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An Expanded Cost-Benefit Analysis (CBA) of the Reventazón Hydroelectric Project (PHR), in Costa Rica

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Contents

1. Introduction to the Project

1.1. The PHR—Reventazón Hydroelectric Project

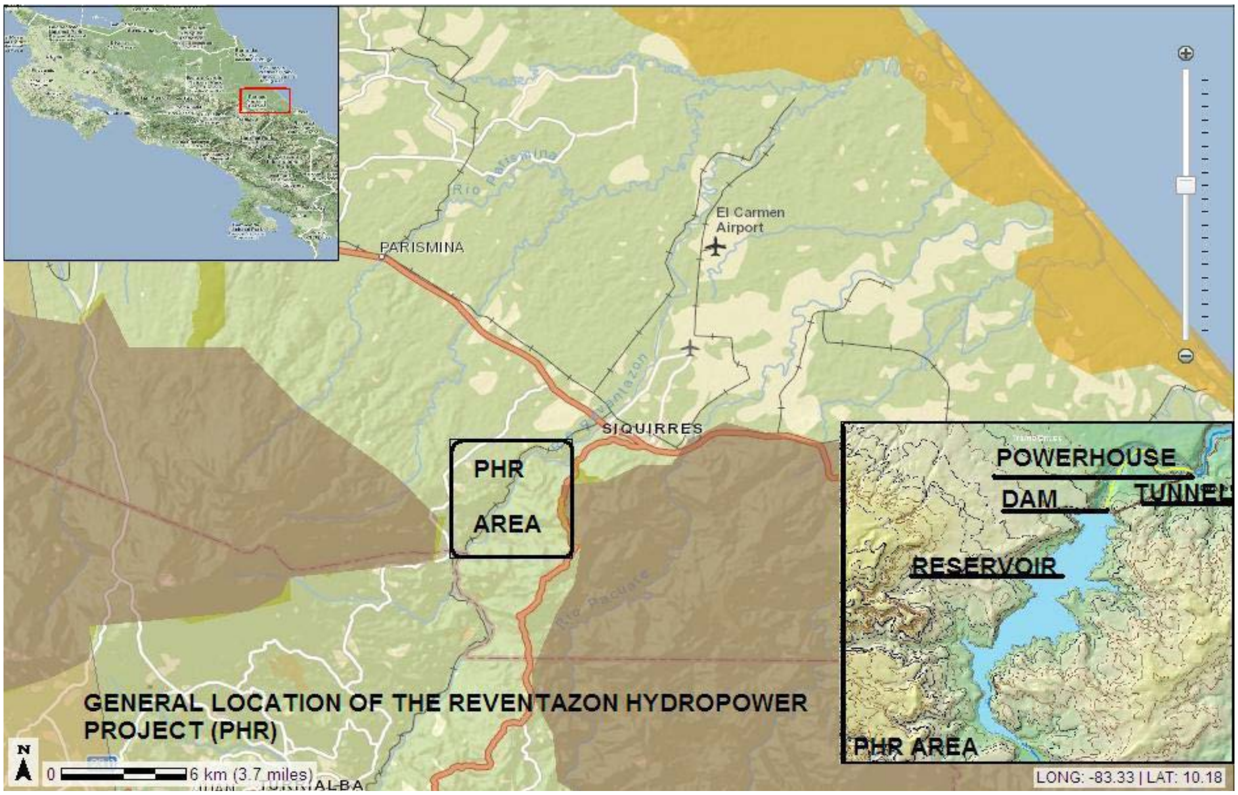
The Reventazón Hydroelectric Project ("PHR") is a new hydropower facility with a capacity of 305 MW that is currently under construction in the lower basin of the Reventazón River in Limon Province, Costa-Rica, about 8 km southeast from the city of Siquirres (see Map 1). The project includes construction of a 130 m high dam, flooding of a 6.9 km^2 (690 ha), 8 km long reservoir and a 4.2 km river diversion between the dam and powerhouse. The PHR will be the hydropower facility with the largest energy production in Costa Rica. It is also the fourth and most downstream hydroelectric dam operated by the Instituto Costarricense de Electricidad (ICE) on the extensively developed Reventazón River.

The RHP is a large project. Total cost for the project is over $1,380 million. IDB loans cover about 67% of this amount, or a total of $920 million from two loans: $570 million (CR-L1056) and $250 million (CR-L1049) Such large projects produce important national benefits (electricity production) but can also have important impacts on the environment and affected communities.

The Project's adverse environmental and social impacts, if left unmitigated, could be significant. Key potential impacts and risks include: a loss of connectivity within the Barbilla-Destierro biodiversity sub-corridor (Jaguar Corridor, a critical natural habitat) due to the flooding of the future reservoir; significant direct and cumulative impacts of the project's construction and operation on the Reventazón River's aquatic natural habitat; potential serious economic impacts on at least 16 land-owning households; loss of whitewater rafting activities in the Florida section of the river after the reservoir is constructed; and potential adverse impacts during Project operation on the complex and ecologically sensitive Reventazón-Parismina-Tortuguero hydro-biological system.

A mitigation strategy and management framework has been developed in collaboration with ICE. This strategy, which addresses the Project's key impacts and risks, includes: restoring the connectivity of the biodiversity corridor at the tail of the reservoir; helping conserve an ecologically similar river system as a healthy and free-flowing aquatic habitat to compensate for the project's impact on the Reventazón River; adaptive management of potential downstream impacts; management of construction activities according to best environmental and occupational health and safety practices; and significant improvement of ICE's land acquisition, compensation, and involuntary resettlement practices. ICE is committed to ensuring adequate implementation of the mitigation strategy, including securing additional resources to fund these activities.

