INTERNATIONAL COURT OF JUSTICE

DISPUTE CONCERNING THE CONSTRUCTION OF A ROAD IN COSTA RICA ALONG THE SAN JUAN RIVER

NICARAGUA *v.* COSTA RICA

REJOINDER OF COSTA RICA

VOLUME III

ANNEXES 4 - 14

2 FEBRUARY 2015

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ANNEX 4

University of Costa Rica, Centre for Research in Sustainable Development
Department of Civil Engineering

Second Report on Systematic Field monitoring of Erosion and Sediment Yield along Route 1856

November 2014

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VICERECTORÍA DE INVESTIGACIÓN

CENTRO DE INVESTIGACIÓN EN DESARROLLO SOSTENIBLE

CIEDES

Second Report on Systematic Field monitoring of Erosion and Sediment Yield along Route 1856

By:

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San José, Costa Rica

November, 2014

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1 Introduction

The Universidad de Costa Rica's Centre for Research in Sustainable Development (CIEDES) has continued its assessment of the average erosion rates occurring along Route 1856. CIEDES previously submitted a report on the subject in September 2013 to the Ministerio de Relaciones Exteriores y Culto de la República de Costa Rica as part of ongoing litigation in the International Court of Justice.

This second report represents the continuation and refinement of studies carried out in-situ on what are some of the sites with worst erosion along Route 1856. Two mayor changes have been introduced in respect to the 2013 report by CIEDES. State of the art LiDAR topography has replaced manual measurements at all slopes studied in 2013, and a photogrammetric survey has been completed for three additional sites with difficult access. A fourth additional site was not included because it is undergoing extensive mitigation work.

Both changes have resulted in more accurate measurements of the volume of soil erosion which has occurred in the studied sites, this in turn has improved the reliability of the erosion rates estimated in this report. The addition of three sites between Río Infiernito and Boca San Carlos ensure the erosion rates this report presents are representative of those occurring in the section of Route 1856 which is subject to the most intense erosion.

The study area is defined by the road corridor of Route 1856 adjacent to the Río San Juan from the vicinity of Marker II to a point approximately 18.2 km downstream of Marker II. Visit dates of particular importance are those of May 27, October 22 and 28, 2014. LiDAR topography was carried out on the first two dates for Sites 1-4 and 8-10, an Unmanned Aerial Vehicle was used to carry out a survey of Sites 11-13 on the latest date.

Erosion data is now presented in a more direct fashion than the 2013 report. Erosion rates are now estimated only for the area of each erosion feature without distributing it over the entire slope. This information could also be obtained from the 2013 report, thus the data used and presented remains the same, only the way in which it is presented has changed.

It is important to comment that the section of Route 1856 between Marker II and Río Infiernito has been subject to mitigation work during 2014. Most of the sites included in this report have been left un-mitigated or partially mitigated so they may continue to serve as control sites for erosion along the road. All sites will be fully mitigated when final design and construction takes place.

Laser topography was acquired and pre-processed by engineers working in the Transportation Infrastructure Programme of UCR's National Laboratory of Materials and Structural Models (LANAMME). The equipment used was a Leica Scanstation C10 Laser Scanner. The LANAMME personnel involved in acquiring and processing the laser topography are:

Eng. José Francisco Garro Mora, M. Sc.

Eng. Jairo Sanabria Sandino

Eng. Cristian Valverde Cordero

Karen Herrera Arrieta

Digital photogrammetry was acquired and processed by Aitec International Group S.A using a 1.8m-wingspan Skyhunter UAV equipped with GPS navigation, an Inertial Measurement Unit, a Sony Nex-5T camera and an AFSS flight stabilization system. Processing was carried out using ERDAS IMAGINE and Simactive Correlator 3D software. Aitec is an international company with over 22 years of experience in photogrammetry and remote sensing, the engineer in charge of this process was:

Eng. Nelson Mattie

Final processing of the three-dimensional models generated through LiDAR and UAV surveys was carried out by CIEDES using AutoCAD Civil 3D and Global Mapper to measure erosion volumes at each site. Other activities carried out by CIEDES include visual inspection of the Route during each visit and the topographic survey of Site 5's sediment trap. CIEDES personnel responsible for this project include:

Eng. Rafael Oreamuno Vega, M. Eng. Project lead and Director of CIEDES

Eng. Roberto Villalobos Herrera

Luis Carlos Murillo Fonseca

2 Methodology

This section discusses the sites selected for study and the methods used to study them.

2.1 Evaluated sites

A total of 11 sites have been evaluated in this report. Their coordinates and a brief description are given in Table 1. Also, their location relative to each other and the San Juan River is shown in Figure 1.

The sites monitored in 2013 and included in the 2013 report were selected because they could be accessed by road during both wet and dry seasons, so that they could be monitored on an ongoing basis. In addition at least one or more monitored sites was dominated by rill, gully, landslide, or sheet erosion.

In 2013, access to the Road in the stretch between Río Infiernito and Boca San Carlos was particularly difficult. Consequently, it was not certain that measurements could be made in that stretch throughout the year. For that reasons, sites in that area were not included. For the reasons explained in our 2013 Report, the sites included in the 2013 report were representative of the erosion processes occurring on the Road.

In this 2014 Report, additional sites have been added to the monitoring programme. Of particular note to this report is the inclusion of Sites 11-13. These sites were not included in the 2013 report due to the access constraints mentioned above which hindered reaching and studying the sites in the limited time frames available for visits to Route 1856. Sites 11, 12 and 13 correspond to Eroding Sites 8.1, 9.4 and 9.5 as numbered in Volume II of Nicaragua's Reply of August 04, 2014. Site 8.2 was not included in the monitoring study because it does not display a single, dominant type of erosion in a way which would enable us to derive a reliable estimate of an erosion rate for one type of erosion.

Eroding Sites 8 and 9 have been subject to great scrutiny by Nicaragua's experts. The opportunity to use an Unmanned Aerial Vehicle (UAV) has been exploited to obtain photogrammetric data for these sites. This data is of great value because it directly addresses the main criticism levelled at our 2013 report, the absence of measurements in what Dr. Kondolf considers to be the worst eroding portion of the road.

The data obtained using the UAV also permits a comparison between the estimates carried out by Hagans & Weaver and the estimates set out in this report. The large gullies in Sites 11-13 have allowed the team to establish whether the rate of land surface lowering due to erosion in the largest gullies is fact higher than that based on the long-term monitoring of smaller gullies. As is explained below, erosion rates established for Dr Kondolf's Sites 8.1, 9.4 and 9.5 based on the UAV survey were

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found to be lower than the highest rate established for gullies at the long-term monitoring sites, and are in fact comparable to the rates recommended by UCR in their 2013 Report.

Dr Kondolf's Sites 10-17 were not included for two reasons. First, the erosion features there are not discussed by Nicaragua's experts in as much detail as Dr Kondolf's Sites 8 and 9 and no estimates for their erosion were given by either Dr Kondolf or Hagans and Weaver (who provided estimates only for Sites 8.1, 8.2, 9.4, 9.5, and 9.6). Second, they were not monitored in 2014 because they are located some distance away, putting them out of range of the UAV used for the survey and necessitating a separate flight programme. On the basis of our observations of sites 10-17, we reached the view that these sites were not eroding at any higher rate than the sites we monitored in 2013, or in 2014 (in this report), so that our estimates based on monitored sites are representative of erosion on all slopes.

Site 8 is described as partially mitigated because the stream which eroded this site has been diverted away from it, the volume of eroded fill at this point has not been altered by this mitigation work. Sites 12 and 13 are scheduled to be intervened in the short term as part of mitigation works in Route kilometre 18 downstream of Marker II.

A discrepancy exists between the number of evaluated sites and the site numbers used in this report. This is due to Site 6 and Site 7. Both of these sites are tubular sediment traps placed in concrete gutters, they were discussed in detail as Sediment trap #3 and Sediment trap #4 in our previous report, however they have not been included in the present report.

Table 1. List of sites and their coordinates.

Site number		Description	Coordinates
UCR	Mende et. al.		
1	NA	Large rotational landslide on cut slope. Un-mitigated.	84°21'43.571" W 10°59'30.461" N
2	T-33	Large rotational landslide on cut slope. Un-mitigated.	84°20'45.712" W 10°56'55.931" N
3	T-37	Gully on cut slope. Un-mitigated.	84°20'27.579" W 10°56'50.991" N
4	T-42	Rills on cut slope. Un-mitigated.	84°19'33.653" W 10°55'15.459" N
5	T-39	Sediment trap.	84°20'07.509" W 10°56'27.451" N
6	C-29	Sediment trap. This site is not used or discussed in this report. Refer to 2013 report for details.	84°19'26.847" W 10°55'07.199" N
7	T-58a	Sediment trap. This site is not used or discussed in this report. Refer to 2013 report for details.	84°18'18.025" W 10°54'50.528" N
8	T-8b	Gully on fill slope. Partially mitigated.	84°21'19.775" W 10°59'26.769" N
9	T-57a	Gully on fill slope. Un-mitigated.	84°18'21.896" W 10°54'52.695" N
10	T-45b	Rills on fill slope. Un-mitigated.	84°19'31.562" W 10°55'09.799" N
11 (8.1)	T-65	Large gully on fill slope. Un-mitigated.	84°17'22.664" W 10°54'24.191" N
12 (9.4)	T-68	Large gully on fill prism. Mitigation imminent.	84°17'02.137" W 10°53'39.912" N
13 (9.5)	T-70	Large gully on fill prism. Mitigation imminent.	84°16'54.725" W 10°53'35.477" N

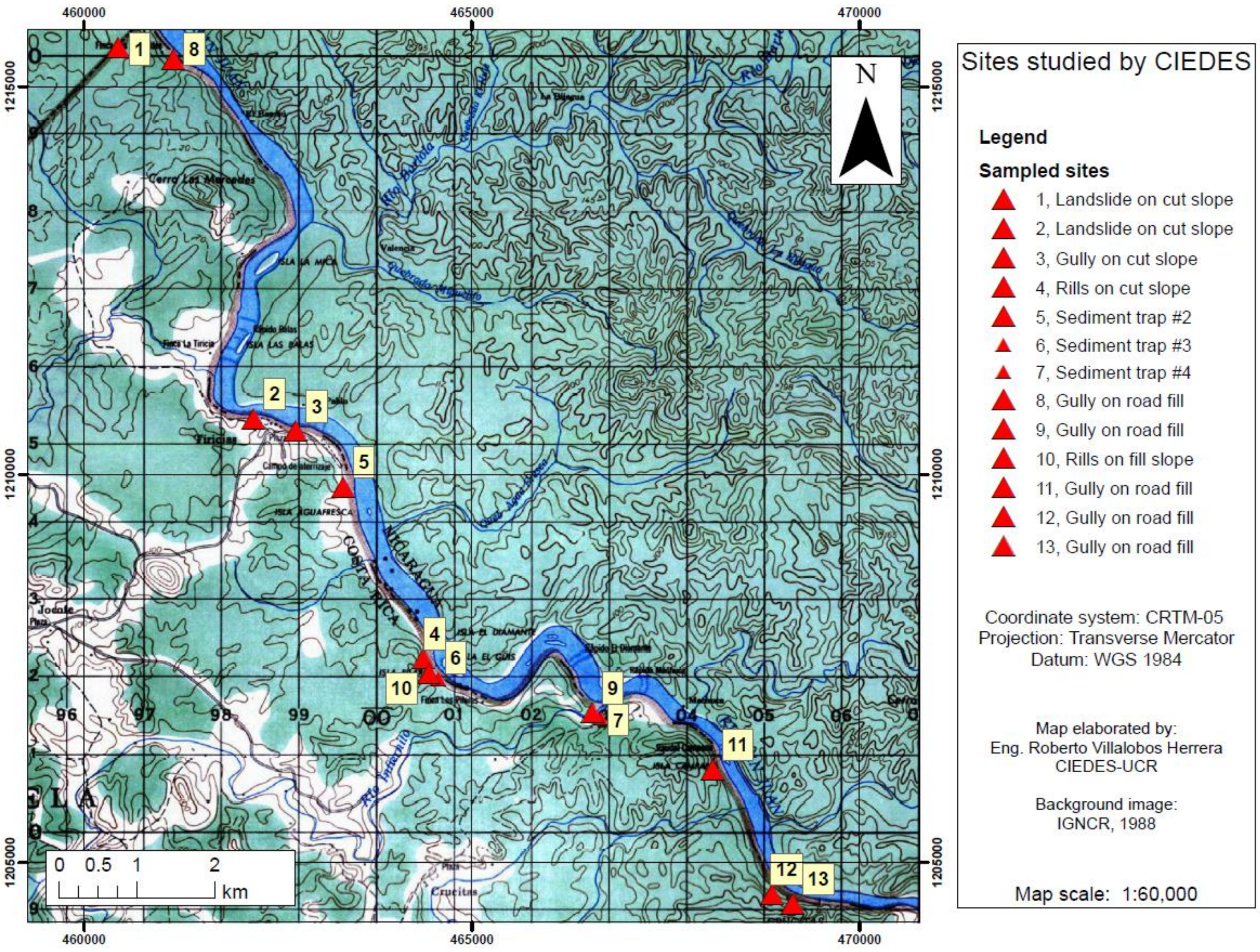

Figure 1. Map of the sites studied by CIEDES.

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2.2 Data acquisition

There has been a marked refinement in the methods used to assess the erosion volume and rate occurring at each selected site. The basic principle behind our work has been to use the best methods available to us for our research. During 2014, LANAMME made available to us their Laser Scanner and a team of engineers trained in its use. This equipment has been used twice on those sites which can be accessed by road in lieu of the manual measurements used during 2013. Aitec Group, a private international company, was contracted to deliver photogrammetric data from three sites with difficult road access. These sites were not visited during 2013 and are thus new additions to the monitored sites on Route 1856.

2.2.1 Land LiDAR

The raw product of a laser scanner is a point cloud which can be used to generate accurate three-dimensional representations of the scanned area. These point clouds are produced by a laser scanner which emits a laser beam onto a surface at a known direction; the scanner records the time taken for the beam to return and uses this time to determine the distance to the object. In this way direction and distance is known for each point were a laser beam impacts a surface. By emitting hundreds of thousands of beams per scan session, a laser scanner generates a cloud of points which can be accurately located in three-dimensional space. A low-resolution digital camera is then used by the scanner to paint each point with colour; this enables a user to distinguish vegetation from uncovered soil. An example of a raw point cloud is shown in Figure 2.

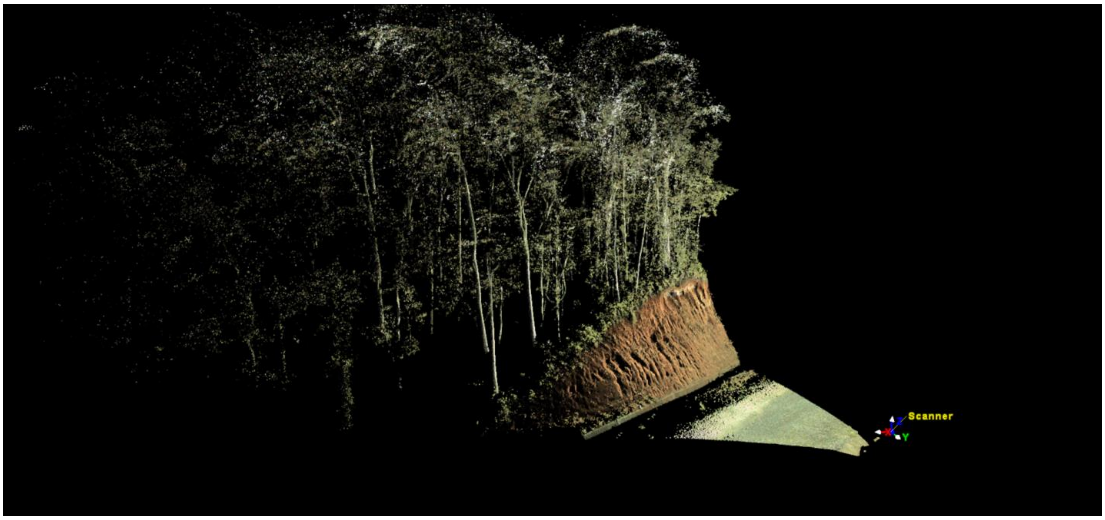

Figure 2. Point cloud acquired at Site 4 on May 27, 2014.

Point clouds are not error-free. They're acquired by laser scanning and therefore anything which is not directly in the sensor's line of sight is not registered. This generates gaps in the point clouds which must be interpolated using specialized software to obtain a complete surface model. These gaps were minimized by careful placement of the laser scanner at each point.

3D surface models derived from each site's point cloud have replaced the simple polygonal shapes, themselves based on manual measurements, used in the 2013 report. However, a point cloud is a much more accurate representation of the reality of each site than a simple polygon. As such, the use of laser scanning greatly increases the reliability of the erosion estimates presented in this report.

Two visits to Route 1856 were carried out with LANAMME personnel and their Leica Scanstation C10. These were carried out on May 27, 2014 and October 22, 2014. The procedure followed at each location was to determine the features to be scanned and the selection of the scanner's position. During the May visit a stake was driven into the ground to mark each position and reproduce the scanner's position during the October visit.

2.2.2 UAV Photogrammetry

Photogrammetry is a type of remote sensing which converts aerial photographs into accurate three-dimensional models of reality. A drone aircraft equipped with a GPS system, an Inertial Measurement Unit and a high-resolution camera is able to acquire detailed RGB digital photographs of the ground while simultaneously recording the aircraft's elevation, the coordinate of the centre of the image, and the pitch, roll, and yaw of the aircraft. The photographs and the navigation and position information form the raw data obtained by Aitec by flying an UAV over portions of Route 1856.

The UAV survey of Sites 11-13 was carried out on October 28, 2014. Two flights were carried out, the first surveyed Sites 12 and 13. The second flight surveyed Site 11. The procedure for each flight included loading the pre-set flight path into the UAV's on-board autopilot. After lift-off the 1.8 m wingspan drone used its navigation system and its flight stabilization system to follow the pre-set flight path. Photographs with an overlap of 70% and associated positioning information were acquired during the entire flights.

An example of an unprocessed photograph obtained using the UAV is shown in Figure 3. This photograph in particular shows recent and on-going mitigation efforts to stabilize slope T-72. The mitigation work on this site forced its exclusion from this report as it is being actively intervened.

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Figure 3. Raw photograph of Route 1856 acquired using an UAV showing on-going mitigation work at slope T-72 (Eroding site 9.6), October 28, 2014.

2.3 Data analysis

In this sub-section the methods used to process the raw data are presented. The procedures are described in full using Site 4 and Site 12 as examples. The results obtained are presented in Section 3.

2.3.1 Land LiDAR

The methods described below were applied to Sites 1-4 and 8-10. The raw data used at each site is a point cloud generated by a laser scanner.

The processing methods can be separated into two distinct stages, pre-processing and processing. The pre-processing required for the raw laser data used in this report involved transforming point clouds obtained by LANAMME into contour data. This pre-processing was handled exclusively by LANAMME personnel using Leica Cyclone proprietary software. Pre-processing consisted of removing vegetation points and background data not relevant to the site under study from the point cloud. The remaining points were then used to generate a complex mesh surface model. Finally contours at 10 cm elevation intervals were extracted from the surface model and exported as .dxf files for processing in Autodesk's Civil 3D software. Figure 4 shows an example of the resulting contours for Site 4.

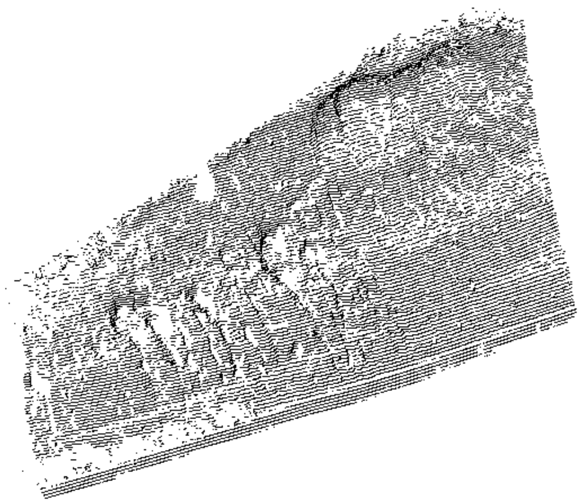

Figure 4. Pre-processed contour data for Site 4 on May 27, 2014.

Final processing of the laser scanned data was carried out by CIEDES personnel. The goal of the processing stage of data analysis was to estimate the volume of soil lost due to erosion at each of the scanned sites. This was done using AutoCAD Civil 3D to construct a reference surface based on the state of the slopes surrounding each erosion site. This was possible because the erosion sites consist of man-made cut and fill slopes.

The reference surface is a representation of the initial condition at each site obtained by filling in the erosion features found on the site's slope. This process can be observed by contrasting the Triangulated Irregular Network (TIN) surface models shown in Figure 5. The terrain model was generated using the contours shown in Figure 4. The Reference Surface model uses straight lines connecting the top and bottom edges of the slope to generate a model resembling the initial condition of this cut slope.

Once both surface models are complete the Volumes Dashboard tool in AutoCAD Civil 3D was used to calculate the volume difference between both surfaces. The results of these calculations are the volume of soil lost at each site due to erosion. These volumes were then distributed over each feature's scanned area to produce an average erosion depth. Finally this erosion depth was distributed over time to produce an average erosion rate.

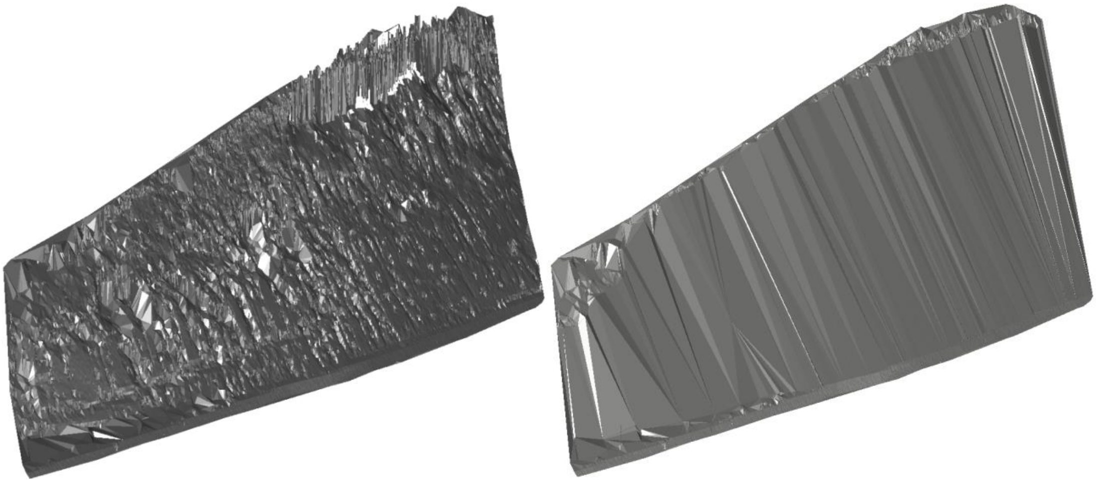

Figure 5. Terrain model on May 27, 2014 (left) and Reference Surface model for Site 4.

2.3.2 UAV Photogrammetry

The procedure used to process Sites 11-13 can also be divided into a pre-processing stage and a processing stage. Pre-processing consisted of the steps required to produce ortho-rectified photographs and digital elevation models of the corridor containing Sites 11-13, this was carried out by Aitec. Processing, carried out by CIEDES, involved using the elevation models to estimate the total erosion at each site.

The pitch, roll and yaw recorded by the UAV's IMU are related to the aircraft's local tangent plane. These values must be translated into angles referred to a projection such as Universal Transverse Mercator (UTM); Simactive Correlator 3D software was used for these calculations. Further pre-processing steps include generating digital surface models, and then digital terrain models are created by removing vegetation. Finally, orthophotos are generated with a 7 cm/pixel spatial resolution. All elevation models and orthophoto mosaics are projected using UTM and WGS-84.

Figure 6. LAS point cloud generated during pre-processing of UAV photogrammetry.

Figure 6 shows an example of the point clouds generated as an intermediate step required to obtain the elevation models. This location is immediately downstream of Site 11 and corresponds to Erosion Site 8.2 in Volume II of Nicaragua's Reply of August 04, 2014. Figure 7 is an example of a digital surface model obtained for Route 1856 using UAV photogrammetry.

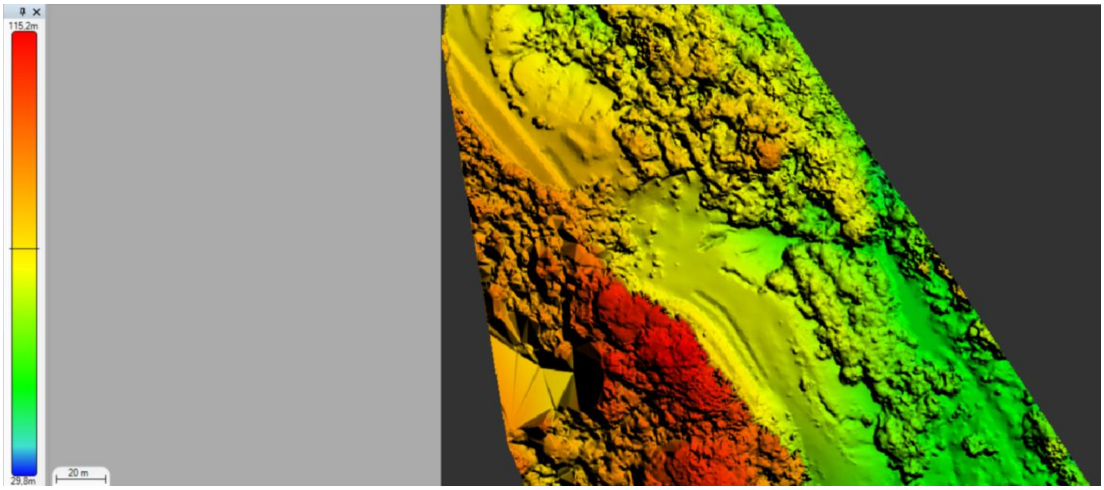

Figure 7. Digital surface model of Route 1856. Site 11 is visible in the top left-hand corner of the image.

Final processing of Sites 11-13 used the digital elevation models supplied by Aitec to calculate erosion volumes for three large gullies. This was carried out using Global Mapper's Measure tool along several cross-sections such as the one shown in Figure 8. The red line shown represents the surface elevation used to calculate the cut and fill volumes of the cross-section. At each cross-section the software calculates the eroded volume of a strip of terrain 10 m wide (5 m on either side of the cross-section). Cross-sections were spaced every 10 m as needed to cover the entire erosion feature.

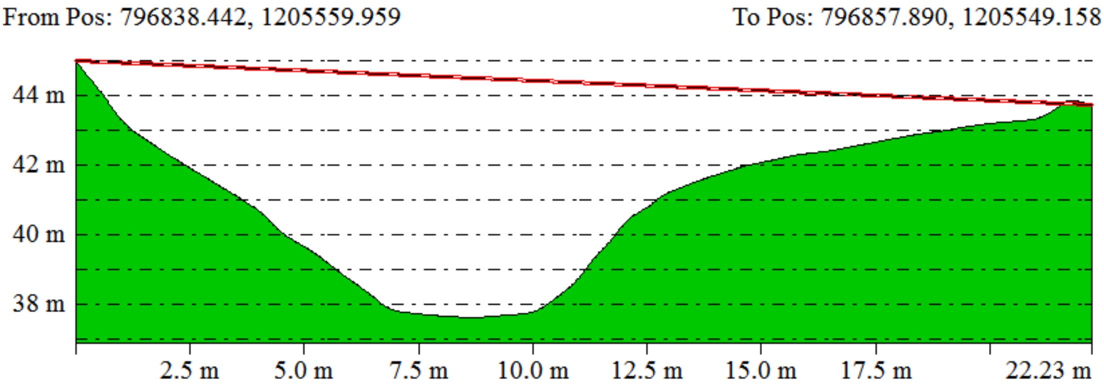

Figure 8. Cross-section 2, Site 12.

Figure 9 shows the cross-sections used to calculate the erosion volume at Site 12. The shaded area represents the area of the gully used to distribute the volume calculated with the cross-sections. Both the orthophoto and the elevation model are presented to illustrate the correspondence between each other. Note how the gully's boundaries as determined by the area polygon in the orthophoto align with the edges of the gully in the elevation model.

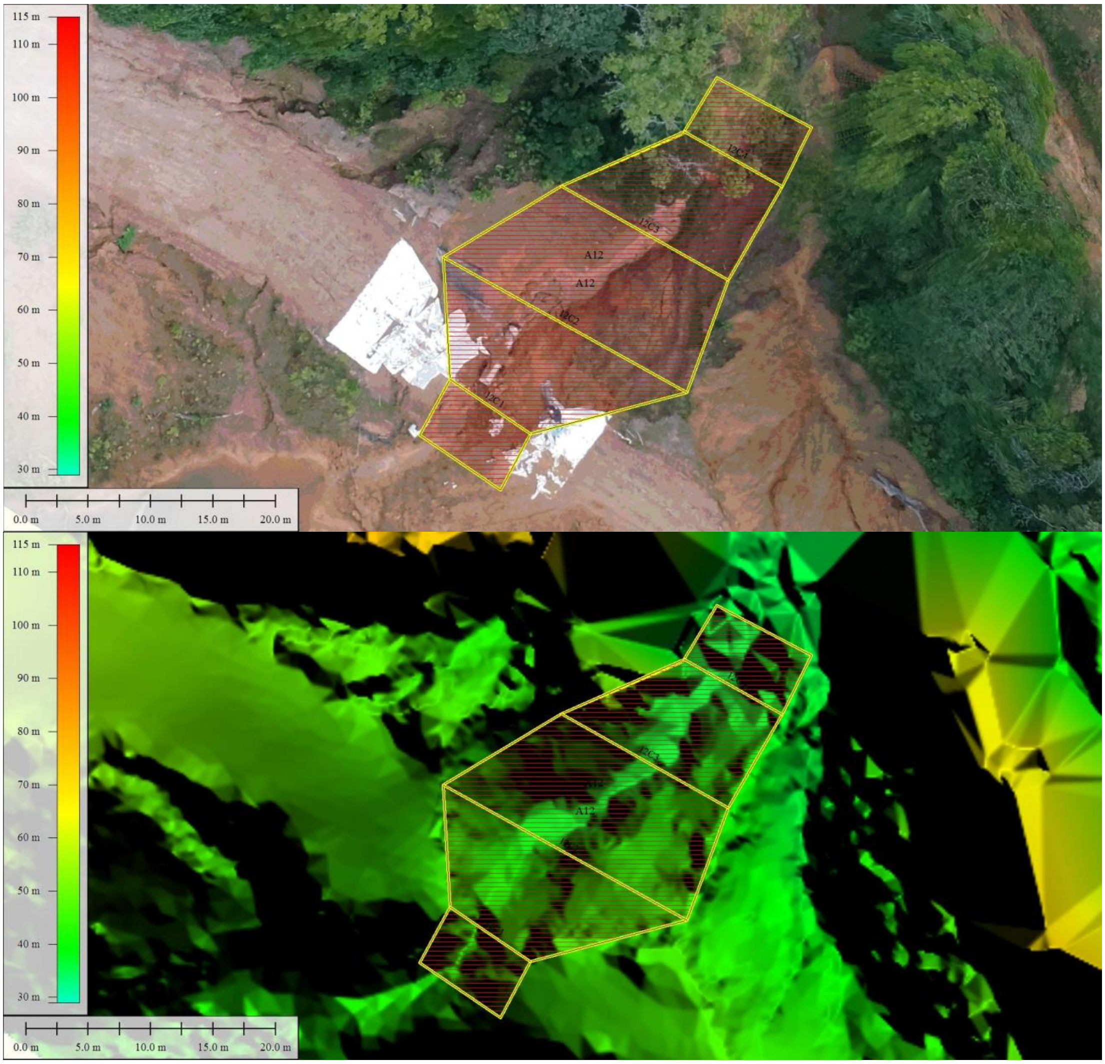

Figure 9. Orthophoto and Digital Elevation Model of Site 12 on October 28, 2014.

The procedure described above of cross-section volume calculations was repeated for Sites 11 and 13.

2.4 Sheet erosion

The method used to estimate sheet erosion has also been refined from that used for the 2013 report. The underlying principle of using a sediment trap to capture eroded soil generated at a cut slope which only presents sheet erosion is repeated from 2013. The method used to record sediment depth has been improved.

As mentioned in the 2013 report, during the final visit on September 21 Sediment trap #2, numbered as Site 5 in Figure 1, was observed to be full. This impeded continued measurements in the same sediment trap as the area the trap was too large to remove the sediment by hand. The opportunity of cleaning the trap with machinery presented itself when maintenance and mitigation works resumed in Route 1856.

During August, 2014 a back-hoe excavator was used to remove the sediment accumulated in Sediment trap #2. This process required the replacement of the silt fence which formed the sides of the trap. Iron L-beam sections 1 m in length were also driven into the sediment trap and the length of each beam left unburied was recorded. Finally, the precise location of each boundary post and L-beam was recorded using a topographic total station. Figure 10 illustrates the sediment trap and the placement of L-beams within it.

Figure 10. Sediment trap #2 on October 1, 2014.

As a result of the late cleanup and set-up date of August 19, 2014, only two pairs of sediment depth were used. These correspond to the October 1 and October 22, 2014, visits. An initial measurement was carried out on August 19, 2014 however this was

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not used because minor issues with the silt trap placement had to be resolved on that date.

The surface elevation of the sediment at each of the traps boundary posts and L-beams was used to generate a surface model of the sediment found in the trap on both October visits. An example of these surfaces can be seen in Figure 11. The fill volume between each of the October surfaces and a reference surface set below the sediment elevation was calculated. The difference between both fill volumes corresponds to the volume of sediment deposited in the trap in the interval between measurements.

This volume was assumed to have been generated uniformly over the same 837 m^2 of tributary area used in the 2013 report, and the date interval was used to extrapolate an annual erosion rate for sheet erosion. The final value given at the end of this report is an average of the 2013 and 2014 estimates of annual erosion rates.

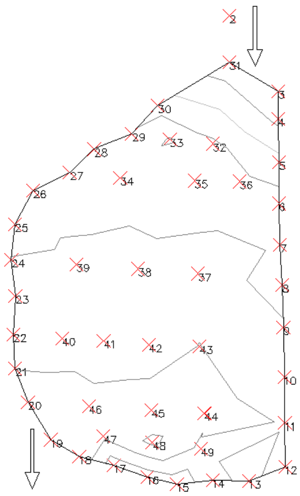

Figure 11. Survey points and elevation model of Sediment trap #2 on October 22, 2014.

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3 Results

This section contains the results obtained by CIEDES in Route 1856. Discussion is focused on the 2014 results, 2013 results are presented for comparative purposes.

3.1 Sheet erosion on cut slopes

The difference in sediment volume between the October measurements of Sediment trap #2 is of 2.59 m^3. This volume of soil is removed from the sediment trap's catchment area of 837 m^2 through sheet erosion processes. The extent of this tributary area remains unchanged from our 2013 report and is not discussed in detail here.

Table 2. Estimated volume of sediment stored by the sediment trap.

Date	Estimated volume stored by the sediment trap (m^3)
October 1, 2014	16.94
October 22, 2014	19.53

Assuming sheet erosion to occur evenly over the tributary area, a value of 3 mm of average erosion depth obtained by dividing the erosion volume over the area it was generated in. As an average erosion depth of 3 mm occurred over a 21 day time span, the annual erosion rate is 5.38 cm/yr.

Two other erosion rates of 6.15 cm/yr. and 9.47 cm/yr. were calculated for this same tributary area and sediment trap during 2013.Our final estimate for sheet erosion on cut slopes is the average of the 2013 and 2014 rates, this gives and erosion rate of 7.00 cm/yr.

3.2 Cut slope erosion

This section presents and briefly discusses the results obtained at Sites 1-4. The erosion features in these sites are located on cut slopes. Sites 1 and 2 contain two of the three large rotational landslides found in the study area.

It is no accident that large rotational landslides are present only on cut slopes. Fill slopes along Route 1856 are too weakly cohesive for this type of failure to develop on them. Site 3 is still one of the largest gullies found on cut slopes, and Site 4 is a steep cut slope with very intense rill erosion.

The erosion estimates generated using these sites are still considered to be conservatively high as these sites represent worst case erosion scenarios.

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Table 3. Results summary for cut slopes.

Date	Scanned area (m^2)	Feature area (m^2)	Total volume loss (m^3)	Total erosion rate (m/yr.)	Volume difference (m^3)
Site 1					
September 21, 2013	NA	80.00	80.05	0.40	NA
May 27, 2014	161.96	71.67	98.52	0.45	18.47
October 22, 2014	284.92	114.93	123.61	0.31	25.09
Site 2					
September 21, 2013	NA	150.00	443.75	1.18	NA
May 27, 2014	247.00	134.63	195.23	0.47	-248.52
October 22, 2014	148.70	134.63	186.54	0.40	-8.69
Site 3					
September 21, 2013	NA	16.00	9.08	0.23	NA
May 27, 2014	44.71	24.61	20.16	0.27	11.08
October 22, 2014	43.15	24.61	23.50	0.27	3.34
Site 4					
September 21, 2013	NA	0.30	0.09	0.15	NA
May 27, 2014	173.89	173.89	89.50	0.17	NA
October 22, 2014	285.90	173.89	96.65	0.16	7.15

3.2.1 Site 1

Site 1 has been subject to important changes over time. Figure 14 illustrates an increase in vegetation cover of the landslide and an increase in the landslide's area along its left margin. Vegetation prevents the direct impact of water on the slope and reduces erosion where it is found.

Overall an increase in the volume of eroded soil has been recorded for this site for the period between May and October, 2014.However when the addition in area is taken into account a net decrease in erosion depth occurs. 2013 estimates were found to be acceptable, when compared to the May 2014 volume calculation.

Sediment produced at this site is deposited in an impounded stream and thus its sediment contribution to the Río San Juan is considered negligible.

3.2.2 Site 2

Site 2 is another large rotational landslide on a cut slope which shows the two processes illustrated by Site 1, a lateral expansion of the landslide and an increased vegetation cover. Site 2 differs from Site 1 in that it has a much more deeply seated slip surface.

Figure 15 shows that the slope on the left margin of the landslide has failed along a deep slip surface. The failed material has suffered a vertical displacement into the old landslide area. This is registered in the volume calculations as a net decrease in the eroded volume as material from the left margin of the landslide has been deposited in the landslide's toe.

A comparison between the volume loss for 2013 and May 2014 shows the 2013 report overestimated sediment production at this point by a factor of 2.27. Sediment from this site also reaches an impounded stream; therefore it makes no direct contribution to sedimentation in the Río San Juan.

3.2.3 Site 3

Site 3 is a large gully partially covered with a geotextile along its left margin. Unlike Sites 1 and 2 this site shows no drastic change over time. Most erosion takes place at the head of the gully and its upper edges where the steepest slopes are found. This site has shown a near constant erosion rate according to the laser topography measurements.

2013 results for this site show the gully's area and volume were underestimated in comparison to May 2014.

3.2.4 Site 4

Erosion estimates in Site 4 were greatly changed during 2014 in comparison to 2013. The most significant difference is an increase in the area subject to evaluation and erosion estimation from 2013 to 2014. A single 1 m long section of a rill was measured in 2013, in comparison over 173 m^2 of rilled slope have been studied in 2014.

2014 laser topography shows near constant erosion rates for this site, with no large changes between May and October.

3.3 Fill slope erosion

Fill slopes along Route 1856 have higher erosion rates than cut slopes. This because cut slopes present more cohesion and compaction than fill slopes. Unlike cut-slopes two different methods have been used to evaluate fill sites, as mentioned above Sites 8-10 were subject to land LiDAR while sites 11-13 were subject to photogrammetric survey using an UAV.

Table 4. Results summary for Sites 8-10.

Date	Scanned area (m^2)	Feature area (m^2)	Total volume loss (m3)	Total erosion rate (m/yr.)	Volume difference (m^3)
Site 8					
September 21, 2013	NA	120.58	90.43	0.75	NA
May 27, 2014	86.16	86.16	99.38	1.00	8.95
October 22, 2014	86.00	86.16	101.44	0.76	2.06
Site 9					
September 21, 2013	NA	7.36	7.97	1.08	NA
May 27, 2014	40.37	18.41	7.41	0.35	-0.56
October 22, 2014	35.59	18.41	8.72	0.30	1.31
Site 10					
May 27, 2014	145.77	91.45	18.73	0.07	NA
October 22, 2014	228.17	91.45	23.78	0.07	5.05

3.3.1 Site 8

This gully shows the highest erosion rate of any site studied along Route 1856. A preliminary intervention carried out in early 2013 failed to properly mitigate this site. Since then a total of 101.44 m^3 of fill have been lost to erosion caused by the intermittent flow of a small stream over the road fill.

Recently mitigation works along this stretch of the road have reduced the flow of water over the gully. This has resulted in a dramatic decrease in erosion at this site, an average of 6 cm/yr. of erosion were calculated to have occurred in Site 8 between May and October 2014.

3.3.2 Site 9

Site 9 corresponds to a pair of gullies which have developed at the end of a fill prism near Río Infiernito. Only one of these gullies was subject to erosion estimation during 2013 however the volume estimate was found to be much greater than the measurement using LiDAR. Like most sites there haven't been dramatic changes in shape or size of either gully at this site.

According to the 2014 measurements the erosion rate in this gully is approximately half of that occurring in Site 8; however it is close to the average erosion rate found for Sites 11-13 (25 cm/yr.).

3.3.3 Site 10

Site 10 is a new site added for study during 2014. This site presents rill erosion occurring on a fill slope. Here average erosion rates are found to be constant in time and smaller than the erosion rate for rill erosion in cut slopes. The low erosion rate is attributed to the narrowness of the rills at this site, so even if individually they are very deep the ridges between each rill raise the average. Therefore a site which visually seems to be severely eroded may in reality produce limited amounts of sediment. This site highlights the perils of conducting erosion estimates based on images rather than in-situ measurements.

3.3.4 Sites 11-13

The use of stereo photogrammetry to survey and estimating erosion at three sites in Route 1856's most inaccessible section (between Río Infiernito and Boca San Carlos) was highly anticipated. The results obtained from these measurements show that while these sites may be visually impressive their erosion rates are not extraordinary and are comparable to the rates measured in sites included in the 2013 report. Sites 12 and 13 present streams flowing intermittently over the road fills.

Table 5. Results summary for Sites 11-13.

Site	Feature area (m^2)	Total volume loss (m^3)	Average depth (m)	Average erosion rate (m/yr.)
11	173.90	134.49	0.77	0.22
12	500.00	659.86	1.32	0.38
13	720.00	303.11	0.42	0.12

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3.4 Comments on studies presented by Nicaragua on July 2014

3.4.1 On the scope of the 2013 study:

The inclusion of three sites between Río Infiernito and Boca San Carlos, as well as the updated methods used in our measurements and estimations serve to counter the most important criticisms made to the 2013 report. Dr. Kondolf, in his July 2014 report states that "The most fundamental weakness of the UCR study is its failure to measure erosion downstream in the more severely eroding sites." this weakness has been thoroughly eliminated.

The addition of Sites 11-13 has proved that the original sites included in the 2013 report are worst case examples of the erosion processes occurring in Route 1856. Site 8 has an erosion rate of 76 cm/yr.; this is double the erosion rate in Site 12 (38 cm/yr.). The total erosion volumes are in fact larger in Sites 11-13 however their surface area is also much larger than the sites evaluated in 2013, leading to lower average rates.

3.4.2 On the methodology of the 2013 study:

The new results obtained with state of the art equipment and procedures demonstrate that the 2013 estimated erosion rates for each site were very good approximations to the reality of each site. Sites 2 and 9 show the greatest difference between 2013 and 2014 estimates however the difference was conservative, that is higher erosion rates were estimated during 2013 than the ones determined through accurate LiDAR surveying in 2014.

As mentioned in the introduction, the use of new methods during 2014 responds to the adoption of tools which were unavailable during 2013.

3.4.3 Rotational landslides

Confusion has surrounded statements contained in the 2013 report referring to gully erosion and landslide erosion. This is perhaps the result of the use of 'landslide' as a synonym to 'rotational landslide'. This simple error doesn't "undermine the scientific credibility of the report" (Kondolf, 2014), it simply highlights the fact that English is the third and second language of the authors.

For the sake of clarity we repeat the 2013 statement with different wording, no deep-seated rotational landslides have been observed to occur together with gullies on fill slopes along Route 1856. Mass failure does occur in the same site. As a gully erodes a fill, steep scarps are generated, especially at the gully's head. These scarps may then fail and collapse into the gully. This process is part of a gully's erosion mechanism.

Deep-seated rotational landslides are not observed in the fill slopes of Route 1856 because fills these lack the cohesion required for a massive block of soil to fail as a unit. The landslides mentioned by Dr. Kondolf in his report are shallow mass movements which are less much less massive, by virtue of their shallow nature, than rotational landslides.

3.4.4 Omitted erosion features at Site 4

In page 46 of his July 2014 report, Dr. Kondolf states that landslides are present in the slope adjacent to Site 4. He has indicated shallow mass movements in the oblique aerial photographs acquired on October 2012. These mass movements mobilize small amounts of soil, most of which has remained on the cut slope as evidenced by Figure 12, which covers a similar area to Figure 28 b) of Dr. Kondolf's report.

Dr. Kondolf has also mentioned that large erosion features were omitted from study in Site 4, a simple comparison between the rills present in Figure 12 and those present in Site 4, visible in Figure 17, show that this statement is also false. The rills studied as part of Site 4 are the deepest and largest in the entire slope of which Site 4 is part.

Figure 12. Cut slope adjacent to Site 4 on August 19, 2014.

Another false statement issued by Dr. Kondolf refers to the condition of the riverside edge of the road, of which he states:

> A broader look at this site shows the riverside edge of the road is uneven and contains multiple irregularities, and broad arcuate features, which can be interpreted as scarps of landslides in the loose, sidecast fill material. These failures are large enough that they have visibly eroded into the original constructed width of the road. (Kondolf, 2014).

Again Kondolf refers to features observed in an October 2012 image of the site. Figure 13 shows the riverside edge of the road as observed in August 2014, it clearly shows mitigation efforts and re-vegetation of this slope. There is no evidence of landslide scarps of erosion into the road. This case shows how Dr. Kondolf has used outdated images of Route 1856 to comment on the state of the road, leading on occasion to demonstrably false statements such as the ones he has made in relation to Site 4 and the adjacent slopes.

Figure 13. Landside edge of Route 1856, August 19, 2014.

3.4.5 Site 5

The shallow mass movements mentioned by Dr. Kondolf near Site 5 were not included in the selected sites because this was a slope immediately adjacent to the river which needed mitigation. CIEDES was informed that this was a priority site for intervention and therefore would not be available for continued study. Once again Dr. Kondolf has used outdated photographs which do not reflect the current reality of Route 1856.

3.4.6 Erosion estimates by Mr. Danny Hagans and Dr. Bill Weaver

In Annex 2, Volume 2 of Nicaragua's July 2014 Reply erosion estimates are presented for selected sites along Route 1856. The sites included in their report are Severely Eroding Sites (8.1), (9.4), and (9.5) which correspond to Sites 11, 12 and 13 in this report. The method used by Hagans & Weaver in their report is to measure the area of large gullies present at each site using December 2013 satellite images, and then to assume an average erosion depth which is multiplied by the feature's area to generate a volume. They have assumed average erosion depths of 3m for Site 11. This depth is the product of an assumption because they do not have any elevation data or topography for these sites.

The results obtained from the elevation model generated by UAV photogrammetry of these sites indicate that the true average erosion depth for Site 11 is 0.77m. A direct comparison between the assumed and measured depths was not carried out for Sites 12, 13 and (9.6); because they have been subject to intervention during 2014. Sites 12 and 13 were intervened by filling in portions of the eroded road, subsequent erosion has returned these sites to conditions similar to those observed in the Hagans & Weaver report. These interventions were limited to the top portion of each fill, and are insufficient to explain the discrepancy in erosion volume estimated by Hagans & Weaver.

Dr Kondolf's Site 9.6 was not surveyed using the UAV because by, the time of that survey, it was already in the process of being mitigated. Slopes are re-profiled or terraced during mitigation, and their surfaces may be protected using geofabrics and/or vegetation planting. Consequently, historical erosion cannot be measured and current rates are reduced following mitigation. For these reasons, mitigated sites would not provide erosion rates typical of un-remediated slopes. The decision to exclude mitigated sites makes the erosion rates determined by UCR more conservative, because the mitigation programme is progressively lowering erosion rates at slopes along the Road.

However it is evident that the average depth assumptions of Hagans & Weaver for Site 11 were mistaken by a very wide margin creating an impression of severity which is not supported by measurements of the site. The error in Hagans & Weaver's unsupported estimate for Site 11 undermines the credibility of their estimates at the remaining sites.

Table 6. Comparison of eroded sediment estimations.

Site number	Surface area (m^2)		Total volume eroded (m^3)		Volume difference (%)
	UCR	H & W	UCR	H & W	
11 (8.1)	174	110	135	330	+245
12 (9.4)	460	574	660	1722	Not calculated
13 (9.5)	720	715	303	2860	Not calculated

3.5 Recommended erosion rates for use in volumetric calculations.

Table 7, below, is a list of the annual erosion rates we recommend for use in the volumetric calculations. These rates correspond to those estimated using the latest available measurement at each Site. This is, October 22, 2014 for Sites 1-10; and October 28, 2014 for Sites 11-13.

In line with the procedure followed in the 2013 report, the highest erosion rate estimate is recommended for each type of erosion feature and slope, so that the rates listed represent the maximum or 'worst case' rates of erosion measured at the monitoring sites over a two year period.

Table 7. Maximum annual erosion rates recommended for volumetric calculations

Erosion feature	Fill slope erosion rate (m/yr.)	Cut slope erosion rate (m/yr.)
Rotational landslide	0.40*	0.40
Gully	0.76	0.27
Rill	0.16**	0.16
Sheet	0.14***	0.07

* As no rotational landslides were measured in fill slopes, the cut slope landslide erosion rate is recommended.

** The 2013 report conservatively used the same erosion rate for rills in cut slopes and fill slopes and this has been repeated in this report. The estimated erosion rate for rills in fill slopes is lower (0.07 m/yr.) therefore the higher erosion rate recorded in cut slopes (0.16 m/yr.) has been conservatively recommended for both sites.

*** Recommended sheet erosion rate is estimated by doubling rate measured for a cut slope to account for uncompacted condition of soil in fill prisms.

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4 Conclusions

The use of LiDAR has improved the accuracy of the erosion rate estimates presented in this report by providing an accurate representation of 7 erosion sites.

LiDAR topography of Sites 1-4 and 8-10 has shown that most erosion rate estimates carried out in 2013 were correct to within 5 cm/year relative to the October 2014 estimates. Erosion rates for Sites 2 and 9 were overestimated in 2013.

Average erosion rates have decreased or remained constant in all between May and October, 2014 estimates using LiDAR topography. Erosion rates are expected to continue decreasing as vegetation cover and mitigation works progress on the road.

Site 8 presents the highest erosion rate of all the evaluated sites, including those downstream of the 2013 study area.

The flow of small, intermittent streams over fill prisms generate some of the most intense erosion along Route 1856. This phenomenon occurs in Sites 8, 12 and 13, therefore they can be compared directly between each other.

UAV stereo photogrammetry of Sites 11, and 12 and 13 established that the average erosion rates of these gullies on fill slopes are half or less than the average erosion rate of Site 8.

A comparison of the total volume loss in Site 6 between the measurements of May and October, 2014 show a net loss of only 2 m^3, this corresponds to an average erosion rate of 6 cm/yr. The dramatic decrease in erosion at this site is due to the proper channelling of the intermittent stream which used to erode this site. Similar mitigation work elsewhere, that is the construction of proper stream crossings and vegetation of the slopes, is expected to generate similar decreases in erosion rates. Deep-seated rotational landslides have not been observed on any fill slope along Route 1856 from Marker II to Site 13.

The erosion estimates presented by Hagans & Weaver in their July 2014 report are based on conjecture and assumptions which have been disproved on the basis of a survey of the same sites they evaluated. Erosion loss volumes at these sites are less than half of those originally estimated by Hagans & Weaver.

The erosion rates presented in Section 3.5 are representative of the most severe erosion rates occurring along Route 1856. They may be conservatively applied to erosion features anywhere on the road by simply multiplying them by the projected surface area of each erosion feature.

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6 Annex – Photographic inventory of studied sites

Figure 14. Photographs of Site 1 on May 27, 2014 (top) and October 22, 2014 (bottom).

Figure 15. Photographs of Site 2 on May 27, 2014 (top) and October 22, 2014 (bottom).

Figure 16. Photographs of Site 3 on May 27, 2014 (top) and October 22, 2014 (bottom).

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Figure 17. Photographs of Site 4 on May 27, 2014 (top) and October 22, 2014 (bottom).

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Figure 18. Photographs of Site 8 on May 27, 2014 (top) and October 22, 2014 (bottom).

Figure 19. Photographs of Site 9 on May 27, 2014 (top) and October 22, 2014 (bottom).

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Figure 20. Photograph of Site 10 on May 27, 2014.

Figure 21. Photograph of Site 10 on October 22, 2014.

Figure 22. Photograph of Site 10 on October 22, 2014.

Figure 23. Orthophoto of Site 11 on October 28, 2014.

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Figure 24. Orthophoto of Site 13 on October 28, 2014.

6.1 Surface area estimate for slopes in Km 18.

The three-dimensional surface area of slopes T-68b, T-69b, T-70b, T-72b, and T-74b was measured on Global Mapper at the request of Dr. Andreas Mende. These surface area measurements take into account the inclination of the slopes to calculate the real surface area of the slope.

Table 8. Surface area of selected slopes in Route 1856.

