derived from the break of the Fundão Tailings Dam. Therefore, the following specific objectives apply:

- To present the guidelines for management of tailings released by the break of the Fundão Dam, for the cases in which the need for removal is defined;
- To indicate the viable methodologies for removal, transportation and disposal of tailings;
- To indicate the main methods for disposal of tailings;
- To assess the potential areas for disposal of this material.

The analyses and studies related to the topics above are shown in document no. RT- 023_159-515-2282, (**Attachment Section 5.0).**

9.2 Rehabilitation Plan for Springs and Degraded APPs

According to what was defined in the TTAC, Fundação Renova will, as a compensatory ction, reclaim 40 thousand hectares of APPs – Permanent Preservation Areas, as well as 5 thousand springs within the Doce River basin. The actions will be carried out over a period of ten years, as outlined below:

- Of the 40,000 ha of degraded APPs to be recovered, 10 thousand ha will be through reforestation and 30 thousand by means of natural regeneration
- A minimum fund of R$ 1.1 billion will be allocted to the recovery of the APPs
- Of the 5 thousand springs, the plan is to reclaim 500 each year.

The reclamation of the degraded springs will continue to be carried out in partnership with Instituto Terra, as they will be responsible for the 500 springs to be reclaimed in the first year.

For the recovery of the degraded APPs, Fundação Renova is discussing with IBIO – Instituto BioAtlântica as well as international NGOs the formation of a consortium to plan and manage the reclamation activities.

9.2.1 Reclamation of springs

The long term plan for the recovery of the 5000 springs will be developed by the above-mentioned consortium of NGOs. For the first, year, Fundação Renova established a partnership with Instituto Terr.

Instituto Terra created a program named Programa Olhos d´´Água with the objective of recovering 300 thousand springs in the Doce River basin between 2016 and 2046. Becoming aware of the Agreement signed between Samarco and its shareholders, and the Federal and State Governments of Minas Gerais and Espírito Santo, Instituto Terra contacted Fundação Renova to express its interest in working on this program of spring reclamation. The scope of work under the auspices of Instituto Terra contemplates the recovery of 500 springs by March 2017, meeting the requirements of the first year of recovery established by the TTAC.

In this work developed jointly with Fundação Renova, Instituto Terra is applying the same methodology of its Programa Olhos d´´Água, which involves:

- Mobilization of 500 rural producers, through field visits and dissemination in the local and regional media – period – two months
- Implementation of the process of reclamation and protection of 500 springs – period – 6 months

- Development of technical projects (georeferncing and sketch)
- Acquisition and distribution of material for fencing and planting saplings
- Getting signature on the letter of commitment from the beneficiary farmers
- Fencing (outsourced)
- Technical assistance to the rural producer in the fencing and planting activities according to the technical project.

In addition, as part of the activities scheduled in the context of spring recovery, complementary actions will be carried out beyond what was defined in the TTAC, as listed below:

- Installation of catchment basins to harvest rainwater – period – 18 months;
- Installation of 250 septic tanks on the properties of the farmers involved – period – 18 months;
- Monitoring of the flow rate and the quality of the water of 20% of the recovered springs – period 18 months;
- Monitoring of the vegetation cover around 10% of the recovered springs – period 18 months;
- Development of evidence based reports of the project- period 18 months;

Figures 55 and 56 show examples of the actions of installation of septic tanks and construction of small dams on the rural properties.

Figure 55: Installation of septic tanks (archive Instituto Terra).

Figure 56: Construction of catchment basins (archive Instituto Terra).

For the first year of spring reclamation, the Doce River Basin Committee – CBH-Doce River Hydrographic Basin Committee Doce, defined three prioritary sub-basins, namely, Pancas and Santa Maria do Doce in Colatina and Suaçui Grande in Governador Valadares. Figure 57 shows schematically the sub-basins which were prioritized in the recovery of the first 500 springs.