Map 1 General Location of the Reventazón Hydroelectric Project (PHR)



1.2. Expanding the CBA of the PHR

As part of project preparation, a standard Cost-Benefit Analysis (CBA) was carried out for the PHR. This paper builds on that CBA and will prepare an enhanced analysis that explicitly incorporates environmental and social aspects by applying the approach presented in the IDB Technical Note No.IDB-TN-428 (John A. Dixon, "Economic Cost-Benefit Analysis (CBA) of Project Environmental Impacts and Mitigation Measures," IDB, 2012). This implementation guideline suggests comparing the traditional CBA of a project (referred to as CBA Result 1) with a more comprehensive CBA that explicitly includes the economic value of mitigation measures and remaining environmental impacts. This enhanced CBA analysis is referred to as CBA Result 3.

In expanding the CBA for the PHR, each environmental impact is examined within a Total Economic Value (TEV) framework to identify those components of value that are likely to be most important and most readily valued. See Figure 2 and the subsequent tables for a description of the TEV approach and demonstrations of the TEV framework.

The enhanced CBA responds to Operational Policy 703, specifically directives B.5 and B.9, by explicitly identifying and incorporating environmental impacts into the CBA. Directive B.5 indicates that "[t]he EIA should be supported by economic analysis of project alternatives and, as applicable, by economic cost-benefit assessments of the project's environmental impacts and/or the associated protection measures." Directive B.9 states that the Bank will not support projects that degrade or convert critical natural habitats or that damage critical cultural sites unless "comprehensive analysis demonstrates that overall benefits from the operation substantially outweigh the environmental costs, and [contain] mitigation and compensation measures acceptable to the Bank—including as appropriate, minimizing habitat loss and establishing and maintaining an ecologically similar protected area that is adequately funded, implemented and monitored." The enhanced CBA—CBA Result 3—explicitly includes the benefits and costs associated with environmental and social impacts.

1.3. A Horse and Rabbit Stew

One problem in conducting the desired analysis in the case of the PHR is that it becomes a bit of a "horse and rabbit stew"—this being the case when one makes a stew by adding one horse and one rabbit and then wonders why all one can taste is horse meat! In this case, the total PHR budget is over $1,380 million, including financing costs (Ignacio Coral Martínez, "PHR Evaluación Económica y Social," IDB, 2012). In contrast, the numbers we find in the economic analysis of environmental impacts are in the range of $100,000 to several million dollars. These amounts are smaller in size than the rounding errors in the overall project!

There are traditionally two ways to address this issue: either the project planners do not worry about any "reasonable" environmental costs and these costs are included and accommodated in the project implementation, or the environmental numbers are seen as so small compared to the overall project benefits and costs that they are ignored, implying that they have no impact on the overall numbers.

In this example, we present information on the values associated with the individual environmental impacts, as well as the changes (as slight as they may be) to the overall economic analysis of the project. The results are presented as CBA Results 1 and 3, based on the information in the different project documents.

Please note that the traditional CBA prepared for the project (Martínez, "PHR Evaluación Económica y Social,") has a rather unique approach to CBA, so I have re-estimated the traditional CBA using the basic data in the reports but here present it in a more simplified, stylized format. Since the present case study is *not* about re-analyzing the traditional CBA, but rather demonstrating how the environmental issues can be identified, quantified and included in the analysis, this is an acceptable didactic device.

2. Major Environmental and Social Impacts and their Economic Valuation

Using the Total Economic Value approach, we consider each of the major environmental impacts of the PHR and identify the main sources of economic values, both those that can be quantified and those that cannot easily be quantified, and provide monetary estimates of economic impacts (to the extent that such estimates are possible). If it is not possible to quantify an economic value, then a note can be made of the qualitative value involved. The costs of mitigation and safeguard measures are also included in the analysis.

As outlined in the guidelines note (Dixon, "Economic Cost-Benefit Analysis (CBA) of Project Environmental Impacts and Mitigation Measures"), this process requires estimating values for a series of costs and benefits. These are defined as follows:

Annual Costs A:	normal project costs
Annual Costs B:	project costs with environmental costs, unmitigated
Annual Costs C:	costs of environmental intervention after project redesign
Annual Costs D:	remaining environmental costs after redesign
Annual Benefits A:	normal project benefits
Annual Benefits B:	project benefits plus any positive environmental externalities

Annual Benefits C: additional benefits after mitigation, if any

CBA Result 1: Costs A + Benefits A

CBA Result 2: Costs B + Benefits B

CBA Result 3: Costs A + Costs C + Costs D + Benefits B + Benefits C

The goal is to move from CBA Result 1, the traditional project analysis, to CBA Result 3, the more comprehensive analysis that includes all environmental benefits and costs as well as mitigation measures. CBA Result 2 is an intermediary step that recreates the traditional project analysis (CBA Result 1) but also includes all environmental costs (and benefits as appropriate) within the same analysis.

In some cases, the proposed mitigation measures will remove or offset the environmental impact; hence, the economic value of the impact is zero. There will be, however, associated mitigation costs (Annual Costs C). In other cases, there may be some remaining environmental impacts even after mitigation has taken place (Annual Costs D). Two environmental impacts—the biodiversity corridor and the river ecosystem impacts—are cases where economic costs of loss of environmental services are not calculated. Rather, in each case the costs of appropriate mitigation measures (in the case of the biodiversity corridor) or compensatory expenditures (in the case of the river ecosystem) are added to the Annual Costs C of the expanded analysis. For ease of exposition, most figures are "rounded-off." This does not marginally affect the results.

We now consider each of the environmental impacts of the project and how they affect Annual Costs B, C and D and Annual Benefits B and C. Note that Annual Costs B are estimated based on "guesstimates" of the potential size of unmitigated environmental impacts. In this case study, we assume that they are annual additional costs of $5 million for the first 4 years, $3 million in year 5, and $2 million in all the following years.

2.1 Biodiversity Corridor

The PHR reservoir, once it is filled, will cut part of an existing biological corridor located within the Volcanica Central Talamanca Biological Corridor (CBVC-T) that connects two large expanses of protected areas: on the left bank, the Cordillera Volcanica Central Forest reserve, and on the right bank, the Siquirres River Watershed Protection Zone. Within the CBVC-T lies the Barbilla Destierro Biological Sub-corridor (SBBD), which has been identified by the NGO

Panthera as a critical habitat for the movement of jaguars and their prey species throughout the protected areas.