Slope	T-68b	T-69b	T-70b	T-72b	T-74b
Surface area (m^2)	728	1292	1809	3951	2386

ANNEX 5

Instituto Costarricense de Electricidad (ICE), SBU Projects and Associated Services, Centre for Basic Engineering Studies, Department of Hydrology

Second Report on Hydrology and Sediments for the Costa Rican River Basins draining to the San Juan River

December 2014

INSTITUTO COSTARRICENSE DE ELECTRICIDAD (ICE)

ENGINEERING AND CONSTRUCTION
CENTER FOR BASIC ENGINEERING STUDIES
DEPARTMENT OF HYDROLOGY

SECOND REPORT ON HYDROLOGY AND SEDIMENTS FOR THE COSTA RICAN RIVER BASINS DRAINING TO THE SAN JUAN RIVER

DECEMBER 2014

SAN JOSÉ, COSTA RICA

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1. INTRODUCTION

This report has been prepared at the request of the Honorable Luis Guillermo Solis Rivera, President of the Republic of Costa Rica, and the Honorable Manuel Antonio González Sanz, Minister of Foreign Affairs of the Republic of Costa Rica. It provides information concerning the processes related to the sediment in the San Juan River.

Background

The Instituto Costarricense de Electricidad (ICE) is a national institute dedicated to the identification, design, development and operation of electricity and telecommunication projects. Since the founding of the Institute in 1949, the Electrical Division has specialized in conducting hydrological and sedimentological measurements and studies.

Several of the main basins draining to the San Juan River have been monitored by ICE because of their hydrological potential. Sediment, precipitation and discharge information can be found in these basins for periods of time that vary from decades to years.

Using available information and the technical expertise a *Report of Hydrology and Sediments for the Costa Rican River Basins Draining to the San Juan River* was written in 2013. Many of the issues covered in that report are re-analysed, redefined and explained herein.

Present report

This report is intended to describe the processes related to sediments in the San Juan River, with special emphasis on the sediment budget and its calculation. Compared to the previous one, it presents a different approach to the sediment transport phenomenon based both on a change from a classical deterministic paradigm to a more realistic stochastic one and on a better understanding of the sediment transport phenomenon itself due to application of different theoretical relations and new methodologies. As a consequence, results are expected to change compared to the previous report.

A description of general aspects of the study area is presented in the first chapter, followed by a brief description of the meteorological, hydrological, sedimentological and spatial information used in the study in the second chapter. It is essential to point out that most of the spatial information was improved in terms of density of information and hydrological and meteorological congruence. Also, the period of measurements was extended by more than a year in all the gauging stations active to date.

In the third chapter the suspended sediment production for all the sedimentogical stations is presented. The corresponding time and suspended sediment rating curve intervals of uncertainty were calculated. In the sixth chapter, this uncertainty analysis was used in the calibration process.

The bed load calculation process was improved by the use of the Engelund-Hansen approach. The results allowed calculation of the bed sediment production with its corresponding confidence intervals as presented in the fourth chapter.

To increase the density of information in the lower part of the hydrological system an assessment of the Boca San Carlos and Boca Sarapiquí sediment production was made using the probabilistically modeled flow duration curve mentioned in Krasovskaia & Gottschalk (2014) and the sediment duration curve approach proposed by Garcia (2014).

A soil erosion model was used to build a spatially distributed sediment model for the San Juan River Basin confined in the study area. The methodology used was based mainly on the CALSITE model (Bradbury, 1995). Some improvements were made such as the increase in the spatial resolution of the pixels, the analysis of the whole catchment area as one hydrological congruent unit, the uncertainty weighted calibration and the application of different delivery ratio functions.

It can be noted that the uncertainty analysis was also carried out for the USLE model. This implies that the sediment spatial distribution has its own uncertainty, thus, the unmeasured items of the budget have it too.

Once the distributed model was built, the sediment budget was made, using the main basins as unit areas. Results from investigations conducted by Oreamuno-Vega & Villalobos-Herrera (2014) and Mende (2014) were applied to determine the Route 1856 production added to the budget sediment of the Río San Juan River and therefore its contributions to Lower San Juan River and Colorado River.

One of the highlights of this study, as it can be seen throughout this report, is the natural variability in the sediment load of the San Juan River. It is not an overstatement to say that the sediment production caused by the Route 1856 is, probably, statistically inconsequential to the variability of the sediment behavior in the San Juan River.

2. STUDY AREA

The study area is located in the San Juan River Basin (Figure 2.1) and comprises, specifically, only the area draining directly to the San Juan River before the diversion at the Delta (region highlighted in pale red in Figure 2.1).

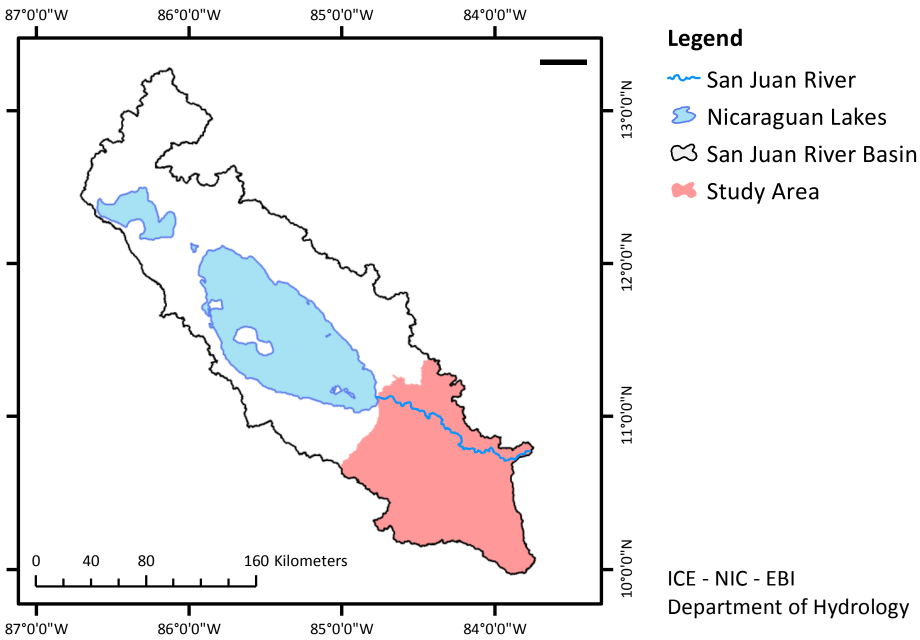


Figure 2.1 San Juan River basin system.

It is important to note that the San Juan River Basin is a hydrological system of more than 40 500 km^2; moreover, it possesses two *hydrological dampers* (the lakes) that decouple the behavior of the upper part of the basin from its lower part. This particular condition allowed us to model the study area as a separated system with a single sediment inlet at the lake.

The study area covers, approximately, 11 474 km^2 and it was segmented in 13 drainage units which are shown in Figure 2.2. Six of them are located in the Nicaraguan Southern slope, while the other seven are in the Costa Rican Northern slope. Finally, general information for each basin, as well of the whole study area, is presented in Table 2.1.

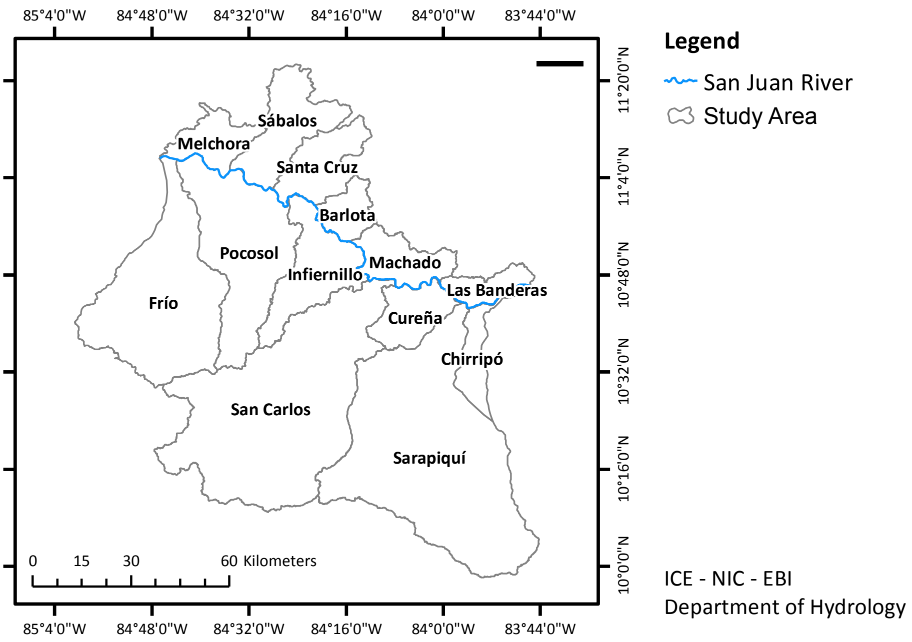


Figure 2.2 Study area.

Table 2.1 Major basins draining directly to the San Juan River

Basin	Country	DA (km^2)	P (km)	E (msnm)	Pa ($mm\ yr^{-1}$)
Las Banderas	Nicaragua	198	79.0	52	3953
Machado	Nicaragua	352	110.2	92	3344
Barlota	Nicaragua	219	74.7	142	3050
Santa Cruz	Nicaragua	418	118.8	129	3014
Sábalos	Nicaragua	571	148.0	125	2615
Melchora	Nicaragua	305	108.2	80	1942
San Carlos	Costa Rica	2642	313.5	474	3777
Cureña	Costa Rica	353	93.3	52	3634
Sarapiquí	Costa Rica	2770	280.4	701	4660
Chirripó	Costa Rica	236	118.1	39	3828
Frío	Costa Rica	1577	215.9	189	2758
Pocosol	Costa Rica	1224	212.3	68	2788
Infiernillo	Costa Rica	609	165.8	88	3556
Study area		11474	705.5	338	3560

Note: DA = drainage area; P = perimeter; E = average elevation; Pa = mean annual precipitation.

3. BASE INFORMATION

This chapter describes the meteorological, hydrological and sedimentological information used as input for the construction and calibration of the erosion model.

3.1. Meteorological data

A list of the 52 ICE meteorological gauging stations analyzed in this report is shown in Table 3.1. Over 63810 storms were analyzed along the period 1995-2014 with the aim of estimating USLE's erosivity R factor according to the EI30 index methodology (Wischmeier & Smith, 1960). Finally, mean annual precipitation totals and R factor values were used to derive an empirical relation of the erosivity factor as a function of the mean annual precipitation.

Table 3.1 Properties of the meteorological gauging stations located in the San Juan River tributary basins

COD	Station name	NSAR	Coordinates CRTM-05			RP	
		USLE	X (m)	Y (m)	Z (masl)	BRC	ERC
69505	Vara Blanca	1295	482664	1125351	1773	1996	2014
69507	Colonia Los Angeles	1558	476730	1137081	1026	1999	2014
69520	Aguacate	938	396767	1167718	652	2000	2014
69522	Pueblo Nuevo	1067	414140	1154413	572	2000	2014
69524	Caño Negro	1727	415438	1149218	785	1995	2014
69530	La Marina	684	458754	1147733	434	2006	2014
69532	Laguna Cote	1295	399677	1169607	679	1999	2014
69544	Guayabos	1083	410359	1155732	613	1999	2014
69547	Pajuila	1370	415692	1160962	783	1999	2014
69548	Jilguero	1909	421499	1154373	600	1996	2014
69549	Dos Bocas	1199	399737	1167140	583	1999	2014
69550	La Union	1007	406603	1162405	557	2000	2014
69551	Guatuso	952	409692	1179373	72	2000	2014
69561	El Sabalo	1420	390511	1171644	935	1995	2014
69563	San Gerardo	1571	411748	1143736	1530	1995	2014
69570	Pastor	1283	417358	1152088	689	1999	2014
69571	Sitio Presa Sangregado	1510	416734	1158476	547	1995	2014
69574	Canalete	533	386324	1198090	98	2006	2014
69576	Bijagua	1164	384826	1186690	451	1999	2014
69578	El Bum	993	500265	1179119	59	2000	2014
69583	Alto Baca Lucía	1243	408793	1164851	778	1999	2014
69587	Pocosol	1439	426992	1144530	750	1999	2014
69588	Isla Bonita	1317	481741	1131555	1165	1999	2014
69596	Chachagua	1190	433813	1151398	319	2000	2014
69598	Santa Lucia	1165	410061	1172486	351	1999	2014
69600	Cerro Zurqui	1768	499839	1113344	1516	1999	2014

continued

Table 3.1 Properties of the meteorological gauging stations located in the San Juan River tributary basins *(continued)*

COD	Station name	NSAR USLE	Coordinates CRTM-05			RP	
			X (m)	Y (m)	Z (masl)	BRC	ERC
69602	Carrillo	1137	505479	1124178	570	1999	2008
69604	La Montura	1597	502920	1118140	1146	1999	2011
69608	Proyecto Venado	1162	418871	1167585	262	1999	2014
69610	Peñas Blancas	996	442741	1156930	80	1999	2014
69612	Alto Palomo	1172	466137	1125544	1986	1997	2014
69614	Bajos del Toro	1056	467318	1129356	1449	1999	2014
69616	Picada de Palmira	1211	462774	1127816	2072	1998	2014
69618	Rio Segundo	1147	466594	1131745	1435	1997	2014
69620	Quebrada Gata	1376	471100	1134912	1094	2000	2014
69622	Quebrada Pilas	1585	471526	1131014	1596	1996	2014
69624	Rio Desague	1411	471463	1128533	1826	1997	2014
69626	Quebrada Gonzalez	798	506817	1123628	520	2008	2014
69628	Toma De Agua Arenal	640	401496	1164871	532	1999	2014
69632	Nuevo Arenal	871	402192	1166190	624	1999	2014
69634	La Picada de Turrialba	829	523738	1108575	2633	1999	2013
69636	Finca Gavilanes	799	519316	1107279	2111	1999	2014
69638	Chindama	1589	520317	1118862	729	1999	2014
69642	Volcancito	1494	485405	1132750	1372	2000	2014
69646	Audubon	1241	421535	1139979	821	2000	2014
69648	Aleman	1125	418150	1139009	952	2000	2014
69650	Gorrion	1399	467617	1127911	1769	1995	2014
69652	Alto Rio Segundo	1733	464564	1132961	1615	1995	2014
69654	Fila Toro	1404	422861	1135038	1634	2000	2014
69656	S.P. Peñas Blancas	1224	433779	1145779	473	2000	2014
69658	Cota 1600	1342	486235	1130838	1574	2000	2012
69662	Toma Peñas Blancas	797	433825	1146444	333	2001	2014

Note: COD = station code; NSAR USLE = number of storms analyzed for USLE's R factor estimations; X = East coordinate; Y = North coordinate; Z = elevation; RP = recording period; BRC = beginning of the recording period; ERC = end of the recording period.

3.2. Hydrological data

The location of ICE's hydrological gauging stations, as well as basin definitions and main drainage network, is shown in Figure 3.1. For each of these stations relevant information such as coordinates, the time period during which the measurements were carried out (at daily and hourly scale), the tributary drainage area and the mean discharge recorded in the river over the corresponding period, among others, is presented in Table 3.2 and Table 3.3.

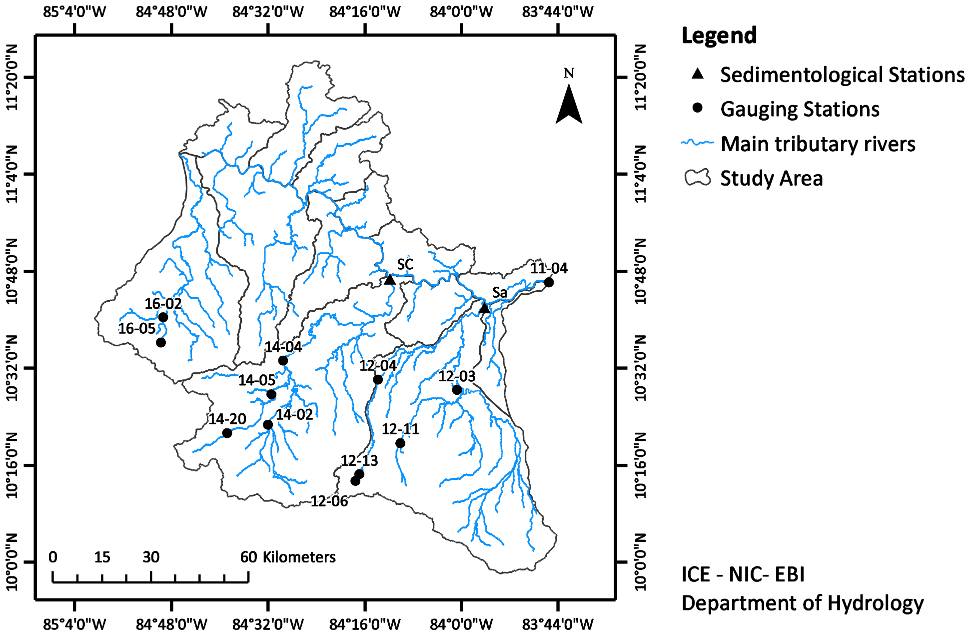


Figure 3.1 Hydrological gauging stations located in Costa Rican basins draining to the San Juan River

Table 3.2. Properties of the hydrological gauging stations located in the San Juan River tributary basins

COD	Station name	Coordinates CRTM-05		Sampling record period					
				Daily scale			Hourly scale		
		X	Y	BRC	ERC	EF	BRC	ERC	EF
11-04	Delta Colorado	526434	1190821	2010	2014	3.6	2010	2014	3.6
12-03	Puerto Viejo	498692	1158025	1968	1999	30.5	1995	1998	3.0
12-04	Veracruz	474785	1161207	1971	2014	42.1	1995	2014	17.6
12-06	Toro	467991	1130400	1993	2014	20.6	1993	2014	18.7
12-11	San Miguel	481560	1141878	1998	2014	9.7	1998	2014	9.4
12-13	Río Segundo	469116	1132339	1999	2014	15.4	1999	2014	14.6
14-02	Jabillos	441528	1147419	1963	2014	51.2	1994	2014	18.4
14-04	Terron Colorado[a]	446162	1166915	1980	2008	28.7	1995	2008	11.8
14-05	Peñas Blancas[b]	442605	1156821	1968	2014	45.9	1995	2014	18.9
14-20	Pocosol	429133	1145006	1980	2014	34.0	1992	2014	20.8
16-02	Guatuso	409975	1180225	1968	2014	45.9	1995	2014	18.3
16-05	Santa Lucía	409268	1172575	1982	2014	31.8	1994	2014	18.5

Note: COD = station code; X = East coordinate; Y = North coordinate; BRC = beginning of the recording period; ERC = end of the recording period; EF = number of effective years.

[a]Since 1980 Terron Colorado hydrological station is regulated by the construction of Arenal Reservoir Dam. [b]Since 2002 Peñas Blancas hydrological station is regulated by the Peñas Blancas hydropower plant.

Table 3.3. Properties of the hydrological gauging stations located in the San Juan River tributary basins

COD	Station name	River name	Basin	DA (km^2)	Qa ($m s^{-1}$)	
					Daily	Hourly
11-04	Delta Colorado	Colorado	San Juan	11479[a]	1002.7	1002.5
12-03	Puerto Viejo	Sarapiquí	Sarapiquí	841	113.4	114.0
12-04	Veracruz	Toro	Sarapiquí	195	26.2	29.2
12-06	Toro	Toro	Sarapiquí	41	4.3	4.3
12-11	San Miguel	Volcán	Sarapiquí	59	11.1	11.2
12-13	Río Segundo	Segundo	Sarapiquí	17	2.6	2.6
14-02	Jabillos	San Carlos	San Carlos	538	51.1	51.9
14-04	Terrón Colorado	San Carlos	San Carlos	1552	153.4	169.5
14-05	Peñas Blancas	Peñas Blancas	San Carlos	297	35.0	35.5
14-20	Pocosol	Peñas Blancas	San Carlos	124	17.9	17.5
16-02	Guatuso	Frío	Frío	241	28.0	30.2
16-05	Santa Lucía	Venado	Frío	34	3.9	4.1

Note: COD = station code; DA = drainage area; Qa = mean annual discharge.
[a]The value reported corresponds to study area only; catchment area, including Lake Nicaragua and basins draining directly into it, is, approximately, 40541 km^2.

Streamflow measurements have been performed by ICE since the 1950s for hydropower purposes. Classical measurement devices –such a mechanical current meters– as well as more modern ones –such as Acoustic Doppler current profilers– have been used along the study area in order to generate discharge and suspended sediment rating curves for each of the hydrological gauging stations presented in Table 3.2 and Table 3.3, and for the mouth of the Sarapiquí and San Carlos Rivers.

The number of discharge samples taken, as well as the measuring devices and the sampling period are shown in Table 3.4.

Table 3.4 Measurements of streamflow discharge in the hydrological and sedimentological gauging stations in the San Juan River tributary basins.

COD	Station name	Number of samples	Measuring device	SP	
				BRC	ERC
11-04	Delta Colorado	78	Acoustic Doppler current profiler	2010	2014
12-03	Puerto Viejo	514	Mechanical current meter	1968	1999
12-04	Veracruz	597	Mechanical current meter	1971	2014
12-06	Toro	438	Mechanical current meter	1993	2014
12-11	San Miguel	115	Mechanical current meter	1998	2014
12-13	Río Segundo	206	Mechanical current meter	1999	2014
14-02	Jabillos	789	Mechanical current meter	1958	2014
14-04	Terrón Colorado	396	Mechanical current meter	1968	2014
14-05	Peñas Blancas	771	Mechanical current meter	1968	2014
14-20	Pocosol	693	Mechanical current meter	1978	2014

continued

Table 3.1 Properties of the meteorological gauging stations located in the San Juan River tributary basins *(continued)*

COD	Station name	Number of samples	Measuring device	SP	
				BRC	ERC
16-02	Guatuso	1021	Mechanical current meter	1968	2014
16-05	Santa Lucía	459	Mechanical current meter	1976	2014
BSa	Boca Sarapiquí	27	Acoustic Doppler current profiler	2011	2014
BSC	Boca San Carlos	27	Acoustic Doppler current profiler	2011	2014

Note: COD = station code; NSS = number of subsamples; SP = sample recording period; BRC = beginning of the registration period; ERC = end of the recording period.

3.3. Sedimentological data

Similarly to streamflow measurements, suspended sediment sampling has been carried out by ICE in the Costa Rican Northern Slope since the 1960s. Sediment samples were collected in field by the URM Unit and then processed by the ULQ Unit where suspended sediment concentration, grain size distribution and characteristic diameters were figured.

For this particular report, over 2350 suspended sediment samples from ICE's sedimentological database were analyzed with the purpose of defining suspended sediment rating curves for the fourteen river points outlined in Table 3.4. Relevant information such as the number of individual samples collected per river point and the sampling period is presented in Table 3.5.

Table 3.5 Properties of suspended sediment gauging stations located in the San Juan River tributary basins.

COD	Station name	NSS	NS	NSDD	SRP	
					BRC	ERC
11-04	Delta Colorado	255	41	40	2010	2014
12-03	Puerto Viejo	792	264	264	1970	1998
12-04	Veracruz	855	285	285	1972	2012
12-06	Toro	369	123	123	1995	2013
12-11	San Miguel	168	56	56	1998	2010
12-13	Río Segundo	78	26	26	1999	2009
14-02	Jabillos	1029	343	343	1967	2013
14-04	Terrón Colorado	162	54	54	1998	2009
14-05	Peñas Blancas	936	312	312	1970	2011
14-20	Pocosol	834	278	278	1980	2012
16-02	Guatuso	1113	371	371	1970	2013
16-05	Santa Lucía	465	155	155	1984	2011
BSa	Boca Sarapiquí	92	28	23	2011	2014
BSC	Boca San Carlos	89	27	23	2011	2014

Note: COD = station code; NSS = number of subsamples or individual samples; NS = number of samples; NSDD = number of samples with discharge data; SRP = sample recording period; BRC = beginning of the registration period; ERC = end of the recording period.

Bed load samples have been collected at monthly basis in the Colorado River (at Delta Colorado hydrological gauging station) and in the mouth of the Sarapiquí and San Carlos Rivers since 2010. The number of bed load samples analyzed as well as the corresponding sampling period is shown in Table 3.6.

Table 3.6 Properties of grain size distribution curve gauging stations located in the San Juan River tributary basins.

COD	Station name	NSS	NS	NSDD	SRP	
					BRC	ERC
11-04	Delta Colorado	156	32	28	2010	2014
BSa	Boca Sarapiquí	75	25	21	2011	2014
BSC	Boca San Carlos	72	24	20	2011	2014

Note: COD = station code; NSS = number of subsamples or individual samples; NS = number of samples; NSDD = number of samples with discharge data; SRP = sample recording period; BRC = beginning of the registration period; ERC = end of the recording period.

Suspended sediment concentrations, bed load grain size distributions and discharge time series records were used to estimate sediment transport at hydrological gauging stations shown in Table 3.5. Sediment transport rates for all hydrological gauging stations, except Boca Sarapiquí and Boca San Carlos, were calculated based on a Riemann Sums approach (time series approach, hereafter); sediment transport rates at Boca Sarapiquí and Boca San Carlos were estimated based on statistical modelling of dimensionless flow duration curves (duration curve approach, henceforth) following Foster (1933).

3.4. Spatial information

A 30 m hydrologically correct digital elevation model (DEM) was generated for the study area (see Figure 3.2) using Topo to Raster interpolation algorithm from the ArcGIS® geographic information system (GIS). Digitalized contour lines based on the Instituto Geográfico Nacional de Costa Rica (IGNCR, 1988) official 1:50000 cartography were used as input for the Costa Rican Northern Slope while point data extracted from ASTER GDEM (METI-NASA, 2014) was used as base information for the Nicaragua Southern Slope. Drainage enforcement process was applied using stream line data digitalized from the 1:50000 U.S. National Imagery and Mapping Agency cartography (1970).

Land cover map of the study area is presented in Figure 3.3. The map was constructed based on RapidEye satellite imagery from 2009-2010 period and automatic classification procedures where used for the Costa Rican Northern Slope while vectorization based on visual interpretation was used for the Nicaraguan Southern Slope.

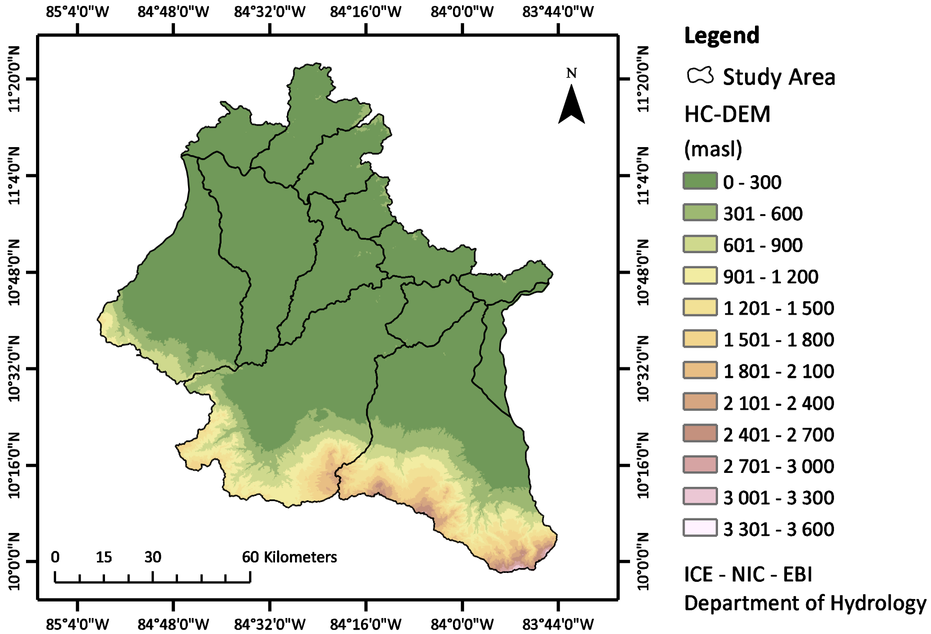


Figure 3.2 Hydrologically correct digital elevation model of the study area.
Note: Based on IGNCR (1988), METI-NASA (2014) & U.S. NIMA (1970).

The soil type map of the study area, according to the USDA classes and subclasses soil taxonomy classification, is presented in Figure 3.4. Soil information was based on the 1:200000 soil orders and suborders map of Costa Rica published by ACCS (2013) and digitalized information from INETER (2008, p. 58).

Finally, a continuous mean annual precipitation field (Figure 3.5) for the entire study area was provided by the National Institute of Meteorology (IMN, hereafter). The map was constructed based on IMN's rainfall stations and INETER (2004) official mean annual precipitation map over the period 1971-2000.

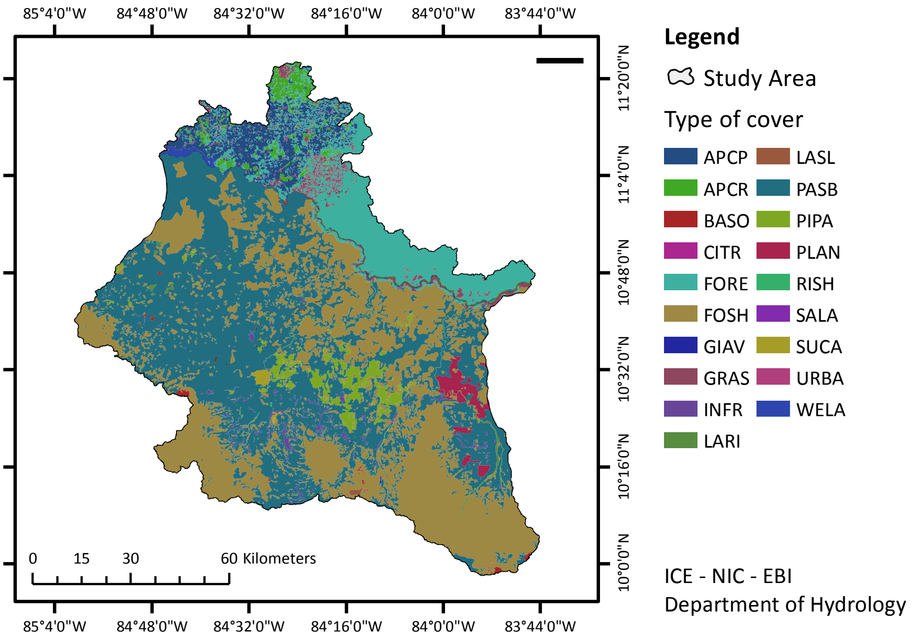


Figure 3.3 Land cover map of the study area

Note: Based on RapidEye satellite imagery from 2009-2010 period. APCP = annual and Permanent crops mixed with pastures; APCR = annual and Permanent crops; BASO = bare soil; CITR = citric plantation; FORE = forest; FOSH = forest, tree plantation, shrubs; GRAS = grass; GUAV = guava plantation; INFR = infrastructure; LARI = lake, river; LASL = landslide; PASB = paddock with some bushes or trees; PIPA = pineapple plantation; PLAN = plantain plantation; RISH = river shore; SALA = set-aside land; SUCA = sugar cane plantation; URBA = urban area; WELA = wetland.

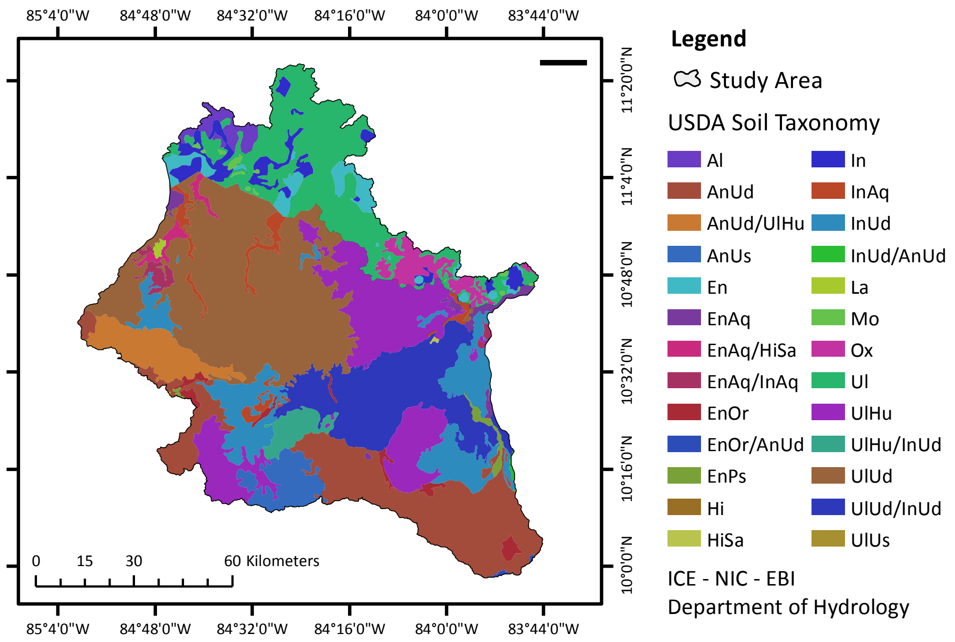


Figure 3.4 USDA soil taxonomy map of the study area.

Note: Based on "*Subórdenes de suelo de Costa Rica* [GIS file]", by Asociación Costarricense de la Ciencia del Suelo [ACCS], 2013, and "*Estudio del suelo del departamento de Río San Juan*", by Instituto Nicaragüense de Estudios Territoriales [INETER], 2008. Al = Alfisols; AnUd = Andisols Udands; AnUd/UlHu = Andisols Udands or Ultisols Humults; AnUs = Andisols Ustands; En = Entisols; EnAq = Entisols Aquents; EnAq/HiSa = Entisoles Aquents or Histosols Saprists; EnAq/IcAq = Entisoles Aquents or Iceptisols Aquepts; EnOr = Entisols Orthents; EnOr/AnUd = Entisoles Orthents or Andisols Udands; EnPs = Entisols Psamments; Hi = Histosols; HiSa = Histosols Saprists; In = Inceptisols; InAq = Inceptisols Aquepts; InUd = Inceptisols Udepts; InUd/AnUd = Inceptisols Udepts or Andisols Udands; Mo = Mollisols; Ox = Oxisols; Ul = Ultisols; UlHu = Ultisols Humults; UlHu/InUd = Ultisols Humults Inceptisols Udepts; UlUd = Ultisols Udults; UlUd/InUd = Ultisols Udults or Inceptisols Udepts; UlUs = Ultisols Ustults.

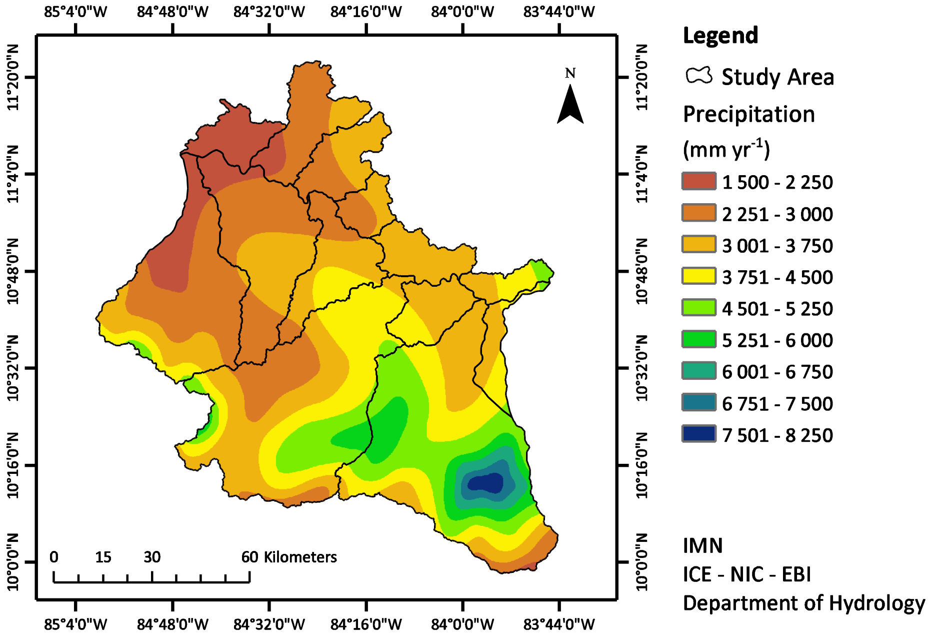


Figure 3.5 Mean annual precipitation field for the entire study area.
Note: based on IMN's rainfall stations and "*Precipitación media anual en milímetros (mm) Periodo 1971-2000*", by Instituto Nicaragüense de Estudios Territoriales [INETER], 2004.

4. SUSPENDED SEDIMENT LOAD

This chapter describes the methodology used in order to estimate the suspended sediment load of the twelve hydrological gauging stations shown in Table 3.2. Suspended sediment load rating curves were estimated based on suspended sediment concentration samples and mean annual suspended sediment production values were calculated based on Riemman Sums. Finally, confidence intervals for the mean annual suspended sediment production are calculated based on time and sample variability.

Discharge (Table 3.4) and suspended sediment (Table 3.5) samples were analyzed in order to generate suspended sediment rating curves (SSRC, henceforth) for the fourteen river points mentioned in the previous chapter. Suspended sediment concentrations were transformed to suspended sediment load (SSL) using ec. 1

$$Q_s = \frac{Q}{(10^6 C_s^{-1} - 1)} \qquad \text{ec. 1}$$

where Q_s is the suspended sediment load in t s^{-1}, Q is the instantaneous discharge in m^3 s^{-1} and C_s is the suspended sediment concentration in mg l^{-1}. Concentrations were estimated both as simple and discharge weighted averages based on the velocity profiles generated by the acoustic Doppler current profiler. As no significant differences were noted between both methodologies the choosing criterion was based on sample size and ordinary mean value was selected as averaging procedure for concentration samples. A comparison between both methodologies is shown in Figure 4.1.

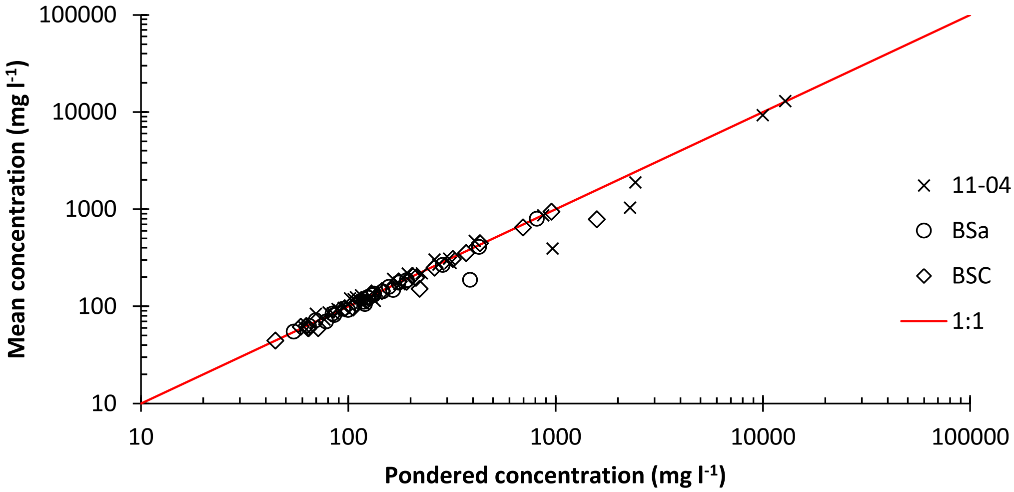


Figure 4.1 Simple averaged concentrations and discharge weighted averaged concentrations comparison for the Colorado (11-04), Sarapiquí (BSa) and San Carlos Rivers (BSC).

It is important to consider that, even though the SSRC represents a relation between discharge and sediment load, this correlation does not necessarily implied causation. They are two different phenomena that, in some cases, are triggered by the same variable (i.e., precipitation events) and, in some others, are completely uncorrelated (e.g. high concentrations registered due to massive erosion processes such as gully and landslides).

With that idea in mind it was decided to use all the points in the discharge-concentration data sets to generate the SSRC corresponding to each hydrological station. A power function was selected because this kind of relation between these two particular variables is widely accepted for hydrological purposes. Also, a power function of the form $y = a\,x^b$ goes through the origin for all values of *a* and *b* –an imperative condition to the physical process being modeled.

So, a power function was fitted for each hydrological station using the least squares approach. Confidence and prediction intervals at 95% were estimated at each case with the aim of quantifying uncertainty. As an example, the SSRC for Delta Colorado gauging station is shown in Figure 4.2. The SSRC corresponding to the other thirteen river points reported in Table 3.5 can be found in the Appendix to this Report.

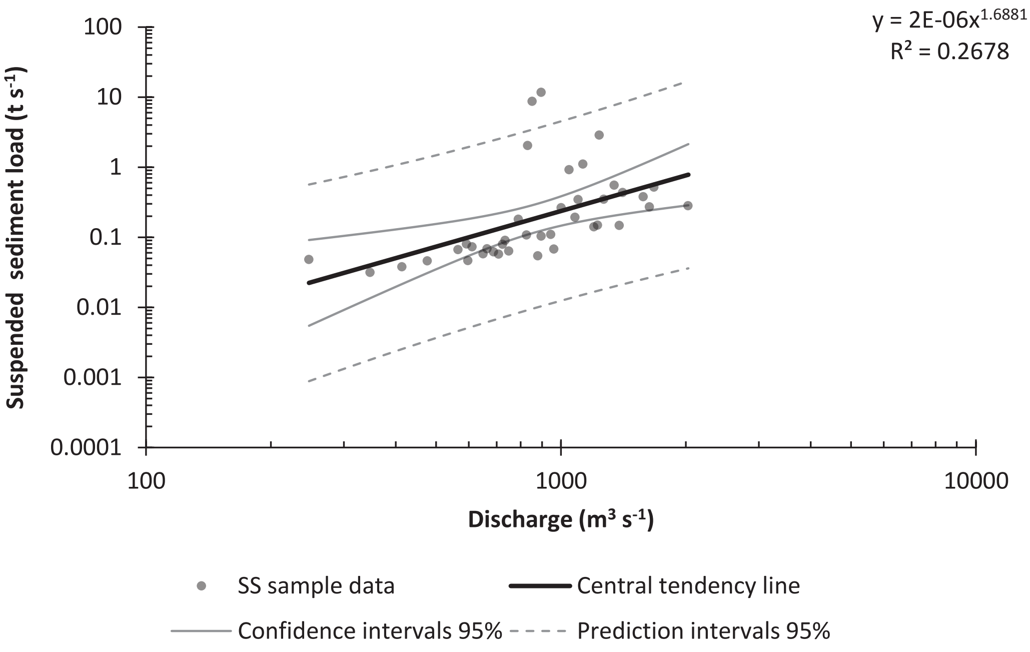


Figure 4.2 Suspended sediment load rating curve in Delta Colorado (11-04) gauging station.

SSRC were used, along with the discharge records, to generate daily and hourly SSL time series at each of the river points. Mean annual sediment production was then estimated as the integral of the SSL time series divided by the effective length of each record period. As the daily and hourly time series are discrete instead of continues variables, a Riemman Sums approach was implemented in order to approximate the integral of the SSL time series as a sum of rectangles of constant width and variable height.

Moreover, following Jansson (1992), correction factors between daily and hourly estimates were calculated for each river point. According to Jansson, estimates based on hourly data yield higher sediment production values than those based on daily records. These differences are due to the increase in the coefficient of variation (CV) of the time series and the power nature of the SSRC function.

Sediment production values were estimated for hourly and daily time scales along the same time period for all the hydrological station showed in Table 4.1. Correction factors were calculated as the ratio between the respective hourly and daily production values. Finally, the production values based on daily records along its whole record period was multiplied by the correction factor mentioned before.

Table 4.1 Suspended sediment production observed in the gauging stations

COD	Station name	Suspended sediment load (t yr^{-1})				
		Mean	**TLCI**	**TUCI**	**SSRC LCI**	**SSRC UCI**
11-04	Delta Colorado	7 599 000	2 611 000	12 586 000	4 023 000	15 148 000
12-03	Puerto Viejo	161 000	141 000	182 000	140 000	186 000
12-04	Veracruz	86 000	37 000	135 000	62 000	123 000
12-06	Toro	12 000	7 000	17 000	8 000	18 000
12-11	San Miguel	22 000	12 000	33 000	13 000	40 000
12-13	Río Segundo	2 000	1 000	3 000	1 000	6 000
14-02	Jabillos	215 000	155 000	274 000	170 000	274 000
14-04	Terrón Colorado	1 175 000	988 000	1 362 000	783 000	1 806 000
14-05	Peñas Blancas	141 000	115 000	167 000	116 000	172 000
14-20	Pocosol	130 000	85 000	175 000	98 000	174 000
16-02	Guatuso	55 000	49 000	61 000	48 000	62 000
16-05	Santa Lucía	3 000	3 000	4 000	3 000	4 000

Note: COD = station code; TLCI = lower 95% confidence interval due to time series variability; TUCI = upper 95% confidence interval due to time series variability; SSRC LCI= lower 95% confidence interval due to uncertainty in the suspended sediment rating curve; SSRC UCI= upper 95% confidence interval due to uncertainty in the suspended sediment rating curve.

The mean annual suspended sediment production values estimated using this methodology are presented in Table 4.1, as well as 95% confidence intervals due to time series variability and uncertainty in the SSRC; additionally, confidence intervals as normalized anomalies are included in Table 4.2. Lastly, information of Table 4.1 is included in Table 4.3 and Figure 4.3 as specific sediment yield –i.e. normalized by drainage area.

Table 4.2. Confidence intervals as normalized anomalies for the suspended sediment production observed in the gauging stations

COD	Station name	UTSV (normalized anomalies)		USSV (normalized anomalies)	
		LCII	UCI	LCII	UCI
11-04	Delta Colorado	-66%	+66%	-47%	+99%
12-03	Puerto Viejo	-13%	+13%	-13%	+15%
12-04	Veracruz	-58%	+58%	-28%	+43%
12-06	Toro	-40%	+40%	-32%	+47%
12-11	San Miguel	-48%	+48%	-43%	+79%
12-13	Río Segundo	-28%	+28%	-61%	+192%
14-02	Jabillos	-28%	+28%	-21%	+28%
14-04	Terrón Colorado	-16%	+16%	-33%	+54%
14-05	Peñas Blancas	-18%	+18%	-18%	+22%
14-20	Pocosol	-34%	+34%	-25%	+34%
16-02	Guatuso	-11%	+11%	-12%	+14%
16-05	Santa Lucía	-12%	+12%	-21%	+27%

Note: COD = station code; UTSV = uncertainty due to time series variability; USSV = uncertainty due to sample variability in the suspended sediment rating curve; LCI = lower 95% confidence interval; UCI = upper 95% confidence interval.

Table 4.3. Specific sediment yield observed in the gauging stations

COD	Station name	Specific sediment yield (t yr^{-1} km^{-2})				
		Mean	TLCI	TUCI	SSRC LCI	SSRC UCI
11-04	Delta Colorado	662	227	1 096	350	1 319
12-03	Puerto Viejo	191	167	215	166	220
12-04	Veracruz	450	191	709	324	643
12-06	Toro	291	174	408	199	429
12-11	San Miguel	380	197	562	218	679
12-13	Río Segundo	116	84	148	45	338
14-02	Jabillos	389	281	496	307	497
14-04	Terrón Colorado	755	635	875	503	1 160
14-05	Peñas Blancas	481	393	569	396	588
14-20	Pocosol	1 051	689	1 413	793	1 405
16-02	Guatuso	216	192	239	189	247
16-05	Santa Lucía	96	84	107	75	122

Note: COD = station code; TLCI = lower 95% confidence interval due to time series variability; TUCI = upper 95% confidence interval due to time series variability; SSRC LCI= lower 95% confidence interval due to uncertainty in the suspended sediment rating curve; SSRC UCI= upper 95% confidence interval due to uncertainty in the suspended sediment rating curve.

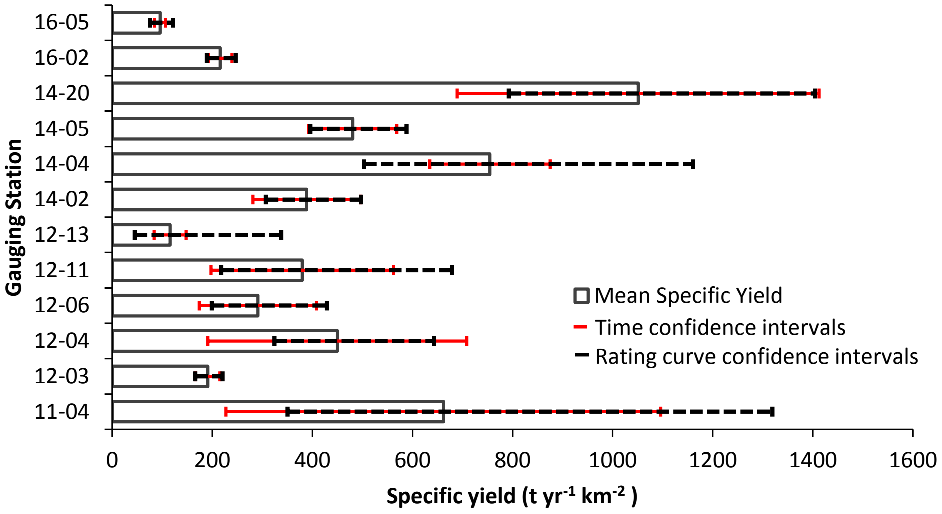


Figure 4.3 Specific sediment yield observed in the gauging stations.

5. BED LOAD TRANSPORT AT THE COLORADO RIVER

This chapter describes the methodology used for estimating the bed sediment load of the Delta Colorado gauging station. The procedure used to generate a bed sediment load rating curve based on Engelun-Hansen formula is outlined and confidence intervals for the mean annual bed sediment production are calculated based on time and sample variability.

Grain size particle distributions from the bed load material were analyzed in order to estimate the characteristic particle diameters D_{50} and D_{84} and cross section hydraulic parameters were derived from the acoustic Doppler current profiler streamflow measurements. Hydraulic and sedimentological data from Delta Colorado gauging station, as well as from the mouth of the Sarapiquí and San Carlos Rivers, was used as input into Engelund-Hansen transport formula according to the procedure outlined in Garcia (2007).

Bed slope was estimated from the Engelun-Hansen hydraulic resistance relation (García, 2007, p. 125) for the Colorado, Sarapiquí and San Carlos Rivers at the control points defined by Delta Colorado, Boca Sarapiquí and Boca San Carlos gauging stations. It was noted that the slope was implicitly defined in the formula mentioned above so it could be solved as a fixed-point iteration problem. Steffensen's method for accelerated convergence was used and a solution was found in 58 of 69 cases. As the Engelun-Hansen hydraulic resistance formula does not fulfill the fixed theorem conditions (the first derivative must exist and be bounded for all numbers in the defined interval) convergences cannot be ensure for all cases and divergences is expected for some of the samples.

In the particular case of the Colorado River, the median value of the slope at Delta Colorado gauging station, based on 26 out of 28 bed load samples (two of them did not yield a solutions for the reasons mentioned before), was estimated at 1.79 x 10^{-4} m/m. This value is in the same order of magnitude as the slopes reported by Andrews (2014) and reproduced in Table 5.1 for the Boca Sarapiquí-Delta and Delta-Caribbean Sea reaches. This correspondence between theoretical (derived from Engelun-Hansen hydraulic resistance relation) and field measured slopes –even when these belong to different river reaches– seems to indicate that the Engelund-Hansen formula is a good reference for modeling bed load transport at the lower part of the San Juan River Basin.

Table 5.1 Slope reported in Andrews (2014) and the calculated slope using the Engelund-Hansen method as presented in García (2007)

River reach	Slope value (m m^{-1})
Boca Sarapiquí - Delta	1.70E-04[a]
Delta –Caribbean Sea	1.50E-04[a]
Colorado River measuring cross section	1.79E-04[b]

[a]Based on "*An evaluation of the methods, calculations and conclusions provided by Costa Rica regarding the yield and transport of sediment in the Río San Juan Basin*", by E.D Andrews, 2014. [b]Estimated according to the Engelun-Hansen method as presented in "*Sediment transport and morphodynamics*", by M.H. García, 2007.

Engelund-Hansen transport formula was used to generate a bed load rating curve (BLRC) for the Delta Colorado gauging station (see Figure 5.1). Confidence and prediction intervals were estimated in order to quantify uncertainty due to dispersion in the sampled data. The function was derived using the computational procedure for normal flow outlined in Garcia (2007, p. 125) along with the hydrological and sedimentological measurements mentioned in Chapter 3.

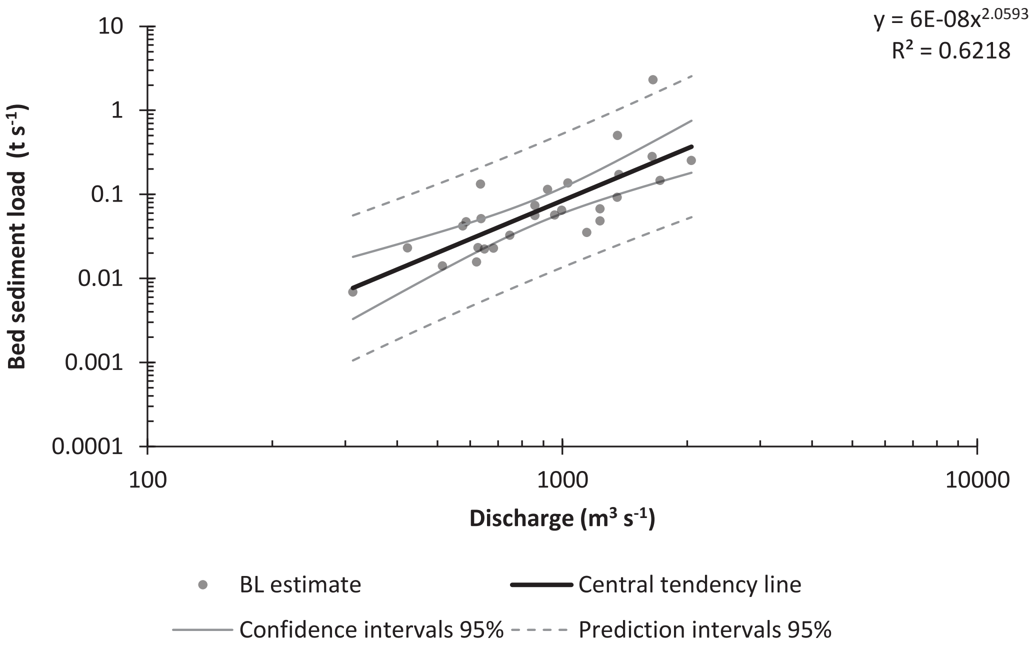


Figure 5.1 Bed load rating curve in the Delta Colorado (11-04) gauging station.