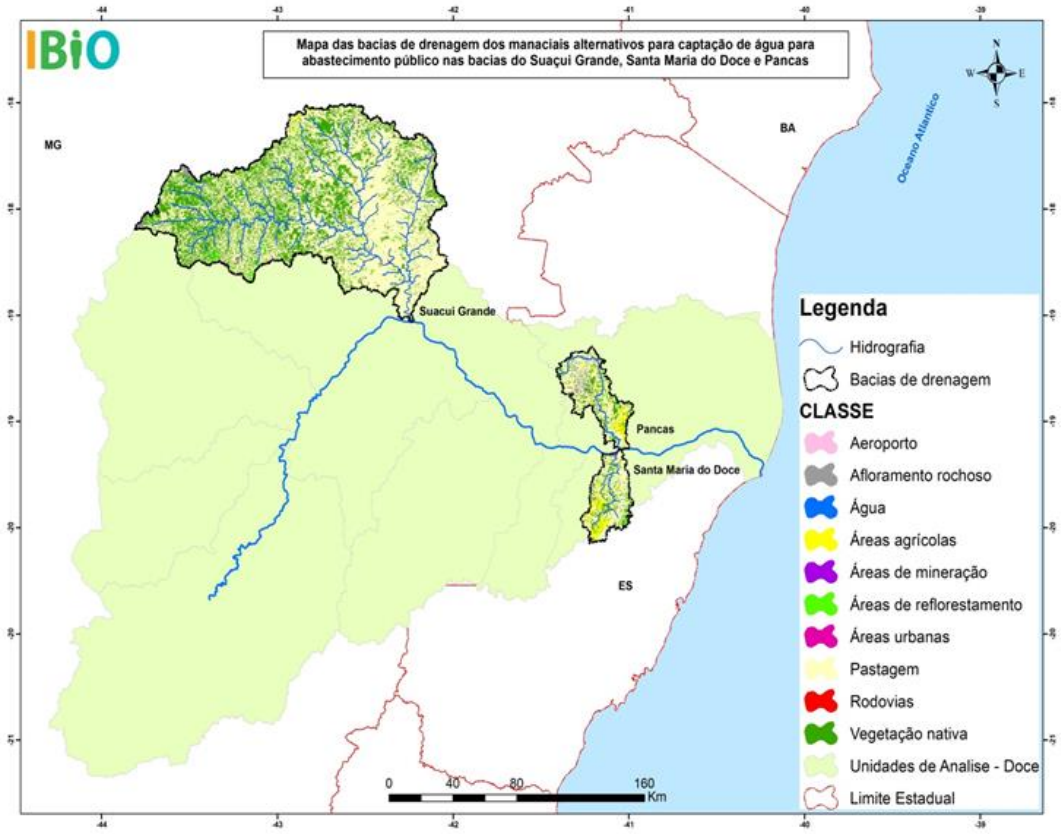

Figure 57: Sub-basins prioritized for reclamation of first 500 springs.

9.3 Evaluation of impacts and recovery of fauna

9.3.1 Conservation of the aquatic biodiversity

This section has the objective of defining the guidelines for the evaluation of the impact on aquatic biodiversity due to the dam break, in all of Environmental Area 1 and along the impacted seacoast, including the estuarine region.

The starting point of this program will be the execution of an impact assessment to understand and check on the impacts caused to this environment. These studies will provide input for decision making, the process of evaluation of the aquatic biodiversity conservation status, and the adoption of recovery and conservation measures related to the fauna and the aquatic environment. To this end, the following specific objectives are applicable:

- Studies and monitoring of ecotoxicology, fresh water environment, sea and estuarine environment, beaches, mangroves, marine and estuarian ichthyofauna
- Marina megafauna (turtles, birds and mammals)

As defined by the terms of clause 165 of the TTAC, the monitoring program will be implemented and executed within five years.

9.3.2 Conservation of land fauna and flora

The objective of this section is the definition of guidelines for the evaluation of the impact on land biodiversity due to the dam break, in all of Environmental Area 1.

In compliance with the TTAC, a specific impact assessment is being carried out for land fauna and flora which is endangered, to be concluded by 31 December 2016. This evaluation consists of a reconstitution of the baseline conditions, using remote imaging prior to the event, consultation of specialists and analysis of available literature, as well as the evaluation of the impact vectors, to determine who the endangered land species may have been affected by the collapse of the dam. Based on these results, it will be possible to perform the definition of the recovery actions.