The SBBD's importance has been recognized in Costa Rica and plans have been developed that will help protect this service even after the reservoir is filled. The proposed mitigation plan will restore and maintain connectivity within the SBBD through restoration and maintenance of habitat at the tail of the reservoir. It is expected that these actions will protect the physical connectivity of the corridor and will allow the biological functions of the corridor to be maintained.

Based on the proposed management documents, these measures will cost a total of about \$2.8 million over the period of 2013 to 2015, with a recurring cost of \$445,000 per year after that, and are expected to fully compensate for the impacts of the reservoir on the biodiversity corridor. As a result, there should be no change in the ecosystem benefits and services provided by the corridor. These costs are therefore added as part of Annual Costs C (costs of environmental intervention after project redesign) in the enhanced CBA.

The additional costs from these measures are as follows:

2013 (project year 4)	\$1.8 million
2014 (project year 5)	\$0.5 million
2015 and thereafter	\$0.5 million

There is little or no active recreational use or tourism use of the jaguars in this area and the question therefore is one of maintaining the "ecosystem health" of the biological corridor once the reservoir is filled. Any economic benefits from maintaining healthy jaguar populations fall elsewhere and are not included in this report. If the biological corridor were cut, however, with adverse impacts on the jaguar population, there could be economic impacts elsewhere (valuing for jaguar viewing, plus option, bequest and existence values for conservation of the jaguar) but these are not considered here. TEV Table 3 presents the range of economic values associated with the jaguars and possible valuation techniques for each value. Since we cannot estimate any of these economic values in this case, we use a "cost of prevention" approach whereby one looks at the costs of preventing the loss of these values as a measure of what society is willing to give up (pay) to maintain these benefits.

2.2. Change in River Ecosystem

Constructing a dam and reservoir will change the existing river ecosystem irreversibly. To compensate for this loss (without trying to estimate the "values" of this change), an offsetting investment of $2.66 million is made in 2013 to 2015 in the Rio Parismina to enhance that river and thereby help compensate for the impacts of dam and reservoir construction on the Reventazón River. Recurring costs are estimated at $780,000 per year. This "offset" payment is a compensation for a resource (the site of the dam and reservoir) that will be changed forever by the project.

The additional costs for these measures are as follows:

2013 (project year 4)	$1.1 million
2014 (project year 5)	$0.8 million
2015 and thereafter	$0.8 million

There are no estimates of the direct economic losses to the river ecosystem created by the dam and reservoir, but they are expected to be low. There are three species of fish that are migratory through the affected area, but these species are not endemic to this river and are found in several other major rivers in Central America. In addition, the PHR is only the latest of many hydropower developments (including impoundments) found on the Reventazón River.

The offset expenditures in the other river are expected to compensate for any losses in the PHR area of the Reventazón. TEV Table 4 illustrates those goods and services that are lost in the area of the PHR (and appropriate valuation techniques) and that are compensated for by the investments in the "offset" location. In the absence of unique and endangered species in the area of the PHR, this appears to be a reasonable assumption. Hence, once the offset measures are put in place, there are no quantified environmental costs to add to the CBA. The costs of the mitigation and offset measures are added to Annual Costs C in the expanded CBA.

2.3. Recreational Uses of the River

A major quantifiable cost of the PHR is the impact on whitewater rafting and ecotourism uses of the Florida section of the River. Once the project is completed and the reservoir is filled, this stretch of the river will be lost.

Using the TEV approach, the major uses lost include both commercial and private rafting activities on this section of the river. These are examples of "direct, non-consumptive" uses and can be valued directly and included in the expanded analysis. TEV Table 5 lists the goods and services involved (and potential valuation techniques). Potential losses include both "producers' surplus" on the part of those providing the rafting services and "consumers' surplus" from those taking part in the recreational rafting. The analysis here will focus on estimating the producers' surplus only, since this is the part that the PHR may need to compensate once the reservoir is built. Estimating and compensating for lost consumers' surplus to visitors who do *not* come to the Reventazón is a much more complicated and problematic valuation issue, especially if the lost resource (in this case the Florida rapids) is not particularly unique. Many potential rafters will go to other locations.

Estimating the economic cost of this loss of producers' surplus involves a number of steps. First, one has to estimate the present level of use of the river, including both commercial uses and non-commercial uses. Second, it is necessary to estimate the "economic rent" portion of those revenues from commercial uses that would be lost. This is not the same as the gross value of revenues lost, since there are costs involved in providing these services. For non-commercial uses, other approaches are used to value the loss in benefits. Since non-commercial uses are thought to be very small, they are ignored in the present analysis.

"Economic rents" are an economic concept that reflects the "extra" profit one makes from using a resource. In a perfectly competitive world, there are no economic rents; if any business or service were to make an economic rent, then others would enter the market and offer similar goods or services and drive down prices so that all producers (service providers) would only be covering costs plus a normal profit margin. Extra profits would be "dissipated"—lost. As an example think, of a company renting rowboats at a lake—if the company has a monopoly to rent boats, it may charge something extra, and since there are no other options, the consumer can either pay the higher fee or not undertake the activity. If other companies can offer boats, however, then the number of boats offered will increase, and the price charged per use will be driven down to a point where all operators earn just enough to cover their costs and make a "normal" profit.

A similar story applies to the PHR. Scarcity or rationing creates economic rents—and the environment is often a scarce resource. Therefore, a company that offers an environmental resource as part of its "package" can often capture some economic rents. In the case of the PHR, one expects that he river-running outfit (Rios Tropicales) is capturing some modest economic rents from offering the river runs on the Florida section of the Reventazón. Note that if the company has a license on the Florida section whereby no one else can offer river rafting there, one would expect that the economic rents would be larger.