Bed load production values were estimated directly from hourly streamflow time series because both hourly and daily recording periods were equal for this particular gauging station. Mean annual bed load production values for the Colorado River at Delta Colorado gauging station, as well as the 95% confidence intervals due to time series variability and uncertainty in the BLRC, are shown in Table 5.2.

Table 5.2 Bed load sediment production in the Delta Colorado Station (11-04).

COD	Station name	Bed sediment load (t yr^{-1})				
		Mean	TLCI	TUCI	BLRC LCI	BLRC UCI
11-04	Delta Colorado	2 898 000	719 000	5 077 000	1 798 000	4 809 000

Note: COD = station code; TLCI = lower confidence interval due to time series variability; TUCI = upper confidence interval due to time series variability; BLRC LCI= lower confidence interval due to uncertainty in the bed load sediment rating curve; BLRC UCI= upper confidence interval due to uncertainty in the bed load sediment rating curve.

6. ESTIMATION OF SEDIMENT LOAD AT THE MOUTH OF THE SARAPIQUÍ AND SAN CARLOS RIVER AND AT THE SAN JUAN RIVER

This chapter describes the methodology used to estimate both suspended and bed sediment load at the mouths of the rivers Sarapiquí and San Carlos and at the San Juan River upstream the Delta. The procedures used to generate dimensionless flow duration curves are described and different flow separation scenarios at the Delta are assessed.

As no hydrological gauging stations were installed at the mouths of the rivers Sarapiquí and San Carlos, or at the San Juan River upstream the Delta, no hydrological records were available for these points. Due to lack of discharge time series the Riemman Sums approach could not be used and sediment load estimates at this points were made based on probabilistic methods.

> A flow duration curve (FDC) represents the relationship between the magnitude and frequency of daily, weekly, monthly (or other time interval) flow for a particular river basin, providing an estimate of the duration (percentage of time) a given streamflow was equaled or exceeded over the historical period. (Vogel and Fennessey, 1994; in Krasovskaia & Gottschalk, 2014, p. 48)

According to Krasovskaia & Gottschalk (p. 49), "… a flow duration curve is a plot of the sample empirical quantile function, i.e. the *p*-th quantile or percentile of streamflow of certain duration versus exceedance probability *p*", *p* being

$$p = 1 - P(Q \leq q)1 - F_Q(q). \qquad \text{ec. 2}$$

As flow duration curves could be seen as empirical probability distributions, it is natural to consider that they could be modeled by a theoretical probability distribution –such as the 2-parameters lognormal distribution– with practically no loss of information. Moreover, for normalized data, it is known that this distribution can be expressed as a function of the coefficient of variation only and could yield the equivalent of a dimensionless flow duration curve.

For the lognormal distribution with mean $m_Q = 1$ the cumulative distribution function of runoff Q with the coefficient of variation V_Q is written as:

$$F_Q(q; V_Q) = \int_0^q \frac{1}{q\sqrt{2\pi \ln(1 + V_Q{}^2)}} e^{-\frac{1}{2}\frac{\left(\ln q + \frac{1}{2}\ln(1+V_Q{}^2)\right)^2}{\ln(1+V_Q{}^2)}} dq \qquad \text{ec. 3}$$

while its quantile function can be expressed as

$$q_p = e^{z_p\sqrt{ln(1+V_Q{}^2)}-0.5\,ln(1+V_Q{}^2)} \qquad \text{ec. 4}$$

where z_p is the Gaussian variate of the probability *p*.

Finally, the flow duration curve value for duration *p* (Q_p) is then a plot of this dimensionless sample quantile function of streamflow times the long term mean value versus exceedance probability *p* and it can be calculated as

$$Q_p = m_Q\,F_Q^{-1}(1-p; V_Q) \qquad \text{ec. 6}$$

Daily and hourly flow duration curves were modeled according to this methodology for the twelve hydrological gauging stations aforementioned in Table 3.2. The empirical (time series based) and theoretical (probability distribution based) hourly duration curve for Delta Colorado gauging station is shown in Figure 6.1.

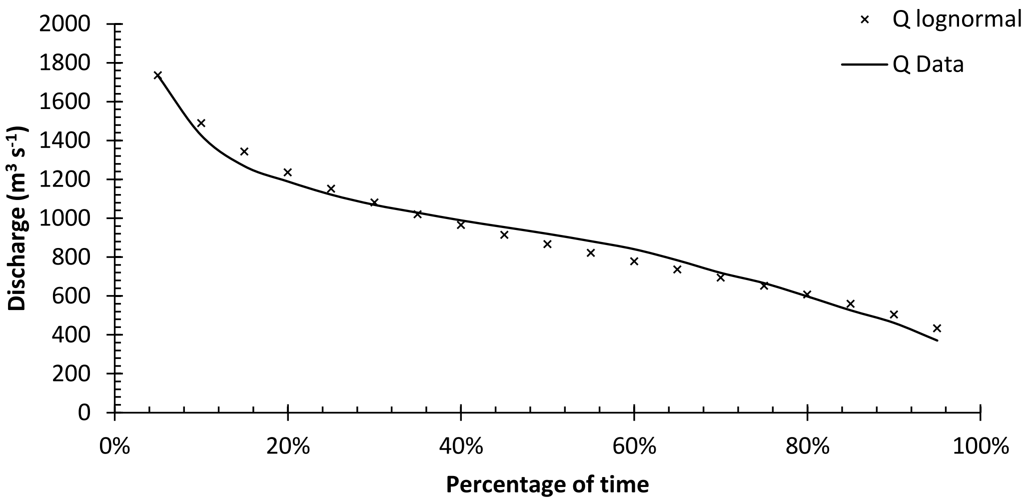


Figure 6.1 Empirical (time series based) and theoretical (probability distribution based) hourly duration curve for the Delta Colorado Station (11-04).

The fit between the theoretical curves and the empirical data was evaluated by the Nash-Sutcliffe efficiency coefficient (NSE)

$$E = 1 - \frac{E[(M-O)^2]}{s_O^2} = 2r_{OM}\frac{s_M}{s_O} - \left(\frac{s_M}{s_O}\right)^2 - \frac{(m_M - m_O)^2}{s_O^2} \qquad \text{ec. 7}$$

where *M* stands for model and *O* for observations, *r* is the correlation coefficient and *m* and *s* denote mean and standard deviation. The NSE is a very complex performance criterion because it includes not only a measure of best linear fit, but also takes into account bias in mean and variances.

QQ plots for the empirical and theoretical quantiles were constructed for each gauging station at daily and hourly scale and the NSE was estimated for each of them. These values, along with the drainage area of each gauging stations are shown in Figure 6.2. It is noted that the correspondence between observed and modeled quantiles is high, with efficiency values greater than 0.92 (0.94) at hourly (daily) scale in 13 out of 14 cases and greater than 0.70 (0.80) in all of the cases.

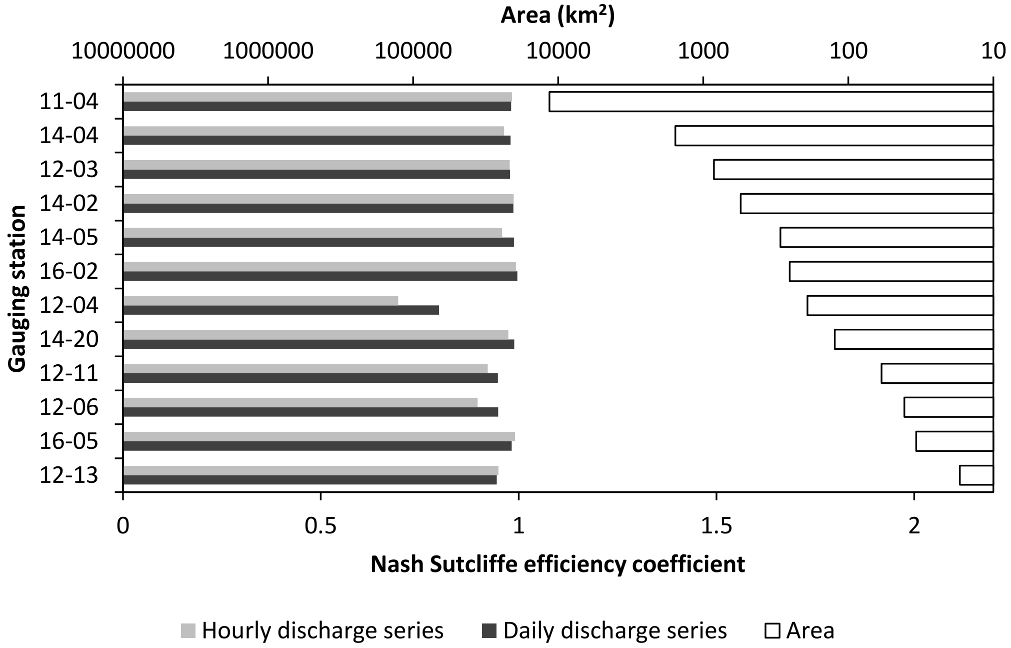


Figure 6.2 Nash Sutcliffe efficiency coefficient between the modeled duration curve and the duration curve obtained based on the discharge time series.

Moreover, according to García & Fernández (2014, p.25), mean annual suspended sediment load estimates for a particular gauging station could be made by applying its SSRC to its corresponding flow duration curve. This procedure yields a suspended sediment load duration curve that can be numerically integrated in order to estimate mean annual suspended sediment load.

Modeled (probability distribution based) flow durations and suspended sediment load rating curves (see Appendix) were used as input and mean annual suspended sediment load estimates were made for gauging stations in the study area using the methodology previously described. A comparison between this modeled sediment duration curve approach and the time series approach explained in Chapter 4 is presented in Figure 6.3 (black crosses). Coefficient of determination R^2 and Nash-Sutcliffe efficiency coefficient *NSE* were reported as 0.9996 and 0.9864. As it can be seen from Figure 6.3, agreement between both methodologies is remarkably good. This comparison was made also for bed load estimates (hollow circle) at Delta Colorado gauging station and the result was comparable to the other ones (see the hollow circle in Figure 6.3).

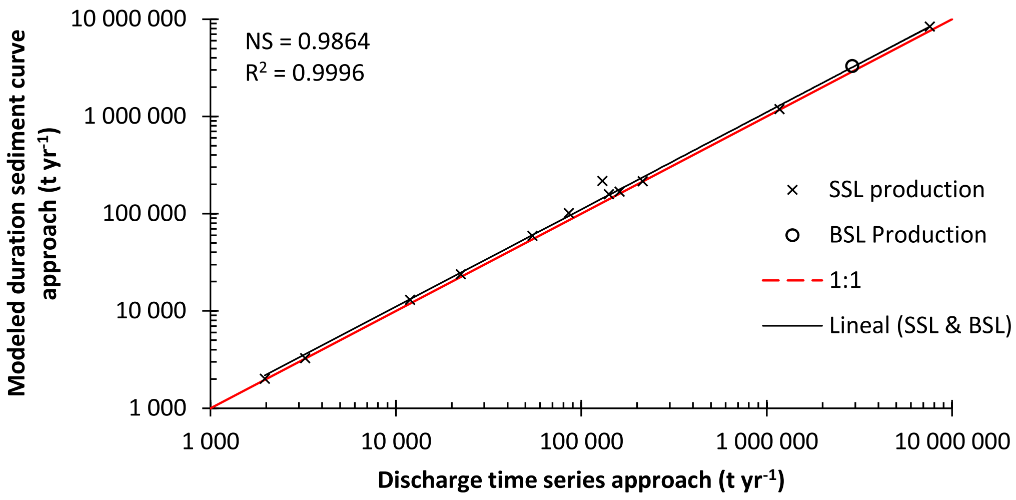


Figure 6.3 Suspended and bed sediment load using modeled duration curves and discharge time series approach.

So far it has been shown that both suspended load and bed load mean annual estimates can be made with great accuracy using flow duration curves (observed or modeled) and its respective sediment rating curves. This means that sediment estimates could be made for ungauged river points provided discharge mean values, standard deviation (or coefficient of variation) of daily or hourly data and a sediment rating curve.

For the particular case of the mouth of the Sarapiquí and San Carlos Rivers, both suspended load and bed load sediment rating curves were available so that only the long term mean values of discharge and the standard deviation (or coefficient of variation) of hourly and daily data were needed to be estimated in order to calculate mean annual sediment loads. Long term mean discharge values were estimated based on rainfall-area methodology using information –drainage area and mean discharge– from Terrón Colorado (14-04), Puerto Viejo (12-03) and Veracruz (12-04) gauging stations and mean areal precipitation extracted from the precipitation field shown in Figure 3.5.

On the other hand, coefficient of variation was estimated based on the fact that this particular moment ratio, in the same catchment, tends to decrease as the drainage area increases. This behavior is, most likely, due to damping of meteorological and hydrological processes and the fact that every tributary that flows into the main river represents the sum of two correlated random variables –so the resulting signal will tend to be more and more normal as this process continues.

Hourly and daily coefficients of variation of six hydrological gauging stations located in Costa Rican Northern Slope are shown in Figure 6.4 as function of their drainage area. As was stated, a reduction on the coefficient of variation could be noted for both time scales as drainage area increases. Two power functions were fitted to the data with R^2 values of 0.94 and 0.99 for hourly and daily data, respectively. These functions were used to estimated, based on basins areas, the coefficient of variation at the mouth of the Sarapiquí and San Carlos Rivers for both time scales.

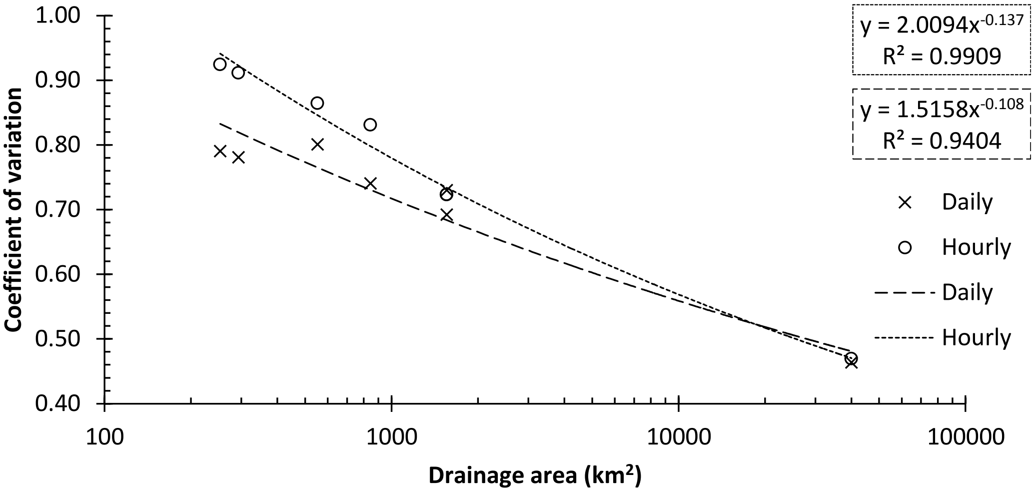


Figure 6.4 Daily and hourly coefficient of variation, as a function of the basin drainage area, based on 6 gauging stations located in the San Juan River tributary basins (Costa Rican slope).

Annual sediment load estimates were made for the Sarapiquí and San Carlos Rivers according to the methodology set out above. Results are presented in Table 6.1 along with the respective drainage area, discharge mean value and hourly and daily coefficients of variation.

Table 6.1 Drainage area, discharge mean value, hourly and daily coefficient of variation and mean annual sediment load for the Sarapiquí and San Carlos Rivers

COD	Station	DA (km^2)	Qa^a ($m^3 s^{-1}$)	CVD^b	CVH^b	SSY^c ($t\ yr^{-1}$)
BSa	Boca Sarapiquí	2 643	377	0.647	0.683	2 342 000
BSC	Boca San Carlos	2 771	266	0.644	0.678	2 927 000

Note: COD = station code; DA = drainage area; Qa = mean annual discharge; CVD = daily coefficient of variation; CVH = hourly coefficient of variation; SSY = suspended sediment yield.
[a]Based on rainfall-area methodology. [b]Based on coefficient of variation-area functions. [c]Based on modeled sediment duration curves.

Due to a lack of information published on sediment transport on the San Juan River upstream the Delta, heavier assumptions were made in order to estimate a mean annual sediment loads at this particular point. Based on Gómez-Delgado, Leitón-Montero & Aguilar-Cabrera (2013, p.14), it was assumed that the mean annual discharge at Delta Colorado gauging station was roughly 90% of the San Juan River mean annual discharge upstream the Delta and that both suspended and bed sediment load rating curves at Delta Colorado gauging station were good approximations of the San Juan River sediment rating curves at this point. Also, in order to assess the sensibility of sediment transport calculations to this assumption and to take into account that discharge separation varies along the year, sediment transport rates were also estimated assuming Colorado River to San Juan River mean annual discharge ratios of 85 and 95%.

The latter assumption does not meet the law of conservation of mass because linearity is lost due to the power nature of sediment rating curves. This means that if we assume that discharge at the Colorado River (Q_C) is a given fraction, say α, of the discharge at the San Juan River (Q_{SJ}) and, therefore, discharge at the Lower San Juan River (Q_{LSJ}) is equal to $[(1-\alpha)/\alpha]\ Q_{SJ}$, the mean annual sediment loads estimated with these discharges will not add up –i.e., the San Juan River sediment transport estimates will be greater than both the Colorado River and the Lower San Juan Rivers added.

Although this condition seems unnatural, a similar result would have been obtained even by having discharge records and sediment measurements in all three points due to natural variability on hydrological variates. The main difference would be that, in this latter case, uncertainty could be quantified and a space of possible solutions –i.e. triplets of mean annual sediment loads at each site– could be found given a level of confidence.

That been said, it is important to acknowledge that, although the procedure outlined before is not perfect, <u>it is the most accurate one given the data available</u>. Also, as the San Juan River and the Colorado River are more hydraulically similar to each other than to the Lower San Juan River, it was decided to estimate the San Juan River annual sediment loads based on Delta Colorado discharge time series and the Lower San Juan River annual sediment loads as the difference between the other two.

Three scenarios were assessed where the San Juan River discharge was modeled as the Delta Colorado gauging station discharge magnified by a factor of (100/ PSJR), where PSJR corresponded to 85, 90, and 95% and stands for the hypothetical Delta Colorado-San Juan River mean annual discharge ratio. Modified discharge time series where transformed into suspended and bed load time series and statistics of them were calculated. Results for the San Juan River are presented in Table 6.2 for both suspended and bed sediment loads and the three discharge scenarios. It can be seen that, for PSJR = 90, the suspended and bed sediment mean annual loads at the San Juan River are, approximately, 9.1 and 3.6 million tons per year, respectively.

A graphical comparison between the suspended and bed load ratio to total sediment load of the San Juan River, for the mean values shown in Table 6.2, can be found in Figure 6.5. It is noted that this ratio remains practically the same for the percentage-of-discharge interval assumed and the methodologies used to calculate both suspended and bed sediment loads.

Table 6.2 Sediment loads in the San Juan River given different percentage of discharge flowing to the Colorado River

PSJR	Qa ($m^3\ s^{-1}$)	Sediment yield ($t\ yr^{-1}\ km^{-2}$)				
		Mean	TLCI	TUCI	SSRC LCI	SSRC UCI
				Suspended sediment		
95	1055	8 286 000	2 847 000	13 725 000	4 300 000	16 951 000
90	1114	9 078 000	3 119 000	15 036 000	4 598 000	19 153 000
85	1180	9 997 000	3 435 000	16 559 000	4 919 000	21 873 000
				Bed sediment		
95	1055	3 221 000	799 000	5 643 000	1 967 000	5 447 000
90	1114	3 600 000	893 000	6 307 000	2 157 000	6 227 000
85	1180	4 050 000	1 005 000	7 095 000	2 373 000	7 191 000

Note: PSJR = Assumed percentage of San Juan River discharge flowing to Colorado River; Qa = Mean annual discharge; TLCI = lower 95% confidence interval due to time series variability; TUCI = upper 95% confidence interval due to time series variability; SSRC LCI= lower 95% confidence interval due to uncertainty in the suspended sediment rating curve; SSRC UCI= upper 95% confidence interval due to uncertainty in the suspended sediment rating curve

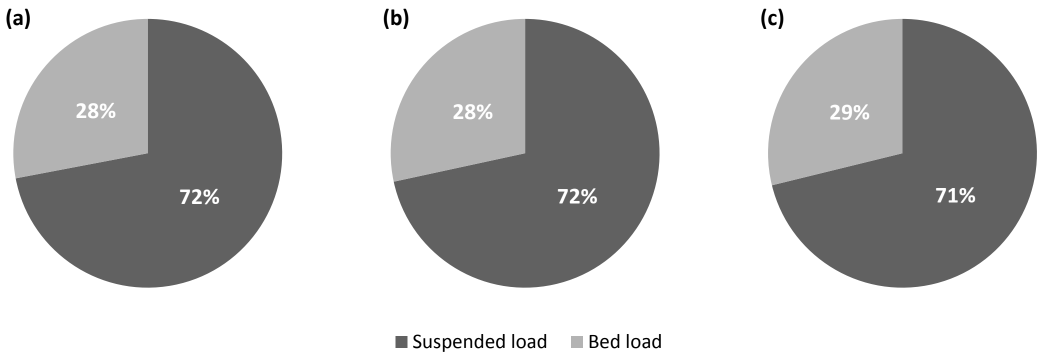


Figure 6.5 Suspended and bed sediment mean annual loads distribution at the San Juan River assuming the percentage of discharge flowing to the Colorado River equals to (a) 95, (b) 90 and (c) 85%.

Using the information presented in Table 6.2 and the suspended (Table 4.1) and bed (Table 5.2) sediment mean annual loads estimated for the Colorado River at Delta Colorado gauging station, it was possible to approximate the Lower San Juan River sediment loads given the limitations mentioned before. Results are presented in Table 6.3 for both suspended and bed sediment loads and the three discharge scenarios.

Table 6.3 Sediment loads in the Lower San Juan River given different percentage of discharge flowing to the Colorado River

PSJR	Qa ($m^3 s^{-1}$)	Sediment yield ($t\ yr^{-1} km^{-2}$)				
		Mean	**TLCI**	**TUCI**	**SSRC LCI**	**SSRC UCI**
				Suspended sediment		
95	1055	687 000	236 000	1 139 000	277 000	1 803 000
90	1114	1 479 000	508 000	2 450 000	575 000	4 005 000
85	1180	2 398 000	824 000	3 973 000	896 000	6 725 000
				Bed sediment		
95	1055	323 000	80 000	566 000	169 000	638 000
90	1114	702 000	174 000	1 230 000	359 000	1 418 000
85	1180	1 152 000	286 000	2 018 000	575 000	2 382 000

Note: PSJR = Assumed percentage of San Juan River discharge flowing to Colorado River; Qa = Mean annual discharge; TLCI = lower 95% confidence interval due to time series variability; TUCI = upper 95% confidence interval due to time series variability; SSRC LCI= lower 95% confidence interval due to uncertainty in the suspended sediment rating curve; SSRC UCI= upper 95% confidence interval due to uncertainty in the suspended sediment rating curve

Finally, graphical representations of how the suspended and bed sediments load are divided at the Delta, based on mean values presented in Table 6.3, are shown in Figure 6.6 and Figure 6.7.

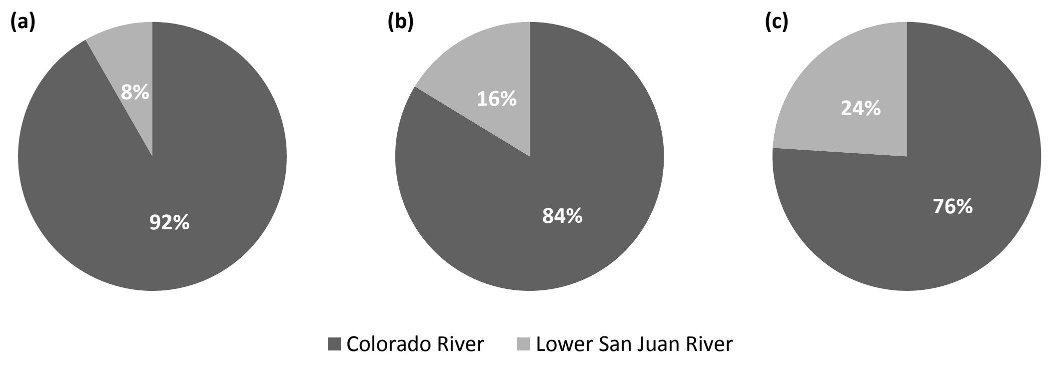


Figure 6.6 Suspended sediment mean annual loads at the Colorado and the Lower San Juan River as a percentage of the San Juan River suspended sediment mean annual load assuming the percentage of discharge flowing to the Colorado River equals to (a) 95, (b) 90 and (c) 85%.

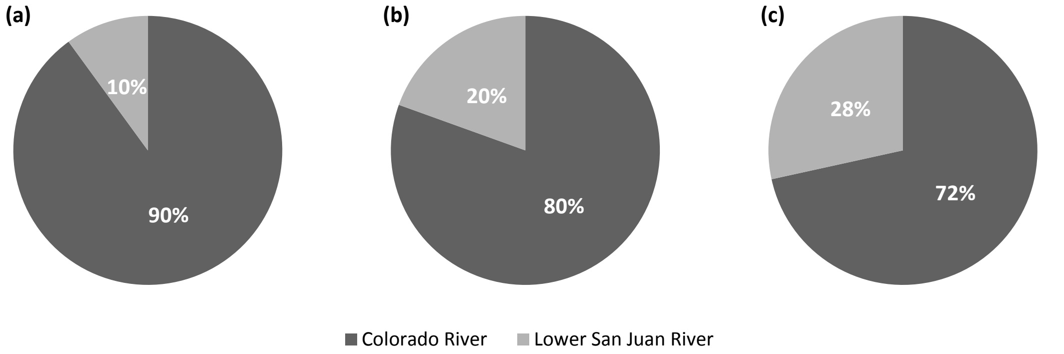


Figure 6.7 Bed sediment mean annual loads at the Colorado and the Lower San Juan River as a percentage of the San Juan River bed sediment mean annual load assuming the percentage of discharge flowing to the Colorado River equals to (a) 95, (b) 90 and (c) 85%.

7. SOIL EROSION MODEL

This chapter describes the input data, calibration procedures and implementation of the erosion model built for estimating sediment yield along the San Juan River Basin. The Universal Soil Loss Equation (USLE) was used as base of the erosion model in order to approximate erosion spatial distribution along basins draining directly to the San Juan River.

7.1. Input data

The USLE is a multiplicative equation where potential soil erosion (*E*) is approximate by the product of five different factors: crop and cover management factor (*C*), soil erodibility factor (*K*), slope (length and steepness) factor (*LS*), rainfall erosivity factor (*R*) and conservation practice factor (*P*). Raster models for each of them –except the P factor which was conservatively assumed equal to 1 across the entire study area– were built based on the information shown in Chapter 3.

Land cover coding for USLE's C factor is presented in Table 7.1 along with the corresponding area for each geographic unit.

Table 7.1 Types of cover found in the San Juan River tributary basins and the corresponding area for each geographic unit

Code	Land cover category	Area (km^2)		
		CR	NI	SJR SA
CITR	Citric plantation	0.4	-----------	0.4
SALA	Set-aside land	0.5	-----------	0.5
GUAV	Guava plantation	0.8	-----------	0.8
RISH	River shore	4.8	-----------	4.8
LASL	Landslide	8.5	-----------	8.5
BASO	Bare soil	20.7	-----------	20.7
URBA	Urban area	0.2	20.8	21.1
SUCA	Sugar cane plantation	24.2	-----------	24.2
WELA	wetland	1.9	30.1	32.0
LARI	Lake, river	59.7	20.4	80.0
INFR	Infrastructure	107.9	-----------	107.9
GRAS	Grass	40.3	111.1	151.4
PLAN	Plantain plantation	123.5	-----------	123.5
APCR	Annual and Permanent crops	-----------	193.1	193.1
PIPA	Pineapple plantation	284.3	-----------	284.3
APCP	Annual and Permanent crops mixed with pastures	0.5	520.9	521.4
FORE	Forest	52.8	1 143.5	1 196.3
FOSH	Forest, tree plantation, shrubs	3 998.3	1.3	3 999.6
PASB	Paddock with some bushes or trees	4 687.1	21.9	4 709.0

Note: CR = Costa Rica, NI = Nicaragua; SJR SA = San Juan River study area.

Minimum and maximum C factor values based on these categories, as well as the mean value and the interval's middle point, are shown in Table 7.2. Coefficients of variation were estimated for each category based on the uniform, symmetric (unbiased) triangular, asymmetric (biased) triangular and normal probability density distributions. In the case of normal distribution, it was assumed that minimum and maximum values represent 95% confidence intervals for the corresponding parent distribution.

Table 7.2 Types of cover found in the San Juan River tributary basins and central tendency descriptors, limiting values and coefficient of variation (according to different probability density distributions) of coverage USLE Factor C.

Code	Limiting values		CTD		Coefficient of variation CV			
	Min	Max	Mean	MID	UD	STD	ATD	ND
CITR	0.0030	0.400	0.1748	0.20150	0.57	0.40	0.40	0.49
SALA	0.3000	0.900	0.6071	0.60000	0.29	0.20	0.20	0.25
GUAV	0.0030	0.400	0.1915	0.20150	0.57	0.40	0.40	0.49
RISH	0.9000	1.000	0.9833	0.95000	0.03	0.02	0.02	0.03
LASL	0.9000	1.000	0.9833	0.95000	0.03	0.02	0.02	0.03
BASO	0.9000	1.000	0.9833	0.95000	0.03	0.02	0.02	0.03
URBA	0.0030	0.015	0.0093	0.00900	0.38	0.27	0.27	0.33
SUCA	0.0400	0.800	0.2505	0.42000	0.52	0.37	0.38	0.45
INFR	0.0030	0.015	0.0093	0.00900	0.38	0.27	0.27	0.33
GRAS	0.0020	0.900	0.0939	0.45100	0.57	0.41	0.45	0.50
PLAN	0.0100	0.600	0.2446	0.30500	0.56	0.39	0.40	0.48
APCR	0.0100	0.500	0.2475	0.25500	0.55	0.39	0.39	0.48
PIPA	0.1000	0.800	0.4244	0.45000	0.45	0.32	0.32	0.39
APCP	0.0020	0.400	0.0997	0.20100	0.57	0.40	0.42	0.50
FORE	0.0001	0.100	0.0177	0.05005	0.58	0.41	0.43	0.50
FOSH	0.0001	0.300	0.0380	0.15005	0.58	0.41	0.44	0.50
PASB	0.0020	0.400	0.0997	0.20100	0.57	0.40	0.42	0.50

Note: Min = minimum value; Max= maximum value; CTD = central tendency descriptors; MID = interval's middle point; UD = uniform distribution; STD = symmetric triangular distribution; ATD = asymmetrical triangular distribution (mean value as central vertex); ND = normal distribution. Based on "*Strategic environmental assessment* [Volume 5]", by Food and Agriculture Organization of the United Nations [FAO], 2001; "*Capacidad de uso y erosión de los suelos en el Valle central del río Guadalquivir*", by Junta de Andalucía, n.d.; "Evaluación del Factor C de la RUSLE para el manejo de coberturas vegetales en el control de la erosión de la cuenca del río Birrís, Costa Rica", by E. Lianes, M. Marchamalo & M. Roldán, 2009, *Revista de Agronomía*, 33(2), 217-235; "Use of the Universal Soil Loss Equation to predict erosion in West Africa", by E.J. Roose, 1977, Proceedings of the national conference on soil erosion; and "*Estudio de erosión para la República de Guatemala*", by J. Saborío-Bejarano, 2000 in "*Evaluación de la erosión potencial y producción de sedimentos en tres cuencas de Costa Rica*", by F. Gómez-Delgado, 2002.

A plot of the coefficients of variation estimated assuming different probability density distributions is presented in Figure 7.1. It can be seen from this figure that the uniform distribution systematically assigns higher values that the other probability distributions, followed by the normal and both triangular distributions. The asymmetric triangular distribution was chosen above the other ones because, along with the symmetric triangular distribution, yielded the lowest coefficient of variation –thus it represents a lower bound for uncertainty and it was the only one that considers skewness in data.

Finally, the spatial distribution of the USLE C factor along study area, based on the land cover map from Figure 3.3 and the mean C factor values presented in Table 7.2, is shown in Figure 7.2.

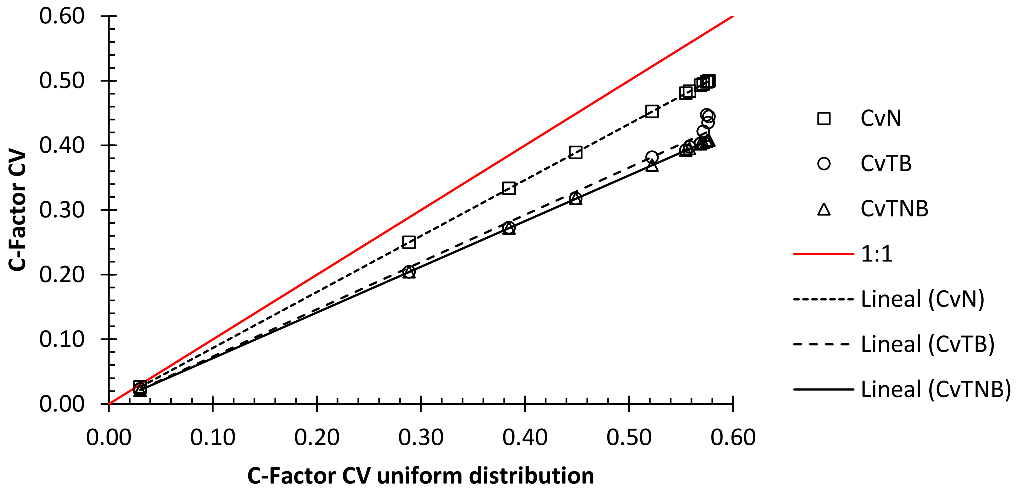


Figure 7.1 Comparison of C Factor coefficient of variation assuming different probability density distributions.

Types of soil found in the San Juan River tributary basins, according to the USDA Soil taxonomy classification, and the correspondent presence area for each geographic unit are presented in Table 7.3. Minimum and maximum C factor values based on these categories, as well as the mean value and the interval's middle point, are shown in Table 7.4 along with coefficients of variation estimated for different probability density distributions.

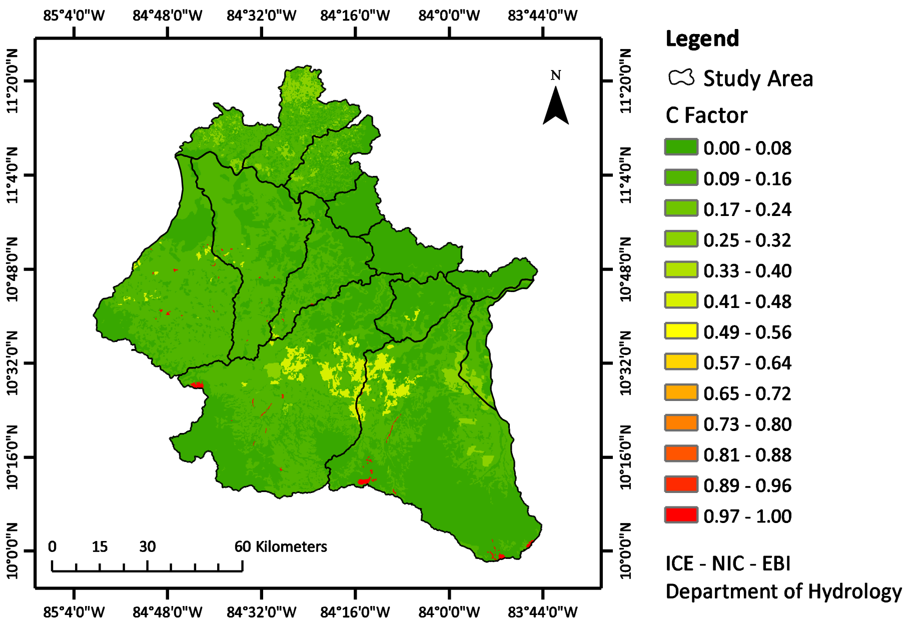


Figure 7.2 C factor for the study area

Table 7.3 Types of soil found in the San Juan River tributary basins and the correspondent area for each geographic unit

Code	USDA soil taxonomy		Area (km^2)		
	Class	Subclass	CR	NI	SJR SA
UlUs	Ultisols	Ustults	0.01	-------------	0.01
Hi	Histosols	-----------------------	0.21	-------------	0.21
HiSa	Histosols	Saprists	3.13	-------------	3.13
InUd/AnUd	Inceptisols/Andisols	Udepts/Udands	5.25	-------------	5.25
EnOr/AnUd	Entisoles/Andisols	Orthents/Udands	5.78	-------------	5.78
Mo	Mollisols	-----------------------	7.12	25.97	33.09
EnPs	Entisols	Psamments	44.87	-------------	44.87
EnAq/HiSa	Entisoles/Histosols	Aquents/Saprists	72.08	-------------	72.08
EnAq/IcAq	Entisoles/Iceptisols	Aquents/Aquepts	78.20	-------------	78.20
EnAq	Entisols	Aquents	91.90	0.18	92.08
EnOr	Entisols	Orthents	109.34	-------------	109.34
Al	Alfisols	-----------------------	-------------	122.05	122.05
UlHu/InUd	Ultisols/Inceptisols	Humults/Udepts	162.87	-------------	162.87
InAq	Inceptisols	Aquepts	189.85	0.07	189.92
Ox	Oxisols	-----------------------	-------------	226.60	226.60
En	Entisols	-----------------------	66.34	171.79	238.13
AnUs	Andisols	Ustands	286.28	-------------	286.28
In	Inceptisols	-----------------------	48.76	251.03	299.79
AnUd/UlHu	Andisols/Ultisols	Udands/Humults	397.18	-------------	397.18

continued

Table 7.3 Types of soil found in the San Juan River tributary basins and the correspondent area for each geographic unit *(continued)*

Code	USDA soil taxonomy		Area (km^2)		
	Class	Subclass	CR	NI	SJR SA
InUd	Inceptisols	Udepts	969.94	-------------	969.94
UlUd/InUd	Ultisols/Inceptisols	Udults/Udepts	1 191.32	-------------	1 191.32
Ul	Ultisols	-----------------------	96.17	1 264.92	1 361.09
UlHu	Ultisols	Humults	1 408.84	0.43	1 409.27
AnUd	Andisols	Udands	1 489.49	-------------	1 489.49
UlUd	Ultisols	Udults	2 679.00	0.11	2 679.12

Note: SJR SA = San Juan River Basin study area; CR = Costa Rica, NI = Nicaragua

Table 7.4 Types of soil found in the San Juan River tributary basins and the correspondent mean, mid, max & min erodability factor with the associated coefficient of variation assuming different probability density distributions

Code	Limiting values		CTD		Coefficient of variation CV			
	Min	Max	Mean	Mid	UD	STD	ATD	ND
UlUs	0.009	0.024	0.014	0.017	0.262	0.186	0.223	0.227
Hi	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
HiSa	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
InUd/AnUd	0.009	0.025	0.017	0.017	0.272	0.192	0.192	0.235
EnOr/AnUd	0.017	0.020	0.019	0.019	0.047	0.033	0.033	0.041
Mo	0.022	0.022	0.022	0.022	0.000	0.000	0.000	0.000
EnPs	0.006	0.006	0.006	0.006	0.000	0.000	0.000	0.000
EnAq/HiSa	0.001	0.023	0.012	0.012	0.529	0.374	0.374	0.458
EnAq/IcAq	0.009	0.025	0.020	0.017	0.272	0.192	0.167	0.235
EnAq	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000
EnOr	0.017	0.020	0.019	0.019	0.047	0.033	0.033	0.041
Al	0.017	0.024	0.020	0.021	0.099	0.070	0.072	0.085
UlHu/InUd	0.009	0.025	0.015	0.017	0.272	0.192	0.220	0.235
InAq	0.025	0.025	0.025	0.025	0.000	0.000	0.000	0.000
Ox	0.006	0.006	0.006	0.006	0.000	0.000	0.000	0.000
En	0.006	0.025	0.017	0.016	0.354	0.250	0.229	0.306
AnUs	0.019	0.019	0.019	0.019	0.000	0.000	0.000	0.000
In	0.017	0.017	0.017	0.017	0.000	0.000	0.000	0.000
AnUd/UlHu	0.012	0.014	0.013	0.013	0.044	0.031	0.031	0.038
InUd	0.009	0.025	0.017	0.017	0.272	0.192	0.192	0.235
UlUd/InUd	0.009	0.025	0.016	0.017	0.272	0.192	0.205	0.235
Ul	0.009	0.024	0.014	0.017	0.262	0.186	0.223	0.227
UlHu	0.012	0.014	0.013	0.013	0.044	0.031	0.031	0.038
AnUd	0.009	0.019	0.013	0.014	0.206	0.166	0.166	0.179
UlUd	0.009	0.024	0.015	0.017	0.262	0.205	0.205	0.227

Note: Min = minimum value; Max= maximum value; CTD = central tendency descriptors; MID = interval's middle point; UD = uniform distribution; STD = symmetric triangular distribution; ATD = asymmetrical triangular distribution (mean value as central vertex); ND = normal distribution. Based on "*Evaluación de los estados de la erosión hídrica de los suelos de Costa Rica: Informe técnico Nº 2-E*", by Food and Agriculture Organization of the United Nations [FAO], 1989.

Analogous to Figure 7.1, a comparison between the coefficients of variation assigned to each soil type is shown in Figure 7.3. Like in the previous case, asymmetric triangular distribution was chosen over the others for the same reasons exposed above. At last, spatial distribution of the USLE K factor along the study area is presented in Figure 7.4.

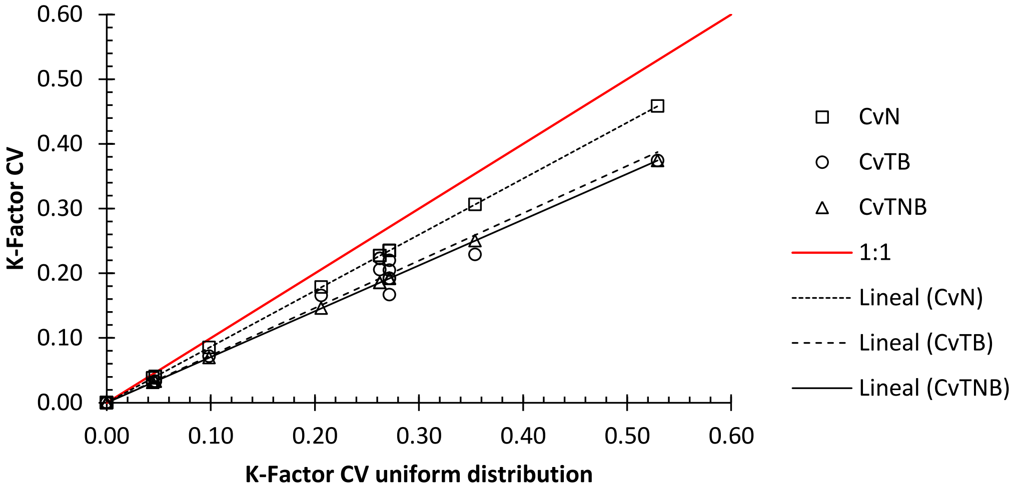


Figure 7.3 Comparison of erodability coefficient of variation assuming different probability density distributions.

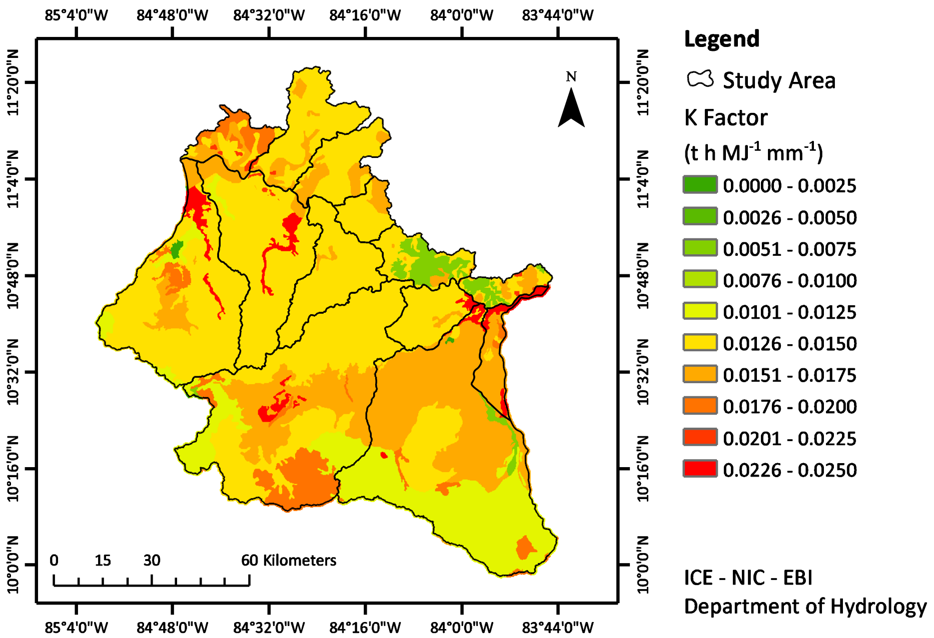


Figure 7.4 K factor in the study area.

USLE's erosivity R factor was estimated based on an empirical equation derived using rainfall information from the 52 meteorological stations located in the Costa Rican Northern Slope (Table 3.1). A power function was fitted using the least squares approach and confidence and prediction intervals at 95% were estimated at each case with the aim of quantifying uncertainty (see Figure 7.5).

The function thus estimated was then applied to the precipitation field presented in Figure 3.5 in order to create an R factor field. Spatial distribution of this variable can be found in Figure 7.6.

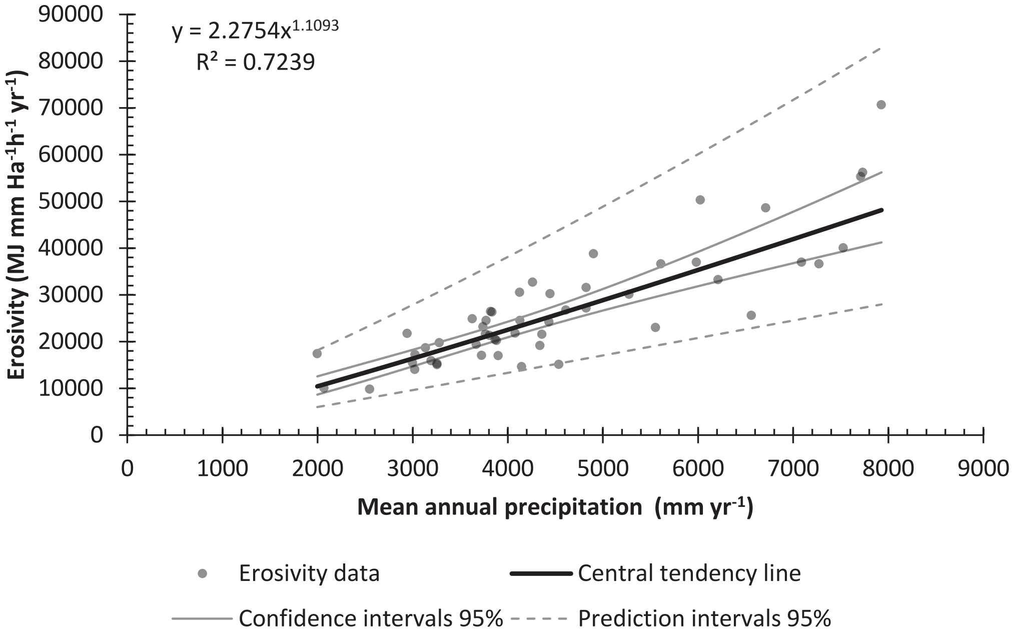


Figure 7.5 R-factor as a function of mean annual precipitation for the study area.

It is noted that the R factor field resembles the precipitation field –which is obvious given that one is a function of the other– but, due to the power nature of the empirical function used, the R factor field tends to present a higher spatial asymmetry than the precipitation one. Moreover, a standard deviation field was calculated assuming the 95% prediction intervals from Figure 7.6 as minimum and maximum bounds for an asymmetric triangular probability density function with the central vertex at the central tendency line.

Finally, USLE LS factor was estimated following Bradbury (1995, pp. 36-37). Length of slope values were limited to 300 m in order to consider that beyond this distance sheet flow usually becomes shallow concentrated flow collecting in swales, small rills, and gullies. Spatial distribution of the USLE LS factor is shown in Figure 7.7 where a logarithmic scale was used for visualization purposes only.

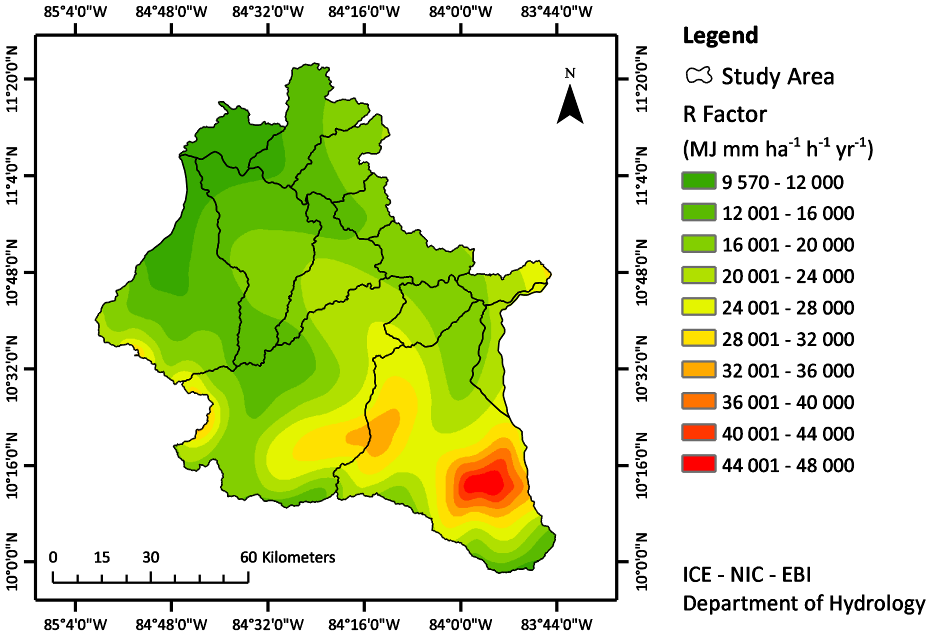


Figure 7.6 R factor for the study area.

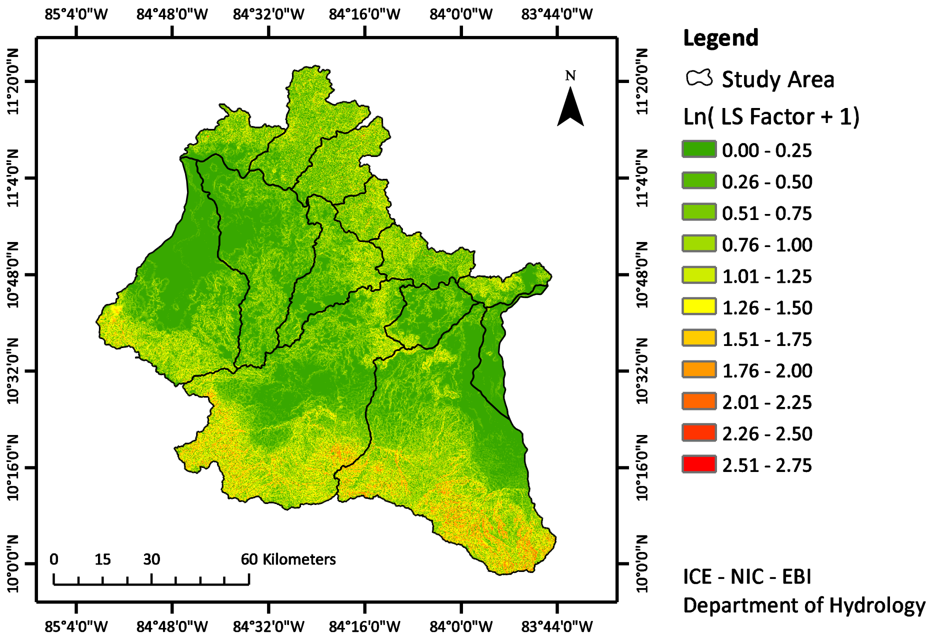


Figure 7.7 LS factor in the study area.

7.2. Potential erosion based on USLE model and uncertainty analysis

Spatial information from section 7.1 (C factor, K factor, R factor and LS factor) was used as input for the USLE model and potential erosion was estimated for the study area (see Figure 7.8).