In order to fulfill the objective of evaluation of impacts and monitoring of populations and communities of fauna in the states of Minas Gerais and Espírito Santo, we will also perform a survey of primary data – focus on vertebrates – and secondary, focused on different indicator groups for land fauna, including invertebrates, in both states, in addition to an evaluation of impacts and subsequently an action plan for conservation.

9.4 Strengthening of the screening process and reintroduction of wildlife

With the objective of strengthening the structures for screening and reintroduction of wildlife, Fundação Renova will build and equip two screening and rehabilitation centers for wildlife (CETAS). These are units responsible for the management of wild animals who are received as a result of inspections, rescue or voluntary delivery by private persons. This management is carried out by a team of veterinarians, biologists and special handlers. The structures existing in Brazil receive thousands of animals every year and are focused on identifying, marking, screening, evaluating, recovering, rehabilitating and assigning these wild animals, in addition to performing and providing input for scientific studies, teaching and extension courses.

The two centers will be built and equipped according to the guidelines of the terms of reference to be issued by IBAMA, and be installed in municipalities which are bathed by the Doce River or by impacted sections of the Gualaxo do Norte and Carmo rivers (environmental area 2), with one in Minas Gerais and the other in Espírito Santo. The sites, design and installation schedule are being evaluated and discussed bête the parties in the Biodiversity Technical Chamber, chaired by ICMBio. This definition should be forthcoming by 02 March 2018. Furthermore, the Foundation will assure resources for the operational maintenance of the CETAS for a period of three years, counting from the delivery of each unit. Except for the expenses with personnel, according to the management plan of the project to be established by the administrative entity in charge.

9.5 Improvements in the Water Supply Systems

The program to make improvements in the water supply systems seeks to comply with Clause 171 of the TTAC, according to its terms:

> *In the municipalities in which some localities had their public water supply system temporarily disabled as a result of the Event, the Foundation will build alternative catchment and distribution*

systems and improve the water treatment plants for all these localities of these municipalities which abstract water directly from the Doce River channel, using proper technology, seeking to reduce by 30% (thirty percent) their dependence on the direct supply of water from the river in relation to the levels prior to the Event, as a reparatory measure.

The municipalities in line for service within the TTAC are: (i) Alpercata; (ii) Gov. Valadares; (iii) Tumiritinga; (iv) Galiléia; (v) Resplendor; (vi) Itueta; (vii) Baixo Guandu; (viii) Colatina; and (ix) Linhares.

The districts to receive service under the TTAC are :a) in Mariana: (i) Camargos; (ii) Pedras; (iii) Paracatu de Baixo; b) in Barra Longa: (i) Gesteira; (ii) Barreto; c) in Santana do Paraíso: (i) Ipaba do Paraíso; d) in Belo Oriente: (i) Cachoeira Escura; e) in Periquito: (i) Pedra Corrida; f) in Fernandes Tourinho: (i) Senhora da Penha; g) in Governador Valadares: (i) São Vitor; h) in Tumiritinga: (i) São Tomé do Rio Doce; i) in Aimorés: (i) Santo Antônio do Rio Doce; j) in Baixo Guandu: (i) Mascarenhas; k) in Marilândia: (i) Boninsenha; l) in Linhares: (i) Regência.

For the municipalities with over one hundred thousand inhabitants, the reduction of dependence of direct water supply from the Doce River may be up to fifty percent (50%), with the values incurred as a result of what may exceed the percentage referred to above, considered as a compensatory measure.

Currently the program of implementation of alternative intake is in the phase of hydrogeological studies for the evaluation of water supply from surface and underground sources to assure the perenniality of the sources which will be provided as an alternative supply of Doce River water for the cities, complying with Deliberation No. 16 of the CIF.

With the start of the rainy season of 2016/2017, some of the alternative intakes in Program 32 were prioritized and are in progress to assure the water security of the cities in question during this period. However, since these are emergency works specific for this season, we will not at this time perform the perenniality studies mentioned above for these sources. These studies will be initiated at a timely moment to validate the works executed as deliverables of Program 32.

After the conclusion of the evaluation study of the water supply of the sources, it will be possible to define whether it is necessary to complement these alternative intakes developed for the rainy season, according to the result of the sustainability of the sources presented by the study.