In the case of Rios Tropicales (RT) and the Florida section, in order to estimate the economic rents lost from the closure of this section of the region, we need data on the number of daily users (clients), the amount charged per user, the "rent" portion of that charge, and the number of days per year that the river is used. With these numbers, we can estimate the economic rent (the extra profit) that the operator of the tours receives from using this part of the river. If this use of the river is curtailed or lost these rents are also lost. The present value (PV) of the future loss of these rents represents the economic cost to the operator of losing this section of the river (this assumes that levels of use are similar year to year).

For example, if the company runs two trips of six passengers each day for 200 days per year, and charges $75 per client, the gross revenues would be as follows:

(12 clients per day) x ($75 per client) x (200 days per year) = $180,000 per year gross revenues

The economic rent portion of this is equal to whatever is the profit above normal costs (including normal profit margins on capital invested). We assume that the economic rent portion is 20%. Therefore the economic rent lost per year from closing the Florida stretch of the river would be as follows:

Economic Rents = (gross revenue of $180,000 per year) x (economic rent portion of gross revenues, equal to 20%) = $36,000 per year

This is an annual loss. Since we assume that the activity would have continued indefinitely into the future without the construction of the PHR, we must estimate the present value (PV) of these future losses. This is the same as the Ricardian use value, and is estimated by dividing this annual loss by the interest rate, in this case 12%. Therefore, an annual loss of $36,000 would have a present value of $300,000. This is the amount of the economic loss to Rio Tropicales from losing use of this section of the river. Different discount rates, it should be noted, produce different results: a 10% discount rate leads to an estimate of the Ricardian use value of $360,000; with a 5% discount rate, the value is $720,000. In Annual Cost D, a one-time payment of $500,000 is made in year 2012 to (over-) compensate for this economic loss. No recurring costs are included since the one-time payment represents the present value of lost future rents by the whitewater rafting outfitters. Note that Annual Costs D represents “remaining environmental costs after redesign”—this is appropriate here since rafting cannot be restored in the stretch of the river.

This calculation also assumes that RT has a legal or traditional right to use the river, and that no alternative site offers similar qualities. If RT has no river use right in Costa Rican law, then RT does not need to be compensated for this loss. Assuming that it does have a right to use the Florida section, the actual calculation of an economically justified compensation requires the data explained earlier. This calculation is a microeconomic valuation of a specific loss. It assumes that the change will not affect the numbers of people coming to Costa Rica (or Costa Ricans using these same services). One can always complicate the analysis with many different scenarios, but the basic principle is clear—the economic rent portion from present (and future) users of the Florida section represents one of the economic costs of the construction of the PHR. This cost should be included in the cost side as Annual Costs D (remaining environmental costs after redesign) of the expanded/enhanced CBA to calculate CBA Result 3.

2.4. Downstream Impacts (Primarily in the Tortuguero Coastal System)

The Reventazón River has already been heavily modified by the construction of numerous hydropower facilities. The PHR, though the largest of the facilities, has very limited storage capacity (estimated at less than 10 days’ worth of water under normal conditions). The actual impact of the PHR on downstream areas once construction is completed and the reservoir is filled is expected to be minimal.

The Reventazón River feeds into a broader system of rivers and wetlands that comprise the coastal Reventazón-Parismina-Tortuguero hydro-biological system. Mitigation measures have been proposed to reduce negative environmental impacts downstream during project construction. These are entered as part of Annual Costs C. After construction is completed, any remaining environmental impacts are expected to be small and have few or no economic costs. Without sufficient data to make any projections, no additional costs are included here.

The proposed environmental management plan also makes provisions for monitoring these downstream impacts over time. The cost of planning and monitoring this activity is quite low: an estimated $230,000 over the period of 2013 to 2015 and an annual recurring cost of $60,000 thereafter. These costs are included in the revised CBA as part of **Annual Costs C**:

2013 (project year 4)	$0.10 million
2014 (project year 5)	$0.06 million
2015 and thereafter	$0.06 million

2.5. Other Impacts, Including Economic "Dislocation"

It is estimated that a total land area of about 20 km^2 will be acquired by ICE for the construction and operation of the PHR. This is a lightly populated part of Costa Rica, and according to the project documents, there is no permanent housing in this area. The affected lands are used for livestock and agricultural production. However, a total of 87 properties will have to be acquired (33 on the left bank and 54 on the right bank), directly affecting 56 landowners.

In most major hydropower developments, the resettlement of households displaced by infrastructure construction and the reservoir are major social and economic costs. Resettlement, fortunately, is not a problem in this case. Although no resettlement of households will be required, a total of 16 land owners are considered "vulnerable" and will receive special attention in order to help ensure their longer-term economic viability. Consequently, a total of about $650,000 is budgeted to meet these needs in 2012 and 2013. This amount has been rounded up to $500,000 in 2012 and $500,000 in 2013 (it is assumed that these costs are in addition to those for acquiring the lands needed for the project).

The costs of these special measures are included in Annual Costs C and are expected to leave the affected households at least as well off as they were before. Therefore, once the compensation plan is successfully implemented, there will be no additional environmental or social costs to add into the revised CBA.

The additional costs for these measures are as follows:

2012 (project year 3)	$0.5 million
2013 (project year 4)	$0.5 million
2015 and thereafter	$0.0 million