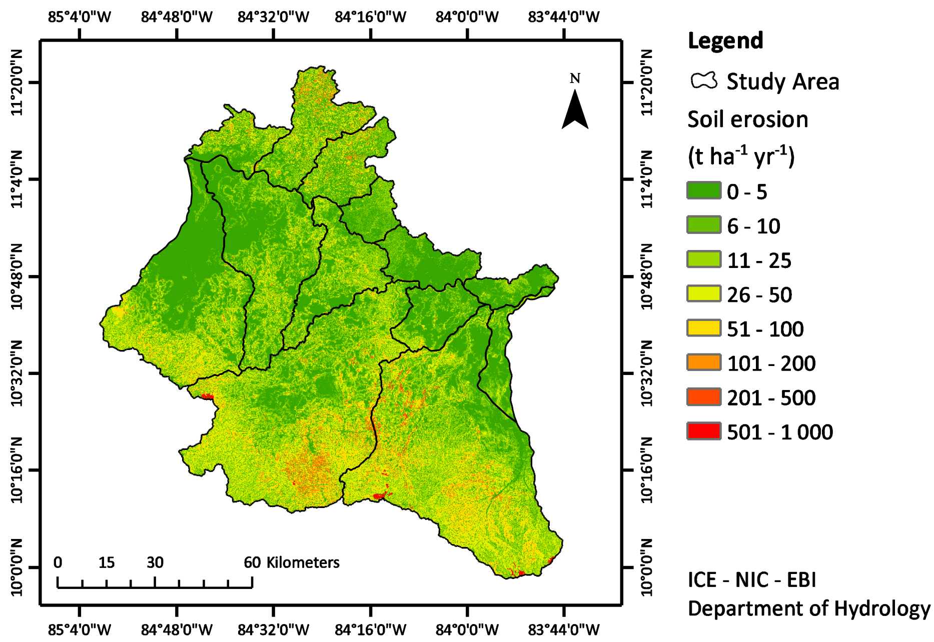


Figure 7.8 Potential erosion in the study area.

Erosion uncertainty was quantified by a partial derivatives approach after Singh, Jain & Tyagy (2007). Theoretically, variance of a multivariate function $Y(X) = Y(x_1, x_2, \ldots x_n)$ with independent variables could be estimated as

$$\sigma_Y^2 = \sum_{i=1}^{n} \left(\frac{\partial f}{\partial x_i}\right)^2 \sigma_{x_i}^2 \qquad \text{ec. 8}$$

where σ stands for the sample variance, X is the vector of variables and n is the length of such vector. In the particular case of USLE equation, ec.8 becomes

$$\sigma_E^2 = \sum_{i=1}^{n\,cells} \frac{\left[(C_iK_iR_i)^2\sigma_{LS_i}^2 + (C_iK_iLS_i)^2\sigma_{R_i}^2 + (C_iLS_iR_i)^2\sigma_{K_i}^2 + (LS_iK_iR_i)^2\sigma_{C_i}^2\right]}{n\,cells} \qquad \text{ec. 9}$$

Variances for the C and K factors were taken from Table 7.2 and Table 7.4 and an R factor variance function was estimated based on Figure 7.5 assuming an asymmetric triangular distribution with central vertex located at the central tendency line of the mean annual rainfall - erosivity function and both minimum and maximum values located at function's 95% confidence intervals. Finally, LS factor variance was left out of calculations because there was neither information nor objective methods to calculate it.

Assuming that C, K and R followed an asymmetric triangular distribution and that the variance of the LS factor equals zero (as no inference of it was made), ec. 9 becomes a lower-bound for modeled potential erosion variance.

Potential erosion estimates were made by two different methods. In the first one, mean areal values were taken for each of the major basins shown in Table 7.5 and calculations were made at basin scale. In the second one, calculation were run at cell scale and then integrated over each basin area. Table 7.5 shows that both methods yielded different results for both the mean value E and the coefficient of variation CV.

Table 7.5 Potential erosion estimates based on aggregated and distributed model approaches

Basin	USLE mean factors				M1		M2	
	C	K	LS	R	SE	CV	SE	CV
Las Banderas	0.022	0.013	0.91	22300	5.67	3.43	4.73	1.067
Machado	0.020	0.010	1.05	18500	3.97	3.29	3.86	0.902
Barlota	0.020	0.015	1.35	16700	6.49	3.52	6.73	0.596
Santa Cruz	0.065	0.015	1.25	16500	19.92	1.40	19.73	0.159
Sábalos	0.109	0.015	1.14	14100	25.39	1.13	26.02	0.088
Melchora	0.091	0.018	0.91	10100	14.80	0.91	16.19	0.148
San Carlos	0.095	0.015	1.31	21200	40.20	0.69	30.20	0.039
Cureña	0.055	0.014	0.51	20300	7.72	1.16	7.21	0.442
Sarapiquí	0.084	0.014	1.45	26800	47.00	0.76	32.80	0.045
Chirripó	0.105	0.018	0.20	21500	8.11	1.06	6.86	0.480
Frío	0.089	0.015	0.72	15000	14.51	0.83	13.74	0.082
Pocosol	0.086	0.016	0.46	15100	9.19	0.90	9.38	0.142
Infiernito	0.070	0.014	0.80	18600	14.93	1.17	12.79	0.193
Study Area	0.083	0.015	1.06	19900	25.92	0.52	21.58	0.029

Note: SE = soil erosion (t ha^{-1} yr^{-1}); CV = coefficient of variation; M1 = first method used to calculate SE which consist on calculating the mean and the coefficient of variation with the aggregated values of USLE factors; M2 = second method used to calculate SE which consist on calculating the mean and the coefficient of variation using the distributed USLE factors

It must be noted that the coefficient of variation diminishes from the aggregated to the distributed model approach and that the mean value of potential erosion fluctuated from one case to the other but tends to be higher in the former one. Based on this information, it is believed that the distributed approach is better than the aggregated one because the latter one does not take into account the spatial variability of the parameters along each of the basins.

7.3. Calibration procedure

A delivery index field was estimated following Bradbury (1995, pp.40-43). The delivery index is defined as a ratio between transport capacity and sediment supply. Thus

> … when transporting capacity is high but there is only a small sediment supply, de DI value is very high indicating that all the available sediment will be carried. When both the transporting capacity and sediment supply are high the Delivery Index values will be intermediate in size as there may be insufficient transporting capacity to carry all the sediment. When the sediment supply is high and the transporting capacity is low the delivery index will be very low. (Bradbury, 1995, p. 20)

According to Bradbury (1995, p. 41), the delivery index was defined after laboratory studies of Govers (1990) and empirical studies by Amphlet and Dickinson (1989) as

$$DI = \frac{P_a^{2.32} min\{A^{0.66} S^{1.44}\}}{SE} \qquad \text{ec. 10}$$

where Pa is the annual rainfall in mm, A is the pixel's drainage area, S is the slope in degrees, min{·} stands for the minimum value down flow path and SE is the soil erosion in ton ha^{-1} yr^{-1}. Moreover, a minimum slope value of 1 was selected based on a recommendation made by Bradbury; he stated that

> … in gently sloping valley floors, high overland flow will form streams connecting to the main river system. If this assumption is not made many areas of high flow-times slope will be disconnected from the main river network due to low slope values in the valley bottoms. (Bradbury, 1995, p. 42)

The delivery index (DI) field estimated according to these assumptions is presented in Figure 7.9.

Sediment yield is calculated as the product of potential erosion and a delivery ratio (DR) value. As DR is a function of DI, pixels with the biggest transport capacity-sediment supply will, theoretically, obtain maximum DR, while pixels with low transport capacity-sediment supply ratio obtain low values of DR.

A delivery function was calibrated in order to minimize squared errors between the observed sediment productions and the ones obtained from the erosion model. As DI defines a partition over the erosion field, the problem reduces to a linear system on DI because all the elements on each partition of the erosion field are multiplied for the same DR value; so, the sum of erosion that gets multiplied by a particular DR(DI) remains constant although the DR function itself varies. In other words

$$SY = \sum_{E} DR(DI)E = \sum_{i=0}^{255} \left[DR(i) \sum_{E\epsilon DI=i} E \right] \qquad \text{ec. 11}$$

and histograms for the empirical potential erosion density distribution like the one showed in Figure 7.10 were built for each of the 14 calibration basins (shown in Table 3.5) and later used as part of the calibration process.

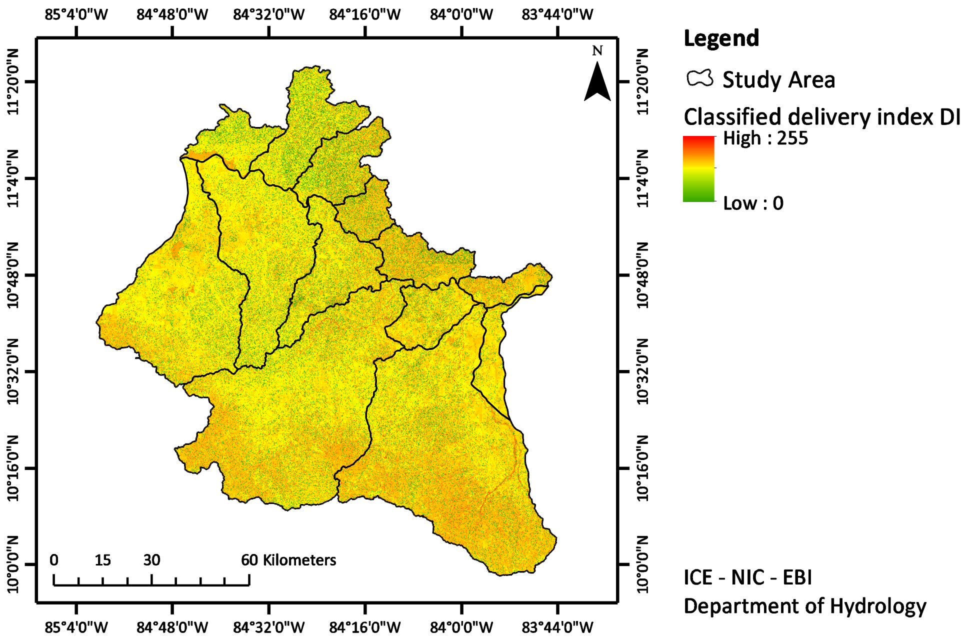


Figure 7.9 Delivery index in the study area.

A weighted sum of the squared errors (WSSE) was used as objective function during optimization processes. Weights were defined as

$$\lambda_i = \frac{\sum_{j=1}^{n}\left(sup\{relative\ error_j\} - inf\{relative\ error_j\}\right)}{n(sup\{relative\ error_i\} - inf\{relative\ error_i\})} \qquad \text{ec. 12}$$

where *sup* and *inf* stand, respectively, for the supremum and infimum of each subset, *n* is the number of calibration basins and the *relative errors* were taken from Table 4.2. This way, basins with the lowest confidence intervals (represented as anomalies here) were pondered by higher coefficients and values with more (relative) uncertainty were given less importance in the calibration process.

Following Bradbury (1995, Appendix D), a piecewise delivery function was tested as first approximation and evolutionary optimization were used to minimized the objective function;

for this case, WSSE = 3.74 and NS = 0.94. A second (linear) delivery function was tested and yielded a constant DR function (slope value was equal to zero) that reduced the WSSE from 3.74 to 2.49 and increased the NS from 0.94 to 0.96. The delivery functions thus calibrated are presented in Figure 7.11 along with the histogram shown in Figure 7.10.

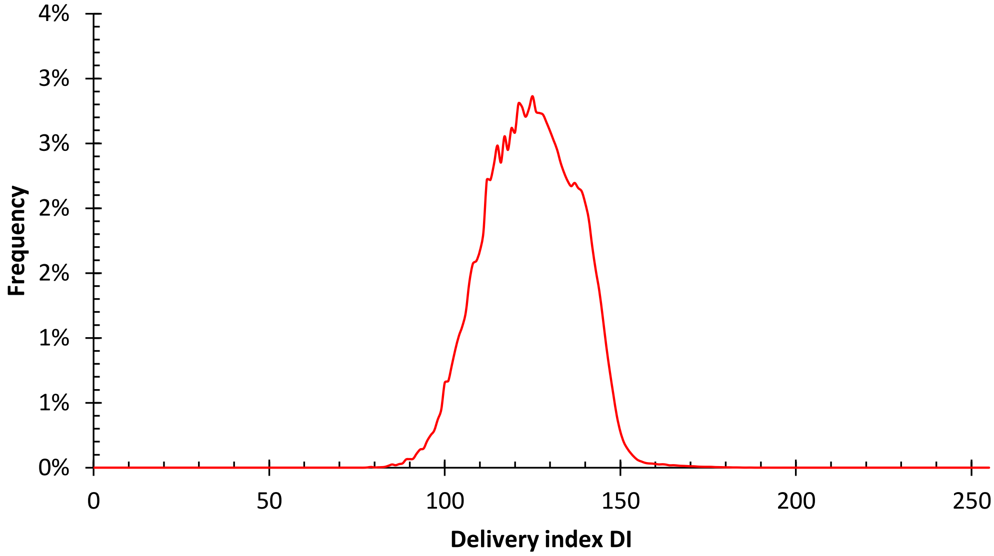


Figure 7.10 Empirical potential erosion density distribution as a function of the delivery index for the study area.

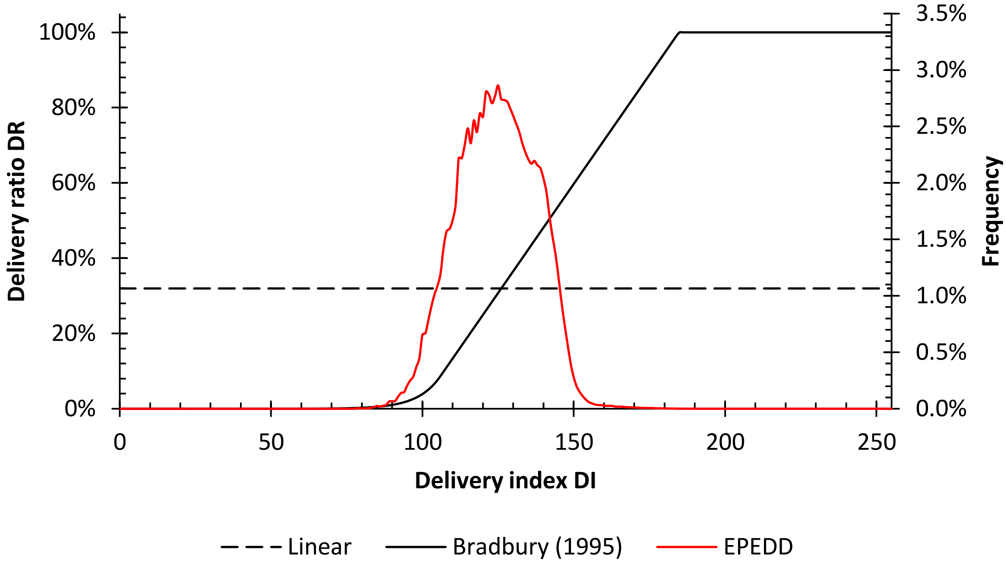


Figure 7.11 Delivery function calibrated for minimal weighted sum of squared errors.

As can be noted in Figure 7.11, the function proposed by Bradbury is somewhat restrictive in the matter that it fixes low and high delivery ratio values at the extremes of the function domain; thus, a straight line must connect these minimum and maximum values to ensure continuity no matter what the potential erosion distribution looks like. In the other hand, potential erosion distribution resembles a normal distribution where most of the erosion values are located in the middle of the DI domain with similar frequency values and practically no asymmetry; given that, a constant DR value for this eroding *symmetrically distributed* area seems good. Thus, the linear function was chosen as delivery function and a sediment yield estimates were calculated for the entire study area.

Observed and modeled values for the fourteen control points are shown in Table 7.6 and in Figure 7.12. It is noted that agreement between observed and modeled data tends to increase as drainage area increases. This particular condition is ideal because the erosion model was built in order to generate a sediment budget of the major basins draining directly to the San Juan River basin system.

Table 7.6 Calibration process for the suspended sediment yield

COD	EPF	DA (km^2)	MSSE ($t\ ha^{-1}\ yr^{-1}$)	MSE ($t\ yr^{-1}$)	MSSY ($t\ yr^{-1}$)	OSSY ($t\ yr^{-1}$)
SJR[a]	0.34	11479	21.57	24 756 000	7 604 000	8 490 000
1203	2.13	841	30.71	2 584 000	794 000	161 000
1204	0.52	195	64.93	1 263 000	388 000	86 000
1206	0.69	41	45.99	187 000	57 000	12 000
1211	0.47	59	27.91	166 000	51 000	22 000
1213	0.24	17	30.61	53 000	16 000	2 000
1402	1.08	538	39.28	2 115 000	650 000	215 000
1404	0.69	1552	36.59	5 680 000	1 745 000	1 175 000
1405	1.48	297	25.56	760 000	233 000	141 000
1420	0.87	124	28.42	352 000	108 000	130 000
1602	2.24	241	25.39	613 000	188 000	55 000
1605	1.24	34	29.56	100 000	31 000	3 000
Bsa	1.00	2771	32.78	9 085 000	2 791 000	2 342 000
BSC	1.00	2643	30.19	7 980 000	2 451 000	2 928 000

Note: COD= station code; EPF = error ponderation factor; DA = drainage area; MSSE = modeled specific sediment erosion; MSE = modeled sediment erosion; MSSY= modeled suspended sediment yield; OSSY = observed suspended sediment yield.

[a]Suspended sediment load assuming 90% of the discharge of the San Juan River goes to the Colorado River. The sediment added by the lake to the system is abstracted from the suspended sediment load because is a component that lies outside the system.

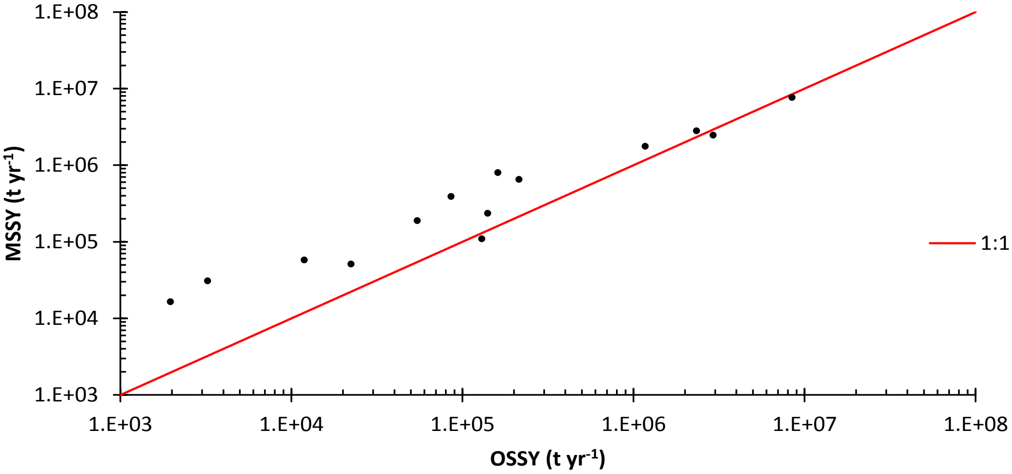


Figure 7.12 Modeled (MSSY) and observed (OSSY) suspended sediment yield compared.

7.4. Sediment yield

The constant function of DR found in the previous section was applied to the potential soil erosion field presented in Figure 7.8 in order to produce a sediment yield field for the entire study area. The spatial distribution of the sediment yield is presented in Figure 7.13.

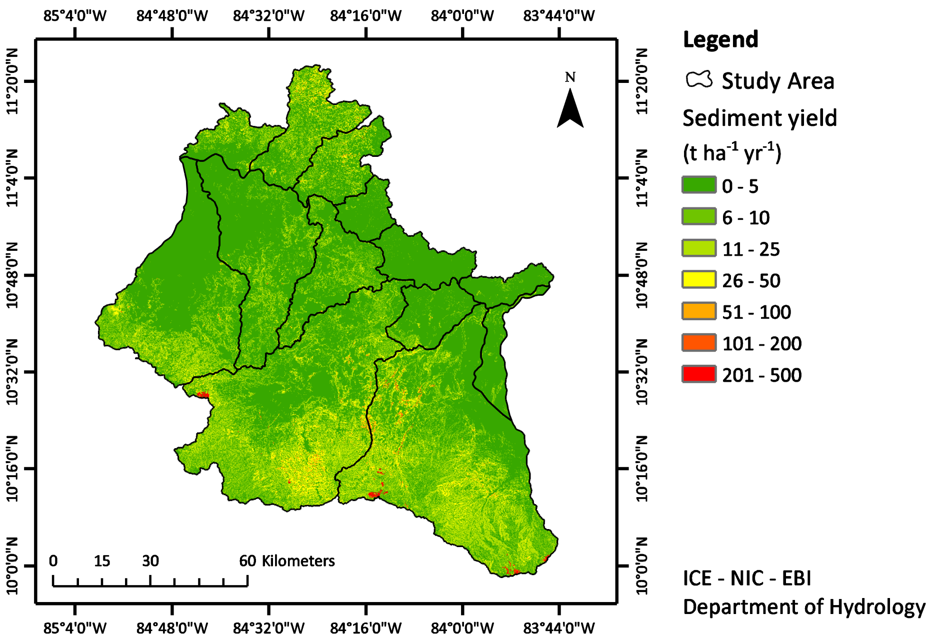


Figure 7.13 Sediment yield in the study area.

Soil erosion and sediment yield estimates are presented in Table 7.7. It is important to remember that, because of the constant delivery ratio used to transform soil erosion into sediment yield, the uncertainty analysis is stills valid for sediment yield and the coefficients of variations shown in Table 7.5 can be applied directly to results presented in Table 7.7.

Table 7.7 Potential soil erosion and sediment yield for major basins draining directly to the San Juan River

Basin	DA (km^2)	SSE ($t\ ha^{-1}\ yr^{-1}$)	SE ($t\ yr^{-1}$)	SSY ($t\ ha^{-1}\ yr^{-1}$)	SY ($t\ yr^{-1}$)
Melchora basin	305	16.19	494 000	4.97	152 000
Sábalos basin	571	26.02	1 486 000	7.99	456 000
Santa Cruz basin	418	19.73	825 000	6.06	253 000
Barlota basin	219	6.73	147 000	2.07	45 000
Machado basin	352	3.86	136 000	1.19	42 000
Las Banderas basin	198	4.73	94 000	1.45	29 000
Frío basin	1577	13.74	2 167 000	4.22	666 000
Pocosol basin	1224	9.38	1 148 000	2.88	353 000
Infiernillo basin	609	12.79	779 000	3.93	239 000
San Carlos basin	2642	30.20	7 979 000	9.28	2 451 000
Cureña basin	353	7.21	254 000	2.21	78 000
Sarapiquí basin	2770	32.80	9 087 000	10.07	2 791 000
Chirripó basin	236	6.86	162 000	2.11	50 000
Study area	11474	21.58	24 758 000	21.58	7 605 000

Note: DA = drainage area; SSE = specific soil erosion; SE = soil erosion; SSY = specific sediment yield; SY = sediment yield.

8. SEDIMENT BUDGET

A sediment budget was constructed based on results presented on previous sections and reports prepared by Oreamuno-Vega & Villalobos-Herrera (2014) and Mende (2014). The San Juan River Basin sediment production was estimate based on the erosion model described in Chapter 7 while sediment increments due to Route 1856 construction were calculated based on Oreamuno-Vega & Villalobos-Herrera erosion rates and Mende slopes' inventory.

For road bed erosion estimates, erosion rates and road widths shown in Table 8.1 were assumed as valid for the entire road based on Dr. Mende's expert judgment.

Table 8.1 Erosion rates for the road bed

Road bed material	Road width (m)	Erosion rate for gentle slopes (m yr^{-1})	Erosion rates for steep slopes (m yr^{-1})
Gravel	10	0.0014[b]	0.0044[b]
Dirt	10	0.0140[a]	0.0440[a]
Trail	5	0.0028[c]	0.0088[c]

[a]Based on "*Report on hydrology and sediments for the Costa Rican river basins draining to the San Juan River*", by F. Gómez-Delgado, J.J. Leitón-Montero & C.A Aguilar-Cabrera, 2013. [b]Assumed as 10% of trail's erosion rate. [c]Assumed as 20% of trail's erosion rate.

Sediment load increments (per basin) due to construction of the Route 1856 were calculated using erosion rates and road widths from Table 8.1, as well as erosion rates published by Oreamuno-Vega & Villalobos-Herrera and GIS data provided by Dr. Mende. A delivery ratio of 0.60 was assumed based on Gómez-Delgado et al. (2013). Results are presented in Table 8.2 and Figure 8.1.

Table 8.2 Sediment load increments, per basin, due to construction of the 1856 Road

Basin	RL	Erosion (m^3)				Total erosion
	(km)	RBE	CSE	FSE	Total	(t yr^{-1})
Major Costa Rican river basins draining directly to the San Juan River						
Infiernito basin	41.0	855	12 348	19 051	32 253	53 863
San Carlos basin	11.1	173	253	399	825	1 378
Cureña basin	29.5	387	1 738	8 966	11 091	18 521
Sarapiquí basin	4.5	172	49	---------	221	369
Chirripó basin	22.8	192	190	107	489	817
Costa Rican area that drains directly to the San Juan River						
Total	108.8	1 778	14 578	28 523	44 879	74 949

Note: RL = road length; RBE = road bed erosion; CSE = cut slope erosion; FSE = fill slope erosion.

Similarly, sediment load increments (per reach) due to construction of the Route 1856 were calculated using the exact same methodology and base information. Results are presented in Table 8.3 and Figure 8.2.

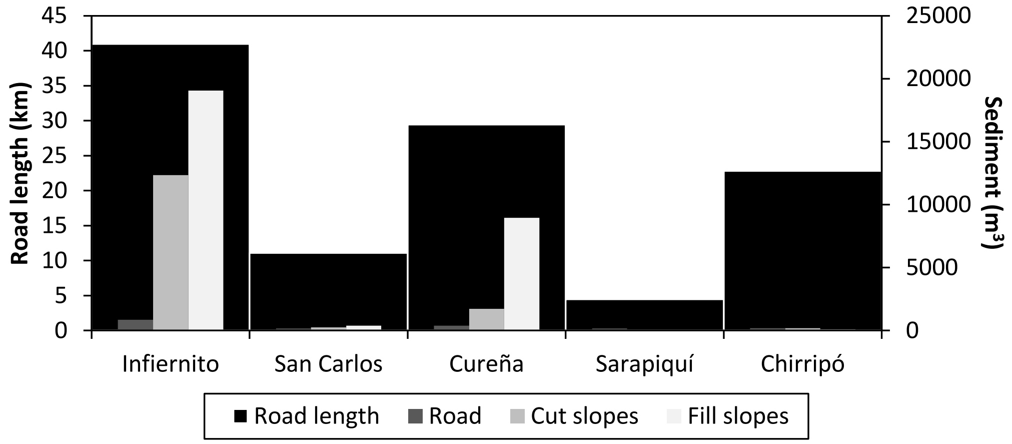


Figure 8.1 Sediment load increments, per basin, due to construction of the route 1856.

Table 8.3 Sediment load increments, per reach, due to construction of the route 1856.

Reach between rivers	Road length (km)	Erosion (m^3)			Total erosion ($t\ yr^{-1}$)
		Road	Slopes	Total	
Major Costa Rican rivers draining directly to the San Juan River					
Pocosol-Infiernito	14.2	375	12 323	12 698	21 205
Infiernito-San Carlos	27.8	569	19 075	19 644	32 825
San Carlos-Cureña	15.4	129	2 809	2 938	4 907
Cureña- Sarapiquí	28.2	511	8 547	9 058	15 127
Sarapiquí-Chirripó	1.7	14	347	361	603
Chirripó-Colorado	21.5	181	0	181	302
Costa Rican area that drains directly to the San Juan River					
Total	108.8	1 778	43 102	44 880	74 949

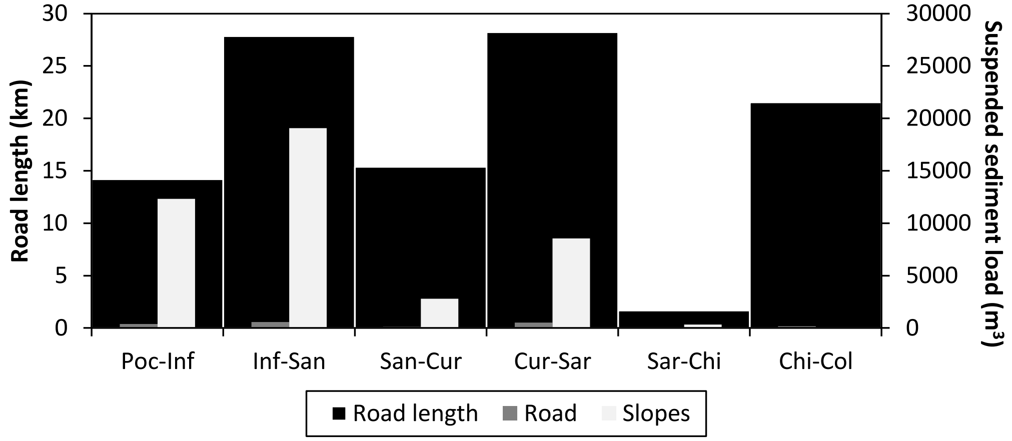


Figure 8.2 Sediment load increments, per reach, due to construction of the route 1856.

Sediment yield estimates for each of the main basins draining directly to the San Juan River were adjusted so conservation of mass could be achieved. Suspended sediment load from Lake Nicaragua was assumed, as reported on Gómez-Delgado et al., equal to 588 000 t yr^{-1}.

Mouths of the Sarapiquí and San Carlos Rivers (Table 6.1) estimates and San Juan River (Table 6.2) estimates were used as control points and the differences between the USLE modeled and time series based modeled mean annual sediment load were redistributed proportionally to sediment yield between the remaining basins. Both modeled and adjusted sediment yield values are presented in Table 8.4.

Table 8.4 Adjusted sediment budged for the San Juan River basin system

Basin	DA (km^2)	SSY (t ha^{-1} yr^{-1})	Erosion (t yr^{-1})	SY (t yr^{-1})	ASY (t yr^{-1})
Melchora basin	305	16.19	494 000	152 000	207 000
Sábalos basin	571	26.02	1 486 000	456 000	622 000
Santa Cruz basin	418	19.73	825 000	253 000	345 000
Barlota basin	219	6.73	147 000	45 000	62 000
Machado basin	352	3.86	136 000	42 000	57 000
Las Banderas basin	198	4.73	94 000	29 000	39 000
Frío basin	1577	13.74	2 167 000	666 000	907 000
Pocosol basin	1224	9.38	1 148 000	353 000	481 000
Infiernillo basin	609	12.79	779 000	239 000	326 000
San Carlos basin	2642	30.20	7 979 000	2 451 000	**2 928 000**
Cureña basin	353	7.21	254 000	78 000	106 000
Sarapiquí basin	2770	32.80	9 087 000	2 791 000	**2 342 000**
Chirripó basin	236	6.86	162 000	50 000	68 000
Study Area	11474	21.58	24 758 000	7 605 000	**8 490 000**
Lake Nicaragua	29067	---------	---------	---------	**588 000**

Note: The values in bold are the ones that were assumed to be correct; therefore, the error was distributed in the remaining ones so that the sum of all equals 8 490 000 t yr^{-1}. DA = drainage area; SSY = specific sediment yield; SY = sediment yield; ASY = adjusted sediment yield.

Due to lack of information published on sediment transport on the San Juan River and the absence of any joint studies on the San Juan River, sediment separation at Delta had to be made based on the assumption that 90% of the San Juan River discharge flows through to the Colorado River and suspended and bed load estimates for the San Juan River (see Table 6.2) were split between the Colorado River (according to Table 4.1 and Table 5.2) and Lower San Juan River (based on Table 6.3). These results, as well as the information of Table 8.4, were used to create the sediment budget diagram of the San Juan River basin shown in Figure 8.3.

However, it must be stated that since no bed load material information was available for the mouth of twelve out of fourteen of the major basins draining directly to the San Juan River and no distributed or lumped models were built in order to indirectly estimate this particular variate, no further assumptions were made and only bed load separation at the Delta is presented in the diagram.

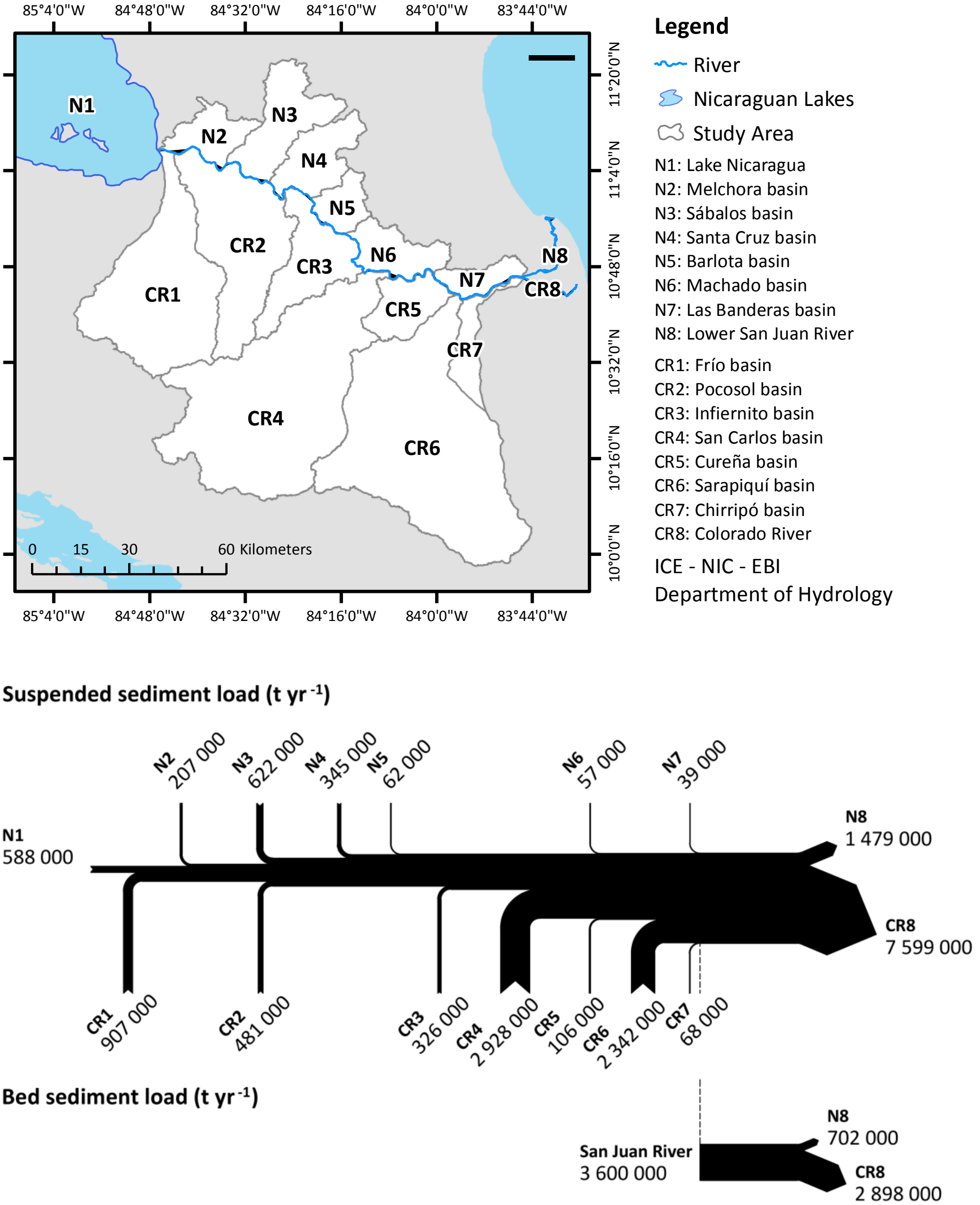


Figure 8.3 Sediment budget of the San Juan River Basin (values in t yr^{-1}).

Different percentages of coarse material were assumed for Route 1856 annual sediment load estimates presented in Table 8.2 and Table 8.3. Sediment separation for both suspended and bed load material was made according to Figure 6.6 (b) and Figure 6.7 (b), respectively, and can be found in Table 8.5 and Table 8.6.

Table 8.5 Suspended and bed load separation of sediment loads increments, due to Route 1856 construction, at the Delta for different assumed percentage of coarse material present in Route 1856 material (as mass)

Sediment load	Sediment yield (t)					
	APCM = 5	APCM = 10	APCM = 15	APCM = 20	APCM = 25	APCM = 30
Suspended						
LSJR	11600	10990	10379	9769	9158	8548
CoR	59601	56464	53327	50190	47053	43917
Bed						
LSJR	731	1461	2192	2923	3654	4384
CoR	3017	6033	9050	12067	15083	18100
Total						
LSJR	12331	12451	12571	12692	12812	12932
CoR	62618	62497	62377	62257	62137	62017

Note: APCM = Assumed percentage of Route 1856's sediment yield composed by coarse [sand] material; LSJR = Lower San Juan River; CoR = Colorado River.

Table 8.6 Suspended and bed load separation of sediment loads increments, due to Route 1856 construction, at the Delta for different assumed percentage of coarse material present in Route 1856 material (as volume)

Sediment load	Sediment yield (m^3)					
	APCM = 5	APCM = 10	APCM = 15	APCM = 20	APCM = 25	APCM = 30
Suspended						
LSJR	6946	6581	6215	5849	5484	5118
CoR	35689	33811	31932	30054	28176	26297
Bed						
LSJR	438	875	1313	1750	2188	2625
CoR	1806	3613	5419	7226	9032	10838
Total						
LSJR	7384	7456	7528	7600	7672	7744
CoR	37496	37424	37352	37280	37208	37136

Note: APCM = Assumed percentage of Route 1856's sediment yield composed by coarse [sand] material; LSJR = Lower San Juan River; CoR = Colorado River.

Also, Colorado River to Lower San Juan River total sediment transport ratios, for each of the aforementioned percentages of coarse material, are presented in Figure 8.4. It must be noted that, according to this figure, these ratios are practically identical for the percentage range used in see Table 8.5 and Table 8.6–as the slope value of the best fit equation is practically zero.

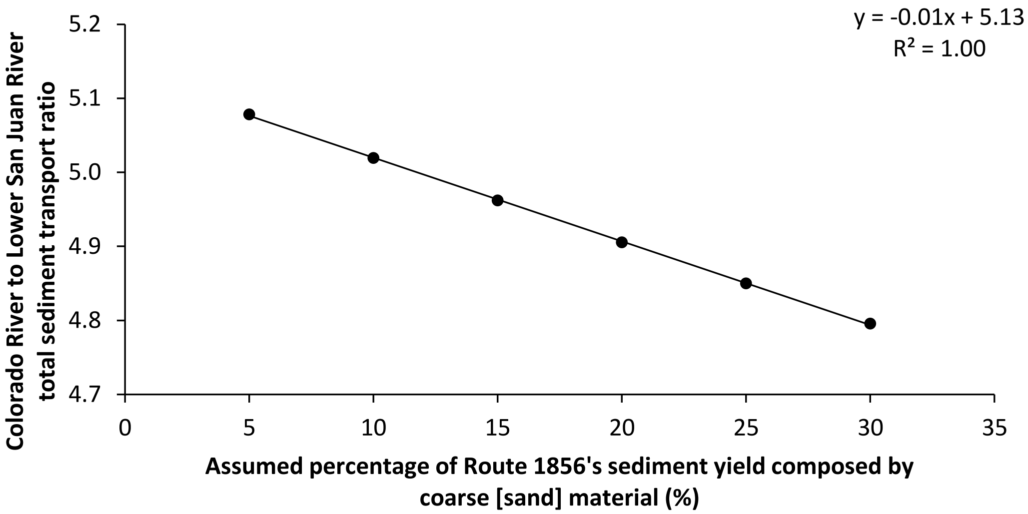
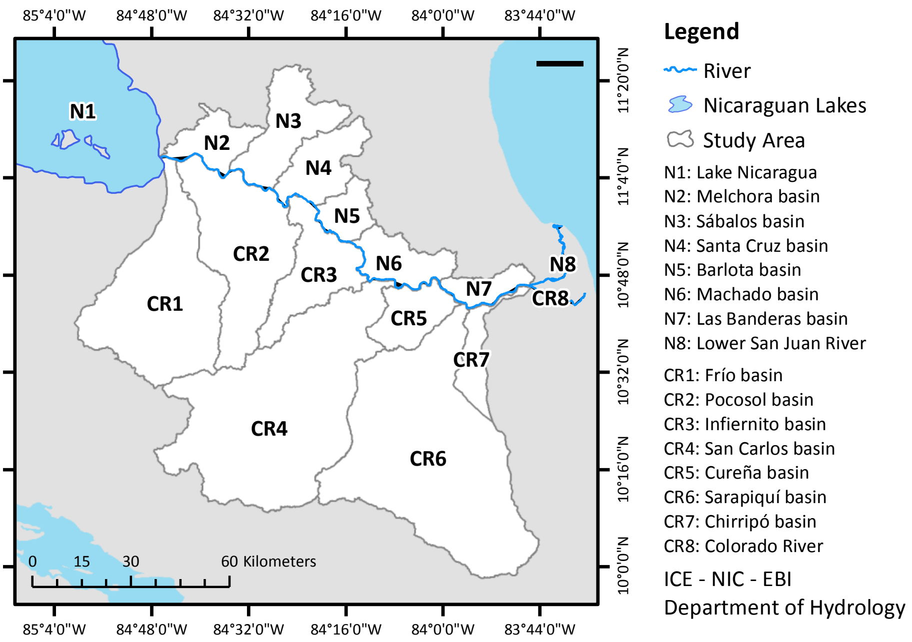


Figure 8.4 Colorado River to Lower San Juan River total sediment transport ratio as a function of the assumed percentage of Route 1856's sediment yield composed by coarse (sand) material.

If it is assumed that 5 to 10 percent of the sediment yield from the Road that is transported to the Delta is sand and a one to nine ratio for the discharge flowing through the Lower San Juan River and the Colorado River, respectively, is also assumed– i.e. that 90% of the San Juan River discharge flows through to the Colorado River– then it could be stated, according to Table 8.5 and Table 8.6, that, as an average, the annual sediment load increments at the outlets of the system are, approximately, less than 12 450 t (or 7 460 m^3), for the Lower San Juan River, and 62 620 t (or 37 500 m^3), for the Colorado River.

Mean annual sediment load increments, due to Route 1856 construction, are presented graphically in Figure 8.5. As it can be seen from this diagram, the effects of Route 1856 over the mean annual sediment load of the San Juan River are not just insignificant; they are, in practice, indiscernible.



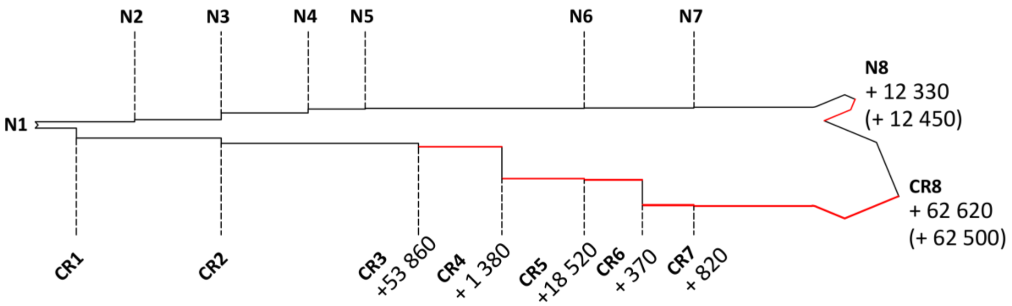


Figure 8.5 Increment of mean annual suspended sediment load of the San Juan River due to Route 1856 construction assuming a 5% (values in parenthesis correspond to 10%) fraction of coarse material.

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10. APPENDIX

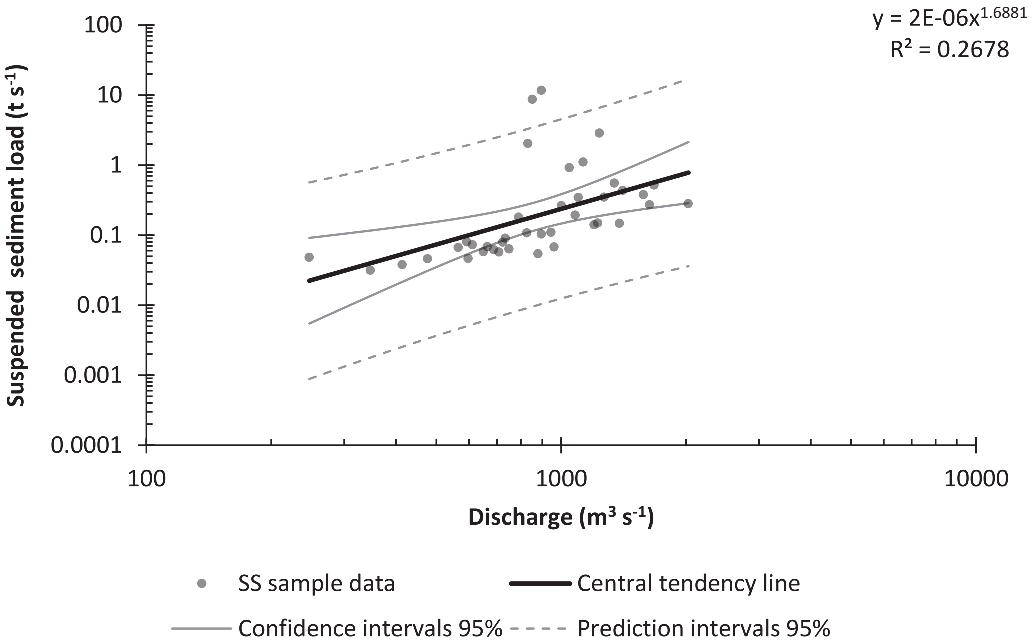

Figure 10.1 Suspended sediment rating curve for the Delta Colorado (11-04) gauging station.

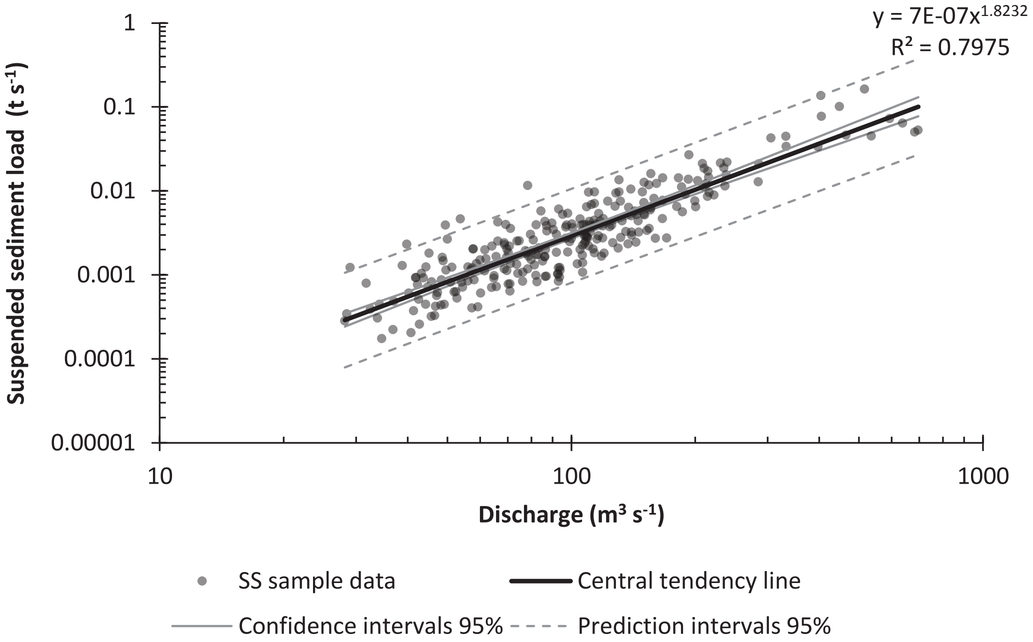

Figure 10.2 Suspended sediment rating curve for the Puerto Viejo (12-03) gauging station.

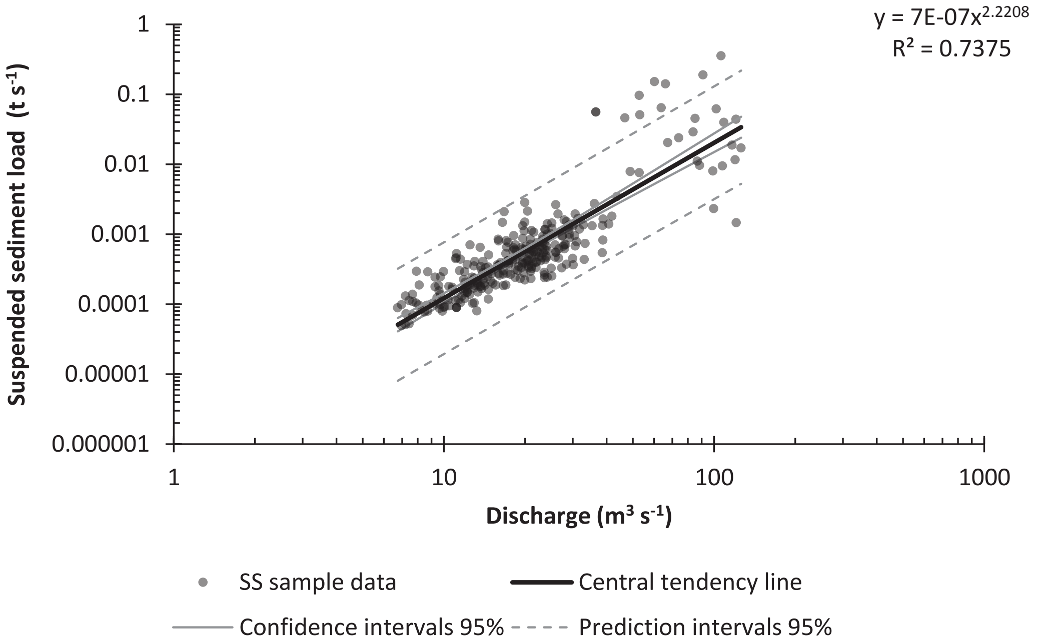

Figure 10.3 Suspended sediment rating curve for the Veracruz (12-04) gauging station.

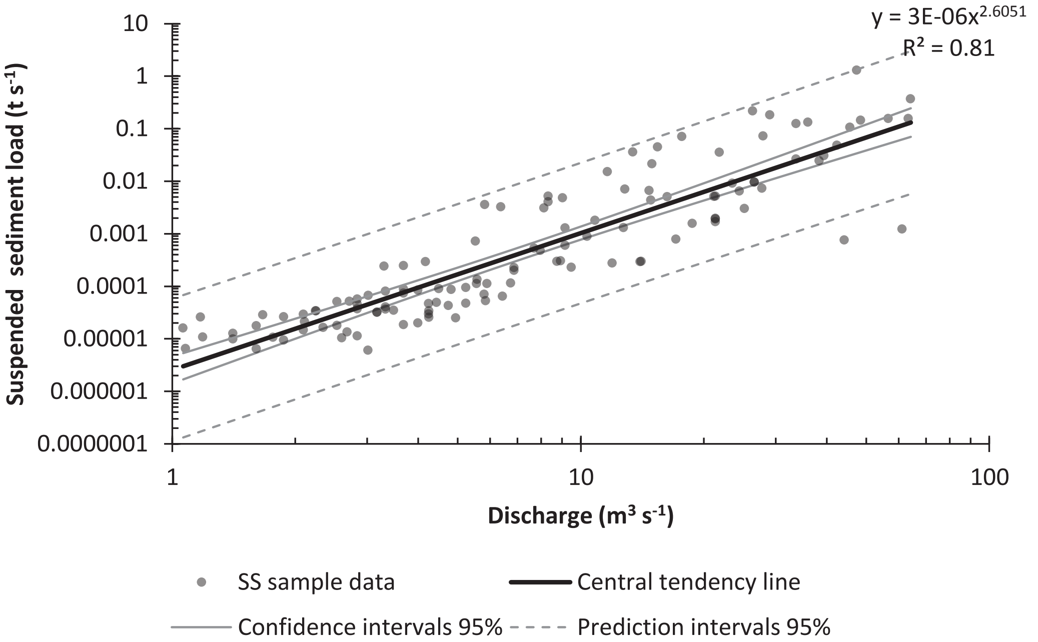

Figure 10.4 Suspended sediment rating curve for the Toro (12-06) gauging station.

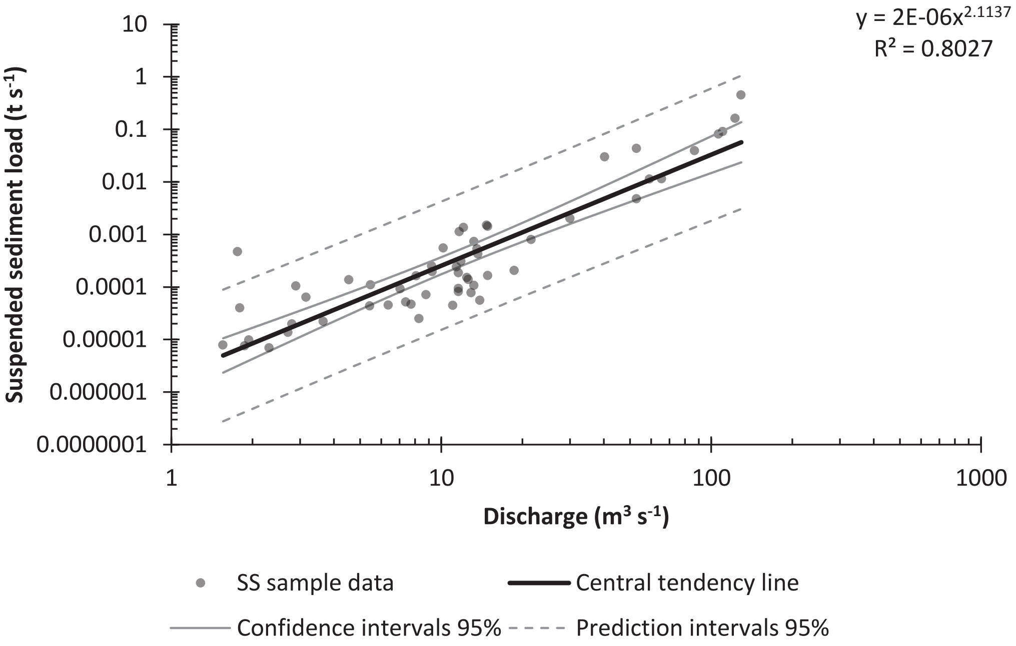

Figure 10.5 Suspended sediment rating curve for the San Miguel (12-11) gauging station.