9.6 Monitoring of water quality and sediments

With the collapse of the Fundão dam, part of the tailings contained in this structure burst downstream, entering in contact with the Santarém creek, the Gualaxo do Norte river and its tributaries, the Carmo river and its tributaries, the Doce River and the seacoast close to the Doce River mouth. As part of the analysis of the impacts of this dam break, Samarco hired laboratories accredited by INMETRO (among them, the following have already worked on the monitoring of the Doce River basin and the sea - LIMNOS, SGS GEOSOL, APLYSIA, TOMMASI, INOLAB, BIOAGRI, LABB and CORPLAB).

The monitoring routine involves the analysis of water and sediments in the Doce River and the sea, including a physical/chemical analysis (Doce River basin and the sea) and ecotoxicity analysis (Doce River basin), at 120 points, with a frequency that varies from daily (marine and turbidity monitoring) to fortnightly. So far, over 1,900,000 results have been generated, presented in over 70 thousand reports.

The main conclusions of these analyses corroborate what has been observed in the geochemical characterization of the impacted area, in other words, the tailings did not bring an increase in the

concentration of trace metals in the aquatic environment. In a report issued in December 2015 ("*Monitoramento da Qualidade das Águas Superficiais do Rio Doce no Estado de Minas Gerais*", See **Attachment Seção 9.0**), the *Instituto Mineiro de Gestão das Águas* – IGAM, concluded that during the passage of the turbidity plume, there was a short term elevation in the concentration of some metals in the water, associated with the resuspension of sediments present in the river bed. In December 2015, based on analyses carried out in the preceding month, less than 30 days after the dam break, the Brazilian Geological Service and the National Water Agency – ANA, issued a report stating that, after an initial elevation in the concentration of metals, the water samples collected along the Doce River no longer showed the presence of dissolved metals in quantities that could be interpreted as contamination. (See Attachment Section 9.0)

The detailed monitoring plan, analysis of the results and conclusions are presented in the document nº RT-023_159-515-2282, (**Attachment Section 5.0**)**.**

9.7 Conservation units

This section has the objective of defining the guidelines for the assessment of the impact on the directly impacted conservation units, i.e., Parque Estadual do Rio Doce/MG, Reserva Biológica de Comboios, Area de Proteção Ambiental Costa das Algas and Refúgio de Vida Silvestre de Santa Cruz.

This program involves reparatory and compensatory measures, establishing the following specific objectives for the reparatory ones:

- Survey of impacts
- Implementation of reparatory actions
- Contribution to the conservation of biodiversity

The compensatory measures have the following specific objectives:

- Pay for the consolidation of two conservation units, namely, Parque Estadual do Rio Doce and Refúgio de Vida Silvestre de Santa Cruz;
- Implement the management plan, as well as the construction of a center in the conservation unit to be created by the public authorities.

9.8 Reference Documents of Section 9.0

DOCUMENT	NAME OF DOCUMENT	Institution	Date
Relatorio IGAM 121215	Monitoramento da qualidade das águas superficiais do rio Doce no estado de Minas Geais	IGAM	Dec15
Relatorio CPRM 151215	Monitoramento especial da bacia do rio Doce – Relatório II	ANA/CPRM	Dec15

10 IMPLEMENTATION AND LICENSING SCHEDULE

The schedule for implementation of the Environmental Recovery and Safety Plan for Areas Affected by the Break of Fundão Dam is shown in the document "Masterplan Renova PRAI" (**See Attachment Section 10.0**).

10.1 Reference Documents of Section 10.0

DOCUMENT	NAME OF DOCUMENT	COMPANY	DATE
Masterplan Renova PRAI 20161110	Cronograma macro das atividades de recuperação e compensação ambiental sendo realizadas pela Fundação Renova	Fundação Renova	Nov/16

11 FINAL CONSIDERATIONS

In light of the foregoing, it is possible to say that the integrated environmental rehabilitation plan (PRAI) related to the event of rupture of the Fundão Dam is extremely important to support a systemic view of the measures already performed and which must still be taken to address the impacts derived therefrom. Evidently, several studies are still in progress and should support updates of this integrated plan. Their findings may give rise to the development of other studies which may add and contribute to the understanding and effective coordinated operation in relation to the event occurred. Therefore, this document will be updated and improved constantly from the studies, negotiations with stakeholders and experiences throughout the process.

Belo Horizonte, 17 November 2016

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Fundação Renova