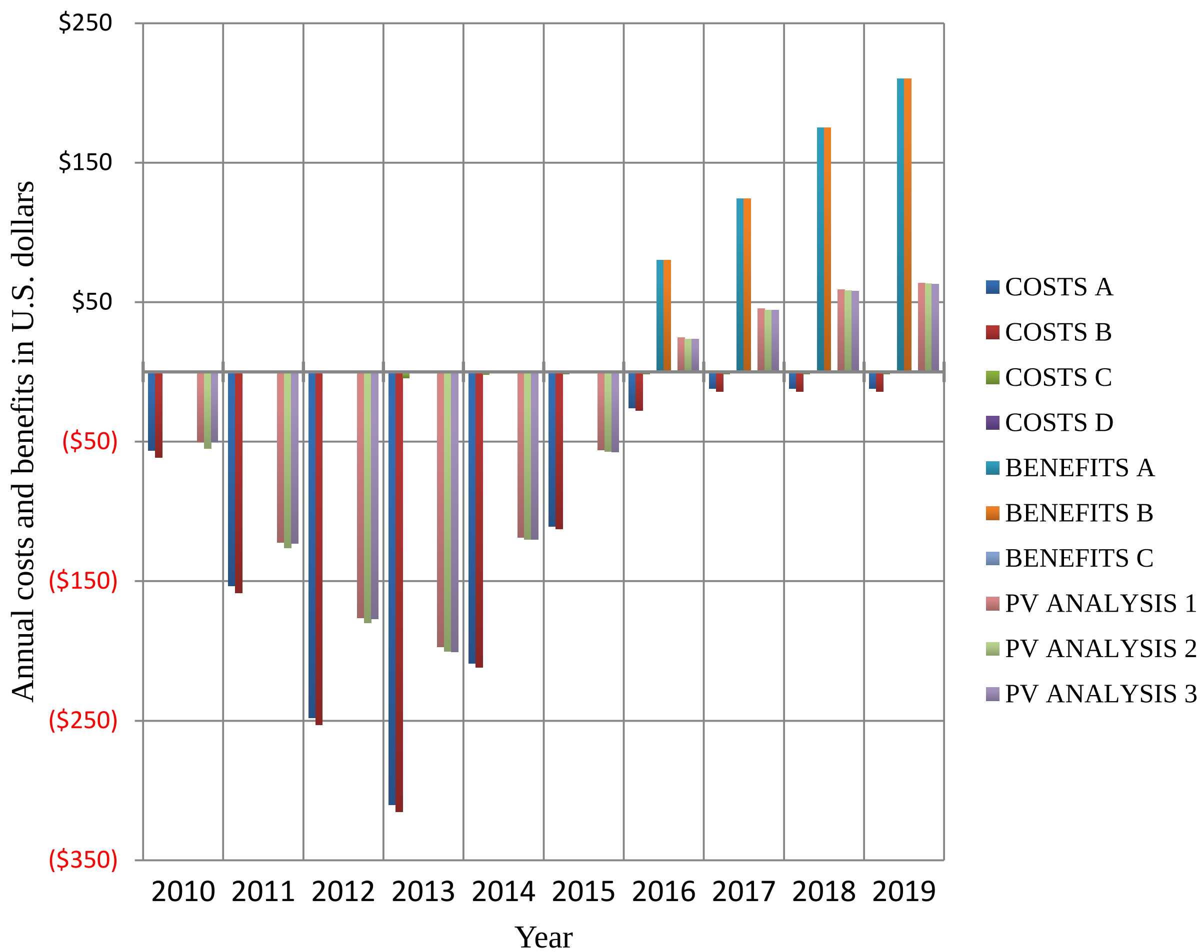
3. Re-estimating the project CBA

CBA Result 1 is the traditional project CBA result. Since the project economic analysis uses both a shorter time horizon (20 years as opposed to the project expected lifetime of 40 years) and a rather unusual way of accounting for costs, the CBA Result 1 presented here is a "synthetic but realistic" creation based on the information on project benefits and costs presented for the base case in the project documents. It assumes a 40-year project life with construction starting in 2010. Benefits begin in the year 2016. A 12% discount rate is used, as specified in the project documents. The estimates of Costs A are direct project costs net of any financing charges or contingencies. The estimates of recurring expenses from year seven (2016) onward are based on the project documentation. The full spreadsheet is presented as Table 2. A shorter 10-year period is presented in Figure 1. This graph shows the various changes that were made to the individual cost and benefit figures to move from CBA Result 1 to CBA Result 3 over the first 10 years of the project. Figure 1 does not include a Net Present Value (NPV) calculation, which requires all 40 years of data (as seen in Table 2).

Figure 1 PHR Expanded Economic Analysis—10-Year Time Horizon

ASSUMPTIONS:

Discount Rate	12%	**Time horizon: 10 years**
Annual Costs A	normal project costs	
Annual Costs B	project costs with environmental costs, unmitigated	
Annual Costs C	costs of environmental intervention after project redesign	
Annual Costs D	remaining environmental costs after redesign	
Annual Benefits A	normal project benefits	
Annual Benefits B	project benefits plus any positive environmental externalities	
Annual Benefits C	additional benefits after mitigation, if any	
CBA Result 1	Costs A + Benefits A	
CBA Result 2	Costs B + Benefits B	
CBA Result 3	Costs A + Costs C + Costs D + Benefits B + Benefits C	



Source: Author calculations

CBA Result 2 is the traditional CBA Result 1 expanded to include (to the extent possible) environmental benefits or costs in a quantitative manner; CBA Result 2 assumes that no mitigation or offset measures take place. In the base case, the assumption is made that unmitigated environmental damages from the project would be an additional $5 million per year for the first four years (2010 to 2013) as major construction takes place, and would then reduce to $3 million in year five (2014) and an additional $2 million per year for years six to 40 (2015 to 2045). These are assumptions—and may well be on the lower end of possible damages. In particular, if the biological corridor is cut, and jaguar migration disrupted, there may be larger and recurring costs from this impact. CBA Result 2 is based on Costs B and Benefits B in Figure 1 and Table 2.

Once the estimates for the environmental dimensions are available (mitigation costs as well as remaining environmental costs) they can be added into the CBA Result 1 to create the CBA Result 3. In the base case, these costs are added as Annual Costs C (costs of mitigation) and Annual Costs D (remaining environmental costs after project redesign). The main costs in Annual Costs C are the various mitigation and monitoring measures to address various impacts: the biological corridor, the "offset" river ecosystem measures, monitoring and addressing downstream impacts in the Parismina and PN Tortuguero area, the costs of helping vulnerable families who will lose land due to construction and reservoir filling, and costs for the environmental supervision unit. Although the largest annual costs occur in years 2013 to 2015, there are sizeable recurring costs after that time. Annual Costs C include two costs: for 2012 and 2013, "economic resettlement costs" of $500,000 per year, and for the other mitigation steps and environmental management a total of $4 million in 2013, $2 million in 2014, and $1.5 million in 2015 and in each succeeding year.