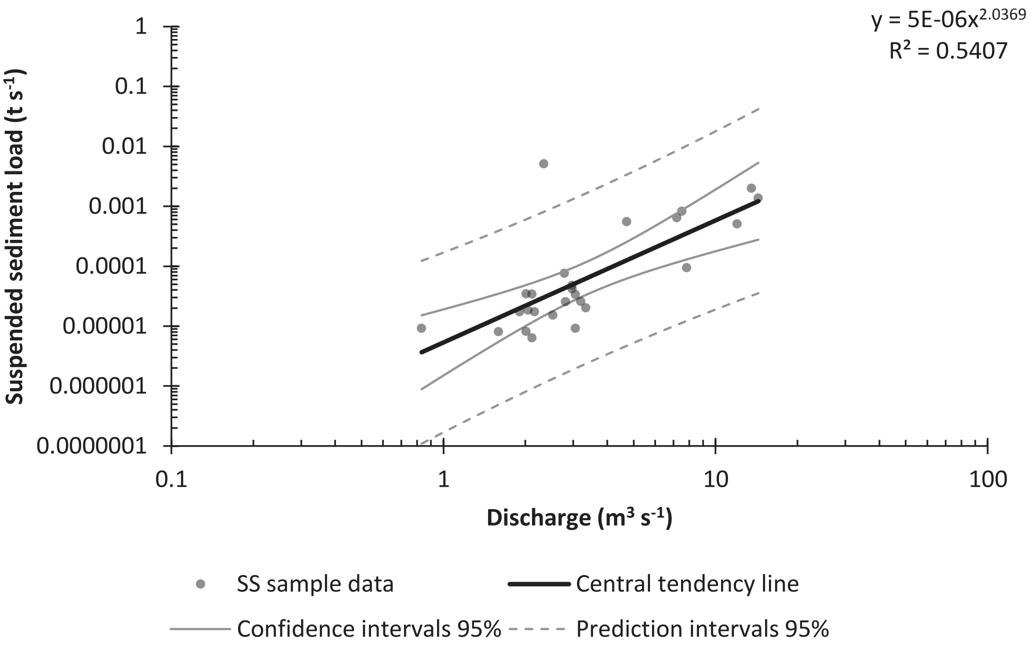

Figure 10.6 Suspended sediment rating curve for the Río Segundo (12-13) gauging station.

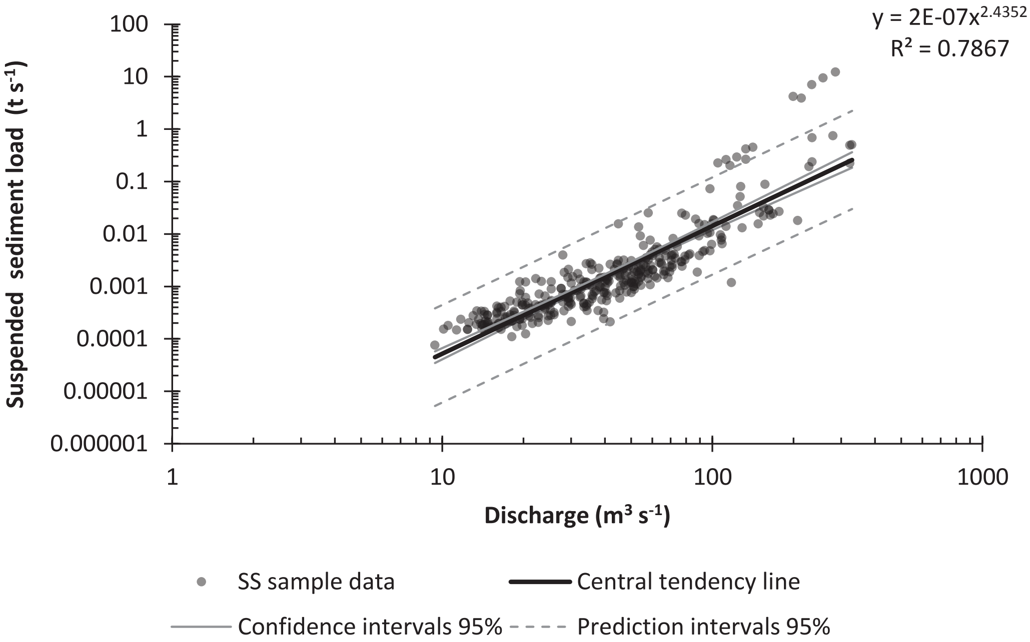

Figure 10.7 Suspended sediment rating curve for the Jabillos (14-02) gauging station.

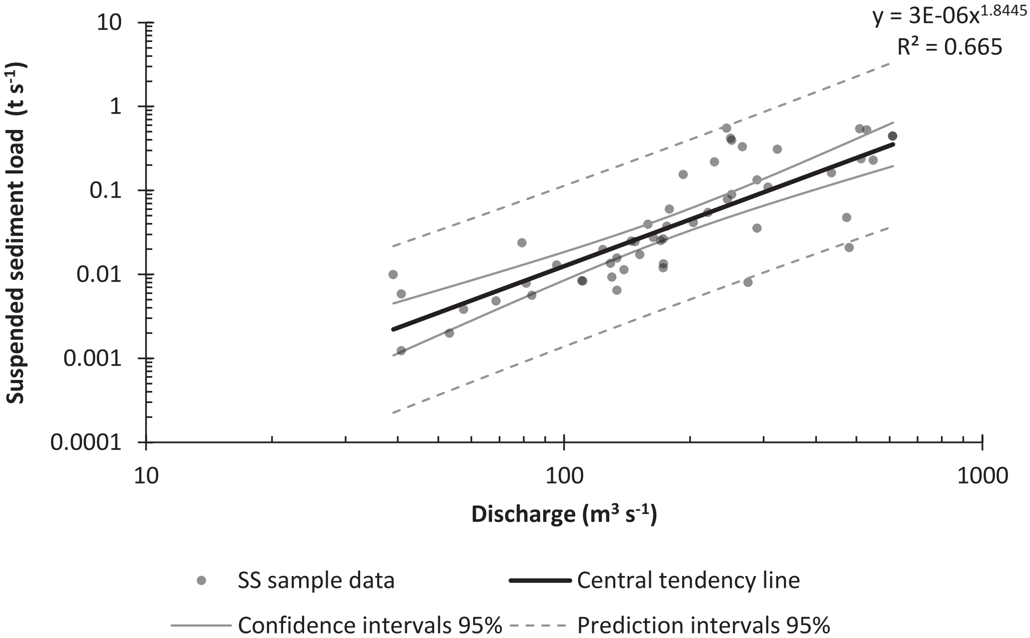

Figure 10.8 Suspended Sediment rating curve for the Terrón Colorado (14-04) gauging station.

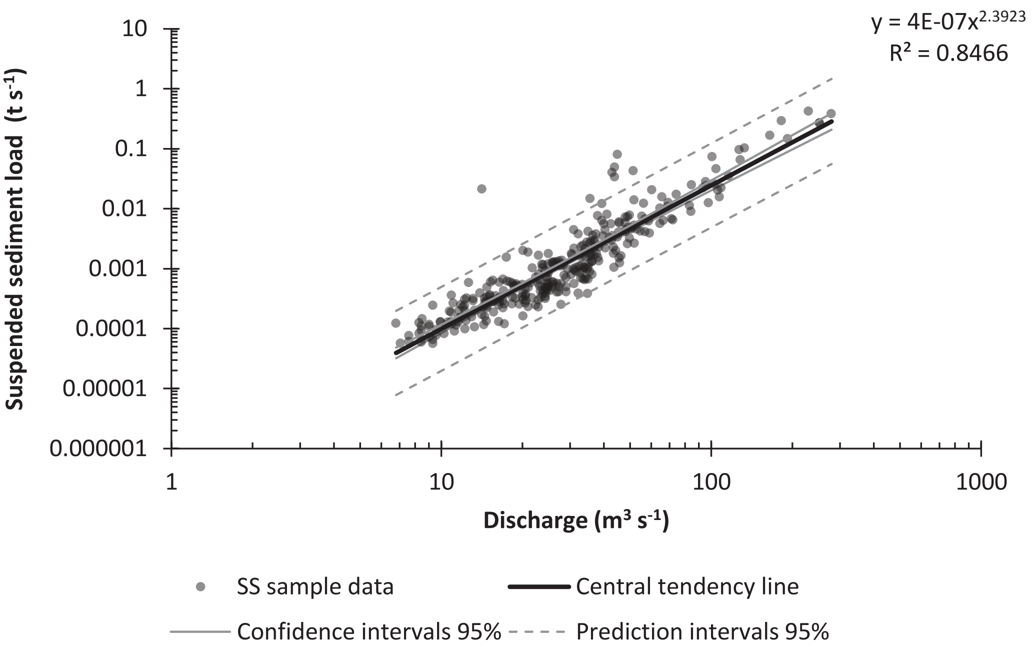

Figure 10.9 Suspended sediment rating curve for the Peñas Blancas (14-05) gauging station.

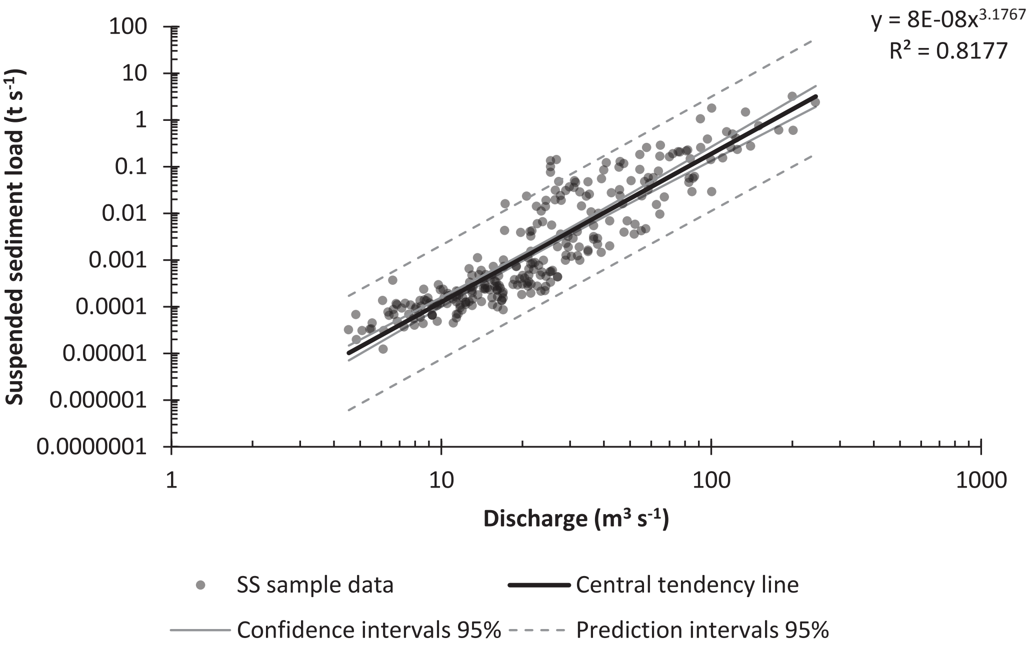

Figure 10.10 Suspended Sediment rating curve for the Pocosol (14-20) gauging station.

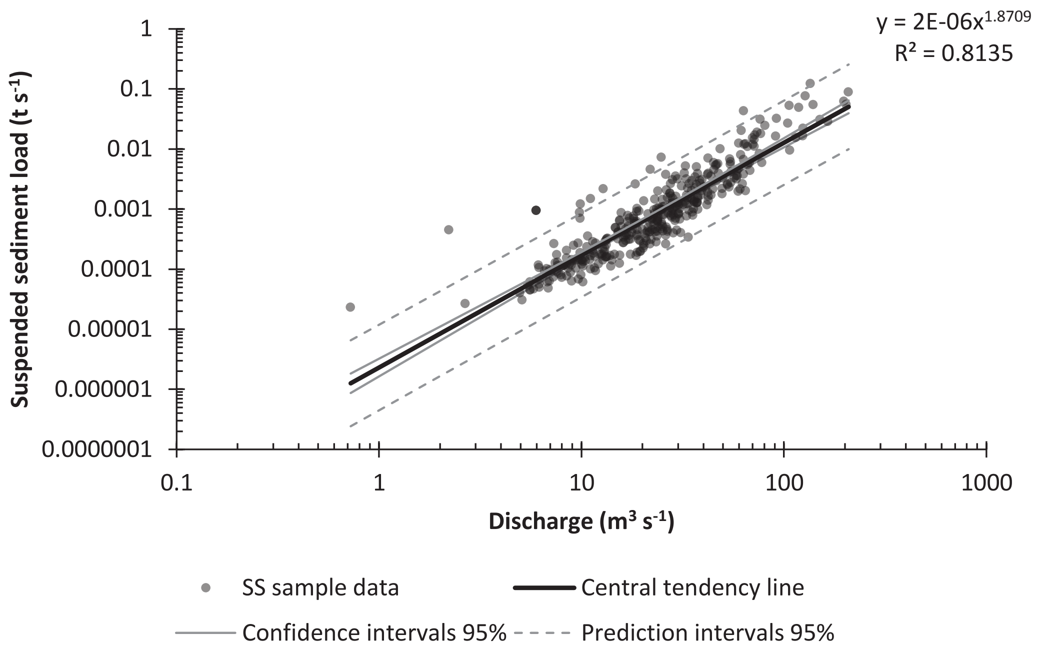

Figure 10.11 Suspended sediment rating curve for the Guatuso (16-02) gauging station.

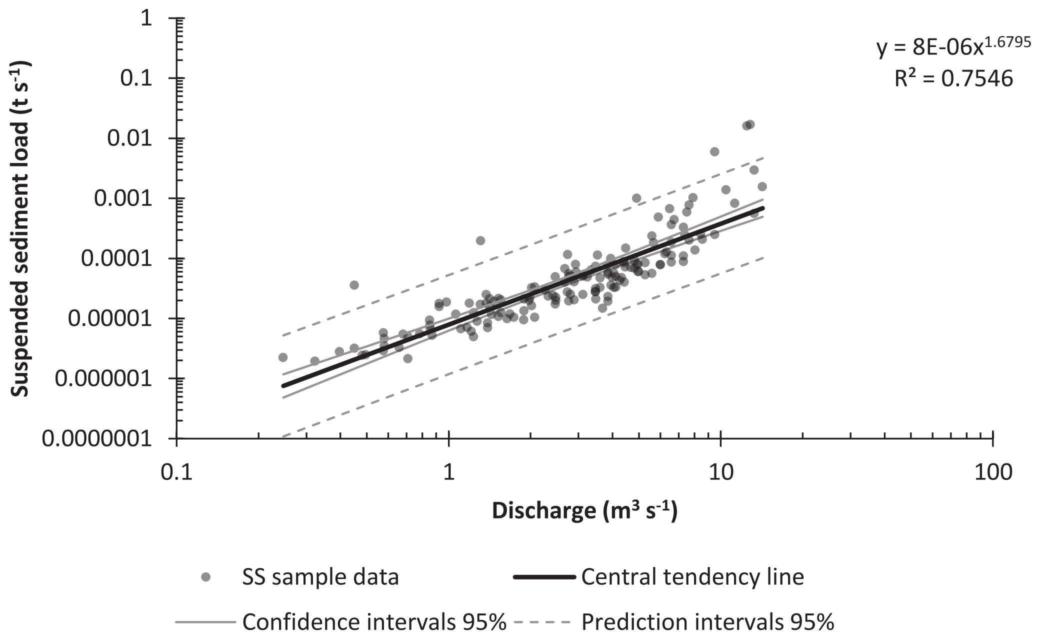

Figure 10.12 Suspended sediment rating curve for the Santa Lucía (16-05) gauging station.

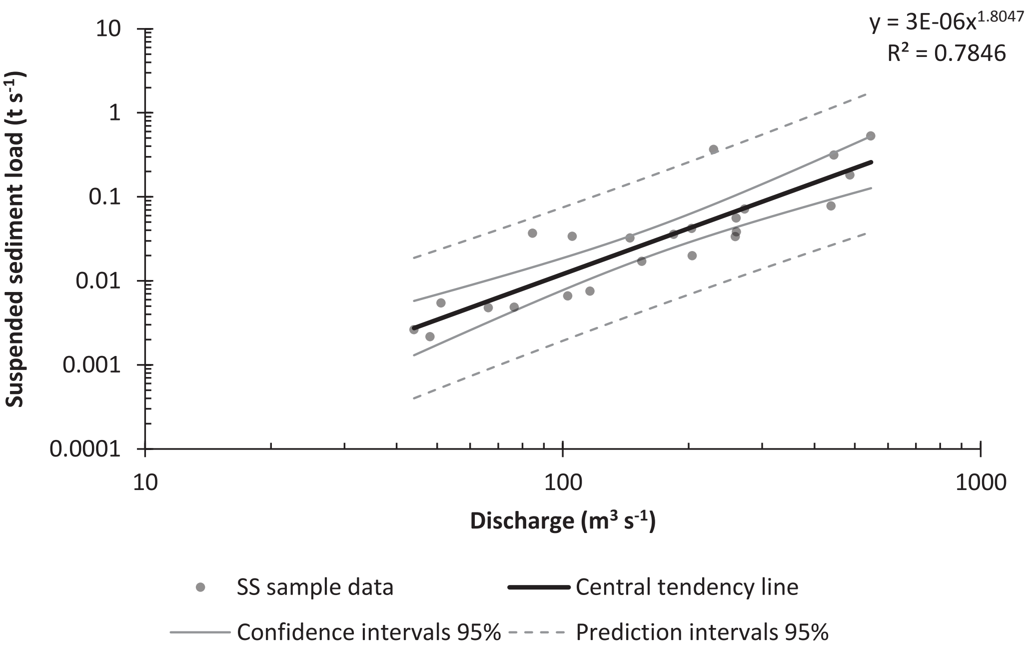

Figure 10.13 Suspended sediment rating curve for the San Carlos (BSC) sediment station.

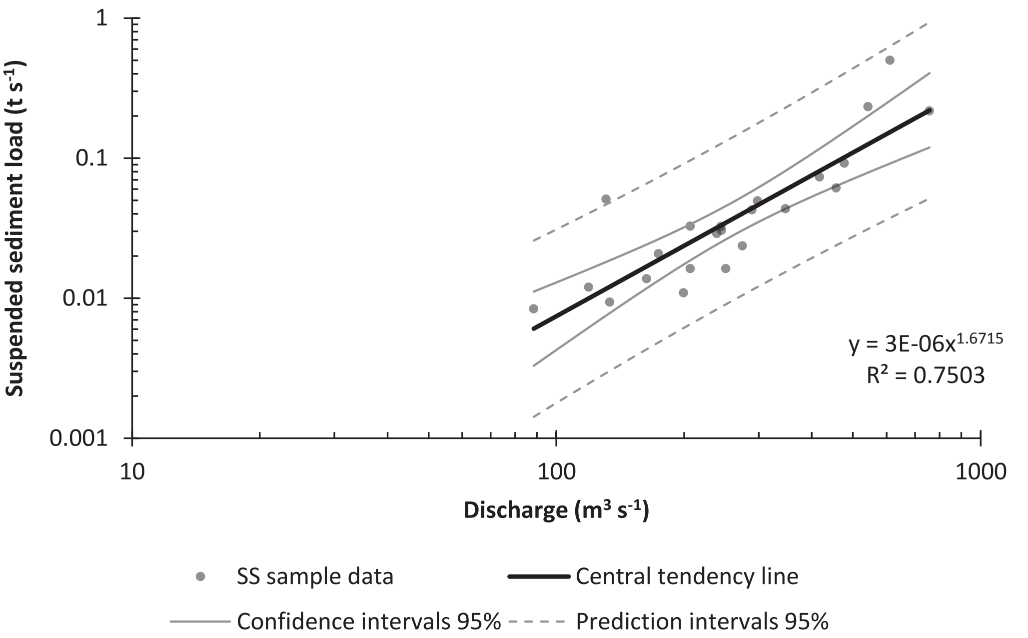

Figure 10.14 Suspended sediment rating curve for the Sarapiquí (BSa) sediment station

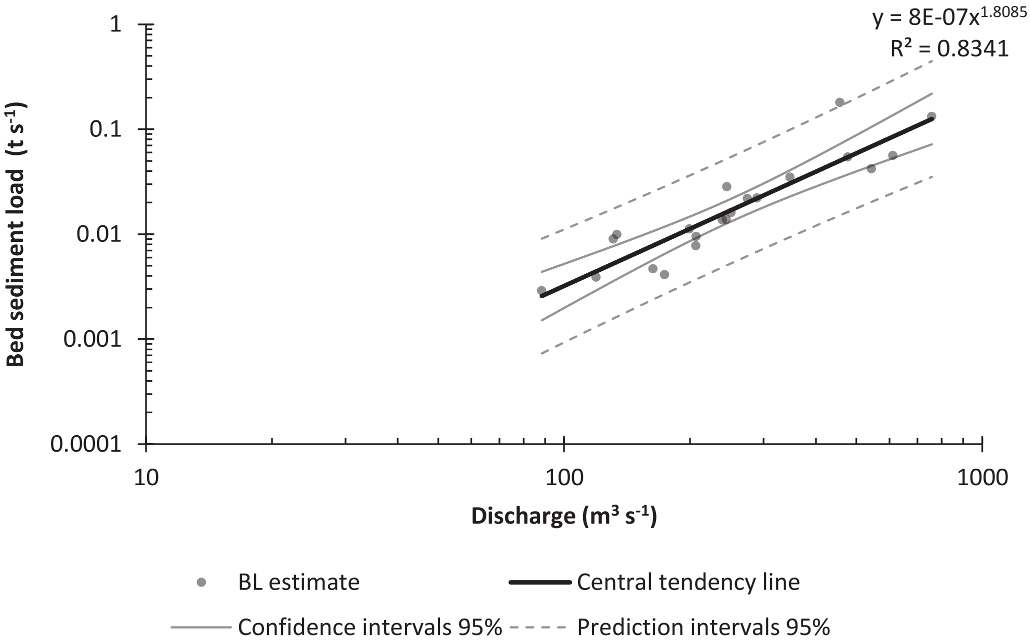

Figure 10.15 Bed sediment rating curve for the Sarapiquí (BSa) sediment station.

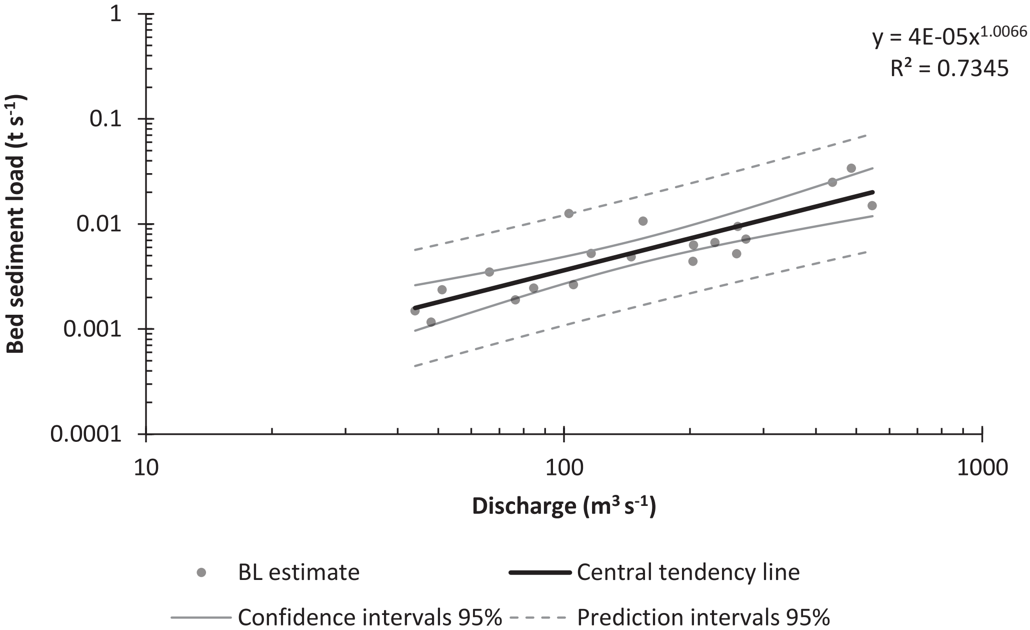

Figure 10.16 Bed sediment rating curve for the San Carlos (BSC) sediment station.

ANNEX 6

Bernald Pacheco Chaves

Response to and Analysis of "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua", July 2014 (Ríos Touma 2014)

October 2014

Technical Report

Response to and Study Analysis of

"Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua",

July 2014 (Ríos Touma 2014).

By

Bernald Pacheco Chaves, Lic. MPM

For

Tropical Science Center

October 2014

This analysis is developed in response to the criticisms made by Dr. Ríos Touma in "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua", July 2014 (Annex 4 to Nicaragua's Reply) concerning the macroinvertebrates study included in the EDA Ecological Component of Route 1856, 2013. In addition, a critical analysis of Dr. Ríos' study is presented.

Bernald Pacheco Chaves is a Costa Rican biologist who has worked in the field of Freshwater Biology in Costa Rica during the last 10 years; he is an Associate Investigator at the Zoology Museum of the University of Costa Rica, where he contributes in the area of Aquatic Entomology and is also Manager of Aquatic Bio monitoring Laboratory AquaBioLab S. A. He has written more than 100 technical studies for environmental impact assessments, most of which are related to the aquatic component. The author's curriculum vitae is included in Appendix A.

1. Response to the criticisms made in the study "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua", July 2014 by Dr. Ríos Touma to the macro invertebrate analysis included in the EDA Ecological Component, CCT 2013

The study by Ríos Touma (2014) states that the 2013 EDA Ecological Component presented no conditions of reference for the rivers where macro invertebrates were sampled, suggesting it was not understood that such reference was provided by the upstream sampling sites (with no direct influence, or target sites). The results in downstream sites (with direct influence of the routes) were compared with the results in upstream sites. The sampling method is clearly explained in the EDA Ecological Component, which was the main reason for not citing the source. Scientific support of the use of this method may be found in Ramirez (2010). Ríos Touma (2014) also contended that it is a deficiency of the EDA Ecological Component that it did not include a granulometry analysis; however, such analysis was not part of the scope and objectives of the EDA and it is not in the follow up ecological assessment. In both cases, the substrate was characterized using a qualitative method which classifies the substrate into blocks, boulders, gravel, sand, silt and clay.

Ríos Touma (2014) criticises the absence of any use of statistics in the macro invertebrate analysis. In fact, the analysis was based on the results of BMWP index adapted to Costa Rica. This index assigns sensitivity scores to macro invertebrates present in the water body, which are used as bioindicators; the most sensitive taxa are given a high score, the more tolerant are given a low score. Once the taxa present were rated, scores are summed up and this summation is compared to a set of categories to determine where it fits. Thus, each study site is given a value ranging from water of excellent quality to water of poor quality.

Ríos Touma (2014) refers to the statement in the EDA 2013 that in 1.5 years the macro invertebrate community has recovered. This is not an accurate reading of the EDA 2013 in its context. The EDA mentions the possibility that some results from the macro invertebrate analysis might have been affected by the fact that the civil works were started 1.5 years prior to the realization of the EDA. During the time elapsed, the macro invertebrate communities could have recovered by a natural resilient process.

Dr. Ríos criticizes the maps included with the EDA 2013, saying that they do not have explanatory legends, but in reviewing the maps of sampling sites included in the EDA 2013, we could not identify where such omission where. To the contrary, all maps have very clear explanatory legends that meet standard mapping practices.

2. **Analysis of the Study "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua", July 2014.**

Some deficiencies were found in the experimental model adopted in Ríos Touma (2014) study and its conclusions. Firstly, Dr. Ríos' study claims that the works of Route 1856 do not alter the deltas of north bank of the San Juan river, but do alter the deltas in the south bank. This statement implies that if there were any impact on the river, it is only restricted to the side of the river adjacent to Costa Rica. The assertion strongly contradicts the concept of riverfront continuum (Vannote *et al.* 1980), which conceptualizes the river as a continuum in which the composition of aquatic communities are changing from the upper basin, through mid and to lower basin, depending on environmental conditions. As a continuum, a strong sediment discharge would be expected to alter the conditions downstream not only and selectively on one bank but rather throughout the aquatic environment, altering both riversides and especially those sites that given their hydrological characteristics are likely to trap sediment and form deltas. Furthermore, if we took the statement by Ríos Touma (2014) that the deltas in the north bank of the river are not affected by sediment from the works of Route 1856, then we would have proof that there is no significant impact on the San Juan river, since the sampling sites in the north bank do not present impacts according to the same study. In summary, the claim that the north bank of the river was not affected by the works of Route 1856, contradicts the statement by Ríos Touma (2014) that the works of this route significantly degraded aquatic communities in the San Juan river.

A second error or omission in the experimental design by Ríos Touma (2014) is that the author does not consider the land use variables. According Roldán & Ramirez (2008), several factors determine the physical and morphological processes of rivers, including local climate, nature of riparian vegetation, land use in their area of influence and direct human intervention. The study by Ríos Touma (2014) applied a weak nonparametric statistical significance test to compare variables between the north bank on the Nicaraguan territory with dense forest cover at least on the banks of San Juan river (Reserve Indio Maiz), with the south bank of this river in Costa Rican territory, which as observed in field trips in 2013 (by land and air) and 2014 (by land) exhibit agricultural and livestock activities in most of the extension of Route 1856. The same study by Ríos Touma (2014) points out the difference in water temperature of the Nicaraguan tributaries to the San Juan river with lower temperature compared to the Costa Rican tributaries of this river which reported higher temperatures; the author attributes this difference to the scarce forest cover in Costa Rica territory. Land use is an important variable which was left out of the analysis performed by Ríos Touma (2014), questioning the validity of her assertion that the works of Route 1856 degraded significantly aquatic communities in the San Juan river.

The study by Ríos Touma (2014) presents an important sampling bias, firstly because 14 of the 16 sampling sites are concentrated in one section of the San Juan river, designated in the EDA 2013 as a critical section, between Infiernito and Boca San Carlos, and leaving most of the length of the project area without sampling (*i.e.* Boca San Carlos-Delta Costa Rica). Sampling sites were not randomly chosen and were remarkably concentrated on the stretch of Route apparently in worst conditions. Only 2 of the 16 sites are out of this critical stretch. This shows lack of objective criteria in the definition of the sampling sites.

The study by Ríos Touma (2014) attributed the accumulation of sediment in the deltas of the south margin of the San Juan river to the works of Route 1856; however, there is no baseline for objective, scientific comparison. To scientifically demonstrate an environmental change and attribute such a change to the construction of Route 1856, data on the conditions of the area prior to the construction would be necessary. The lack of such baseline data makes the attribution of the alleged harm to the works of Route 1856 questionable.

Another weakness in the study of Ríos Touma (2014) is the sampling method used, a sample of D Net with 2 minutes of total effort by sampling site. This is not considered a time sufficient effort to obtain a representative sample of benthic macro invertebrates in a sampling site. Reyes-Morales & Springer (2014) evaluated this method using several subsamples of 5 minutes and recommended a sampling effort of 10 minutes.

Ríos Touma (2014) mentions that many of the taxa found are sensitive to sediment; however, the author bases her argument on scientific literature studies in the United States (Zweig & Rabeni 2001; Carlisle *et al.* 2007). This has two major flaws: first, the studies that the author used as reference do not correspond to the study area, country or even the tropics. The environmental conditions found in temperate areas are very different from the tropics, and it has been reported that macroinvertebrates can respond differently to environmental stimuli even in different regions (Heino 2014). Secondly, the level of taxonomic resolution which it refers to reaches the family and gender level, which is normal in this type of studies; taxonomic identification to species level in macroinvertebrates is often not possible with the scientific literature published to date and it requires a high degree of taxonomic expertise to do so. For this reason, it is very difficult to know whether the species studied in the literature Ríos Touma uses as references correspond or do not correspond to species present in San Juan river; although we do not dismiss the possibility that some species be shared (e.g. some species of cosmopolitan distribution), it is very likely that such species are different from those found in the San Juan river. We should consider the fact that tolerances of macroinvertebrates to sediments may vary depending on the taxonomic resolution used (Bailey *et al.* 2001), and may vary even between different species within the same genus (Flowers 2009).

At this particular point, we detected a strong contradiction in the study of Ríos Touma (2014). On one hand, the author states that aquatic communities in the San Juan have been significantly degraded due to the release of sediments from the construction works of Route 1856; on the other hand, the author provides a list of taxa that she collected in the San Juan river, which are sensitive to sediment on the aquatic environment. Assuming the tolerances of these taxa were really applicable to the study site, Ríos Touma (2014) would be providing evidence on the presence of these "sensitive to sediment macroinvertebrates" in a claimed "degraded aquatic ecosystem". Thus, we could conclude aquatic communities did not suffer degradation as "macroinvertebrates sensitive to sediment" are present in the sampling sites in the San Juan river.

According to Roldán & Ramírez (2008):

> "the physicochemical nature of the waters of a drainage basin, as well as their biological productivity, are a function of the nature of its soil, its use and conservation status…The alluvial sandy and clay substrates are located in the lower reaches of rivers where the current is low. These types of substrate are very poor benthic fauna, as they are a very unstable environment for their establishment. The predominant wildlife here consists of organisms adapted to low oxygen potential, as oligochaetes, molluscs and chironomids (Diptera: Chironomidae). As the river is coming to the valley, the water speed decreases…From an ecological standpoint, water with high amounts of dissolved solids indicates high conductivity which can be a limiting factor for the life of many species as they are subjected to osmotic pressure. A high content of suspended solids or high turbidity is also limiting for the aquatic ecosystem, as it prevents the passage of sunlight, damages and plugs the gas exchange system in aquatic animals (gills, guts) and destroys their habitats natural".

In using macroinvertebrates as bioindicators of water quality it is very common to use the chironomids (Diptera: Chironomidae) as a bioindicator tolerant to changes in the environment (e.g. Sandoval & Molina Astudillo 2000), given that the scope of conditions under which chironomids can be found is more extensive than any other family of aquatic insects (Ferrington *et al.* 2008). At a more local level, the BMWP index adapted to Costa Rica gives this particular family a score of 2 on a 1-9 scale going from greater tolerance (score of 1) a lower tolerance (score 9) (MINAE-S 2007). If we analyze the number of individuals Ríos Touma (2014) presented in Annex 4 of the study, and estimate what percentage of those individuals are chironomids (Diptera: Chironimidae), 68% of the individuals collected belong to this group (829 out of 1219). Then, there is wide dominance of a taxon that is broadly considered as a bioindicator tolerant to impacts in the aquatic environment. Salvatiera *et al.* (2013) reached similar conclusions in a study conducted in the San Juan river; the authors sampled macroinvertebrates as bioindicators at 10 sampling stations along the Rio San Juan, using the artificial substrate method. They found that Chironomidae was present at the 10 sites, being predominant in relative abundance in 90% of them in dry season and 80% of them in the rainy season. Moreover, in applying a sampling method with dredge in 20 sampling sites distributed along the San Juan river, Chironomidae was predominant in 80% of the sites in the dry season, and in 65% of the sampling sites in the rainy season, with percentages ranging between 40 and 100% of individuals per sampling site at sites where this family was found in both seasons.

Conclusion

It is considered that the study of Ríos Touma (2014) does not provide valid evidence to demonstrate significant degradation of aquatic communities in the San Juan river due to sediment discharge by works in Route 1856.

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Appendix A – author's CV

Résumé

PERSONAL INFORMATION

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STUDIES

Colegio Académico Diurno de Palmares: High School.

Universidad de Costa Rica: Bachelor ("Licenciatura") in Biology.

Universidad Tecnológica y Pedagógica de Colombia: Intership.

Instituto Nacional de Aprendizaje: Open water diver (PADI License).

Instituto Tecnológico de Costa Rica, Fundatec: Regular and advanced conversational english.

Universidad para la Cooperación Internacional: Masters in Project Management.

Colegio de Biólogos de Costa Rica: Certification as Especialist in Limnology and Hydrobiology.

WORKING EXPERIENCE

2004 aug. - dec. Assistant at Laboratorio de Entomología, Escuela de Biología, Universidad de Costa Rica.

2004 feb.-2006 dec. Research Assistant at Laboratorio de Productos Forestales, Facultad de Ingeniería, Universidad de Costa Rica.

2007 aug.-dec. Assistant at Museo de Zoología, Escuela de Biología, Universidad de Costa Rica.

2007 oct. Assistant at Course: Tropical Agroecology (section of biomonitoring), Organization for Tropical Studies.

2007 mar.-2008 feb. Research Assistent for Ph. D. Thesis, University of Florida.

2008 mar.-jul. Assistant at Museo de Zoología, Escuela de Biología, Universidad de Costa Rica.

2008 mar.-dec. Assistant at Project of PROGAI-UCR (Integrated Management of the Jabonal River Watershed).

2008 oct.-nov. Consultant for Industrias Infinito S. A. Crucitas Gold Mine, Wildlife monitoring and rescue.

2009 nov. Invited Lecturer for Tropical Biology Course, Undergrad Studies Abroad Program (USAP), Organization for Tropical Studies (OTS).

2010 jan. Invited Lecturer for Tropical Field Ecology Course, Kent State University.

2011 oct.-2012 mar. Consultant at Research Project at Universidad de Costa Rica: "Hymenopteran Parasitoids Associated with Rice Crops in Costa Rica".

2013 abr-dic. Consultant at Environmental Impact Assessment of the Project of Systems of Drinking Water and Sewage of Bluefields City, RAAS, Nicaragua. VEOLIA-TECNITASA.

2013 may-oct, 2014 jul-nov. Consultant at Project of Environmental Diagnosis Assessment, Ruta 1856, Tropical Scientific Center.

2008 feb.-Present: Laboratorio de Biomonitoreo Acuático AquaBioLab S. A. (Manager since 2010 jul.). Studies in aquatic fauna (fresh water macroinvertebrates and fish) and limnology for different porpouses (environmental impact assessments, hydropower Projects, biomonitoring, industrial and agricultural pollution, mining, building, others).

2013 mar –Present: Associate Researcher, Museo de Zoología, Universidad de Costa Rica.

Professional Associations: Colegio de Biólogos de Costa Rica (1695); SETENA-MINAET (CI-214-2008); Wildlife Regent SINAC-MINAE (348-2011).

More than 100 Technical Studies made so far in Environmental Impact Assessment and Bio-monitoring.

OTHER STUDIES AND EXPECIENCES

2000 jun. Curso libre de Ecología de Manglares (UCR).

2007 set. I Simposium: Macroinvertebrados Acuáticos, Investigaciones y Biomonitoreo en Costa Rica (UCR).

2008. Lecturer of Aquatic Biomonitoring Workshops (PROGAI-UCR).

2008 feb. I National Congress: Gestión Integral, Retos y Oportunidades de la Sostenibilidad Ambiental en Costa Rica (UCR).

2009 jun. Miniforo IBEROEKA: Gestión de la Calidad del Agua (MICIT-CYTED).

2009 oct. Speech Presenter: Diversidad Taxonómica y Distribución de Chinches Patinadores (Hemiptera: Gerridae) en Costa Rica (UPTC, Boyacá, Colombia).

2009 oct. XIII Congress of the Mesoamerican Society of Biology and Conservation. Speech Presenter (Belize City, Belize).

2009 oct. 2010 set. Speech Presenter: Diversidad Taxonómica y Distribución de Chinches Patinadores (Hemiptera: Gerridae) en Costa Rica (UCR).

2009 nov. II Simposium: Macroinvertebrados Acuáticos y Limnología. Speech Presenter (UCR-CIMAR).

2009 dic. Course: Regencias de Manejo de Vida Silvestre (Colegio de Biólogos de Costa Rica-SINAC).

2010 nov. III Congreso Colombiano de Zoología. Magistral Conference Presenter. (Medellín, Colombia).

2010 jun.-2011 dec. Comission of Professional Tariffs Member (Colegio de Biólogos de Costa Rica).

2011 ago. Presentación de Resultados del PROMEBIO y Capacitación en el Manejo del Sistema de Información de Biodiversidad. Workshop Presenter (San Salvador, El Salvador).

2011 nov. Meeting Participant: Red de Macroinvertebrados Dulceacuícolas de Mesoamérica (MADMESO) (UCR).

2012 feb. Aquatic Mites Course: I Congreso Latinoamericano de Macroinvertebrados Acuáticos (UCR).

2012 feb. I Congreso Latinoamericano de Macroinvertebrados Acuáticos. Speech Presenter (UCR-CIMAR).

2012 oct. Competitive Advantages to Incorporation in Job Market Workshop Attendant, UCR, San José, Costa Rica.

2013 set. VIII Congreso Centroamericano y del Caribe de Administración de Proyectos "APCON 2013".

2013 oct. Sewage Treatment Systems Workshop, Universidad Nacional de Costa Rica, Guanacaste, Costa Rica.

2014 feb. XXX Congresso Brasileiro de Zoología, Co-Author of Poster, Porto Alegre, Brazil.

Participation in Expert Workshops and Meetings: 1 (El Salvador), 1 (Honduras), 6 (Costa Rica).

Software Experience (Office, ArcView, MAPSource, Past, Adobe Photoshop, OpenProj, MS Project, PC Ord, FBackup).

Sports: Japanese Martial Arts: Karate do (Sho dan), Iaido (Roku kyu), Jodo, Kobudo.

PUBLICATIONS

Scientific Articles

Oceguera-Figeroa, A; A. J. Phillips; **B. Pacheco-Chaves**; W. K. Reeves & M. E. Sidall (2010). Phylogeny of macrophagous leeches (Hirudinea, Clitellata) based on molecular data and evaluation of the barcoding locus. ZSC. 40: 194-203.

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Books

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PUBLICATIONS (In prep.)

Scientific Articles

Moreira F. F. F; **B. Pacheco-Chaves** & M. Spriger. (In prep). Two new *Rhagovelia* (Hemiptera: Heteroptera: Veliidae) from Costa Rica, with key and new records from the country.

Moreira F. F. F; **B. Pacheco-Chaves** & M. Springer (En prep.). Checklist and distribution of the family Gerridae (Hemiptera: Heteroptera) from Costa Rica.

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ANNEX 7

Arturo Angulo Sibaja

Environmental Diagnostic Assessment. Fish Fauna in the San Juan River.
Literature Review Report

November 2014

"Route 1856´s EDA Ecological Component Follow up Ecological Assessment"

TROPICAL SCIENCE CENTER

FISH FAUNA IN THE SAN JUAN RIVER

Literature Review Report

By

M.Sc. Arturo Angulo Sibaja

November 2014

AUTHOR´S BIOSKETCH

M.Sc. Arturo Angulo did his undergraduate and graduate studies at the University of Costa Rica, where he was also involved in several research projects at the Center of Marine Research and the Zoology Museum of the University of Costa Rica. As result of such research, several papers on the ichthyofauna of Costa Rica have been published in different international journals. In 2014, he was awarded with an OAS doctoral scholarship to study animal biology at the University Estadual Paulista, Brazil, and he will begin his studies this year (2015). His research interests center around systematics, taxonomy, biogeography and ecology of fishes, both freshwater (mainly neotropical) and marine (mainly deep-water).

INTRODUCTION

With the goal of providing technical criteria to assist in the analysis of potential impacts of the construction of Route 1856 on the San Juan River, and particularly their fishes, and because sampling in the river was not possible due to the refusal of Nicaragua to allow Costa Rica to carry out studies in the River, a literature review was conducted to find out the species of fish reported by previous studies for the San Juan river. This review is intended to obtain information about the presence, abundance and tolerance of fishes in environments with high sediment yields, at the species, genus and family levels in some cases.

In addition, information on fish species in the tributaries of the San Juan River was obtained, such tributaries providing both sediments and fish fauna to the San Juan river.

RESULTS OF REVIEW

Rojas and Rodriguez (2008), after a monitoring program of approximately one year (February 2004-April 2005) conducted in the Térraba River basin in the Pacific of Costa Rica, including disturbed and undisturbed environments, determined that there is no close relation between richness and abundance of fish species in the basin and water physicochemical variables such as suspended solids, dissolved solids and turbidity; these variables were measured in a total of 4 stations along the basin and associated with the total sediment load in the watershed. These authors recorded in this period and space, a total of 33 species and 14 families of fishes, the most diverse being Cichlidae (n = 5), Characidae (n = 4) and Poecilidae (n = 3) families. These families were also the most frequently collected (over 75% of all specimens caught). The authors demonstrated that environmental variables such as temperature, dissolved oxygen, seasonality (winter-summer) and proximity to the sea, are more important determining the structure and composition of fish communities in this basin.

Both Rojas and Rodriguez (2008) and Cotta-Ribeiro and Molina-Ureña (2009) reported the presence of "tepemechín" *Agonostomus monticola* (Mugilidae) in this basin, which has also been recorded in the San Juan River macro-basin (Bussing 1998). Besides "tepemechín" (*Agonostomos monticola*), Rojas and Rodriguez (2008) reported species such as *Poecilia gillii, P. mexicana* (Poeciliidae) and *Astyanax aeneus*, which have also been recorded in the San Juan river macro-basin (Bussing 1998). Rojas and Rodriguez (2008) also reported species such as *Archocentrus sajica, Astatheros altifrons, Theraps sieboldii* (Cichlidae) and *Priapichthys panamensis* (Poeciliidae), which have "ecological equivalents" (Bussing 1998) in the San Juan river macro-basin, namely *Archocentrus septemfasciatus, Astatheros alfari, Theraps underwoodii* and *Priapichthys annectens*, respectively.

Although Rojas and Rodriguez (2008) did not research the impact of the changes in environmental variables measured (suspended solids, dissolved solids and turbidity, amongst other) to the intraspecific level, in terms of the observed differences in the relative abundance values, given the general results, it can be inferred that differences in the values of these parameters in the water have no significant effect on the diversity and abundance of the relevant taxa, specifically Cichlidae, Characidae, Poeciliidae and Mugilidae families.

This could also apply to the San Juan macro-basin, under the assumption of ecological equivalence (Bussing 1998), and considering parameters which make the two basins comparable, such as the geological origin, land use, climate regime, life zones, the relative geographical proximity and vertical limits. With regards to vertical limits, it should be noted that the sampling in the Térraba basin was performed between 15-145 masl (Rojas and Rodriguez 2008), which overlap with the vertical area of the San Juan River macro-basin (1-31 masl).

Bonatti *et al.* (2005) determined the total sediment yield of the Térraba river basin at 404 ton/km2/year; this was attributed to the combination of a pattern of land use and rainfall erosion. According to the data presented by Rojas and Rodriguez (2008), such level of sediment yield seems not to exert a measurable effect on the dynamics and structure of fish populations in this region.

Similarly, Villegas (2011) reported no statistically significant differences between the abundance of fish species in rivers of the south Pacific region of Costa Rica with or without anthropogenic influence, nor in the capture of species. The most important physico-chemical variables of water in its model of canonical correlation were the flow speed and type of substrate, while variables such as temperature, pH, dissolved oxygen, percentage of oxygen saturation, salinity, oxygen reduction potential, conductivity, ion concentration, total dissolved solids and turbidity (most of them related to the total sediment yield in the basin) had no effect on the structure of fish communities. Villegas (2011) suggests that anthropogenic influences (pollution and sedimentation) in rivers assessed do not alter the conditions of water quality or the formation of assemblies of freshwater fish in the area. It also concludes that fluctuations of environmental variables, abundance, richness, distribution and fish diversity shown are normal and characteristic of these dynamic ecosystems.

Villegas (2011) reports in his study, a total of 24 fish species and 12 families; again, Poeciliidae family (n = 5), Cichlidae (n = 4) and Characidae (n = 4) had the highest diversity values and relative abundances. It is noteworthy that the species *Agonostomus monticola* (Mugilidae) was collected relatively frequently, as the seventh species with highest number of catches (3.37% on the total of catches).

Consistent with the results of Rojas and Rodriguez (2008) on the fishes of the Térraba river basin, Villegas (2011) states that variation in fish diversity and its taxonomic assemblages are a consequence of the discontinuities in geomorphology and structural complexity of ecosystems. So, there is no evidence that such values are associated with the physico-chemical conditions of the water, much less obtained by human impacts. This suggests some level of tolerance by fish communities in response to changes in these parameters (temperature, pH, dissolved oxygen, percentage of oxygen saturation, salinity, oxygen reduction potential, conductivity, ion concentration, total dissolved solids and turbidity).

For the Rio Frio basin, located in the northern Caribbean region of Costa Rica, Ortin *et al.* (2009) determined at 897.0 ton/km2/year, the total sediment yield, which as in the Térraba river is due to a combination of land use patterns and rainfall erosion. This value, when compared to those measured in other basins of the country, such as Térraba, can be considered high, exceeding 2.22 times the reported value for that basin by Bonatti *et al.* (2005). Despite these sediment yield values, in general the basin has a rich fish fauna consisting of a total of 52 species (Angulo *et al.* 2013), where Cichlidae (n = 15), Poeciliidae (n = 9) and Characidae (n = 8) families are dominant in terms of total number of species and relative abundances (Garita and Angulo 2009, Saenz *et al.* 2009). In comparison, the Térraba river basin has a fish fauna composed of a total of 88 species (Angulo *et al.* 2013); however, unlike the Rio Frio, the Térraba river is a coastal river in which the influence of the peripheral fish component (sensu Bussing 1998) is greater (Angulo *et al.* 2013). This could explain the differences in the absolute values of taxonomic diversity between the two basins. Regarding the dominance of the Cichlidae family in the Rio Frio basin, Saenz *et al.* (2009) point out that tolerance to environmental variations and genetic plasticity that characterize this family, influence the fact that this taxon is the best represented, as these attributes give it a more advantageous position over other components of the local fish fauna. Considering the values of total sediment yield reported for this basin, local fish tolerance or adaptation to such conditions could be inferred.

Saenz *et al.* (2009) also reported changes in the composition of fish species in the Rio Frio basin correlated with changes in rainfall levels. During the rainy season (May-September), these authors reported a greater diversity of species (20 vs. 17, during the time of lower rainfall, March-April). Several authors such as Black (1996), Restrepo (2005) and Arroyave-Rincón *et al.* (2012) have demonstrated a positive correlation between levels of rainfall and the total sediment yield in river basins in the tropics. Considering the results of Saenz *et al.* (2009) and this pattern of covariation, as it has been demonstrated for basins in south Pacific of Costa Rica, it could be inferred that a change in the values of sediment yield due to an increase in values of precipitation will not produce a harmful effect on the composition of the local fish fauna, in terms of total number of registered taxa. This would indicate, in accordance with the above, some degree of tolerance or natural adaptation of communities of fishes in the region, due to changes in levels of suspended solids, dissolved solids and turbidity associated with higher sediment yields.

For the Aranjuez river basin, located in the Central Pacific of Costa Rica, Tiffer-Sotomayor (2005) reports dramatic increases during flood events in the mean concentrations of total solids, dissolved solids and suspended solids. Such increases are more than a 51 times the basal levels (117.4 mg/L vrs. 6000 mg/L). In this basin, at least 10 fish species have been reported (Bussing 1998 Tiffer-Sotomayor 2005), including *Agonostomus monticola* (Mugilidae), *Astyanax aeneus* (Characidae), *Archocentrus nigrofasciatus* (Cichlidae) and *Poecilia gillii* (Poeciliidae), species which are also recorded for the San Juan River macro-basin (Bussing 1998, Angulo *et al.* 2013). After such flood events, Tiffer-Sotomayor (2005) does not report dramatic decreases in the relative abundances of these species. This might suggest some tolerance from such species to changes in the mean concentrations of total solids, dissolved solids and suspended solids associated with higher sediment yields as a result of seasonal changes in water levels. Similar conditions and effects have been reported in other basins of the country, Reventazón, San Carlos and Sarapiquí (PROCUENCA-San Juan 2004, Jimenez *et al.* 2005), for example, all of them located in the Caribbean slope and the San Carlos, and the Sarapiquí being part of the San Juan river macro-basin.

Throughout history, the San Juan River macro-basin has undergone a natural sedimentation process its discharge being made through two sites: the Bay or Lagoon of San Juan del Norte, where sediments are accumulated, and the mouth of the Colorado River in Costa Rica, where higher flow discharge occurs (PROCUENCA-San Juan 2004). Particularly, the Colorado River, part of the Tortuguero river basin is home to one of the most diverse freshwater fish fauna of Central America (Bussing 1998, Angulo *et al.* 2013), with about 115 species reported, 46% of the total species known to Costa Rica (Angulo *et al.* 2013). In this basin, families such as Cichlidae (n = 16), Poeciliidae (n = 9) and Characidae (n = 8) are dominant (Angulo *et al.* 2013). A similar pattern in terms of diversity and high levels of sedimentation occurs in adjacent basins, some of them part of the San Juan River macro-basin, where the values of total sediment yield exceed 600.0 ton/km2/year (PROCUENCA-San Juan 2004). For example, in Terrón Colorado station, located on the San Carlos River, a total sediment yield of 817.0 ton/km2/year is reported (PROCUENCA-San Juan 2004). In this basin (San Carlos) Bussing (1998) and Angulo *et al*. (2013) reported a total of 54 fish species; again Cichlidae (n = 15), Poeciliidae (n = 10) and Characidae (n = 8) being dominant.

The Peñas Blancas station, specifically, located on the river of the same name and also part of the San Carlos river basin, has reported a total sediment load of 700.0 ton/km2/year (PROCUENCA-San Juan 2004); in turn, Molina (2008) reports a total of 31 fish species in this sub-basin (Peñas Blancas), where Cichlidae (n = 10), Characidae (n = 5) and Poeciliidae (n = 4) are the dominant groups. Meanwhile, in the Reventazón river basin, which drains into the Caribbean Sea, have been reported (in the Cachí dam station) values of sediment yield up to 1158.9 ton/km2/year (Jimenez *et al.* 2005). In this basin, as in previous cases, a large fish diversity also has been reported, consisting of a total of 65 species; Cichlidae (n = 15), Poeciliidae (n = 6) and Characidae (n = 5) have the greatest diversity (Molina 2011). It should be emphasized that in the Colorado, San Carlos and Reventazón basins, the presence of *Agonostomus monticola* (Mugilidae) has also been reported (Bussing 1998, Molina 2011, Angulo *et al.* 2013). The presence of these taxa in rivers with high sediment yields might suggest high levels of tolerance, as various authors have suggested (Bussing 1998 Tiffer-Sotomayor, 2005, Rojas and Rodriguez 2008, Saenz *et al.* 2009), and is supported by the present revision.

Finally, it has been reported that some piscivorous and insectivorous fish are, to some extent, able of preying better under conditions of high concentrations of suspended solids and turbidity (Chesney 1993, Berry and Hill 2003). This has been attributed to a greater contrast between the pray and the surrounding water, which facilitates prey identification by the predator and makes the predator difficult to detect by the prey (Chesney 1993, Berry and Hill 2003). In the San Juan River macro-basin, a wide variety of piscivorous and insectivorous species has been reported (Bussing 1998); species such as "guapotes" (*Parachromis dovii* and *P. managuensis*, Cichlidae), "pepesca gaspar" *Belonesox belizanus* (Poeciliidae), beaked sardine *Bramocharax bransfordii* (Characidae), "barbudos" (*Rhamdia* spp.) and gar fish (*Atractosteus tropicus*), most of them of economic importance (Bussing 1998) and relatively common in some parts of the macro-basin. Several of these species (*Parachromis* spp, *Belonesox belizanus* and *Atractosteus tropicus*, for example), are particularly abundant in lentic environments with high levels of suspended solids and high turbidity (for example, in areas of Caño Negro and Medio Queso within the Rio Frio basin) (Bussing 1998, Garita and Angulo 2009, Saenz *et al*. 2009). It could then be inferred that there is some degree of tolerance or even adaptation of such species to high levels of sediment, as suggested by Chesney (1993) and Berry and Hill (2003).

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APPENDIX A: CURRICULUM VITAE

Arturo Angulo Sibaja, M.Sc.

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Education
-B.Sc. Biology, Universidad de Costa Rica (2005-2009).
-M.Sc. Biology (with honours), Universidad de Costa Rica (2010-2014).

Languages
-Spanish (100%)
-English (Read 80%, Write 75%, Speak 50%).
-Portuguese (Read 90%, Write 75%, Speak 75%).

Current position
-Research collaborator, assistant curator and database manager, at the fish collection of the Museo de Zoología, Escuela de Biología, Universidad de Costa Rica.

Work experience
-Laboratory of General Biology, Escuela de Biología, Universidad de Costa Rica (2007-2008): Preparation and installation of laboratories (practices), management of equipment, specimens and reagent preparation.
-Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Universidad de Costa Rica (2010-currently): Collaboration in the field and identification in laboratory of ichthyological specimens for multiple projects:

> -Deep-sea fishes from the Pacific of Costa Rica (2010-2013; Responsible: Lic. Myrna López Sánchez).
> -Effects and recovery in the aquatic communities in the Sarapiqui River Basin against the earthquake of Cinchona, Heredia-Alajuela Costa Rica (2011; Responsible: M.Sc. Gerardo Umaña Villalobos).
> -Terms of eutrophication in lakes and reservoirs of Costa Rica (2011; Responsible: M.Sc. Gerardo Umaña Villalobos).
> -Assessment and monitoring of fishery resources, Golfo Dulce, Pacífico de Costa Rica (2012-currently; Responsible: Ph.D. Helena Molina Ureña).
> -Collection of otoliths and soft tissues of fresh-water and marine fishes of Costa Rica (2013-currently; Responsibles: Lic. Myrna López Sánchez and M.Sc. Arturo Angulo Sibaja).

-Unidad de Investigación Pesquera (UNIP), CIMAR, Universidad de Costa Rica (2012): Collaboration in the field and identification in laboratory of ichthyological specimens for multiple projects:

> -Distribution and trophic dynamics of demersal sharks and rays of the continental shelf of the Pacific Costa Rica (2011-2012; Responsible: M.Sc. Mario Espinoza).

-Demersal sharks and rays of the Pacific continental shelf of Costa Rica: location of important reproductive sites and developing recommendations for sustainable management (2011-2012; Responsible: Ph.D. Ingo W. Wehrtmann).

-Independent consultant:

-Instituto Nacional de Biodiversidad (INBio) (2009): Field work and laboratory identification of ichthyological specimens for the project "Sustainable Development of the Rio Frio basin (Diagnostics for assessing the extension or the declaration of a management category in the Rio Frio and / or Medio Queso wetland; rapid ecological Assessment)".

-AquaBiolab S.A. (since 2010): Aquatic biomonitoring.

-International Game Fish Association (IFGFA) (since 2010): Identification of specimens and records validation.

Teaching experience

-School of Biology, University of Costa Rica:

-Laboratory of general biology (B-0107), Instructor (2007-2008).

-Freshwater fishes of Costa Rica: diversity and ecology (B-0798), Instructor (2009-2010-2011-2012-2013-2014).

-Laboratory of introduction to biology II (B-0163), Instructor (2010).

-Aquaculture (B-0347), Instructor (2010-2011-2012-2013-2014).

-Natural History of Costa Rica (B-0300), Instructor (2010-2011-2012-2013-2014).

-Aquinas College Costa Rica Program, Aquinas College, Michigan (E.E.U.U.) – Municipality de Santa Ana, San José (Costa Rica):

-Tropical Ecology/Ecología Tropical (SH260), Professor (2012-2013-2014).

-Tirimbina Biological Reserve– Asociación Costarricense de Acuarismo y Conservación de los Ecosistemas Dulceacuícolas, La Virgen de Sarapiquí:

-Diversity and ecology of freshwater fishes of Costa Rica, Professor (2014).

Scientific publications

(1) Matamoros W.A., P. Chakrabarty, **A. Angulo**, C.A. Garita-Alvarado, & C.D. McMahan (2013) A new species of *Roeboides* (Teleostei: Characidae) from Costa Rica and Panama, with a key to the middle American species of the genus. *Neotropical Ichthyology*, 11, 2, 285-290.

(2) **Angulo, A.,** C.A. Garita-Alvarado, W.A. Bussing & M.I. López (2013) Annotated checklist of the freshwater fishes of continental and insular Costa Rica: additions and nomenclatural revisions. *Check list*, 9 (5), 987-1019.

(3) **Angulo, A.** & J.M. Gracian-Negrete (2013) A new species of *Brycon* (Characiformes: Characidae) from Nicaragua and Costa Rica, with a key to the lower Mesoamerican species of the genus. *Zootaxa*, 3731 (2), 255-266.

(4) **Angulo, A**. (2013) Nombres comunes y técnicos de los peces de agua dulce de Costa Rica. *Filología y Lingüística*, 39 (2), 77-103.

(5) **Angulo, A**. (2014) First record, and range extension, of the Mocosa ruff *Schedophilus haedrichi* (Perciformes: Centrolophidae) from the Pacific coast of Costa Rica. *Marine Biodiversity Records*, 7 (2014), e70 (4).

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(7) **Angulo, A.,** M.I. López, W.A. Bussing & A. Murase (2014) Records of Chimaeroid fishes (Holocephali: Chimaeriformes) from the Pacific coast of Costa Rica, with the description of a new species of *Chimera* (Chimaeridae) from the eastern Pacific Ocean. *Zootaxa*, 3861 (6), 554-574.

(8) Murase, A., **A. Angulo**, Y. Miyazaki, W.A. Bussing & M.I. López (2014) Marine and estuarine fish diversity in the inner Gulf of Nicoya, Pacific coast of Costa Rica, Central America. *Check List*, 10 (6), 1401-1413.

(9) **Angulo, A.,** B. Naranjo-Elizondo, M. Corrales-Ugalde & J. Cortés (2014) First record of the genus *Paracaristius* (Perciformes: Caristiidae) from the Pacific of Central America, with comments on their association with the siphonophore *Praya reticulata* (Siphonophorae: Prayidae). *Marine Biodiversity Records,* 7 (e132), 1-6.

(10) Del Moral-Flores, L.F., E. Ramírez-Antonio, **A. Angulo** & G. Pérez-Ponce de León (In press). *Ginglymostoma unami* sp. nov. (Chondrichthyes: Orectolobiformes: Ginglymostomatidae), una nueva especie de tiburón gata del Pacífico oriental tropical. *Revista Mexicana de Biodiversidad*.

(11) **Angulo, A.**, M. López, W. Bussing, A.R. Ramírez-Coghi & G. Arias-Godínez (In press) Colección Ictiológica del Museo de Zoología de la Universidad de Costa Rica. *En:* Del Moral-Flores, F., J.A., Martínez-Pérez & A.J. Ramírez-Villalobos. *Colecciones ictiológicas de Latinoamerica.* Editorial de la Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México.

(12) **Angulo, A.**, G. Arias-Godínez, M. López & W. Bussing (In press) Catálogo de material tipo depositado en la colección ictiológica del Museo de Zoología de la Universidad de Costa Rica. *En:* Del Moral-Flores, F., J.A., Martínez-Pérez & A.J. Ramírez-Villalobos. *Colecciones ictiológicas de Latinoamerica*. Editorial de la Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México.

(13) **Angulo, A.,** W.A. Bussing & M.I. López (In review) Occurrence of the Ventrad spiderfish *Bathypterois ventralis* (Aulopiformes: Ipnopidae) in the Pacific coast of Costa Rica. *Revista Mexicana de Biodiversidad*.

(14) **Angulo, A.** (In review) *Cetomimus gillii* Goode & Bean 1895 (Cetomimiformes: Cetomimidae): range extension and first record in the Tropical Eastern Pacific. *Marine Biodiversity Records*.

Manuscripts submitted

(15) Del Moral-Flores, L.F. & **A. Angulo** (In review) Catálogo de los peces mexicanos depositados en el Museo de Zoología de la Universidad de Costa Rica (UCR). *Universidad y Ciencia*.

(16) Del Moral-Flores, L.F., **A. Angulo**, M.I. López & W.A. Bussing (In review) Nueva especie del género *Urobatis* (Myliobatiformes: Urotrygonidae) del Pacífico oriental tropical. *Revista de Biología Tropical*.

(17) Molina-Arias, A., **A. Angulo**, A. Murase, Y. Miyazaki, W. Bussing & M. López (In review) Fishes from the Tusubres River basin, Pacific coast, Costa Rica: Checklist, identification key and photographic album. *Check list.*

(18) Cruz-Mena, O.I. & **A. Angulo** (In review) First record, and range extension, of the Pacific hagfish *Eptatretus stoutii* (Myxiniformes: Myxinidae) from the Pacific coast of Costa Rica. *Acta Ichthyologica et Piscatoria*.

(19) Cruz-Mena, O.I. & **A. Angulo** (In review) Filling gaps on the distribution of the Whiteface hagfish *Myxine circifrons* (Myxiniformes: Myxinidae) in the Pacific coast of Costa Rica and Central America. *Check list.*

(20) Cruz-Mena, O.I. & **A. Angulo** (In review) First record of the Snipe eels *Nemichthys scolopaceus* and *Avocettina bowersi* (Anguilliformes: Nemichthyidae) from the Pacific coast of Costa Rica. *Cybium*.

Manuscripts in preparation

(21) **Angulo, A.** (In preparation) Records of Lampridiform fishes from the Pacific coast of Costa Rica. *Journal of fish biology*.

(22) **Angulo, A.**, M.I. López, W.A. Bussing, H. Molina-Ureña & M. Espinoza (In preparation) Deep-water fishes of the Pacific of Costa Rica: an annotated catalog of species with comments on zoogeographical affinities. *Zootaxa*.

Technical reports

(1) Garita, C. & **A. Angulo**. 2009. Evaluación ecológica rápida de peces de Río Frío y Humedal Medio Queso. Informe final. Proyecto Desarrollo Sostenible de la Cuenca de Río Frío. AECID, INBio, ACAHN-MINAET-SINAC. 21 p. (http://www.proyectorioFrío.org/pdf/Evaluacionecologicarapida.pdf).

Popular works

(1) **Angulo, A.** (2011) *Peces dulceacuícolas de Costa Rica*. Avalaible at: http://pecesdulceacuicolascr.jimdo.com.

(2) **Angulo, A.** & C.A. Garita-Alvarado (2013) *Peces comunes de la cuenca del río Sarapiquí, Costa Rica*. Editorial Ciencia, Arte y Tecnología (CA&T) S.A., 135 pp.

Scientific reviewer

-Revista de Biología Tropical (2013).

Research internships

-Louisiana State University Museum of Natural Sciences, Louisiana State University (E.E.U.U.). Julio 2011. Responsibles: Ph.D.c. Caleb McMahan, Ph.D. Wilfredo Matamoros, and Ph.D. Prosanta Chakrabarty.

-Separation and identification of ichthyological material collected in Costa Rica and Panama and review of specimens of *Roeboides* spp. (Characidae) for the description of *R. bussingi*.

-Colección Nacional de Peces, Instituto de Biología, Universidad Nacional Autónoma de México (México). Marzo 2013. Responsibles: M.Sc. Héctor Espinosa Pérez, and M.Sc. Luis Fernando del Moral Flores.

-Review of ichthyological material collected in deepwaters and of specimens of Brycon guatemalensis (Characidae) for the description of B. costaricensis.

Meetings and conferences

(1) **Angulo, A.** & C. Méndez-Vásquez (2012) *Avifauna de Isla Grande, Golfito*. III Congreso costarricense de Ornitología. Escuela de Biología, Universidad de Costa Rica. Poster.

(2) **Angulo, A.** (2012) *Ecomorfología trófica de algunas especies de peces (Pisces, Perciformes) asociadas a arrecifes rocosos/coralinos en la costa pacífica de Costa Rica*. I Congreso de Morfometría. Universidad del Mar, Puerto Angel, Oaxaca, México. Poster.

(3) **Angulo, A.** & C. Méndez-Vásquez (2012) *Análisis morfométrico de tres especies de Astyanax (Characiformes, Characidae) de Centroamérica*. I Congreso de Morfometría. Universidad del Mar, Puerto Angel, Oaxaca, México. Talk.

(4) Méndez-Vásquez, C. & **Angulo, A.** (2012) *Morfogeometría comparada de las especies simpátricas Parachromis friedrichsthalii y P. loisellei (Perciformes, Cichlidae) en Centro América*. I Congreso de Morfometría. Universidad del Mar, Puerto Angel, Oaxaca, México. Poster.

(5) Bussing-Burhaus, W.A., M.I. López-Sánchez, A.R. Ramírez-Coghi, **A. Angulo** & F. Jiménez Hernández (2012) *Diversidad íctica costarricense*. I Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad de Ciencias y Artes de Chiapas, San Cristobal de las Casas, Chiapas, México. Talk.

(6) **Angulo, A.** (2012) *Composición y estructura de las comunidades de peces en los ríos Corozal y Cañaza, Golfito, Puntarenas, Costa Rica*. I Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad de Ciencias y Artes de Chiapas, San Cristobal de las Casas, Chiapas, México. Poster.

(7) **Angulo, A.,** F. Jiménez Hernández, M.I. López-Sánchez & W.A. Bussing-Burhaus (2012) *Diversidad de peces de aguas profundas en el pacífico de Costa Rica*. I Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad de Ciencias y Artes de Chiapas, San Cristobal de las Casas, Chiapas, México. Cartel. Talk

(8) **A. Angulo**, C.A. Garita-Alvarado & B. Naranjo-Elizondo (2012) *Diversidad ictiofaunistica de la cuenca del río Sarapiquí, Costa Rica.* I Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad de Ciencias y Artes de Chiapas, San Cristobal de las Casas, Chiapas, México. Poster.

(9) **Angulo, A.**, M.I. Lopez-Sánchez & A.R. Ramírez-Coghi (2013) *Cuatro nuevos registros de quimeras (Holocephali: Chimaeriformes) para el Pacífico de Centroamerica Meridional*. II Simposio Latinoamericano de Ictiología. Universidad de San Carlos de Guatemala/Sociedad Iciológica Mexicana, Antigua, Guatemala. Poster.

(10) **Angulo, A.**, M.I. López-Sánchez & W.A. Bussing-Burhaus (2013) *Peces de aguas profundas del Pacífico de Costa Rica: diversidad y afinidades biogeográficas*. II Simposio Latinoamericano de Ictiología. Universidad de San Carlos de Guatemala/Sociedad Iciológica Mexicana, Antigua, Guatemala. Talk.

(11) Bussing-Burhaus, W.A., M.I. López-Sánchez, A.R. Ramírez-Coghi, **A. Angulo**, G. Arias-Godínez (2013) *El acervo de la colección ictiológica del Museo de Zoología de la Universidad de Costa Rica (UCR)*. II Simposio Latinoamericano de Ictiología. Universidad de San Carlos de Guatemala/Sociedad Iciológica Mexicana, Antigua, Guatemala. Cartel. Talk.

(12) Pedraza-Marrón, C. del R., O. Puebla-Ranz, A.I. Domingo, **A. Angulo**, C. Garita-Alvarado, J.E. Barraza, E. Espinoza y O. Domínguez-Domínguez (2013) *Relaciones filogenéticas de las especies del género Malacoctenus (Labrisomidae) en el Pacífico Oriental Tropical*. II Simposio Latinoamericano de Ictiología. Universidad de San Carlos de Guatemala/Sociedad Iciológica Mexicana, Antigua, Guatemala. Talk.

(13) López-Sánchez, M., W. Bussing-Burhaus, A.R. Ramírez-Coghi y **A. Angulo** (2013) *Colección Ictiológica del Museo de Zoología de la Universidad de Costa Rica (UCR)*. I Encuentro de Curadores de Colecciones Zoológicas y Botánicas Estatales. Universidad de Costa Rica, San José, Costa Rica. Talk.

(14) **Angulo, A.**, M.I. López-Sánchez & W.A. Bussing-Burhaus (2014) *Estado actual del conocimiento ictiológico en Costa Rica*. I Simposio estudiantil, Escuela de Biologia, Universidad de Costa Rica. Universidad de Costa Rica, San José, Costa Rica. Talk.

(15) **Angulo, A.**, M.I. López-Sánchez & W.A. Bussing-Burhaus (2014) *Diversidad ictiológica en Costa Rica: estado actual del conocimiento y papel del Museo de Zoologia de la Universidad de Costa Rica*. VII Congreso Nacional de Biología. Colegio de Biólogos de Costa Rica, San José, Costa Rica. Talk.

(16) Méndez-Vásquez, C., **A. Angulo** & L. Sandoval (2014) *Efecto de dos tipos de depredadores sobre el comportamiento de respuesta de Melozone leucotis (Aves: Emberizidae)*. IV Congreso costarricense de Ornitología. Universidad Latina, San José, Costa Rica. Talk.

(17) Torres, E., G. Palacios-Morales, **A. Angulo**, E. Espinoza & O. Domínguez-Domínguez (2014) *Barcode of life suggests that Canthigaster punctatissima, C. janthinoptera, and C. jactator (Tetraodontidae) are synonyms*. 2nd Fish Barcode of Life World Conference. El Colegio de la Frontera Sur, Chetumal, Mexico. Poster.

(18) **Angulo, A.**, G. Arias-Godínez, A.R. Ramírez-Coghi & M.I. López-Sánchez (2014) La colección de tejidos de peces del Museo de Zoología de la Universidad de Costa Rica (CTP-UCR). III Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad Michoacana de San Nicolas de Hidalgo, Morelia, Michoacan, Mexico. Poster.

(19) **Angulo, A.**, G. Arias-Godínez, A.R. Ramírez-Coghi & M.I. López-Sánchez (2014) La colección de otolitos sagita de peces actinopterigios del Museo de Zoología de la Universidad de Costa Rica (COP-UCR). III Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad Michoacana de San Nicolas de Hidalgo, Morelia, Michoacan, Mexico. Poster.

(20) **Angulo, A.**, M.I. López-Sánchez, W.A. Bussing-Burhaus, H. Molina-Ureña & M. Espinoza (2014) Peces de aguas profundas del Pacifico de Costa Rica: un catálogo comentado de las especies con notas sobre sus afinidades biogeográficas. III Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad Michoacana de San Nicolas de Hidalgo, Morelia, Michoacan, Mexico. Talk.

(21) **Angulo, A.**, M.I. López-Sánchez & W.A. Bussing-Burhaus (2014) Adiciones a la ictiofauna marina de Costa Rica. III Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad Michoacana de San Nicolas de Hidalgo, Morelia, Michoacan, Mexico. Poster.

(22) Achí-Castro, L., **A. Angulo** & M.I. López-Sánchez (2014) Ilustración científica: Peces de aguas profundas del Pacifico de Costa Rica. III Simposio Latinoamericano de Ictiología. Sociedad Iciológica Mexicana/Universidad Michoacana de San Nicolas de Hidalgo, Morelia, Michoacan, Mexico. Poster.

Workshops

-Universidad de Costa Rica, San José, Costa Rica:
- -Analysis of themes of bioethics (20 hours; 2005).
- -Geometric morphometrics applied to taxonomy (20 hours; 2012).
- -Training and upgrading in chemistry for laboratory assistants and aides, modules I and II (80 hours; 2014).

-Universidad del Mar, Puerto Angel, Oaxaca, México; as part of the I Congreso de Morfometría:
- -Biomechanics and Ecomorphology in vertebrates (4 hours; 2012).
- -Morphological evolution (4 hours; 2012).

-Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Hidalgo, Pachuca Hidalgo, México.
- -Introduction to geometric morphometric (40 hours; 2013)

-Sistema Costarricense de Información sobre Biodiversidad (CRBio) in collaboration with the Global Biodiversity Information Facility (GBIF), the Atlas of Living Australia (ALA) and the Universidad de Costa Rica, San José, Costa Rica:
- -Tools for management, dissemination and use of information on biodiversity (16 hours; 2013).

-Universidad Latina, San José, Costa Rica; as part of the IV Congreso costarricense de Ornitología.
- - Introduction to bioacoustics (4 hours; 2014).

Scientific societies and organizations

-Unión de Ornitólogos de Costa Rica (since 2010).
-Sociedad Ictiológica Mexicana (since 2012).
-Vice-precident of the Asociación Costarricense de Acuarismo para la conservación de los Ecosistemas Dulceacuícolas (since 2013).

Grants

- Louisiana State University Museum of Natural Science, Louisiana State University (E.E.U.U.):
    - -Travel grant, 1000$ (2011).
- -Vicerrectoría de Vida Estudiantil, Universidad de Costa Rica:
    - -Travel grant, 400$ (2012).
- -Sistema de Estudios de Posgrado, Universidad de Costa Rica:
    - -Travel grant, 1200$ (2012).
    - -Travel grant, 1000$ (2014).
- -Vicerrectoría de Administración/Rectoría, Universidad de Costa Rica:
    - -Travel grant, 1000$ (2012).
    - -Travel grant, 834$ (2013).
- -Red Latinoamericana de Ciencias Biológicas (RELAB):
    - -Travel grant, 500$ (2013).
- -Field Museum of Natural History, Chicago (E.E.U.U.):
    - -Travel grant (Visiting Scholarship), 2500$ (2015).
- -Smithsonian Institution's National Museum of Natural History, Washington (E.E.U.U.):
    - -Travel grant (Visiting Scholarship), 3000$ (2015).
- -Coimbra Group of Brasilian Universities – Organization of American States:
    - -Doctoral fellowship, $70000 (2015-2019).

Areas of interest

- -Ichthyology.
    - -Systematics and taxonomy of tropical fishes.
    - -Ecology, behavior and natural history of tropical fishes.
    - -Bioacoustics.
    - -Biogeography, genetics and phylogeography of tropical fishes.
    - -Comparative morphometry.
- -Ornithology.
    - -Systematics and taxonomy of Neotropical birds.
    - -Bioacoustics.
    - -Biogeography.
- -Natural History of Costa Rica.
- -Conservation biology.
- -Experimental design and multivariate tatistics.
- -Geometric morphometrics.

Skills and techniques

-Experience in identifying, collecting, handling (for scientific purposes, collects license valid in Costa Rica, issued by the National System of Conservation Areas (SINAC), according to Resolution No. 007-2013-SINAC) and curation of ichthyological specimens (marine (coastal, pelagic, reef, demersal and deepwater) and freshwater) and in the maintenance of ichthyological collections.

-Experience In the capture, handling, collecting and identification of amphibians, reptiles, birds and aquatic macroinvertebrates, and in implementing the BMWP-CR index for determining water quality.

-Experience in the collection, preparation and identification of plant samples.

-Experience in experimental design and statistical analysis; use of statistical packages (PAST, STATISTICA, JMP, SYSTAT).

-Experience in geometric morphometric analysis; use of programs and statistical packages (IMP, TPS, Morpho J, PAST).
-Management of scientific collections and associated data (File Maker, Specify, Microsoft Excel) and online databases (GBIF Fishnet2).
-Management and analysis database (File Maker, Microsoft Excel).
-Management of computer software and satellite positioning, Geographic Information Systems (GIS) and spatial analysis of ecological data (ArcGIS 9.3, ArcView 3.3).
-Software/Office packages (Word, Powerd Point, Excel, Outlook, Adobe).
Social-Networks (Facebook, Twitter, Google+, Linkedin, ResearchGate).
-Scientist drawing.
-Management and maintenance of aquariums.

ANNEX 8

Pablo E. Gutiérrez Fonseca

Critical statistical analysis of the report "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua" by Blanca Ríos Touma,

November 2014

Report: Critical statistical analysis of the report "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua" by Blanca Ríos Touma, included in Annex 4 in Volume II "Reply of the Republic of Nicaragua: Dispute concerning construction of a road in Costa Rica along the San Juan River (Nicaragua v. Costa Rica)"

By Pablo E. Gutierrez Fonseca

Licenciado in Water Resources, University of Costa Rica

Doctoral Candidate in Ecology and Systematics, University of Puerto Rico, Puerto Rico

A Introduction

In the report titled "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua" (the ***Ríos Report***), which is included as Annex 4 in Volume II of "Reply of the Republic of Nicaragua: Dispute concerning construction of a road in Costa Rica along the San Juan River (Nicaragua v. Costa Rica)", methods and statistical analysis were used to interpret certain data (biological and physicochemical) collected at eight sites (rivers) on the south bank (side of Costa Rica) and eight sites on the north bank (side of Nicaragua), studied during three periods (March, April and May 2014). A review of the methods and statistical analysis in the Ríos Report indicates that there are significant inconsistencies in the interpretation of the relevant data. These are set out in Section [B] below.

Following this, the statistical test used in the work of Ríos Report is set out; then why such testing is not appropriate in each analysis is explained, and the test which is the more appropriate according to the objectives of the Ríos Report is set out. It is important that highlight that when an incorrect statistical test is used to analyze and interpret data, conclusions may be drawn that do not correspond to the reality of the target system.

B Inconsistencies in the Rios Report

(1) Inappropriate type of test

First, the author of the Rios Report used a type of test Test Medium (Median test is a special case of Chi Square) to compare the environmental variables between the deltas (specifically from the eight rivers that were assessed) that allegedly drain from the road (Costa Rican side) and deltas of the streams that drain from forests (Nicaraguan side) (the Rios Report, Section "A. Substrate and environmental variables"). Thus, the author compared the temperature, type of substrate, and electrical conductivity, and reports significant differences between deltas according to environmental variable analyzed (ie, temperature and type of substrate).

However, it is incorrect to use a type of test Test Medium to compare variables between different locations, and the test is not suitable to meet the goal set by the author of the Ríos Report.

The statistic test Test Medium uses a Chi Square to examine data. The Chi Square is a standard method used to determine the similarity between observed and theoretical values derived from the same set, and to establish whether the distribution is due to chance or if it reflects a trend. Test Medium sorts the data from lowest to highest and does a count of how many values are above and below the median values, forming groups. It then uses the equation of Chi Square to compare the observed data with theoretical data for each group.

The statistical proceeding of this method involves the generation of hypotheses to be tested (null hypothesis is that there is no difference; alternative hypotheses are that trends exist) (Zar 1999). Moreover, according to several authors (eg, Zar 1999) this test has low power (explanatory efficiency) for samples of moderate to large size (n> 20). For this reason, it is considered that this test is wholly inadequate to meet the defined objective in the Ríos Report, because there is no hypothesis to be tested with the collected data, which also come from different sets (different river basins that are not associated). It is also inadvisable to use this method with continuous data (eg, temperature, conductivity), as continuous data can be examined with statistical tests of greater power and robustness.

To compare between environmental variables of the deltas south and north, it is suggested that an Analysis of Variance (ANOVA) should be used. The proposed overall of ANOVA is to test significant differences between group means (ie, averages of environmental variables recorded in each river bank) (Gotelli and Ellisno 2004). Thus, ANOVA can respond if there are differences in environmental variables between the two banks tested by the author of the Ríos Report.

(2) Inappropriate type of comparison

Secondly, the author of the Ríos Report compares the periphyton biomass, abundance, taxa richness and EPT (Ephemeroptera, Plecoptera, Trichoptera) by the Kruskal Wallis test analysis of variance for nonparametric data. The author obtains significant differences in several of the cases evaluated (Ríos Report, Section "B. Periphyton" and "C. macroinvertebrates"). However, this test is not recommended because there is covariance in one of the main parameters examined, namely the Drainage Area. In this particular case the recommended test is an analysis of covariance (ANCOVA). According to Gotelli and Ellisno (2004), an ANCOVA test type should be used when a covariate (in this case Drainage Area) somehow contributes to the variation of the response variable (ie, periphyton and macroinvertebrates). The ANCOVA test attempts to eliminate any systematic error that may skew the results and take into account differences in responses due to the characteristics of the object of study, in this case study sites. The purpose of ANCOVA is to eliminate the effect of a variable that influences in a portion or all of the sites (such as Drainage Area).

The drainage area is commonly defined as the area from the headwater to the river mouth, and is clearly delimited by topography (Allan and Castillo 2007). The drainage area of a river is a predictor of the volume of the flow, which through the gradient (from the headwater to the river mouth) produces an increase in the amount of transported water which in turn directly affects the turbidity, temperature and sediment load carried on the way (Allan and Castillo 2007, Dudgeon 2008). This may explain part of the Discussion in the Ríos Report which refers to turbidity ("…It is notable that the only samples that had to be eliminated for the analysis due to higher turbidity than those detected for Chlorophyll a were from south bank (i.e., road impacted) sites."). Therefore, it is apparent that the study sites may naturally fluctuate due to differences in the drainage area, which have an amplitude ranging from 0.1 km^2 to over 25 km^2 (Table 1), being the rivers draining from the south bank (side of Costa Rica) the ones that have an allegedly higher average drainage area (5km^2) compared to rivers draining the north side (~1km^2); the author should have included the drainage area as a covariate in an ANCOVA analysis.

Table 1. Analysis of the Drainage Area of the sites studied in the Ríos Report according to each country. Data were obtained for analysis in the Ríos Report. "Table 1. Location of sampled deltas in the San Juan River, Nicaragua. 'A' points correspond to deltas formed by creeks draining the road at the south bank of the river and 'B' points correspond to deltas formed by draining the Nicaraguan side at the north bank of the river."

Country of the sites studied	Number of Sites	Average Area (km^2)	Standard Deviation (km^2)	Minimum area (km^2)	Maximum Area (km^2)
Nicaragua (North Bank)	8.00	1.34	2.25	0.10	6.80
Costa Rica (South Bank)	8.00	5.00	8.71	0.40	> 25.00

Thirdly, the Ríos Report uses an ordination type non-Metric Multidimentional Scaling (nMDS) using the environmental variables and substrate as vectors to assess differences in the composition of macroinvertebrates (Ríos Report, Section "D. Composition Changes"). Thus, the author uses a nMDS to determine differences in macroinvertebrate assemblage and its relation to environmental variables and the substrate. However, this statistical test is not appropriate to determine the relationship.

An nMDS is a non-parametric statistical test used to simulate gradients with groups of ecological data. Some authors, such as McCune and Grace (2002) suggest that the nMDS is the most effective test data to apply to communities data. Meanwhile, to determine gradients according to environmental variables, the recommended test is a Principal Component Analysis (PCA). Additionally, the relationship between composition of macroinvertebrates and environmental parameters can be examined with other special ordinations (most explanatory power) such as Redundancy Analysis (RDA), or a db-RDA as an alternative method to test complex multivariate models (Gotelli and Ellisno 2004, Ramette 2007). Consequently, in the section dealing with “change in composition”, the author of the Ríos Report incurs a primer error by applying a non-parametric test (nMDS) to determine the relationship between environmental variables and the composition of macroinvertebrates.

The second error of the author in the section dealing with “change in composition” is to assert that the nMDS showed segregating sites (ie, segregation of groups) without performing a statistical test to prove that assertion (Ríos Report, “The non-metric multidimentional scaling analysis (Figure 7) showed a segregation of most sites of the north and south bank across axis 2...”). In statistics, one of the most appropriate tests to determine segregation ways is to apply an ANOSIM (Similarity Analysis). However, in the Ríos Report, a test such as ANOSIM was not conducted, so the segregation of groups suggested in the Ríos Report is entirely subjective and cannot be tested.

The third mistake that the author of the Ríos Report makes in the analysis section of “change in composition” is using nMDS to make a direct relationship between environmental variables and macroinvertebrates. The author suggested that the sites showed segregation and that the macroinvertebrate assemblages were influenced by some environmental parameters which were recorded in the work (Ríos Report “On the other hand the macroinvertebrate communities were influenced by bigger d16, d50, lower temperatures and better-sorted sediments (lower sg coefficient”). However, this observation is subjective because a statistical test that proves a relationship between environmental variables and substrate with the macroinvertebrate assemblages was not performed.

Some of the most common statistical tests to determine the relationship between environmental parameters and macroinvertebrates are Multiple Regression and/or Akaike Information Criterion (AIC). Both tests are used to determine in a precise way (and not subjective as does the author) which physicochemical variables are most important in influencing the fluctuations in the aquatic macroinvertebrate assemblages, and thus explain the segregation of sites (if any segregation indeed exists).

Conclusion

In summary, in the Ríos Report one can observe three remarkable inconsistencies in the methods for the analysis and interpretation of data from eight sites in the south bank (side of Costa Rica) and eight sites on the north bank (side of Nicaragua). First, applying a test Median Test (special case of Chi Square) to compare between sites, when an Analysis of Variance should have been used. Second, applying a Kruskall Wallis analysis of variance to determine differences between sites, knowing that there was a covariate (drainage area) that would influence the results and should be solved by applying an ANCOVA. Third, applying a type nMDS ordination and subjectively determine segregation of sites related to environmental variables, when statistical tests (eg, ANOSIM, Multiple Regression and/or AIC) were not used to ensure such segregation and relationships.

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Gotelli NJ, Ellison AM. 2004. A primer of ecological statistics. Sunderland, MA: Sinauer Associates.

McCune, B. & Grace, J.B. 2002. Analysis of Ecological Communities. Mjm Software Designs, Gleneden Beach.

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Ríos-Touma, B. 2014. "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua". Vol. II "Reply of the Republic of Nicaragua: Dispute concerning construction of a road in Costa Rica along the San Juan River (Nicaragua v. Costa Rica)"

Zar, J.H. 1999. Biostatistical analysis. Prentice Hall, New Jersey, 4. ed.

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Education

PhD Candidate. Ecology and Systematic Program, University of Puerto Rico, Río Piedras campus, Puerto Rico.

Positions

Research Assistant, University of Puerto Rico

Research affiliate at Museum of Zoology University of Puerto Rico, Rio Piedras

Honors & Awards

Best student oral presentation award, second place. First Latin-American Congress of Aquatic Macroinvertebrates. San Jose, Costa Rica 2012.

Distinguished Licenciate Thesis, University of Costa Rica, 2010.

Research Grants

The Rufford Foundation, Rufford Small Grants (Ref: 15017-1), 2014, Key factors for aquatic macroinvertebrate conservation in the face of global climate change, $9006.

Publications

Ramírez, A. & **P.E. Gutiérrez-Fonseca.** 2014. Estudios sobre macroinvertebrados acuáticos en América Latina: avances recientes y direcciones futuras. Revista de Biología Tropical. 62(Suppl2):9-20.

Ramírez, A. & **P.E. Gutiérrez-Fonseca.** 2014. Functional feeding groups of aquatic insect families in Latin America. Revista de Biología Tropical. 62(Suppl2):155-167.

Gutiérrez-Fonseca, P.E. & C.M. Lorion. 2014. Application of the BMWP-Costa Rica biotic index in aquatic biomonitoring: sensitivity to collection method and sampling intensity. Revista de Biología Tropical. 62(Suppl2):275-289.

Gutiérrez-Fonseca, P.E. & L., Ortiz-Rivas. 2013. Substrate preferences for attaching gumfoot lines in Latrodectus geometricus (Aranae: Theridiidae). Entomological News. 123123(5): 371-379.

Gutiérrez-Fonseca, P.E., K.G. Rosas & A. Ramírez. 2013. Aquatic insects of Puerto Rico: a list of families. Dugesiana. (20)2: 215-219.

Gutiérrez-Fonseca, P.E., A. Ramírez, G. Umaña & M. Springer. 2013. Macroinvertebrados del agua dulce de la Isla del Coco, Costa Rica: primer listado y un análisis comparativo con otras islas del Pacífico Tropical Oriental. Revista de Biología Tropical. 61(2):257-268.

Ramírez, A. & **P.E. Gutiérrez-Fonseca.** 2013. The larvae of *Heteragrion majus* Selys and *H. atrolineatum* Donnelly, with a key to known species from Costa Rica (Odonata: Megapodagrionidae). Zootaxa 3609(1): 096–100.

Ramírez, A., Altamiranda-Saavedra M., **Gutiérrez-Fonseca P**. & M. Springer. 2011. The Neotropical damselfly genus *Cora*: new larval descriptions and a comparative analysis of known species (Zygoptera: Polythoridae). International Journal of Odonatology. 14(3): 249-256.

Gutiérrez-Fonseca, P. & M. Springer. 2011. Description of the final instar nymphs of seven species from *Anacroneuria* Klapalék (Plecoptera: Perlidae) in Costa Rica, and first record for an additional genus in Central America. Zootaxa 2965: 16-38.

Gutiérrez-Fonseca, P. 2010. Plecoptera. Revista de Biología Tropical. 58(Suppl. 4): 139-148.

López, L.I., **Gutiérrez P.** y J.M. Mora. 2010. Macrofauna Acuática de la Quebrada Santa Inés, Subcuenca del Río Yeguare, Honduras. Ceiba 51:17-28.

Outreach Publications

Gutiérrez Fonseca, P.E. 2010. Guía ilustrada para el estudio ecológico y taxonómico de los insectos acuáticos del Orden Coleoptera en El Salvador. *En*: Springer, M. & J. Sermeño (eds.). Formulación de una guía metodológica estandarizada para determinar la calidad ambiental de las aguas de los ríos de El Salvador, utilizando insectos acuáticos. Proyecto Universidad de El Salvador (UES)-Organización de los Estados Americanos (OEA). SINAI Editores e Impresores, S.A. de C.V., San Salvador, El Salvador. 64 p.

Sermeño, J.M, Pérez, D. & **P.E. Gutiérrez-Fonseca**. 2010. Guía ilustrada para el estudio ecológico y taxonómico de los insectos acuáticos inmaduros del Orden Odonata en El Salvador. *En*: Springer, M (ed.). Formulación de una guía metodológica estandarizada para determinar la calidad ambiental de las aguas de los ríos de El Salvador, utilizando insectos acuáticos. Proyecto Universidad de El Salvador (UES)-Organización de los Estados Americanos (OEA). SINAI Editores e Impresores, S.A. de C.V., San Salvador, El Salvador. 38 p.

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Proyecto Universidad de El Salvador (UES)-Organización de los Estados Americanos (OEA). SINAI Editores e Impresores, S.A. de C.V., San Salvador, El Salvador. 14 p.

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Pérez, D., Serrano Cervantes, L., Sermeño Chicas, J., Springer, M., Paniagua Cienfuegos, MR., Hernández Martínez, MA., Rivas Flores, AW., Monterrosa Urias, AJ., Bonilla de Torre, BL., Carranza Estrada, FA., Flores Tensos, JM., Gonzáles CA., **Gutiérrez Fonseca, P.,** et al. 2010. Clasificación de la calidad de agua de los principales ríos de El Salvador y su relación con las poblaciones de macroinvertebrados acuáticos. *En*: *En*: Formulación de una guía metodológica estandarizada para determinar la calidad ambiental de las aguas de los ríos de El Salvador, utilizando insectos acuáticos. Proyecto Universidad de El Salvador (UES)-Organización de los Estados Americanos (OEA). Editorial Universitaria UES, San Salvador, El Salvador. 84 p.

Invited talks

Gutiérrez-Fonseca, P.E., CM Pringle & A., Ramírez. 2014. Dinámica a largo plazo de las variables fisicoquímicas y sus efectos sobre la estructura y composición del ensamblaje de macroinvertebrados en ríos de zonas bajas en Costa Rica. Second Latin American Congress of Aquatic Macroinvertebrates. Queretaro, Mexico. [April 7-12].

Ramírez, A*. & **P.E., Gutiérrez-Fonseca**. 2014. Estudios sobre macroinvertebrados acuáticos en América Latina: avances recientes y direcciones futuras. Second Latin American Congress of Aquatic Macroinvertebrates. Queretaro, Mexico. [April 7-12] Speaker*.

Ramírez, A*. & **P.E., Gutiérrez-Fonseca,** C.M., Pringle, M. Ardon-Sayo, G.E. Small. 2013. Long-term ecological research in lowland streams in Costa Rica: The importance of groundwater-surface water interactions on ecosystem dynamics. 50th Annual meeting of Association for Tropical Biology and Conservation. San Jose, Costa Rica. [June 23-27] Speaker*.

Pringle, CM, GE Small*, B Bixby, A Ramírez, JH Duff, M Ardon, AP Jackman, M Snyder, CN Ganong, **P Gutiérrez** and FJ Triska. 2013. Climate-driven acidification in lowland Neotropical streams: Insights from a 25-year dataset on ground water - surface water interactions. 98th Annual meeting of Ecological Society of America. Mineapolis. [August 4-9] Speaker*.

Ramírez, A*. & **P.E., Gutiérrez-Fonseca.** 2012. Alta similitud interespecífica en larvas de Odonata: el caso de Cora (Polythoridae) y Heteragrion (Megapodagrionidae). First Latin American Congress of Aquatic Macroinvertebrates. San José, Costa Rica. [Febrero 6-10] Speaker*.

Gutiérrez-Fonseca, P.E. & A., Ramírez. 2012. How stable are the macroinvertebrates assemblages of tropical streams? First Latin American Congress of Aquatic Macroinvertebrates. San José, Costa Rica. [Febrero 6-10].

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Contributed Papers

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Sánchez-Ruiz, J.A.*, **Gutiérrez-Fonseca, P.E.**, Rosas, K.G., Ramírez, A. 2014. Assessing macroinvertebrate growth rates in the Rio Piedras, a tropical urban stream, Puerto Rico. . Joint Aquatic Societies Meeting - Society for Freshwater Science. Portland, Oregon. [May 18-23] Speaker*.

Ramírez, A*. & **P.E., Gutiérrez-Fonseca**, K., Wagner, J., Sánchez, K., Rosas, B., Vázquez. 2014. Biodiversidad y productividad de los macroinvertebrados acuáticos de un río urbano tropical, Puerto Rico. Second Latin American Congress of Aquatic Macroinvertebrates. Queretaro, Mexico. [April 7-12] Speaker*.

Gutiérrez-Fonseca, P. & A. Ramírez, CM Pringle. 2013. Long-term patterns of aquatic macroinvertebrate assemblages in lowland neotropical streams. 50th Annual meeting of Association for Tropical Biology and Conservation. San Jose, Costa Rica. [June 23-27].

Gutiérrez-Fonseca, P. & A. Ramírez. 2013. Effects of flood disturbance and episodic acidification events on aquatic macroinvertebrates in tropical lowland streams. Society for Freshwater Science. Jacksonville, Florida, USA. [May 19-23].

Gutiérrez-Fonseca, P. & A. Ramírez. 2012. Importance of long-term sampling in the assessment of tropical stream biodiversity. Society for Freshwater Science. Louisville, Kentucky. USA. [May 20-24].

Rosas, K.G.*, **Gutiérrez Fonseca, P.E**. & A. Ramírez. 2012. Trophic basis of Insect secondary production in a tropical urban River. Society for Freshwater Science. Louisville, Kentucky. USA. [May 20-24]. Speaker*

Gutiérrez-Fonseca, P. & A. Ramírez. 2011. Temporal variation in benthic macroinvertebrate assemblages in two tropical headwater streams in Costa Rica. North American Benthological Society. Rhode Island. USA. [May 22-26].

Research Experience

Assistant in the Zoological Museum of the University of Costa Rica. Aquatic Invertebrates Collection, M.Sc. Monika Springer. Costa Rica. 2003- 2008.

Associate Researcher for a collection of aquatic macroinvertebrates in the watershed Yeguare, Valle del Zamorano. Escuela Agrícola Panamericana, El Zamorano. PhD José Manuel Mora. Honduras October 2007 - January 2008.

Teaching Experience

Teaching Assistant, General Biology II. University of Puerto Rico. Winter 2012.

Teaching Assistant, Botany. University of Puerto Rico. Spring 2012, 2013.

Instructor, Macroinvertebrates indicator of environmental quality of surfaces waters, April 20-30 2010, University Rafael Landivar, Guatemala.

Teaching Assistant, Limnology, 2009, University of Costa Rica, Costa Rica.

Teaching Assistant, Aquatic Entomology, 2009, University of Costa Rica, Costa Rica.

Professor, Macroinvertebrates indicator of environmental quality of surfaces waters, June-10 to July-1 2008, University of El Salvador, El Salvador.

Teaching Assistant, Aquatic Entomology, 2008, University of Costa Rica, Costa Rica.

Teaching Assistant, Limnology, 2007, University of Costa Rica, Costa Rica.

Reviewer for

Caldasia (1)

Hydrobiologia (2),
International Review on Hydrobiology (1),
International Review of Limnology (1),
Journal of Freshwater Ecology (1),
Revista de Biologia Tropical (6).

Society memberships

Society for Freshwater Science (after: North American Benthological Society)

Red Mesoamericana de Recursos Bióticos

Sociedad Mesoamericana para la Biología y la Conservación

Workshops

Aquatic Macroinvertebrates of Mesoamérica. Tabasco, México 2010.

Students mentored

Crystal Purcell, University of Dallas, Research Experience for Undergraduate, Summer 2014.

Ismael Oregon, Universidad Metropolitana, Research Experience for Undergraduate, Summer 2013.

Lelanee Ortiz Rivas, University of Humacao, Research Experience for Undergraduate, Summer 2011.

Some groups in the course: Tropical Field Ecology in Costa Rica. Penn State University. Winter 2007 to 2013.

Some groups in the course: Tropical Field Biology and Conservation. Kent State University. Winter 2012.

ANNEX 9

Juan Carlos Fallas Sojo

C*omments on the Report by Dr Kondolf as it pertains to Hurricanes and Tropical Storms*

2014

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COMMENTS ON THE REPORT BY DR KONDOLF (AS IT PERTAINS TO HURRICANES AND TROPICAL STORMS) IN: SECTION 1.2 - RISKS OF LARGE CONTRIBUTIONS FROM RTE. 1856 [Annex I, pages 71-74]

by Juan Carlos Fallas Sojo[1]

In Annex 1 to Nicaragua's Reply (The Kondolf Report), Dr Kondolf states on page 71 that:

> *"…It is not true that a hurricane or tropical storm has never struck the Río San Juan. The eyes of Hurricanes Irene and Olivia in 1971 both tracked just to the north of the Río San Juan".*[2]

This statement is incorrect. In the first instance, Hurricanes Irene and Olivia were not two separate events. These were two different names given to the same event in 1971: the hurricane was called Irene as it passed through the Atlantic Ocean, the Caribbean Sea, and the mainland territory of Nicaragua. When it passed to the Pacific Ocean, it was given the name Olivia beacuse there are separate naming conventions for hurricanes in the Atlantic and Pacific Basins.

Hurricane Irene entered Nicaraguan territory at Punta Gorda[3] (see adjacent map), which is located some 68 km north-east of Delta Colorado, the nearest point on Costa Rican territory where Route 1856 starts.

INETER reported that the accumulated precipitation volume over the drainage area San Juan River for this event, in the Nicaraguan territory, was 100 millimetres[4]. From a hydrological point of view, the total volume of precipitation is not a good indicator of the runoff pattern and the magnitude of a flood hydrograph. The runoff pattern of a basin depends upon the spatial and temporal distribution of the rain. In the San Juan River Basin these characteristics are particularly important because of the attenuation effect of the

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1 Director General, Costa Rican National Meteorological Institute (Instituto Meteorológico Nacional) and Professor of Physics and Meteorology, University of Costa Rica.

2 Kondolf Report, Annex 1, p 71, third paragraph.

3 See http://webserver2.ineter.gob.ni/Direcciones/meteorologia/Desastres/Huracanes/huracan_irene.htm , visited 23 September 2014.

4 Ibid.

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Nicaragua Lake upon the flood hydrograph. Assuming that the total volume of precipitation, mentioned in the INTER reports, precipitated over a time span of two or three days, which is typical for a hurricane storm, 100 millimetres of rain, as a total volume of precipitation, does not represent a severe event and probably will not generate and extraordinary flood hydrograph along the San Juan River channel. For example, over the Sarapiquí River Basin, the total volume of precipitation with 5 years return period, has been estimated in, approximately, 200 mm, over 48 hours. Therefore, a total volume of 100 mm of rain, over the drainage area of the San Juan River Basin in the Nicaraguan territory, does not represent a severe storm for this catchment.

Additionally, in Annex 1 to Nicaragua's Reply, Dr Kondolf states (page 71, paragraphs 5 and 6):

> *"… An example of the heavy rains that can over the Rio San Juan and its Costa Rican tributary basins is the tropical storm that occurred 6-11 May 2004…"*[5]

Dr Kondolf states that a tropical storm affected Costa Rica in May 2004. This is incorrect. The weather system that generated rainfall over the territory of Costa Rica was not a tropical storm; it was a much smaller disturbance in its intensity and persistence, called a *tropical wave* or *tropical easterly*, which is the name correctly given to the disturbance by NASA, as is clear in the image reproduced by Dr Kondolf as Figure 32 on page 72 of his report. Meteorological events of this type and intensity are actually common in this area, and the dynamics of the region are well adapted to assimilate the rainfall intensities, durations and distributions associated with them.

Dr Kondolf's Characterization of Impacts of Tropical Cyclones in Costa Rica

A tropical cyclone is the general term for the type of air circulation associated with a low pressure center. These weather events are designated by their intensity (from lowest to highest): tropical depression, tropical storm or hurricane.

[5] Kondolf Report, Annex 1, p 71, fifth and sixth paragraphs.

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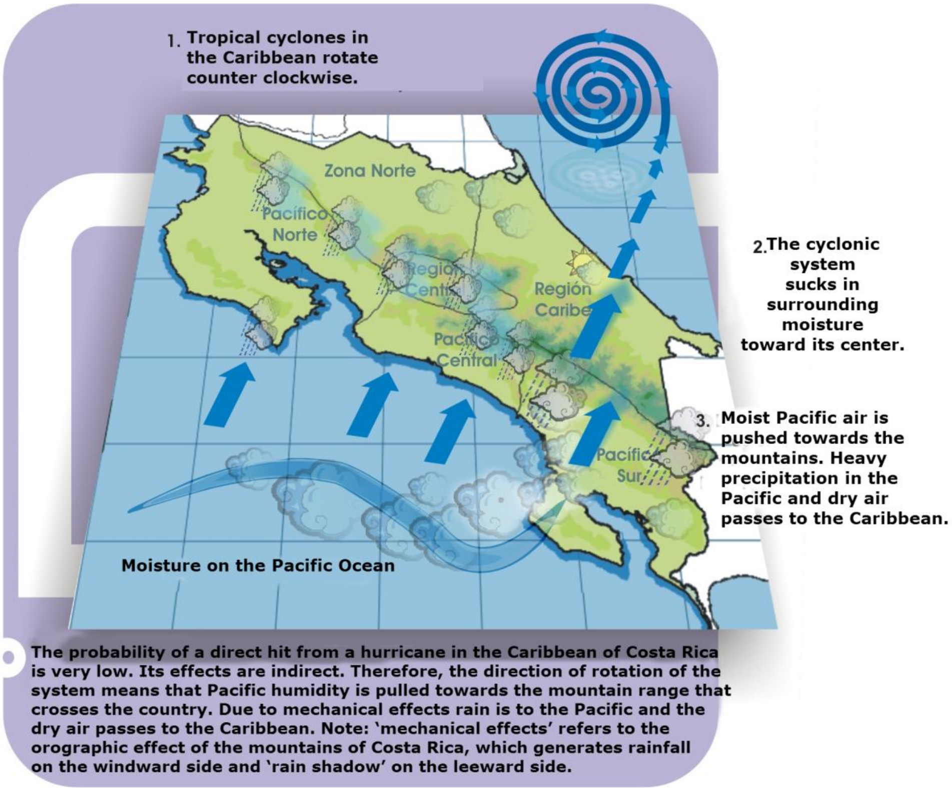

Figure 1. Relationship between a tropical cyclone near the Caribbean coast of Nicaragua and the associated distribution of wind and rain in Costa Rica.