Annual Costs D—i.e., remaining environmental costs after redesign—consist of two amounts: a lump-sum payment to the rafting company to compensate them for the loss of the Florida section of the river (estimated at $500,000 in 2012), and annual costs of $1 million from 2013 onwards. This latter amount is a "guesstimate," and placeholders to reflect that there may well be remaining environmental costs after all construction and mitigation measures are in place.

Table 1 compares the summary results of Net Present Value calculations over a 40-year time horizon for CBA Result 1, CBA Result 2, and CBA Result 3. We note the large upfront investments and the strong flow of hydropower benefits in later years (starting in year seven, or 2016). The costs of environmental mitigation and compensation (measured in the several millions of dollars) are dwarfed by the scale of the project (measured in the hundreds of millions or billions of dollars in benefits and costs). The largest NPV result—CBA Result 1—is $115.16 million, but this result ignores all environmental (and social) impacts. If the environmental impacts are included in the economic analysis but not addressed, we obtain CBA Result 2 and the NPV calculation drops by over 22% to $88.99 million. CBA Result 3, the more comprehensive, enhanced analysis that includes the environmental mitigation measures, produces a result that is 10% larger than CBA Result 2: $96.85 million.

Table 1 Comparison of CBA Results 1, 2 and 3

Table assumes 40-year time horizon, 12% discount rate. Net Present Value.

CBA Result 1 (Traditional project analysis, Costs A and Benefits A)	$115.16 million
CBA Result 2 (Traditional Project analysis with inclusion of environmental impacts—Costs B and Benefits B)	$88.99 million
CBA Result 3 (Comprehensive project analysis of redesigned project including all environmental benefits and costs — Costs A + Costs C + Costs D + Benefits B + Benefits C).	$96.85 million

Source: Author calculations

4. What is Left Out/Areas of Uncertainty

This study was done ex-post and without any additional fieldwork or data collection in Costa Rica. It is based on the extensive existing fieldwork and documentation that is available for the project. The variation between results CBA 1, 2 and 3 are surprisingly small, especially for a hydropower project and one as large as this one. A possible explanation is that several potentially large environmental costs are avoided because of the special characteristics of the project area (low population density, limited economic uses, small reservoir capacity), or the mitigation steps that have been taken or are being proposed. These "avoided costs" include the following:

1. **Resettlement**. No physical resettlement is needed, and hence what could be a major social and economic cost is avoided. In most countries, the construction of hydropower dams and reservoirs often require the resettlement of hundreds or thousands of households (in the case of

the Three Gorges Dam in China, resettlement involved more than 1.3 million people!). Large resettlement costs are avoided in this case in Costa Rica.

2. **Biological Corridor**. The reservoir will have an impact on a major biological corridor that is especially important for the endangered jaguar. However, since the impact falls at the tail end of the reservoir, it is possible to take various mitigative steps to protect the functions of the biological corridor. If this were not the case and the corridor were in fact cut, there would be important issues concerning species sustainability and the values associated with the potential loss of species. The few migratory fish species that are affected by the dam are not endemic to the area; therefore, even if there are impacts on these fish populations, there is no question of species loss or extinction.

The analysis does not address the issue of the "value" of jaguar genetic diversity. By being able to avoid the loss of the corridor functions, the PHR should not create any problems of this sort and the associated valuation issues. This is fortunate since economic valuation of genetic diversity is an extremely difficult valuation area (other than by using the "cost of prevention" approach that was actually applied in this case to preserve a biological corridor in the PHR reservoir).

3. **Loss of River Ecosystem**. There is no question that parts of the Reventazón River will be forever changed or lost due to the construction of the PHR. However, this river has already been affected by developments in other upstream areas, and the decision was made that compensatory investments in an undisturbed river located nearby is an adequate "offset" for the changes brought about by the PHR. The difficult valuation issue of loss of a natural ecosystem is therefore avoided.

4. **Downstream Impacts**. In many cases, hydropower dams have major downstream impacts, both in terms of water quantity and quality. In the case of the PHR, however, since the reservoir has minimum over-time storage capacity, and since no water is extracted for irrigation or other non-power uses, the final impact on downstream deliveries of water—both quantity and quality—is minimal. It should also be noted that a monitoring program will assess these impacts over time and that various measures and policies are in place to minimize sedimentation during construction.

5. Final Thoughts/Next Steps

This case study of the Reventazón Hydroelectric Project (PHR) demonstrates the application of the broader environmental-economic analysis called for the IDB's Operational Directives and outlined in IDB Technical Note No.IDB-TN-428 (Dixon, "Economic Cost-Benefit Analysis (CBA) of Project Environmental Impacts and Mitigation Measures"). Using actual project documents the progression from CBA Result 1 (standard project analysis) to CBA Result 2 (standard project analysis with acknowledgement of environmental costs) to CBA Result 3 (a more comprehensive project analysis where environmental costs and benefits—mitigated and unmitigated—are taken into account).

The difference between CBA Results 1, 2 and 3 are tangible, but not huge. This is explained by the particular circumstances of the PHR—little or no long-term impact on an already heavily modified river system, no resettlement, and the ability to avoid the loss of an important biological corridor. If these conditions had been different, the variation in the results might have been much larger. One cannot say *a priori* what the difference will be—one has to do the analysis and crunch the numbers!

Finally, the approach used here reinforces the usefulness of early involvement of environmental economics expertise in the project design and development. Ex-post analysis is possible (as in this case), but ex-ante analysis should be more robust and open up additional opportunities for avoiding environmental impacts.