Although no hurricane or tropical storm has struck Costa Rica directly during the 20th century and none have done so thus far in the 21st century, some tropical cyclones occurring outside the country have had indirect effects in Costa Rica. However, due to Costa Rica's prominent mountain system, the rainfall associated with these events is greater in catchments draining to the Pacific than it is in catchments draining to the Caribbean, such as that of the San Juan River (Figure 1, above).

Dr Kondolf does not mention the characteristic of the distribution of rainfall resulting from tropical cyclones in the Caribbean (Figure 1), which is clearly evident in the rainfall map for Hurricane Mitch (Figure 2).

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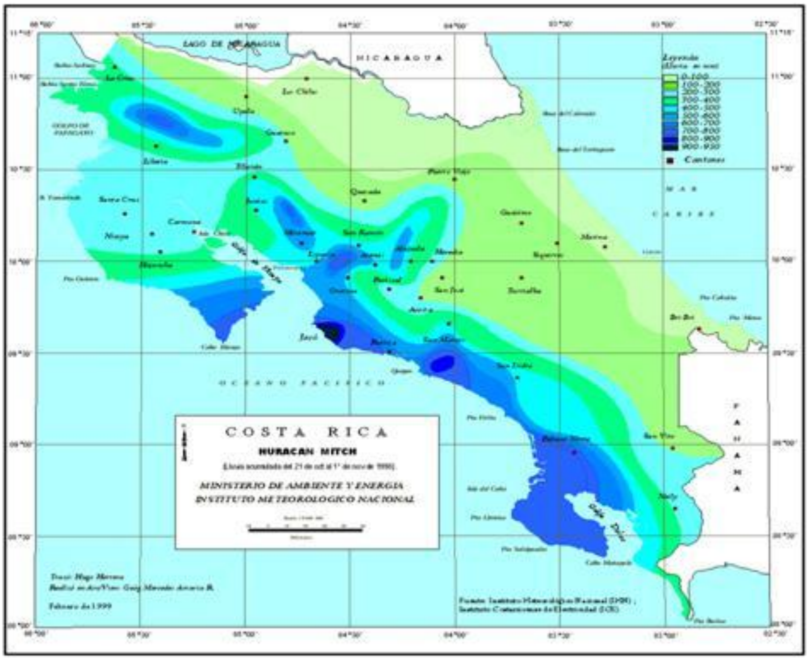

Figure 2. Rainfall distribution in Costa Rica during Hurricane Mitch

This is significant because Dr Kondolf refers to seven fatalities caused by Hurricane Mitch in Costa Rica as though they occurred in the Rio San Juan Basin.[6] This is incorrect. In fact, these deaths not only occurred outside the Rio San Juan basin, they were not even in the Caribbean drainage basin, but occurred in the Pacific drainage basin, on the other side of the continental divide, which is easily understandable considering the circulation (Figure 1) and rainfall distribution (Figure 2).

A clear indication of the regional severity of Hurricane Mitch and its significant impact on the Pacific side in contrast to the Caribbean (Figure 2), is given by the numbers of people who evacuated to storm shelters on the Pacific and Caribbean sides of the continental divide, respectively.[7] Contemporaneous reports indicate, among other things, that 5,411 people were forced to leave their homes. Of these, just 60 people were located in the Caribbean drainage basin, actually in Upala District, in the province of Alajuela (indicated in red in Figure 3, below). Dr Kondolf states in his report that, "thousands were forced from their homes"[8], which is true, but he does not mention that the vast majority of those displaced were on the Pacific, rather than the Caribbean side of the Costa Rican mountains.

6 Kondolf Report, Annex 1, p 72, first paragraph.
7 CEPAL report, LC7MEX7L373, of March 4, 1999 and located on the web: www.cepal.org.publicaciones; visited on 22 and 23 September 2014.
8 Kondolf Report, Annex 1, p 72, first paragraph.

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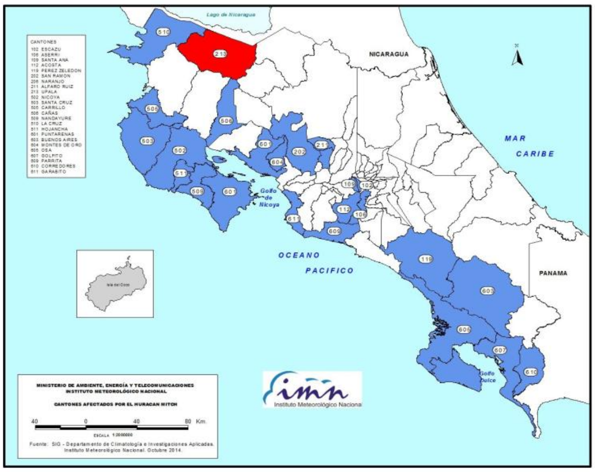

Figure 3. Map of cantons where people were displaced by Hurricane Mitch. Areas in blue are in the Pacific Basin. The area in red is the only canton where people were displaced in the Caribbean Basin. Original map based on data obtained from CEPAL (Comisión Económica para América Latina y el Caribe) – see footnote 6, below.

JUAN CARLOS FALLAS SOJO

Date of Birth: 21 November 1957

Education

- *Licenciatura* in Meteorology, Universidad de Costa Rica, 1987

Over the course of his career, Mr. Fallas Sojo has participated in a wide variety of seminars, courses and workshops on relevant issues, such as: water resources, climate change, disaster risk reduction, etc.

Professional Experience

- Director General of the Costa Rica National Meteorological Institute (Instituto Meteorológico Nacional) since 7 April 2008
- Deputy Director of the Costa Rica National Meteorological Institute (Instituto Meteorológico Nacional) from 15 February 2007 to 4 April 2008
- Information and Commercialization Management Coordinator of the National Meteorological Institute (Instituto Meteorológico Nacional) of Costa Rica from 1 July 1996 to 14 February 2007
- Deputy Chief of the Department of Information and Publication of the National Meteorological Institute (Instituto Meteorológico Nacional) Costa Rica from 1 July 1992 to 30 June 1996
- Task Force Chief at the Department of de Meteorological Sinoptics and Aeronautics, from 1980 to 30 June 1992

Academic Experience

- Professor of Physics and Meteorology, University of Costa Rica, Costa Rica, since 1980
- Professor, Training for Meteorological Staff Class II, joint program University of Costa Rica-WMO (4 sessions)
- Professor of Physics, Centro de Investigación y Perfeccionamiento de la Educación Técnica, CIPET, Costa Rica
- Professor, Training for Meteorological Staff Class IV, National Meteorological Institute (Instituto Meteorológico Nacional), Costa Rica (2 sessions)
- Expert-Instructor within the CIBERAPRENDIZ (Cyber Apprentice) Programme, Fundación Omar Dengo, Ministry of Public Education, Costa Rica, 2003-2006
- Professor of Climatology, Universidad Latina, Costa Rica, 1998– 2007
- Expert-Instructor within the GLOBE Programme, Fundación Omar Dengo, Ministry of Public Education, 1997-2006
- Instructor of Aeronautical Meteorology, Líneas Aéreas de Costa Rica LACSA (Airlines of Costa Rica)

Internacional Experience

Mr. Fallas Sojo has participated in multiple international meetings of a specialized technical nature.

Member of the Executive Committee of the WMO from 2009

Publications

Fenómenos Atmosféricos y Cambio Climático. Guía para el Docente, 1994.
Proyecto del MEP y del IMN-MINAE.

Libros de Ciencias y Estudios Sociales de Sétimo Año, temas de Meteorología, Climatología y Desastres Naturales. EDITORIAL SANTILLANA 1999.

Fenómenos Atmosféricos y Cambio Climático. Visión Centroamericana, Guía para el Docente, San José, C.R. 2003.

ANNEX 10

Professor Allan Astorga Gättgens

Extraordinary sediment inputs due to exceptional events on the San Juan River

December 2014

Extraordinary sediment inputs due to exceptional events on the San Juan River

Dr. Allan Astorga Gättgens

Bachelor's Degree in Geology from the University of Costa Rica, Doctor of Natural Sciences of the University of Stuttgart, Germany. Specialist in sedimentology, environmental geology, land use planning and environmental impact assessment. Professor of the Central American School of Geology at the University of Costa Rica since 1991.

December 2014

1. Introduction

In order to obtain a better understanding of the sediment load entering the San Juan River, particularly in the sector of the basin which is located in Costa Rican territory, this study analyses extraordinary sediment inputs caused by exceptional geologic events.

This issue is very important, given that the basin of the San Juan River has a very dynamic geological situation: an island arc which has evolved into an isthmus. Therefore, these extraordinary sediment inputs represent a periodic or cyclical process that has long played an important role in the natural development of the lower part of the basin and which is responsible for the capacity of the San Juan River to transport significant volumes of sediment toward to the Caribbean Sea.

This document summarizes the results of a study on geological events that occur primarily in the Costa Rican part of the basin of the San Juan River and that explains how, periodically, extraordinary inputs of sediment adds to the natural processes of sediment production, transfer and delta building.

As a methodological basis for the preparation of this study, sediment volumes produced by extraordinary events from the upper part of the basin, as well as their possible frequency and type of sediment, are considered. While this study provides only a preliminary numerical approximation of the quantities of sediment involved, this is sufficient to better understand sediment dynamics of the San Juan River.

The author is a Professor of Sedimentology and Environmental Geology at the University of Costa Rica since 1991, and Consultant in Environmental Impact Assessment, Environmental Management and Environmental Land. He holds the degrees of Licentiate in Geology by the School of Geology at the University of Costa Rica (1987), and Doctor of Natural Sciences by the University of Stuttgart, Germany (1996). A more extensive description of his CV is included as Appendix A.

2. Geography of the basin of the San Juan River

The San Juan River basin has an area of about 42 thousand km^2. It is the largest river basin in Central America (SICA, 2011). It is a binational river basin, occupying parts of Nicaragua and Costa Rica (Figure 1).

Around 70% of the basin is located in Nicaragua, and this part of the basin includes Lake Cocibolca (or Lake Nicaragua) and Lake Managua. The other ~30% is located in Costa Rica (Figure 1).

The basin rises from the Caribbean coastal plains of Río Indio-Maíz (in Nicaragua) and Tortuguero (in Costa Rica), with most of it lying 500 m or more above sea level. The highest points in the basis are volcanic peaks, with heights of 1,500 - 3,000 metres in Costa Rica and a little over 1,600 metres in Nicaragua.

This topography exerts a considerable influence on rainfall, which varies from 4,000 to 6,000 mm in the most humid, upland areas, to 1,000 to 2,000 mm in the drier areas around Lake Cocibolca, where the dry season lasts approximately seven months.

The only outlet from Lake Cocibolca is the San Juan River, which flows for about 205 km from its source at the Lake to the Caribbean. Initially, the river is located entirely in Nicaraguan territory, but five kilometres downstream from El Castillo, its south bank becomes the international border between the two countries (Figure 1). The river's direction is southeast, and some 174 km from its origin, at the proximal head of its delta, it divides into two branches: the lower San Juan River and the Colorado River, which have separate mouths in the Caribbean Sea that are separated by about 20 km.

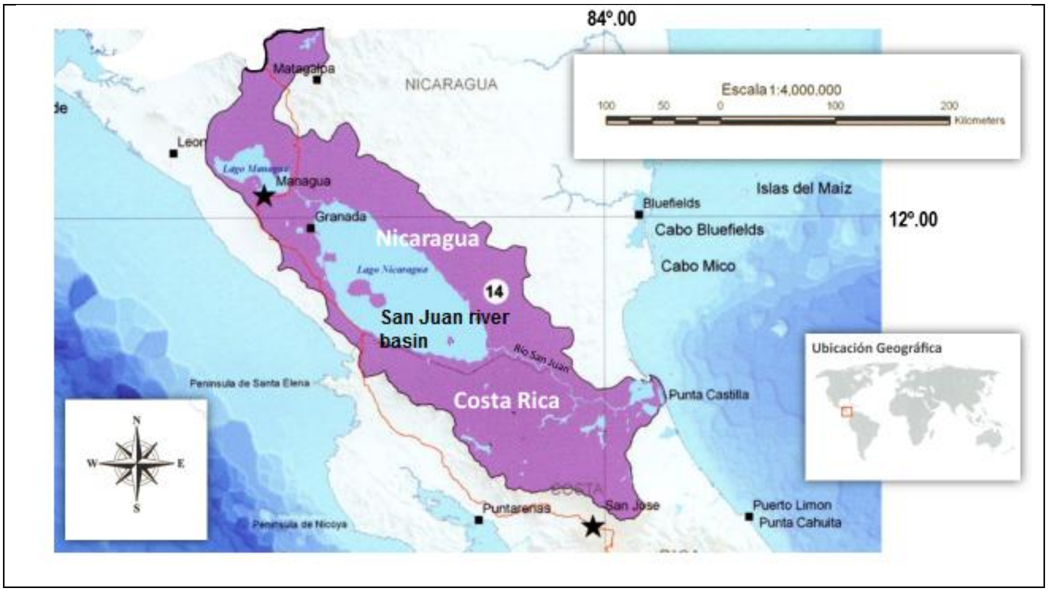

Fig. 1. *Map of the binational basin of the San Juan River (cf. SICA, 2011).*

The characteristic of the tributary network is that rivers draining to Lake Cocibolca in the North part of the basin are short in length, with directions East-West, West-East and South-North, while tributaries draining to and the San Juan River from the North are oriented North-South.

Most of the rivers draining from the Southern sector of the basin originate in Costa Rica, in the Guanacaste mountain range to the West, originating at elevations up to 3,000 metres in the Tilarán mountain range to the South-East. High levels of rainfall along the north flank of the Tilarán mountain range contribute approximately 85% of the discharge of the San Juan River. The estimated average annual discharges of the river are 475 m^3/s at San Carlos de Nicaragua (the source of the San Juan River at Lake Cocibolca), increasing to 1,308 m^3/s at the mouth of Sarapiquí River. Of this discharge, 26% originates from Lake Nicaragua; 6.5% from tributary inputs between San Carlos de Nicaragua and El Castillo; and 67.5% from tributaries confluencing between El Castillo and Sarapiquí (PROCUENCA, 1997: p. 86: Régimen Hidrológico[1]).

[1] **PROCUENCA (1997):** Estudio de Diagnóstico de la Cuenca del Río San Juan y Lineamientos del Plan de Acción. Manejo Ambiental y Desarrollo Sostenible de la Cuenca del Río San Juan. Gobierno de Costa Rica. Gobierno de

3. Geology of the basin of the San Juan River

The basin of the San Juan River is mainly located in the back-arc of the south of Central America, although its most north-western point forms part of the fore-arc basin of the south of Nicaragua (Figure 2). For full details see Astorga et al. (1991).

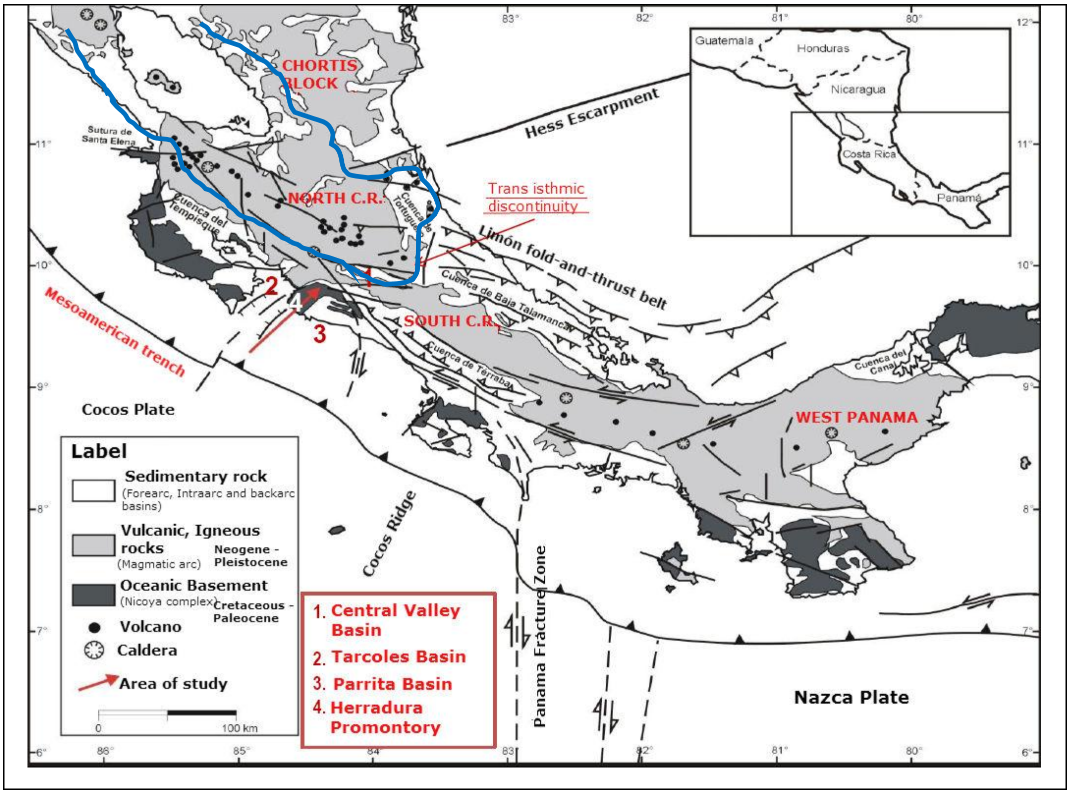

Fig. 2. *Tectonic map of part of the South Central American orogen, with an indication of the main tectonic and neotectonic elements related to the basin of San Juan River (blue line). As you can see this watershed occurs in an area of fore-arc and back-arc in Nicaragua and Costa Rica.*

The basin has a complex geological history that is related to the tectonic evolution of the lithospheric blocks that now make up the Caribbean plate. The Chortis block and South block of Central America have been evolving together since the Upper Paleocene (50 million years ago), when they were united by the Mesoamerican trench (see Astorga, 1997).

Nicaragua. Programa de las Naciones Unidades para el Medio Ambiente. Unidad de Desarrollo Sostenible y Medio Ambiente. Secretaría General de la Organización de Estados Americanos. Washington, D.C. 334 p. (http://www.oas.org/DSD/publications/Unit/oea05s/oea05s.pdf)

Prior to that, they had a separate history. During the Mesozoic era, what today is largely the San Juan basin, including the northern part of the Costa Rican territory, were part of the fore-arc of the Chortis Block.

The traces of this tectonic process are evidenced by the presence of fragments of oceanic crust of the ancestral Farallón Plate, trapped and tectonically deformed (accretionary wedges) in what the author called "Ofiolita de Sábalos" (see Astorga, 1997). These are serpentinized harzburgite rocks, basalts and Mesozoic radiolarites possibly of Jurassic - Lower Cretaceous age.

Since the Upper Paleocene, both regions of what today is the San Juan basin have evolved mainly as a back-arc region, with deposits of important successions of volcaniclastic rocks.

However, during the late Miocene (and possibly linked to the rearrangement of plates and tectonic blocks in the Caribbean region), a back-arc "rift" began to open up. This has been referred to by Astorga et al. (1991) as the San Carlos Basin, and more regionally it is known as the Nicaragua Graben (see Figure 2, above).

The existence of the Lakes Nicaragua and Managua are the best evidence of the existence of this second-generation basin, which is still geologically active. Conversely, the sector of the basin in Costa Rica has been subject to a process of silting up that is rapid on a geological timescale, with slight tectonic uplift, which caused this portion of the basin to be raised, possibly from the Pliocene (about 5 million years ago).

It is highly probable that before this phenomenon occurred, the Nicaragua Graben drained towards the Caribbean Sea in a paleo-San Juan River, in a similar position to the current course of the river. This situation must have occurred at least from the Middle Miocene (10 million years ago).

With the uplift of the basin of San Carlos in Costa Rica, drainage to the Nicaragua Graben was further increased through the San Juan River. Through that process, the San Juan River Basin was created as it exists today, and since that time it has had a relatively homogeneous evolution.

4. General characterization of the San Juan River and its delta

The slope of San Juan River, from its source at Lake Cocibolca to its mouth in the Caribbean Sea, is limited by the low drop in its elevation, of only around 30 m (Figure 3).

It is an antecedent river, meaning that it developed prior to uplifting of the mountains through which it runs. This explains why the river's course "cuts" through mountain highlands that are tens to hundreds of metres high (Figure 3).

The course downstream of Lake Cocibolca may be divided into two contrasting reaches; the mountainous and plain reaches.

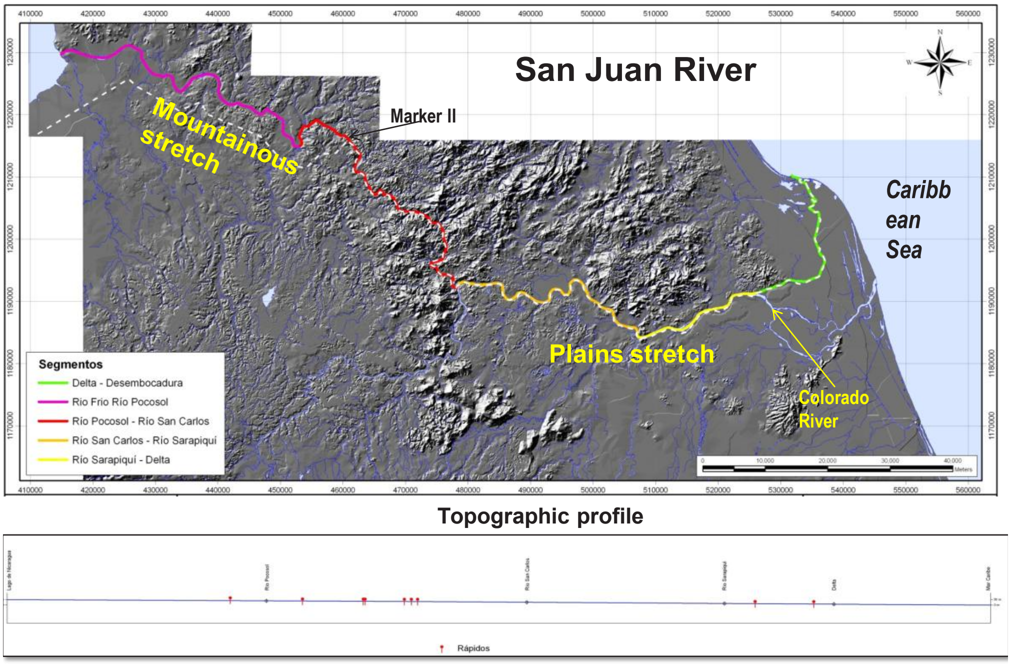

Fig. 3. *Course of the San Juan River from where it flows from Lake Cocibolca to its mouth in the Caribbean Sea, superimposed on a digital elevation model. A topographic profile of San Juan River from the Lake to the mouth is show below the map. There are two reaches: a mountainous reach and a plain one. These reaches can be divided into segments that are indicated on the map and explained in the text. The San Juan River is an antecedent river, meaning that it existed prior to geological uplifting of the mountains that it crosses; this fact demonstrates that this river is ancient, which is corroborated by the presence of a delta at its mouth whose age is estimated at approximately 10 million years (see text for details).*

The mountainous reach extends from its source at Lake Cocibolca to the mouth of San Carlos River. This reach may be divided into two sub-reaches: a) Río Frío - Pocosol and b) Pocosol - San Carlos River. It is in the lower sub-reach that the greatest number of "rapids" occur in the river, where bed rock is exposed in the bed (see Figure 3).

This reach is characterized by the fact that the San Juan River cuts through the topography of the land, with its fluvial valley constrained between mountain ranges. In general, the bed gradient or slope is steeper in this reach compared to the plain reach downstream.

The plain reach extends from the mouth of the San Carlos River to the mouth of the San Juan River in the Caribbean Sea. It too may be divided into sub-reaches (Figure 3): a) San Carlos River - Sarapiquí River, b) Sarapiquí River - Delta and c) Delta - Mouth. This reach has a lower slope or gradient compared to the mountainous reach upstream.

In the plain reach, the fluvial valley of the San Juan River is wider and more open, generally lacking constriction by adjacent to mountain ranges, with a few exceptions on the left bank of the Sarapiquí River - Delta sub-reach.

The San Juan River forks at Delta Costa Rica, which is the start of the river's Delta - Mouth sub-reach (Figures 3 and 4). The San Juan River continues from Delta Costa Rica to its mouth in the Caribbean Sea at the Bay of San Juan del Norte, but much of the discharge (probably 80 to 90%) passes to the Colorado River, which discharges to the Caribbean about 20 km to the south-east. The origin of this fork is explained by the fact that Delta Costa Rica lies at the proximal head of the delta of the river, which has been accumulating sediment and building towards the east for at least the last 10 million years (Figure 4). For full details, see Astorga et al. (1991).

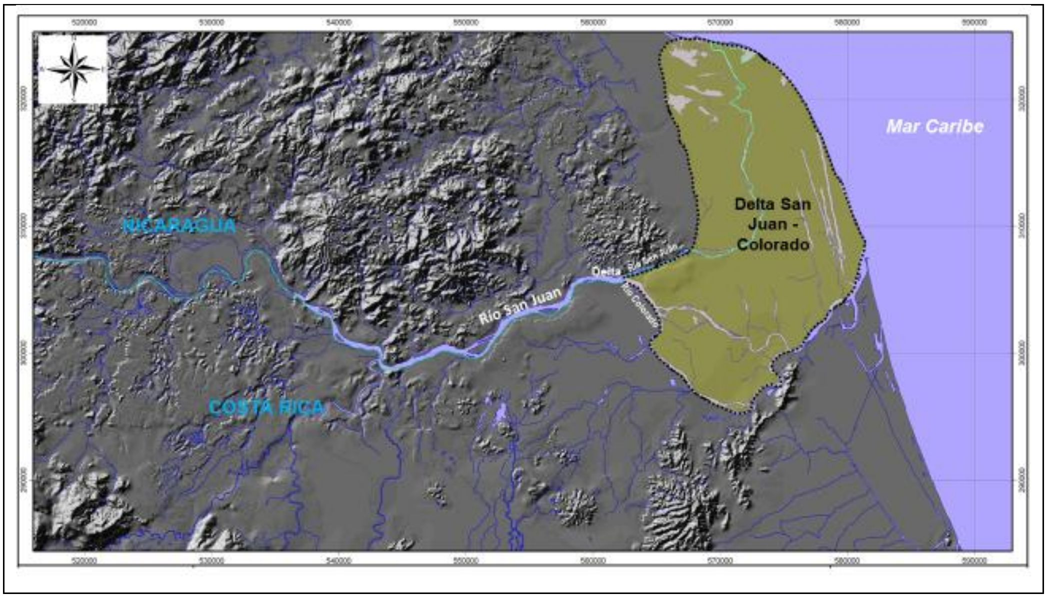

Fig. 4. *Lower sub-reach of the San Juan River. At Delta Costa Rica, the river forks to form the lower San Juan River and Colorado River . The pattern of growth faults (or listric faults) parallel to the coast in the deltaic front of this sedimentary system formed by eastern advance of the delta begin from this location. Note that this is an area includes approximately 250 km^2 of wetlands that extends between both countries.*

Interpretation of the seismic reflection lines by Astorga et al. (1991) identified an important pattern of growth faults (or listric faults) parallel to the coast in the deltaic front of this sedimentary system (Figure 5). These geological faults seem to have played an important role in the control and evolution of the shoreline associated with the delta.

It is believed that these features were formed by eastern advance of the lower San Juan - Colorado delta during the last 10 million years, which has extended through prolongation towards the sea to create a delta with an area of at least 1,000 km^2, much of which is currently submerged. During this period it has, nevertheless, increased the area of the coastal plain by approximately 1,250 km^2.

Another geologic feature to highlight from the work of these authors is the interpretation of the direction of the Hess Fault (or Hess Scarp) which enters the coast approximately in a northeast to southeast direction in the vicinity of the mouth of the lower San Juan River.

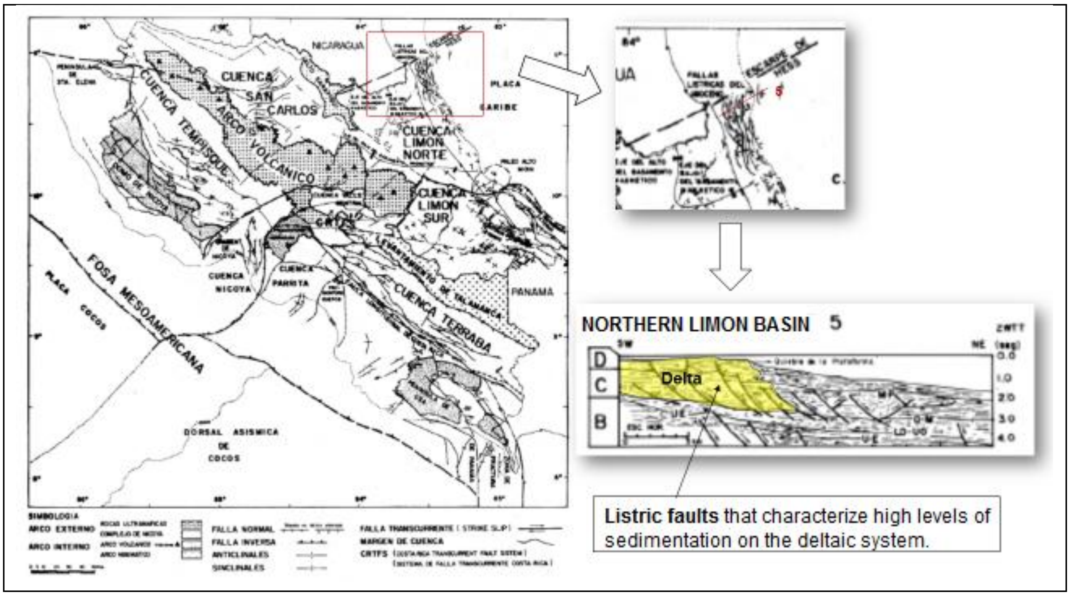

Fig. 5. *Figures taken from the article by Astorga et al. (1991) which show the tectonic structure of Costa Rica, with particular emphasis on the delta of the San Juan - Colorado system. The profile was obtained from the interpretation of seismic reflection sections in the delta, which indicate the maximum age of the feature to Miocene (approximately 10 million years ago) and the abundant presence of listric faults parallel to the coast, evidencing high sedimentation rates and also a possible process of tectonic and neotectonic control in the sedimentation system of the delta.*

5. Extraordinary inputs of sediment due to geological events in the Costa Rican part of the San Juan River basin

Figure 6 shows the digital elevation model of the Costa Rican part of the San Juan River basin. It indicates the main extraordinary sources of sediment toward the San Juan River. Eleven volcanic structures, some of them complex (stratovolcanoes) that are currently active are indicated on the map, including the Rincón de la Vieja, Arenal, Poas, and Turrialba volcanoes.

Extraordinary inputs of sediment to the basin are defined as all of those that result from “catastrophic” or “exceptional” geological events, directly associated with volcanic eruptions (pyroclastic flows and lahars) and earthquakes with magnitudes greater than 6.0, which generate large numbers of landslides (Figure 7). Major flood events are not included because they impact the fluvial system primarily through transporting large volumes of sediment, but are not necessarily a primary source of new sediment.

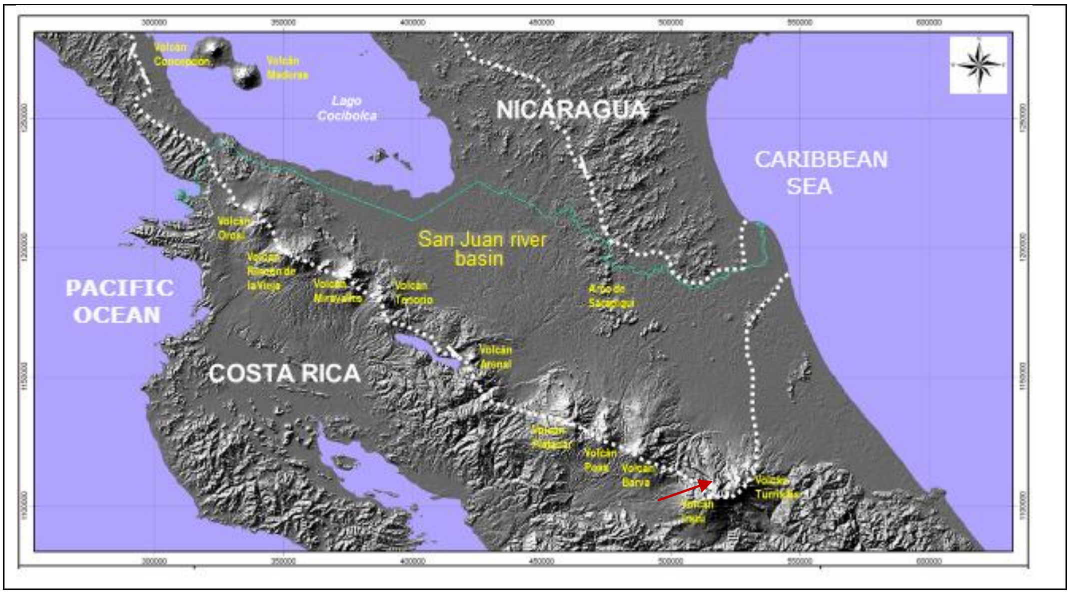

Fig. 6. *Extraordinary sources of sediment input to the San Juan River, from the Costa Rican part of the basin. It should be noted that there are at least eleven currently active or potentially active volcanoes with heights between 2,000 and 3,000 metres above sea level that periodically contribute extraordinary amounts of sediment to the basin.*

Figure 8 presents a timeline of "Historical Seismic events (earthquakes) and volcanic eruptions recorded on the Costa Rican side of the basin of the San Juan River" for the last three centuries.

In this compilation, earthquakes with magnitudes greater than 6.0 have been included, as these are known to induce landslides in the upper parts of the sub-basins in Costa Rica (Figure 7), as well as volcanic eruptions that input sediment to the sub-basins, particularly through the development of volcanic mudflows (known as lahars).

Figure 8 shows that there is a significant volcanic eruption within the Costa Rican portion of the basin of the San Juan River approximately every 40 years. Earthquakes occur more frequently: on average about 13 per century.

Thus, it must be concluded that a "catastrophic" or "exceptional" geological event that provides extraordinary sediment to the basin occurs, on average, about every 20 years.

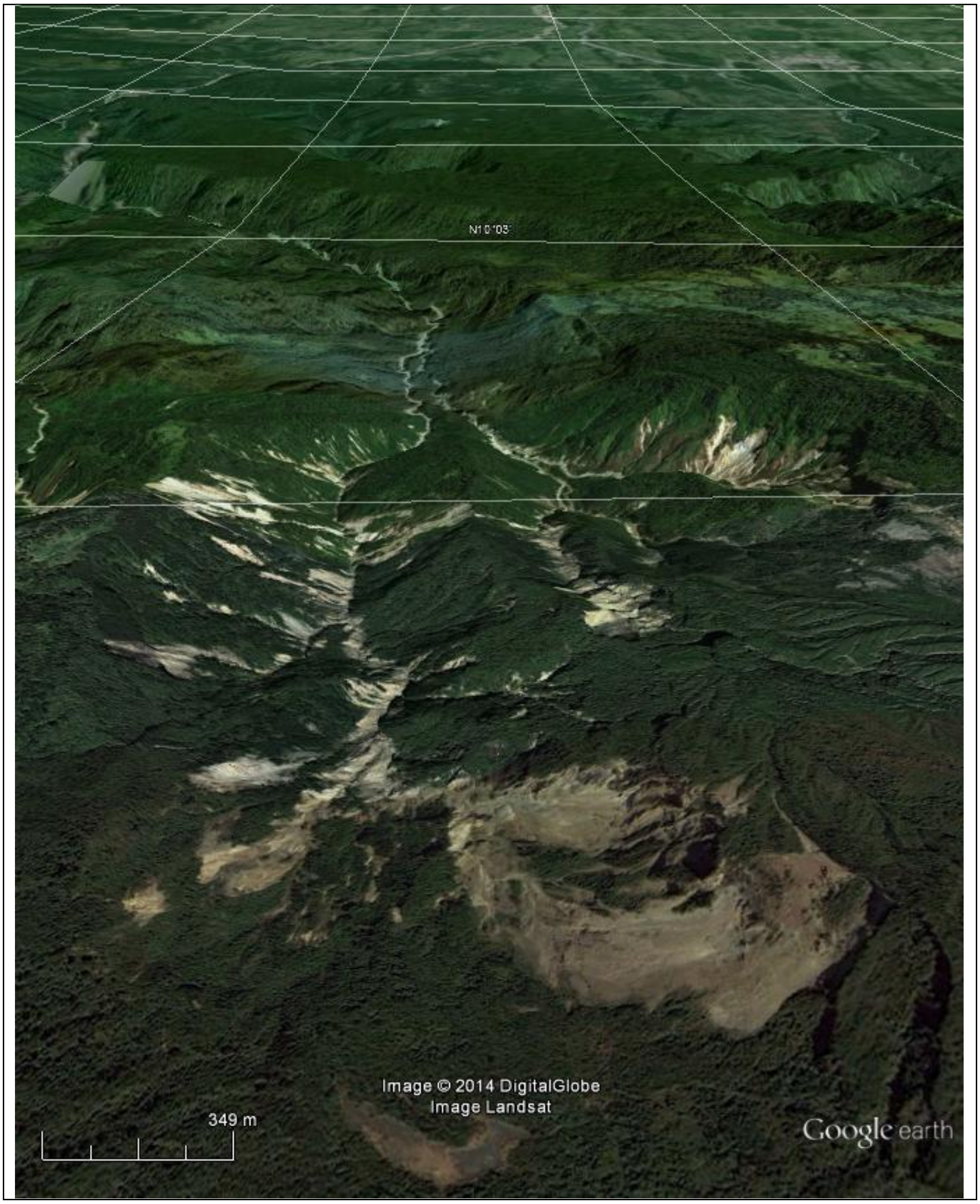

Fig. 7. *Natural erosion processes occurring in the upper part of Irazú Volcano (for approximate location see red arrow in Figure 6). Large and numerous landslides feed sediment into the streams that drain the volcanic mountain range towards the North, especially in the San Carlos and Sarapiqi tributary basins within the San Juan River basin. The sediments consist of gravel, sand, silt and clay in different percentages. As clays, silts and fine sands are easier to transport, they are carried directly to the San Juan River during the rainy season.*

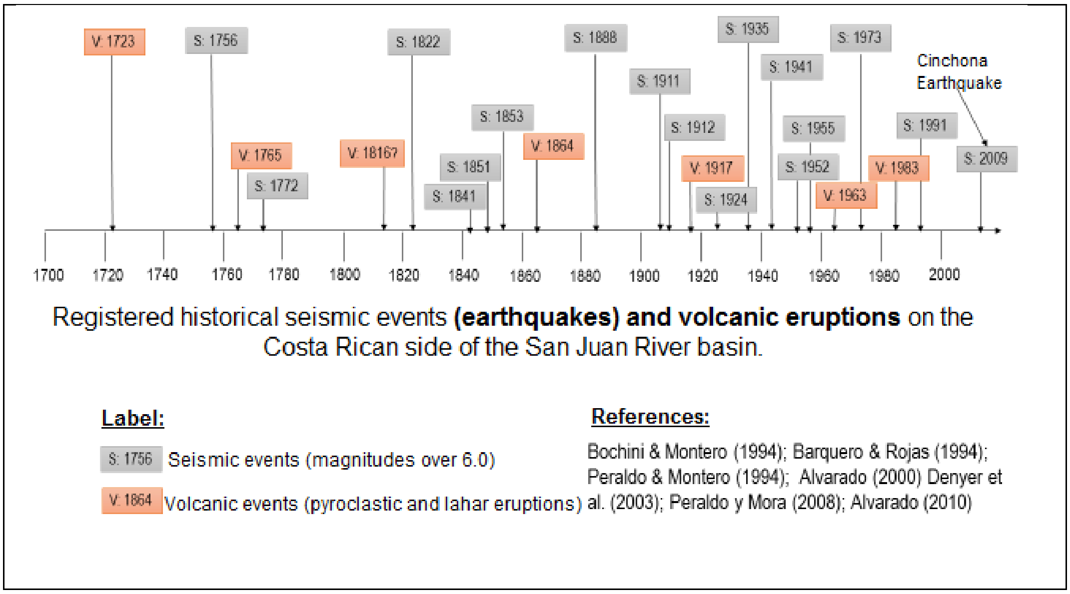

Fig. 8. *Extraordinary sources of sediment input to the San Juan River, from the Costa Rican side of the basin. Note that there are at least eleven currently active or potentially active volcanoes with heights between 2,000 and 3,000 metres above sea level that periodically contribute significant amounts of sediment to the basin and that earthquakes happen even more frequently than volcanic eruptions.*

Technical information about the detailed characteristics of these extraordinary events is limited because systematic geological studies did not begin in Costa Rica until the creation of the Central American School of Geology at the University of Costa Rica in the 1970s. However, the historical data compiled by the authors cited in Figure 8 indicates that these events generate extraordinary sediment inputs (associated with landslides and/or mudflows) to the drainage systems of tributary rivers that transport the sediment to the San Juan River either quickly (for fine sediment) or more gradually (in the case of coarse sediment).

It is relevant in this context to mention the case of the Cinchona earthquake; an event of magnitude 6.2, that occurred on 8 January 2009 in the Central Volcanic Range of Costa Rica, within the basin of the San Juan River.

According to Alvarado (2010), the total volume of sediment generated by this seismic event was between 2.5 to 3.5 million m^3, which is equivalent to between 4 and 5 million tonnes. Sediments ranged from clays to large blocks of volcanic rock, which fragmented during their transport. Alvarado (2010) indicates that numerous landslides and mudslides triggered by the earthquake flowed at speeds between 4.8 and 13.3 m/s in areas with steep gradients decreasing to between 10 and 2.5 m/s in areas with lower gradients as a result of the earthquake (Figures 9 and 10).

Alvarado (2010) points out that the sediment impacts of the Cinchona earthquake have been corroborated in the world (Keefer & Wilson, 1989), Central American (Devoli et al., 2009) and Costa Rican literature (Mora & Mora, 1994) which, *"establish the relationship between the magnitude of earthquakes, the affected area, the slipped area and the generation of mudflows, among other things."* Emphasis is given to the fact that major mudflows and landslides have been generated by earthquakes with magnitudes greater than 5.2 (Mora & Mora, 1994). In the case of the Cinchona earthquake, according to Alvarado (2010), the affected area was around 200 km^2, with 349 measured landslides within an area of 21.7 km^2 within which hillslopes completely slipped (Figure 9). This was clearly an extraordinary event in terms of the quantity of sediment suddenly contributed to the drainage basin.

Given the characteristics of the sediments produced, it is estimated that approximately 50% of the material input to streams and rivers by these landslides were in the clay to sand size range. This suggests that the fluvial systems draining the northern flank of the mountains would have carried that sediment to the San Juan River within a period of weeks to months.

Thus, it is concluded that within a year after such an exceptional event in the upper part of the basin, the fine component of the material extraordinarily contributed (making up between 10 to 50% of the overall volume) is likely to reach the San Juan River, to be transported to its deltaic mouths at the Caribbean Sea.

Based on the timeline of known events, and technical information gathered following the 2009 earthquake, it is possible to conclude that the San Juan River has received extraordinary inputs of sediment (especially clay, silt and fine sand) in varying volumes at approximately 20 year intervals, with these inputs lasting from several months to a maximum of a year or so.

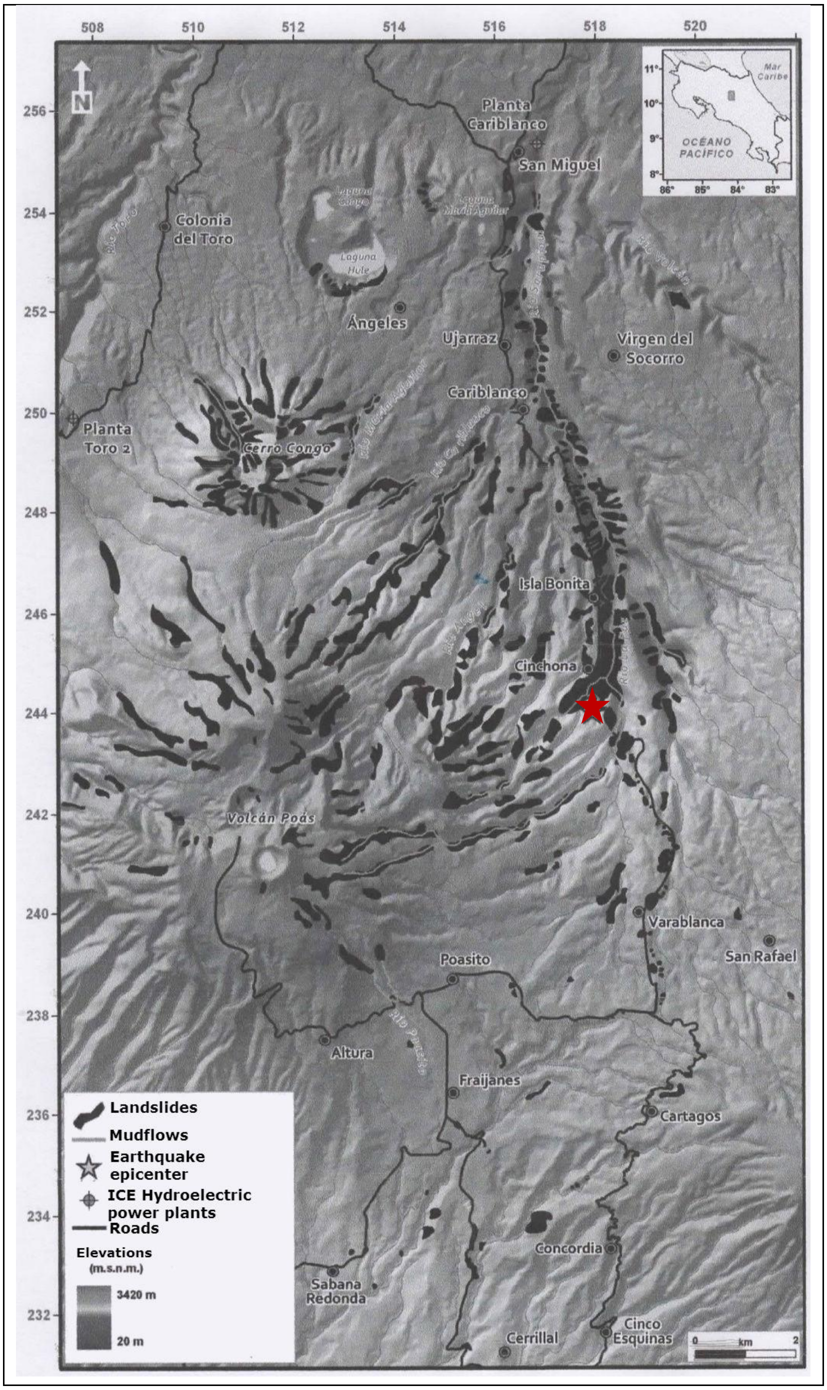

Fig. 9. *The areas marked in black represent the landslides that occurred as a result of the Cinchona earthquake of 2009. The star indicates the site of the epicentre. Image taken from Alvarado (2010).*

Los daños sufridos en el hotel Waterfalls Gardens por el terremoto del pasado 8 de enero han ocasionado desembolsos millonarios por parte del INS.

Fig. 10. *Photographs of landslides triggered in January 2009 showing the types of damage caused by the Cinchona earthquake (see Figure 9 for location).*

This establishes that the San Juan River has been subjected to extraordinary inputs of sediment for centuries and that it has the ability to transport such inputs of sediment, particularly in relation to its morphological resilience to carry additional sediment which periodically, but extraordinarily, adds to the annual load generated by normal processes of erosion that operate semi-continuously within the drainage basin.

The study has established that geological events that occur periodically (on average one every 20 years) in the Costa Rican part of the basin, are able to suddenly contribute exceptional inputs of sediment to the fluvial system, ranging from 1 to perhaps 4 or 5 million additional tonnes of sediment. This has been documented for centuries and has probably been the case for millennia or perhaps 10 million years. It follows that the environmental effects on the ecological conditions of the river are not significant because the fluvial and ecosystems are adapted to these conditions and events.

The additional contribution of sediment represented by the construction of Ruta 1856 must be considered within this context.

According to the latest measurements of slope erosion (based on field surveys of all the slopes along the Road and supplied in the 2014 Mende Report), added to estimates of erosion of the road bed itself provided in the 2014 ICE Report, and assuming a sediment delivery ratio of 0.6, the upper bound estimate of the volume of sediment input to the San

Juan River due to construction of the Road under a 'worst case' rainfall scenario is about 75,000 tonnes per year. This represents about 1.5 to 7.5% of the load periodically supplied to the drainage system by natural geologic events.

Considering the geological setting of the San Juan River Basin, and its long history of periodically receiving extraordinary inputs of sediment, it must be concluded that the environmental impacts of the additional sediment supplied due to construction of the Road are insignificant. This is particularly the case taking into account the fact that periodic contributions due to natural, geologic events may be 10 to 60 times greater than the input produced by sediment from Ruta 1856.

6. Conclusions

The main conclusions of this study are as follows:

1. The hydrographic basin of the San Juan River, is a bi-national basin that has an area of a little over 42,000 Km^2. Of the basin, about 70% is in Nicaragua, with the remaining 30% in Costa Rica.
2. Geologically, the drainage basin of the San Juan River falls into two different geological zones: the volcanic arc, and the back-arc. The geological situation results in the highest parts of the basin being formed by volcanoes, some of which are currently active.
3. The Lakes Nicaragua and Managua, as well as the northern part of Costa Rica, which is known as the San Carlos Basin, form a geologic back-arc structure, tectonically controlled, which originated 15 to 20 million years ago (during the Lower Miocene). Originally this area was covered by the sea, but about 10 million years ago it was separated as a large fresh water lake. The drainage of this lake was an ancient San Juan River, whose mouth was towards the East, in a location close to the present mouth of the River.
4. During the last 10 million years, the San Juan River has built a delta (the San Juan – Colorado Delta) with an area of around 1,250 km^2 and a thickness on the order of 4,500 metres. This delta is the accumulation of literally billions of cubic metres of sediment.

5. The existence of the San Juan – Colorado Delta is testament to the operation of natural sediment erosion, transport and deposition processes that have operated for about 10 million years. In addition to this "normal" sediment input, there have periodically been extraordinary sediment inputs caused by seismic and volcanic events.
6. The record of geologic events in the Costa Rican part of the San Juan River Basin during the last three centuries (i.e. earthquakes and volcanic eruptions that have generated landslides and mudflows) indicates that, on average, such events have occurred about every 20 years. These events input extraordinary volumes of sediment to tributaries draining to San Juan River in the following months to a year.
7. For example, the 2009 Cinchona earthquake, which had its epicentre on the northern slope of the Poás Volcano in Costa Rica and within the basin of the San Juan River, is documented to have triggered 349 landslides within an area of 21.7 km^2 around the epicentre. Between 2.5 to 3.5 million cubic meters of sediment were released, of which about 50% is estimated to have reached the San Juan River in the 12 months following the event.
8. As similar (and stronger) seismic events are documented as having occurred in the basin for centuries, the San Juan River has evolved the capacity to transport heavy and variable sediment loads to its delta, along with the morphological resilience to absorb extraordinary increases in the supply of sediment due exceptional events.
9. Recognising the natural capacity of the San Juan River to transport high and highly variable sediment loads, I conclude that the additional sediment load produced temporarily by the construction of Ruta 1856, which is estimated to be of the order of 75,000 tonnes/year, is insignificant in comparison to the natural sediment load carried by the River and geologically-driven variability in that load.

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APPENDIX A

Curriculum Vitae: Allan Astorga Gättgens

Born in Cartago, Costa Rica, on 26 January 1962. He received his primary education at Escuela República de Guatemala, and secondary education at Instituto de Alajuela. He obtained a Bachelor's Degree in Geology in 1984 and a Licenciatura Degree in Geology in 1987 from Universidad de Costa Rica, with honours. From 1989 to 1996 he pursued post-graduate studies at the Institute of Geology and Paleontology of the University of Stuttgart, Germany, where he obtained a PhD in Natural Sciences with the highest marks.

He worked as assistant in the Seismology Laboratory at the Instituto Costarricense de Electricidad de Costa Rica during 1984. From 1984 to 1999 he worked as geologist for oil exploration at the Primary Production Management of the Refinadora Costarricense de Petróleo (Costa Rican Oil Refinery). He performed oil exploration work specializing in geological mapping and sedimentology at several sedimentary basins in Costa Rica. Between 1991 and 1993 he carried out oil exploration in the South of Nicaragua, as part of an agreement with the Government of Nicaragua. He also conducted geological studies in Panama.

To date, and since 1991, he joined the team of professors of the Central American School of Geology at the University of Costa Rica. He teaches Petrography of sedimentary rocks, Environmental Geology I (environmental impact assessment) and Environmental Geology II (strategic environmental assessment of policies and plans with emphasis on land use). He has also taught courses on National Affairs and Sedimentary Basins and Hydrocarbons.

For several years he taught environmental impact assessment for the master's degree courses of Universidad Estatal a Distancia, Universidad de Costa Rica and Universidad Nacional.

Since 1993 he joined the Inter-institutional Committee of Environmental Impact Assessment of the Ministry of Energy and Natural Resources of Costa Rica, as environmental impact examiner. In 1994 he assumed charge of the Strategic Planning Unit of the Environmental Impact Commission of the Ministry of the Environment. Since 1995 he became part of the environmental impact assessment technical team of the Secretaría

Técnica Nacional Ambiental (SETENA) of the Ministry of Environment and Energy of Costa Rica. Between 1997 and 1998 he was technical director (Secretary General) of the SETENA. As part of his work as environmental examiner, he conducted more than 700 environmental assessment analysis of different types of projects: energy, road works, urban planning, mining, industry, tourism, among other.