Table 2 PHR Expanded Economic Analysis—40-Year Time Horizon

ASSUMPTIONS:		
Discount Rate	12%	**Time horizon: 40 years**
Annual Costs A	normal project costs	
Annual Costs B	project costs with environmental costs, unmitigated	
Annual Costs C	costs of environmental intervention after project redesign	
Annual Costs D	remaining environmental costs after redesign	
Annual Benefits A	normal project benefits	
Annual Benefits B	project benefits plus any positive environmental externalities	
Annual Benefits C	additional benefits after mitigation, if any	
CBA Result 1	Costs A + Benefits A	
CBA Result 2	Costs B + Benefits B	
CBA Result 3	Costs A + Costs C + Costs D + Benefits B + Benefits C	

Year (time=T)	COSTS A	COSTS B	COSTS C	COSTS D	BENEFITS A	BENEFITS B	BENEFITS C	PV ANALYSIS 1 at time T	PV ANALYSIS 2 at time T	PV ANALYSIS 3 at time T
1	($56.50)	($61.50)	$0.00	$0.00	$0.00	$0.00	$0.00	($50.45)	($54.91)	($50.45)
2	($153.40)	($158.40)	$0.00	$0.00	$0.00	$0.00	$0.00	($122.29)	($126.28)	($123.09)
3	($248.00)	($253.00)	($0.50)	($0.50)	$0.00	$0.00	$0.00	($176.52)	($180.08)	($177.23)
4	($310.20)	($315.20)	($4.50)	($1.00)	$0.00	$0.00	$0.00	($197.14)	($200.32)	($200.63)
5	($209.00)	($212.00)	($2.00)	($1.00)	$0.00	$0.00	$0.00	($118.59)	($120.29)	($120.29)
6	($110.80)	($112.80)	($1.50)	($1.00)	$0.00	$0.00	$0.00	($56.13)	($57.15)	($57.40)
7	($25.90)	($27.90)	($1.50)	($1.00)	$80.00	$80.00	$0.00	$24.47	$23.57	$23.34
8	($12.00)	($14.00)	($1.50)	($1.00)	$124.00	$124.00	$0.00	$45.23	$44.43	$44.23
9	($12.00)	($14.00)	($1.50)	($1.00)	$175.00	$175.00	$0.00	$58.78	$58.06	$57.88
10	($12.00)	($14.00)	($1.50)	($1.00)	$210.00	$210.00	$0.00	$63.75	$63.11	$62.95
11	($14.00)	($16.00)	($1.50)	($1.00)	$234.00	$234.00	$0.00	$63.24	$62.67	$62.53
12	($14.00)	($16.00)	($1.50)	($1.00)	$220.00	$220.00	$0.00	$52.88	$52.36	$52.23
13	($14.00)	($16.00)	($1.50)	($1.00)	$218.00	$218.00	$0.00	$46.75	$46.29	$46.18
14	($15.00)	($17.00)	($1.50)	($1.00)	$219.00	$219.00	$0.00	$41.74	$41.33	$41.23

Table 2 Continued

Year (time=T)	COSTS A	COSTS B	COSTS C	COSTS D	BENEFITS A	BENEFITS B	BENEFITS C	PV ANALYSIS 1 at time T	PV ANALYSIS 2 at time T	PV ANALYSIS 3 at time T
15	($15.00)	($17.00)	($1.50)	($1.00)	$246.00	$246.00	$0.00	$42.20	$41.84	$41.75
16	($15.00)	($17.00)	($1.50)	($1.00)	$260.00	$260.00	$0.00	$39.96	$39.64	$39.56
17	($15.00)	($17.00)	($1.50)	($1.00)	$270.00	$270.00	$0.00	$37.14	$36.85	$36.78
18	($15.00)	($17.00)	($1.50)	($1.00)	$298.00	$298.00	$0.00	$36.80	$36.54	$36.48
19	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$33.09	$32.86	$32.80
20	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$29.55	$29.34	$29.29
21	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$26.38	$26.19	$26.15
22	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$23.55	$23.39	$23.35
23	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$21.03	$20.88	$20.85
24	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$18.78	$18.64	$18.61
25	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$16.76	$16.65	$16.62
26	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$14.97	$14.86	$14.84
27	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$13.36	$13.27	$13.25
28	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$11.93	$11.85	$11.83
29	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$10.65	$10.58	$10.56
30	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$9.51	$9.45	$9.43
31	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$8.49	$8.43	$8.42
32	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$7.58	$7.53	$7.52
33	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$6.77	$6.72	$6.71
34	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$6.05	$6.00	$5.99
35	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$5.40	$5.36	$5.35
36	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$4.82	$4.79	$4.78
37	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$4.30	$4.27	$4.27
38	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$3.84	$3.82	$3.81
39	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$3.43	$3.41	$3.40
40	($15.00)	($17.00)	($1.50)	($1.00)	$300.00	$300.00	$0.00	$3.06	$3.04	$3.04
Net Present Value (NPV) of the project at 40 years								**$115.16**	**$88.99**	**$96.85**

Source: Author calculations

6. Terms and Considerations

Total Economic Value (TEV): The TEV concept states that the economic "value" (or "price" for marketed goods and services) is composed of a series of attributes, some of which are more tangible than others. As seen in the standard TEV chart (see Figure 2) the TEV is composed of **Use Values** and **Non-Use Values**.

Use Values are those economic values that come from the direct or indirect use of a resource. Use values are usually divided into **direct use values** and **indirect use values**.

Direct Use Values, also known as extractive, consumptive, or structural use values derive from goods that can be extracted, consumed, or directly enjoyed. In the context of a forest, for example, direct use values include the harvesting of timber, the collection of minor forest products such as fruit, herbs, or mushrooms, and the results of hunting and fishing. In addition to these directly consumed goods, direct use values can also be non-consumptive. For example, people who enjoy hiking or camping in the same forest receive a direct use value, but do not actually "consume" any of the forest resource. Similarly, in a coral reef, direct use values can include the harvesting of shells and catching of fish, or the non-consumptive enjoyment of the reef by scuba divers. All of these benefits are tangible, can be measured, and have economic values, even if the consumption by one individual does not reduce the consumption by another (economists call this non-rival consumption, and these goods are classified as public goods).

Indirect Use Values, also known as non-extractive use values or functional values, derive from the services the environment provides. Many ecosystem services are examples of indirect use values. For example, wetlands often filter water, improving water quality for downstream users, and national parks provide opportunities for recreation. These services have value but do not require any good to be harvested, although they may require someone's physical presence.

Measuring indirect use value is often considerably more difficult than measuring direct use value. The "quantities" of the services being provided are often hard to measure. Moreover, many of these services often do not enter markets at all, so that their "price" is also extremely difficult to establish. The visual aesthetic benefits provided by a landscape, for example, are non-rival in consumption, meaning that many people can enjoy them without detracting from the enjoyment of others.

Non-Use Values are those economic values where no direct interaction with the resource occurs. For example, in a coral reef one finds direct use values (fishing/coral collecting) and indirect use values (shoreline protection/serving as a nursery area for juvenile fish); there may also be important non-use values whereby people who do not visit or use the coral reef still value knowing “that it is there” or seeing photos and films about the reef. The main non-use Values include the following:

- **Option Value**: Option value is a deferred use value. This value occurs when people are willing to pay something to have the “option” of using the resource themselves in the future.
- **Bequest Value**: When the option value is for the next generation (e.g. “I want my children to be able to see the coral reef”), this is called a Bequest Value. It is the potential use of a resource by the next or future generations.
- **Existence Value**: Individuals also derive a benefit from knowing that a resource is there —whether or not they plan to visit it themselves (a use value) or think that they may want to visit it in the future (an option value), or want to ensure its survival for future generations (a bequest value). An existence value is a benefit that comes from just knowing that the resource in question (e.g. blue whales, pandas, orangutans) exists—hence the term “existence value.”

Note that both bequest values and existence value imply no use—either direct or indirect—by the present generation. The size of these values may be small per person (in monetary terms) but may be large in the aggregate, since many people in a country may have these values.

Figure 2 Total Economic Value

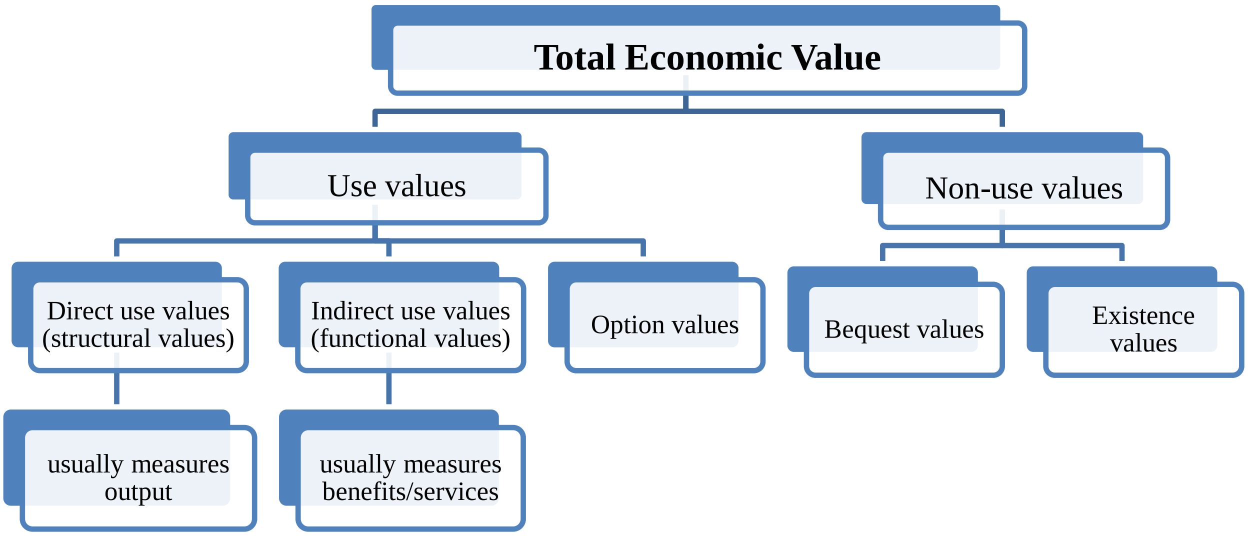


Table 3 TEV for the Biological Corridor

Type of value	Goods or services valued	Valuation techniques
Use Values		
• Direct	Tourism (consumers' surplus)	Travel cost; CVM
	Tourism (producers' surplus)	Lost economic rents
	Research and education	Expenditures
	All direct uses	Preventive expenditures
• Indirect	Tourism (in other parts of Costa Rica)	Travel Cost; CVM
	Research and education	Expenditures
	Biological diversity conservation	CVM
• Option	Biological diversity	CVM
Non-Use Values		
• Bequest	Biological diversity	CVM
• Existence	Biological diversity	CVM

Source: Author

Table 4 TEV for the River Ecosystem

Type of value	Goods or services valued	Valuation techniques
Use Values		
• Direct	Fishing	Change in production approach
	Research and education	Expenditures
	All direct uses	Compensating expenditures
• Indirect	Sediment flows	Preventive expenditures; change in production
	Research and education	Expenditures
• Option	Biological diversity (?)	CVM
Non-Use Values		
• Bequest	Biological diversity (?)	CVM
• Existence	Biological diversity (?)	CVM

Source: Author

Table 5 TEV for Whitewater Rafting

Type of value	Goods or services valued	Valuation techniques
Use Values		
• Direct	Tourism; recreation (producers' surplus)	Lost economic rents
	Tourism; recreation (consumers' surplus)	Expenditures
• Indirect	Tourism (in other parts of Costa Rica)	Travel Cost; CVM
	Research and education	Expenditures
• Option	?	CVM
Non-Use Values		
• Bequest	?	CVM
• Existence	?	CVM

Source: Author

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