To date, and since 1999, he works as a private environmental consultant on environmental impact assessment, environmental management and environmental land management. From 1999 to 2006 he served as international consultant for the Central American Commission on Environment and Development, the Inter-American Development Bank (IADB), the World Bank, the International Union for Conservation of Nature (IUCN), among other organizations, to support the development of the System of Procedures for Environmental Impact Assessment of the Central American countries. As part of this consulting work, he coordinated or participated in the preparation and modernization of the regulations for environmental impact assessment of Belize, Guatemala, Nicaragua, Costa Rica and Panama. In 2004 he was the IADB Coordinator for the preparation of the proposal of Environmental Protection Policies for Central America. In 2006, he acted as coordinator of the EIA Modernization and Strengthening Project in Central America. During the same year he drafted the proposal of a procedure for the application of the Strategic Environmental Assessment for Central America, for which regional courses were given for all the countries of Central America.

From 2007 to 2009 he participated as consultant for the Ministry of Natural Resources and the Environment of Honduras, as the main coordinator in the modernisation of the Regulations of the System for Environmental Evaluation and Control, as well as the EIA Technical Manual of Honduras. From 2009 to 2011 he participated as consultant of the Ministry of the Environment and Natural Resources of El Salvador, responsible for preparing the Environmental Impact Assessment Technical Manual of El Salvador.

Between 2007 and 2010, he participated as a member of the Peace with Nature Initiative of the Government of Costa Rica. He acted as coordinator of the components of Environmental Management and Land Use. He was the coordinator of the preparation of the technical procedure to prepare Environmental Management Plans at State institutions.

He also developed the proposal for the procedure to apply the EAE policies, plans and programmes in Costa Rica.

Between 2007 and 2009 he coordinated the multidisciplinary technical team that developed the basis of land planning of the Greater Metropolitan Area of Costa Rica for the PRUGAM Plan, which includes 31 urban municipalities of Costa Rica. He has worked as Coordinator of environmental studies for land use of over 35 municipalities in the country.

As a consultant in environmental impact assessment he has performed over 100 technical studies on various types of development projects. He has participated in several EAE. He has over 50 publications, technical and scientific documents published. Since 2012 he collaborates with the Costa Rican Ministry of Foreign Affairs on the technical issues of geology and sedimentology of the dispute with Nicaragua.

ANNEX 11

Consejo Nacional de Vialidad (CONAVI)

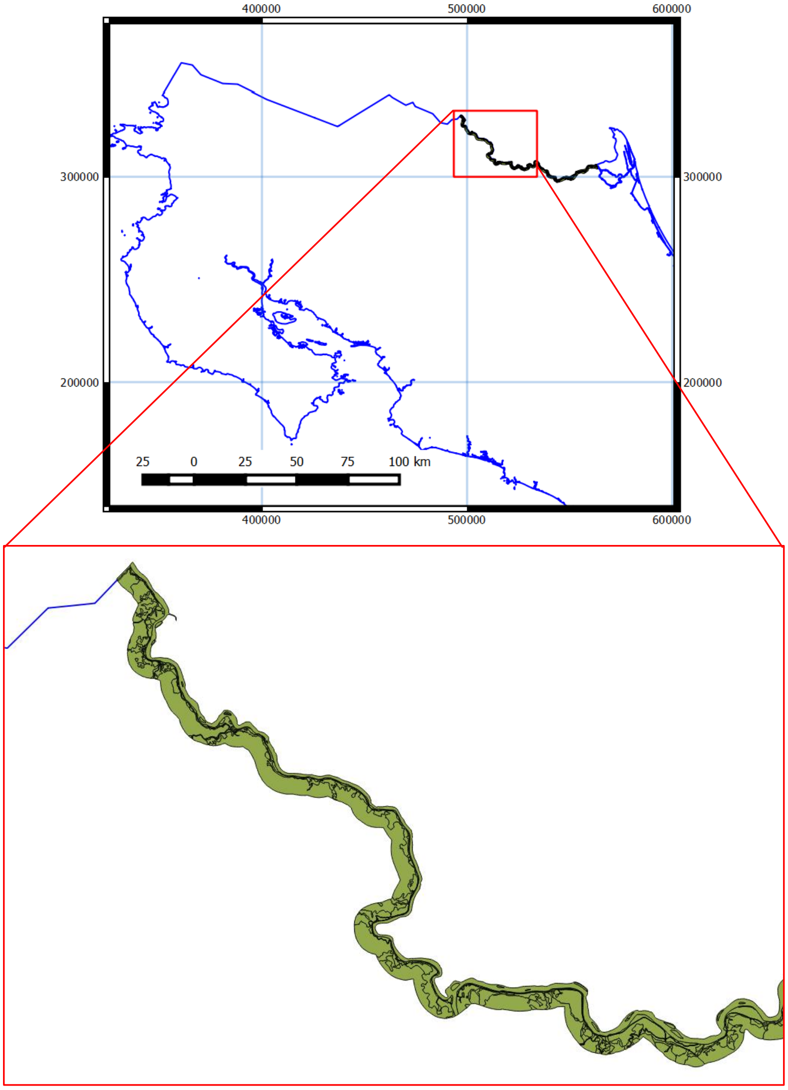
Works on National Road 856: Before and After

December 2014

Tel: (506) 2202-5479 Tel Fax: (506) 2253-1180
Email: jose.mena@conavi.go.cr

WORKS ON NATIONAL ROAD N° 856: BEFORE AND AFTER
Updated as of December 2014

The details shown comprise the works performed by CONAVI between Marker 2 and Caño Cureñita as of December 2014. All of the coordinates are presented in Lambert North projection. In cases where the station is indicated, the origin 0+000 corresponds to the site where the gravel road begins from Marker 2, coordinates E496511, N329581. The following map shows the area of study where the works were performed:

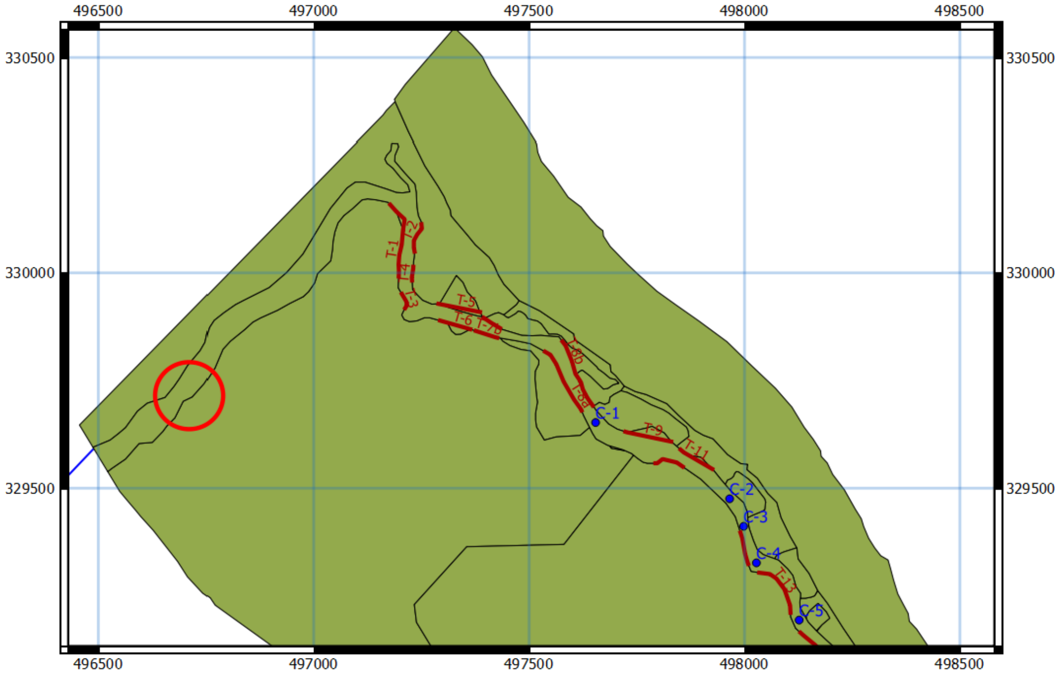


Point: Marker 2

- Name: View toward Marker 2
- Location: E496655 N329700
- Description: Placement of coconut fibre, construction of ford. Station 0+100.

BEFORE	AFTER
	

- Location on the map:

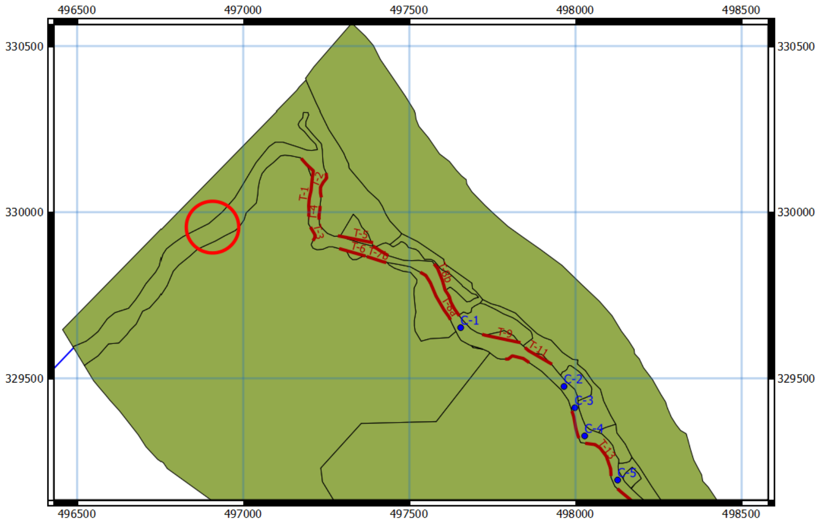


Point: Culvert

- Name: Culvert # 9
- Location: E496918, N 329956
- Description: Placement of a culvert to allow the passage of water which was stagnant. Station 0+213.

BEFORE	AFTER
	 

- Location on the map:

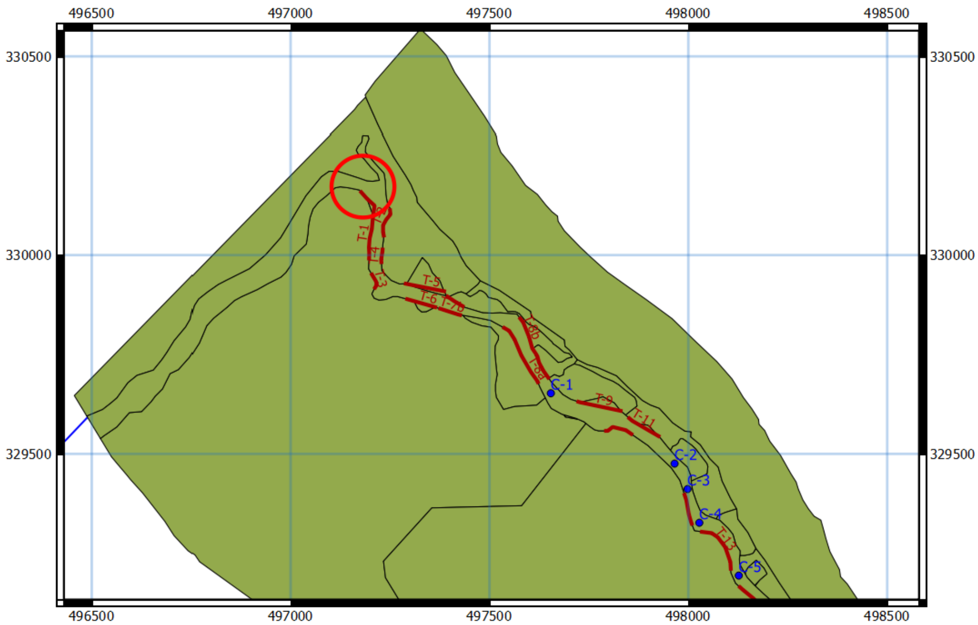


Point: Marker 2

- Name: Entrance to marker 2
- Location: E497210, N330195
- Description: Placement of coconut fibre near the water course has substantially promoted vegetation growth. Station 0+900

BEFORE	AFTER
	

- Location on the map:

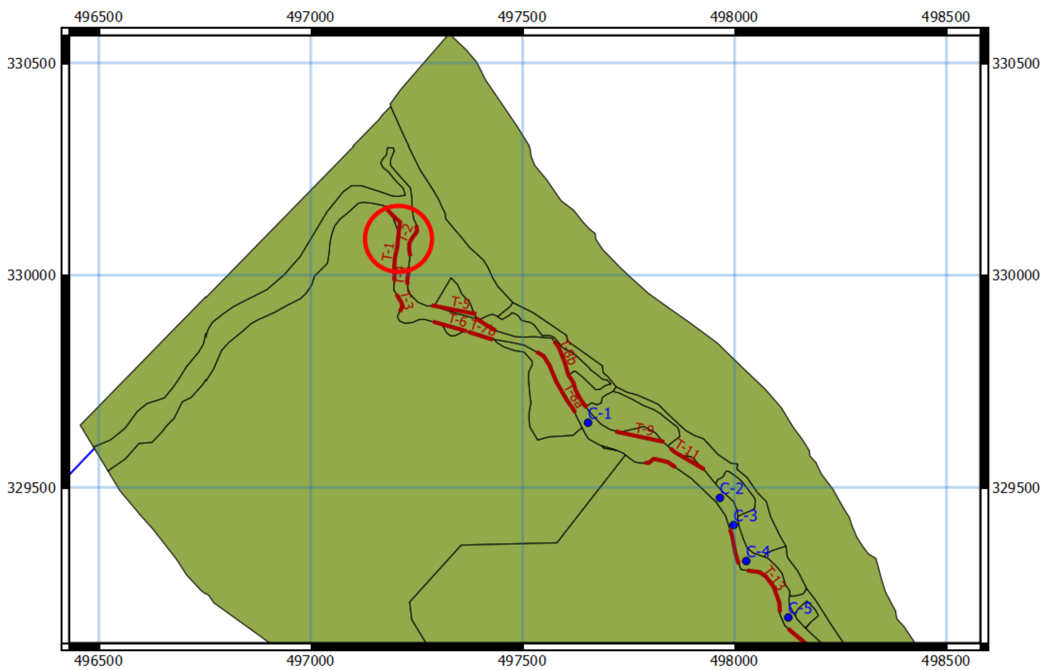


Point: Laying of gravel

- Name: Laying of gravel at entrance to Marker 2
- Location: E497210, N330195
- Description: Laying of gravel to improve the condition of the road. Station 1+000, close to slopes T1 and T2

BEFORE	AFTER
	

- Location on the map:

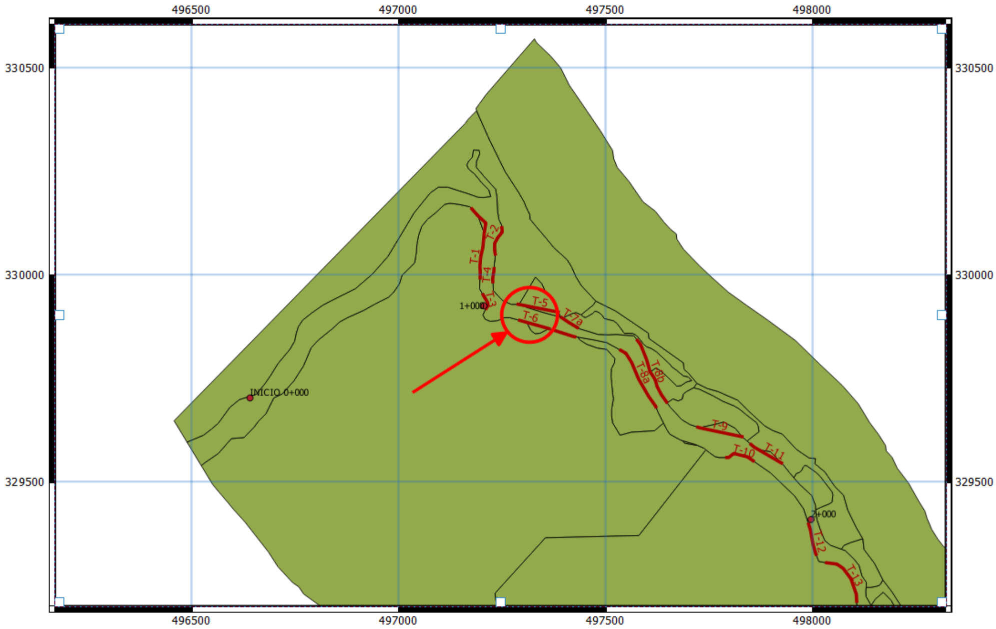


Point: T-6

- Name: Slope
- Location: E497318, N329883
- Description: Contouring of slopes, placement of coconut fibre and placement of lined ditch. Station 1+100, corresponding to slope T-6

BEFORE	AFTER
	

- Location on the map:



Point where gravel was laid

- Name: Laying of gravel
- Location: E: 497075 N:429800
- Description: Laying of gravel to improve the conditions of the road. Station 1+300, close to slopes 8a and 8b.

BEFORE	AFTER
	

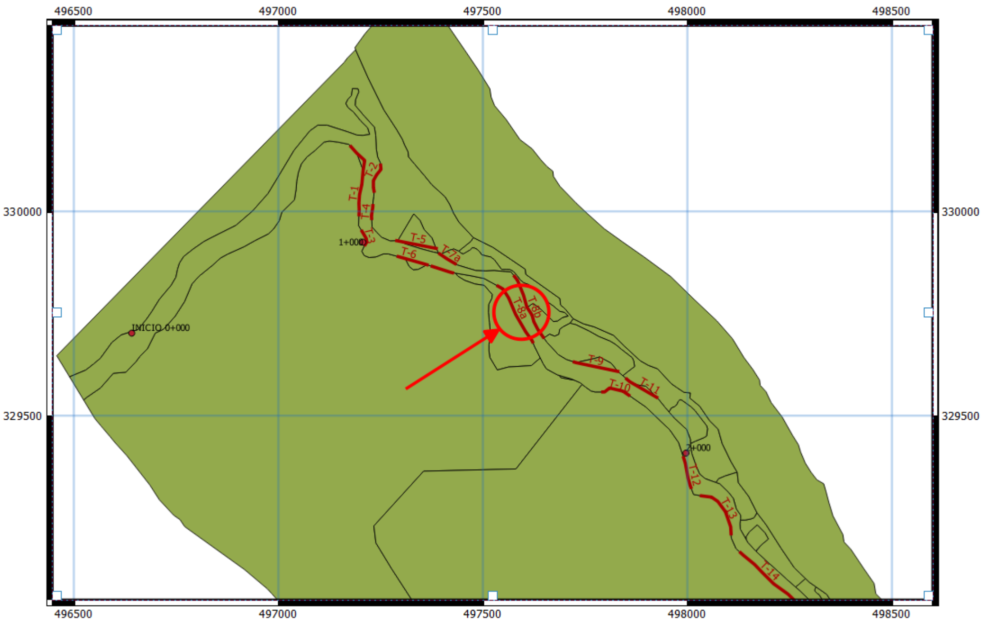
- Location on the map:

Point: T-8a

- Name: Landslide
- Location: E497578, N329755
- Description: Clearing away of landslide material, contouring of slopes, placement of lined ditch. Station 1+427, corresponding to slope T-8a

BEFORE	AFTER
	

- Location on the map:



Point: T-10

- Name: Landslide
- Location: E 497850, N 329600
- Description: Clearing of landslide material off the road. Station 1+800, corresponding to slope T-10

BEFORE	AFTER
	

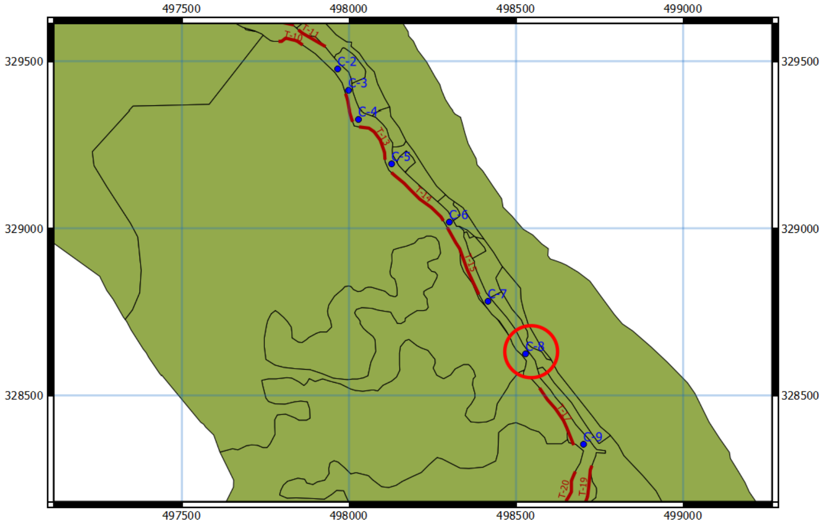
- Location on the map:

Point: C-8

- Name: Culvert # 1
- Location: E: 498517 N: 328350.
- Description: Placement of culvert at a pass where there was an imminent fault and removal of sediment at water course C-8. Station 2+764.

BEFORE	AFTER
 	

- Location on the map:



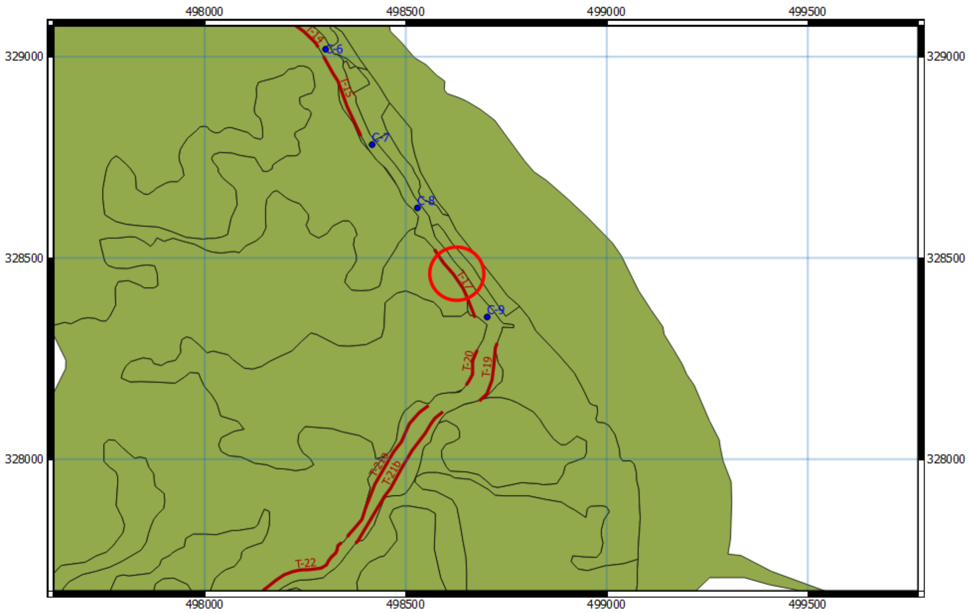
Montes de Oca de la Rotonda de Betania 50 mts Este. Tel: (506)22-02-53-00 Apdo. 616-2010 Zapote, Costa

Point: T-17

- Name: Slope and lined ditch
- Location: E498634, N328436
- Description: Tidying of slope, placement of lined ditch.

BEFORE	AFTER
	

- Location on the map:

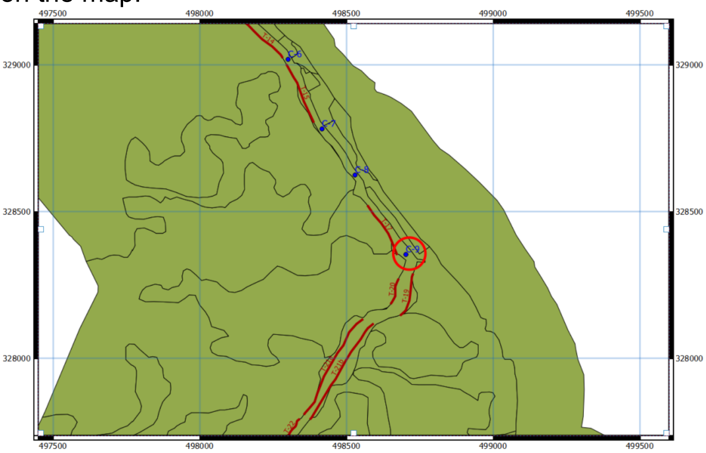


Point: C-9

- Name: Culvert # 2
- Location: E498700, N328350
- Description: Placement of culvert in a land pass undermined due to existing fence. Elimination of fence, placement and compacting of gravel. In addition, construction of a lined ditch at slope near water course C-9. Station 3+270.

BEFORE	AFTER
	 

- Location on the map:

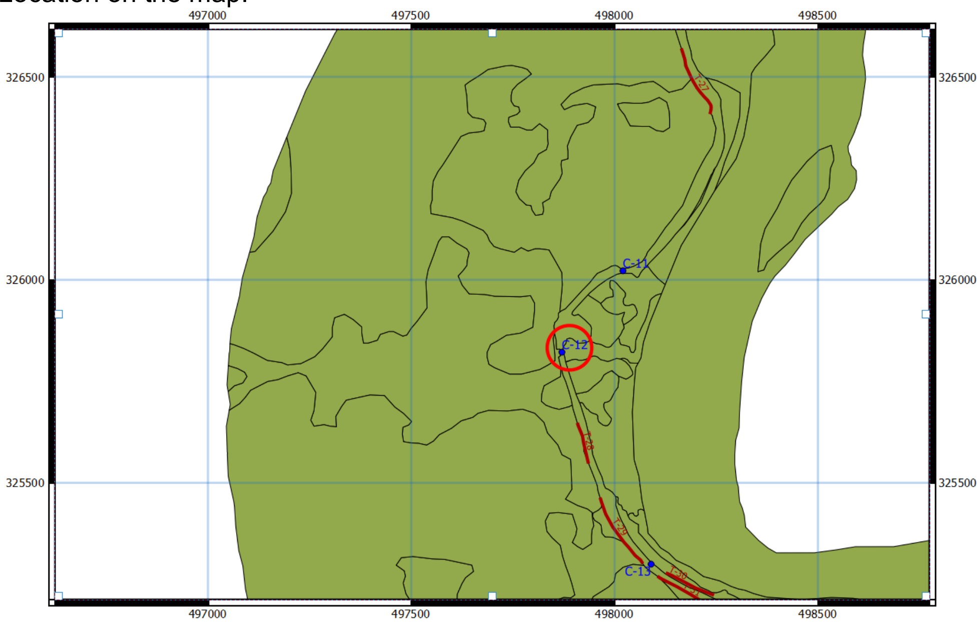


Point: C-12

- Name: Caño Trinidad
- Location: E497870, N325822
- Description: Removal of logs and placement of new panel-type modular bridge. Station 6+500

BEFORE	AFTER
	

- Location on the map:

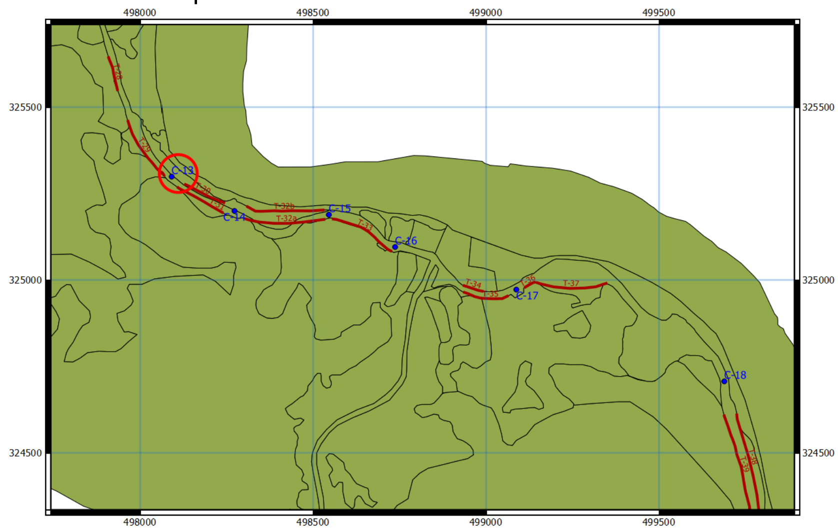


Point: C-13

- Name: Culvert # 8
- Location: E 498089, N 325299
- Description: Placement of culvert. Station 6+900, water course C-13

BEFORE	AFTER
	
	

- Location on the map:

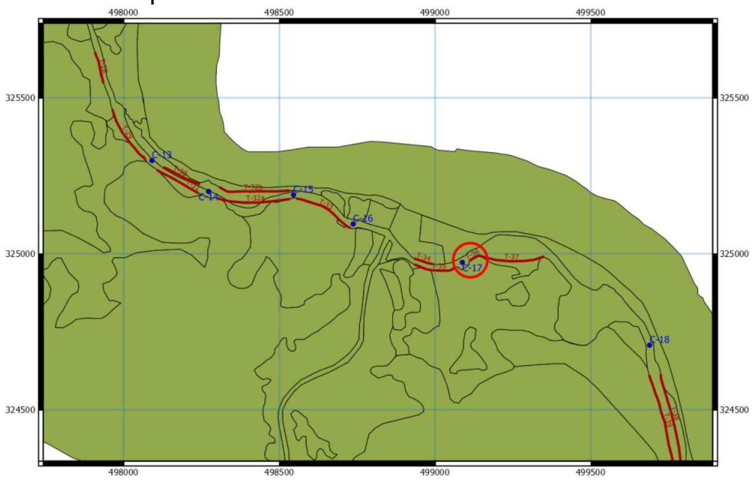


Point C-17

- Name: Culvert # 3
- Location: E499087, N324972
- Description: A concrete culvert is placed in water course C-17. Station 8+034.

BEFORE	AFTER
	 

- Location on the map:

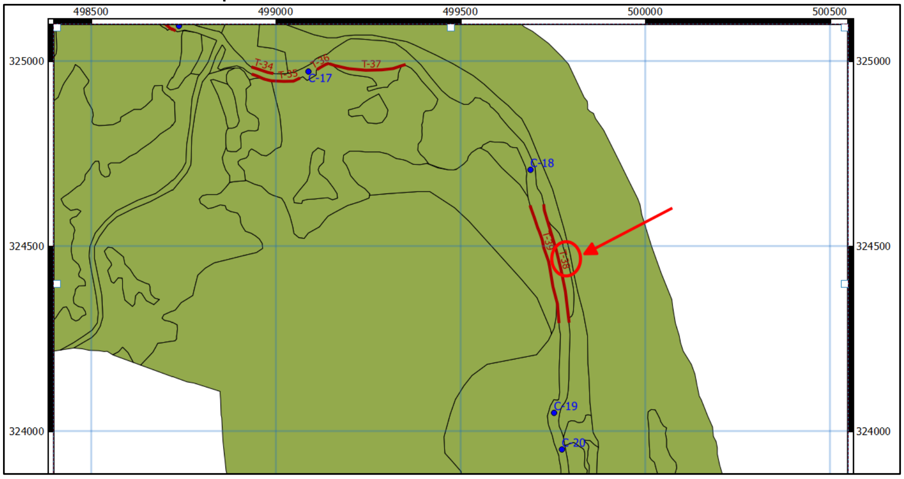


Point: T-38

- Name: Point 1, important slope.
- Location: E499520, N324600
- Description: Lined ditch, contouring of slope, construction of berm at slope T-38. Station 9+040

BEFORE	AFTER
	

- Location on the map:

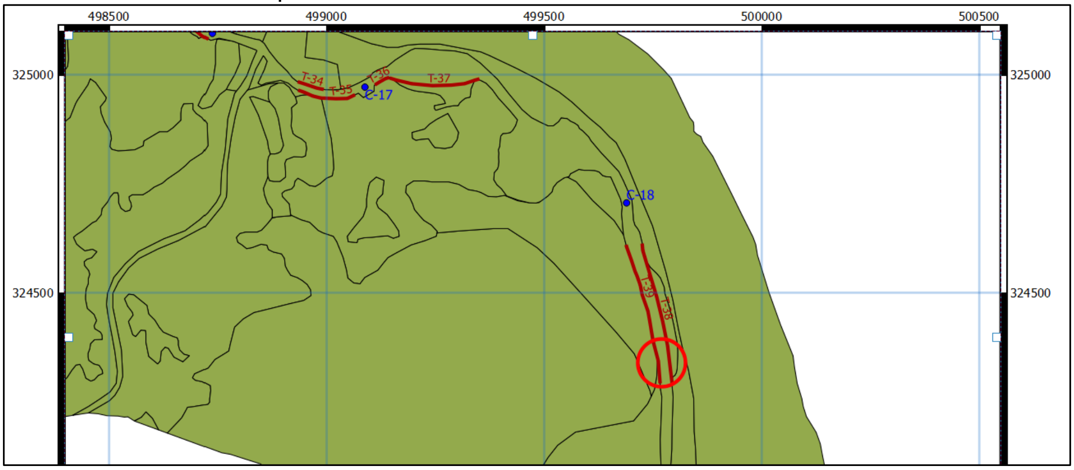


Point: T-39

- Name: Lined ditch and sediment trap
- Location: E499250, N324459
- Description: Sediment trap of the University of Costa Rica (UCR) to control and monitor sedimentation from slope T-39, construction of lined ditch at the slope. Station 9+040

BEFORE	AFTER
	
	

- Location on the map:

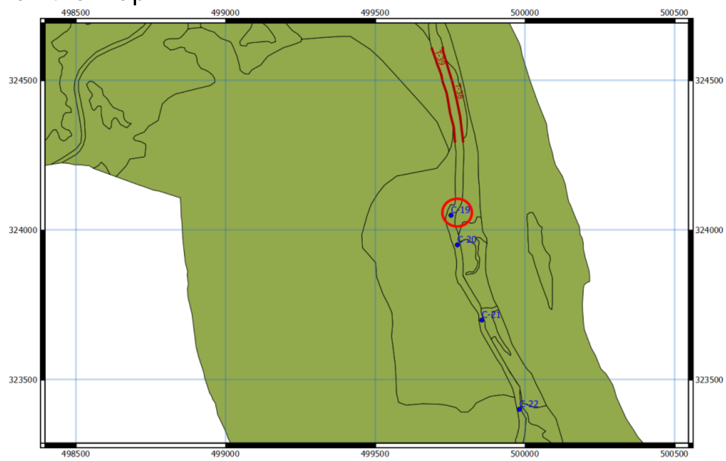


Point: C-19

- Name: Culvert # 4
- Location: E499753, N324049
- Description: Removal of logs and placement of new culvert in water course C-19. Station 9+040

BEFORE	AFTER
	
	

- Location on the map:



Point C-21

- Name: Culvert # 5
- Location: E499856, N323698
- Description: Removal of logs and placement of new culvert in water course C-21. Station 9+783

BEFORE	AFTER
	
	

- Location on the map:

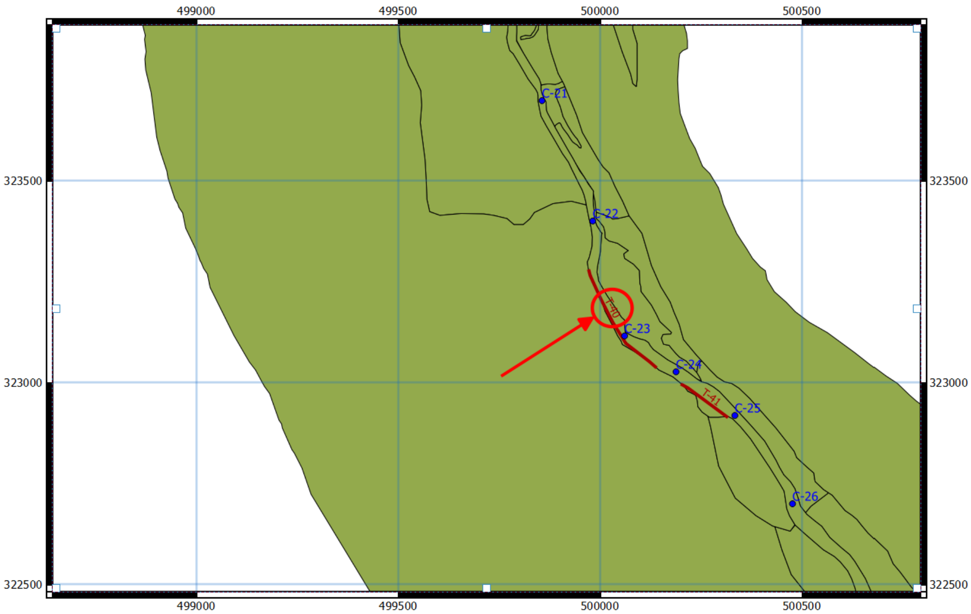
Montes de Oca de la Rotonda de Betania 50 mts Este. Tel: (506)22-02-53-00 Apdo. 616-2010 Zapote, Costa

Point T-40

- Name: Lined ditch and hydroseeding
- Location: E 499982 N 323271
- Description: Planting on slope using hydroseeding on slope T-40. Station 10+350,

BEFORE	AFTER
	

- Location on the map:

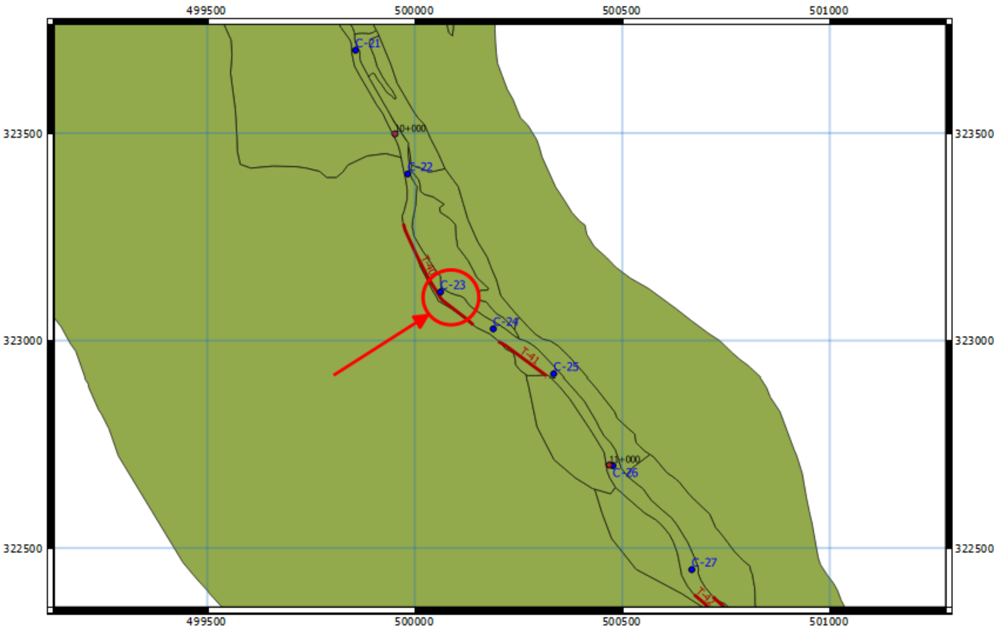


Point T-40

- Name: Lined ditch, hydroseeding and coconut fibre
- Location: E500088 N 323078
- Description: Contouring of slopes, construction of lined ditches, placement of coconut fibre, application of hydroseeding at station 10+428, on slope T-40

BEFORE	AFTER
	

- Location on the map:

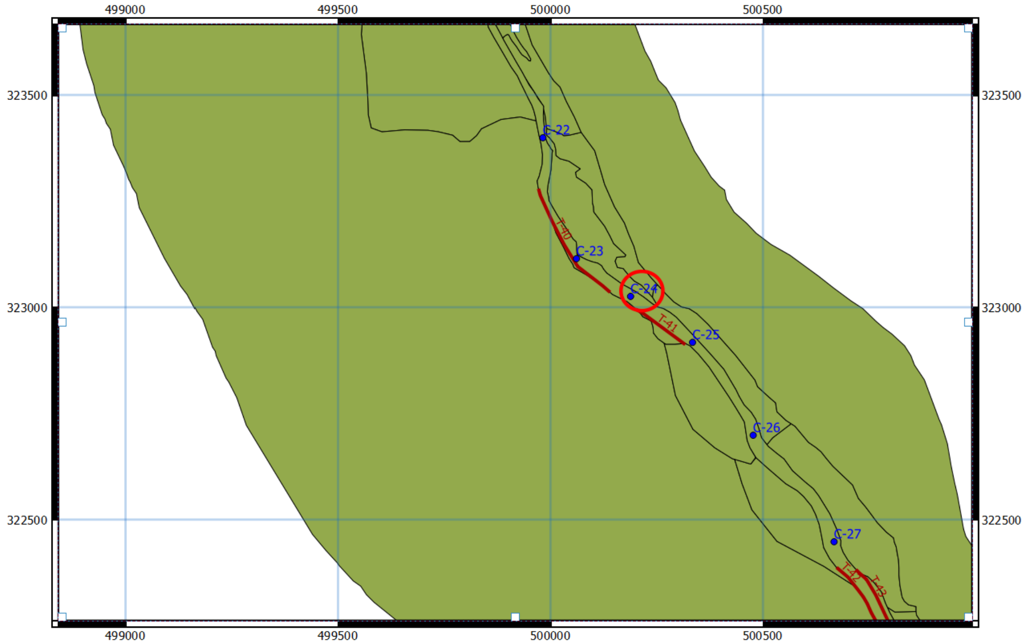


Point C-24

- Name: Culvert # 6
- Location: N:500187 E:323027
- Description: Placement of culvert at water course C-24. Station 10+585

BEFORE	AFTER
	

- Location on the map:



Punto T-41

- Name: Lined ditch, contouring of slope with fibre and planting.
- Location: E500075, N323103
- Description: Contouring of slopes, construction of lined ditch, placement of coconut fibre, application of hydroseeding at station 10+630, on slope T-41

BEFORE	AFTER
	

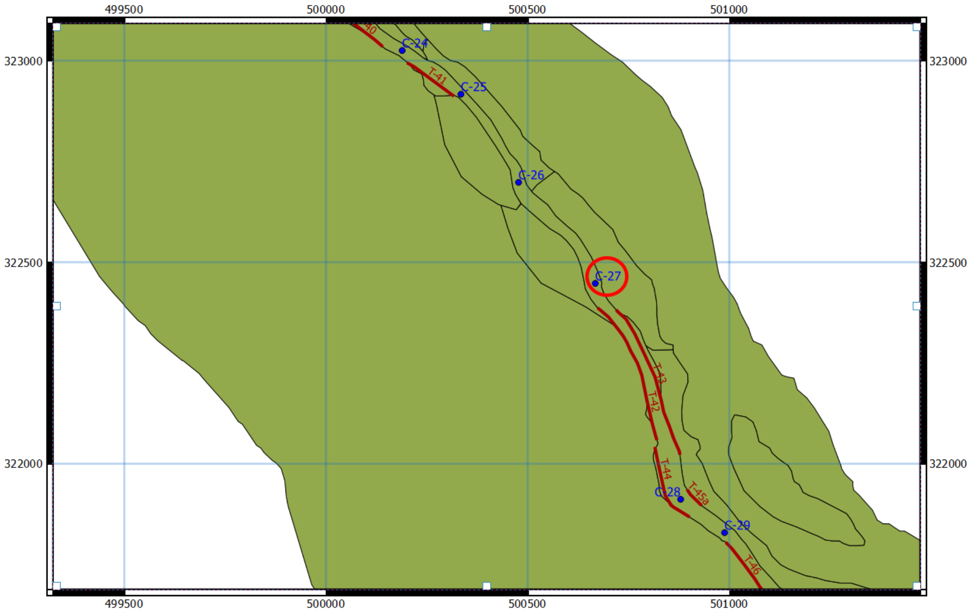
- Location on the map:

Point: C-27

- Name: Repaired log bridge.
- Location: N: 500667 E: 322447
- Description: The bridge was deteriorated to the point where passing through it was dangerous, therefore it was repaired, facilitating its use.

BEFORE	AFTER
	

- Location on the map:

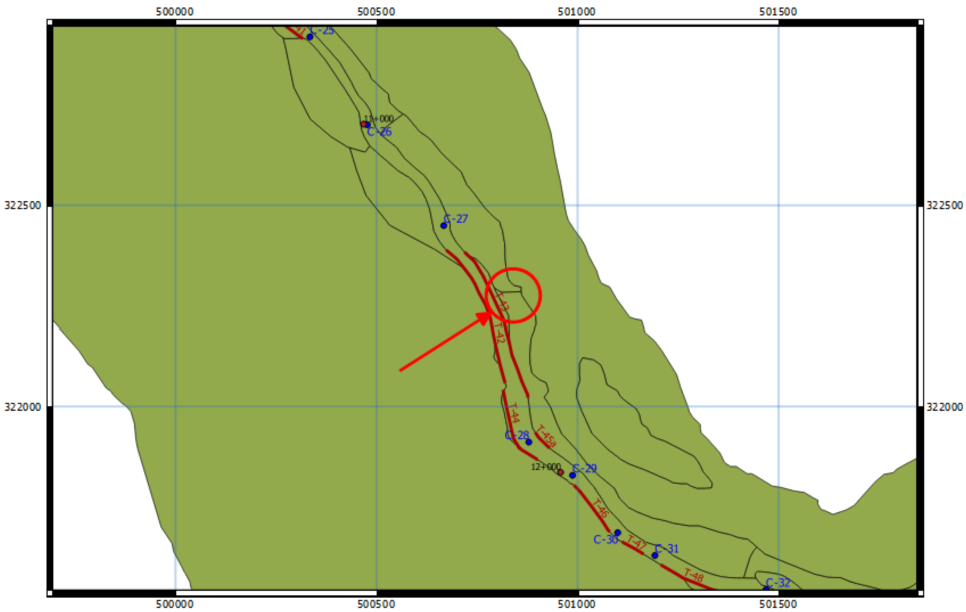


Point: T-43

- Name: Lined ditch, contouring of slope with fibre.
- Location: E500797, N322258
- Description: Contouring of slopes, construction of lined ditch, placement of coconut fibre, at station 11+825, on slope T-43. There has been a very significant growth of vegetation along all the slope.

BEFORE	AFTER
	
	
	

- Location on the map:



Point C-30

- Name: Culvert # 7
- Location: E 501099, N321688
- Description: Culvert placed on log pass over water course C-30. Station 12+200

BEFORE	AFTER
	
	

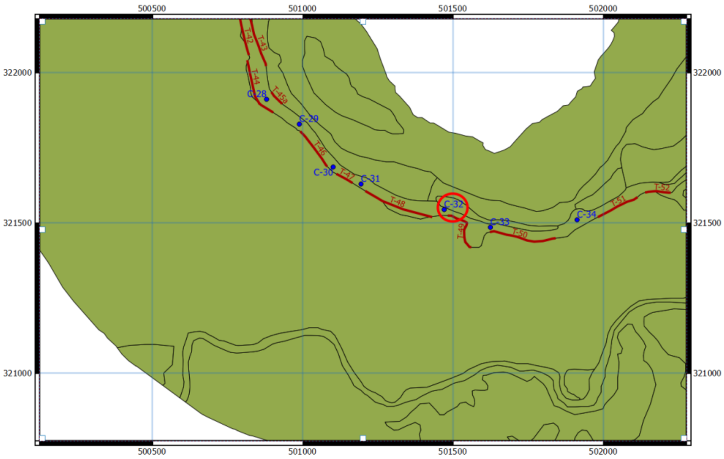
- Location on the map:

Point: C-32

- Name: Dissipaters
- Location: E 501457 N 321529
- Description: Construction of energy dissipaters in flow conditions with high gradient at water course C-32. Station 11+825.

BEFORE	AFTER
	
	

- Location on the map:

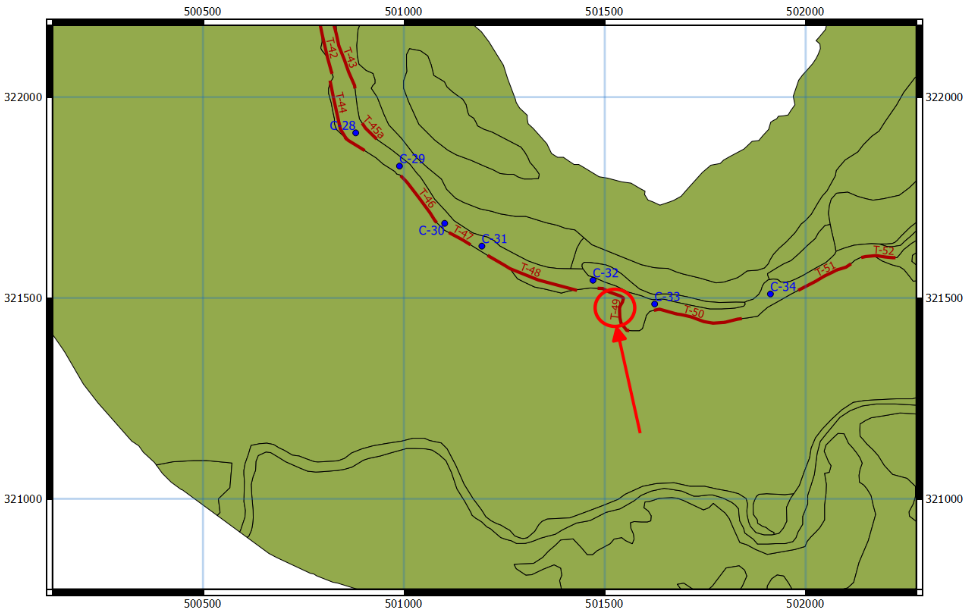


Point T-49

- Name: Lined ditches
- Location: E 501457 N 321529
- Description: Construction of lined ditches along slope T-49. Station 12+635

BEFORE	AFTER
	

- Location on the map:

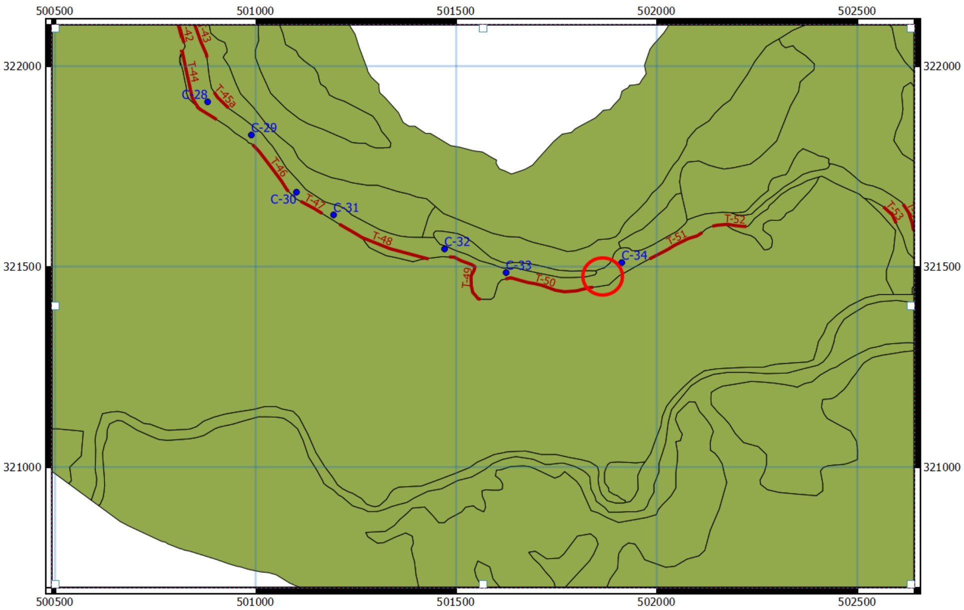


Point: T-50

- Name: Site for excess material
- Location: E 501855, N 321475
- Description: Site contemplated to deposit excess material from the digging performed at the end of slope T-50. Station 13+050

BEFORE	AFTER
	

- Location on the map:

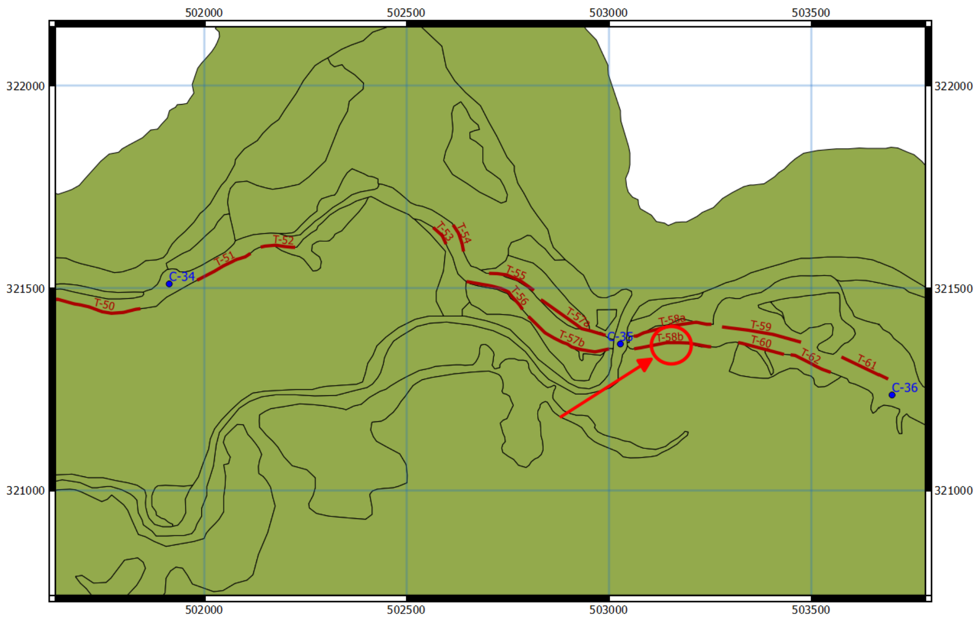


Point T-58b

- Name: Infiernito
- Location: E503111, N321375
- Description: Contouring of slopes, lined ditch, hydroseeding and placement of silt fence sediment traps along slope T-58b. Station 14+600.

BEFORE	AFTER
	

- Location on the map:

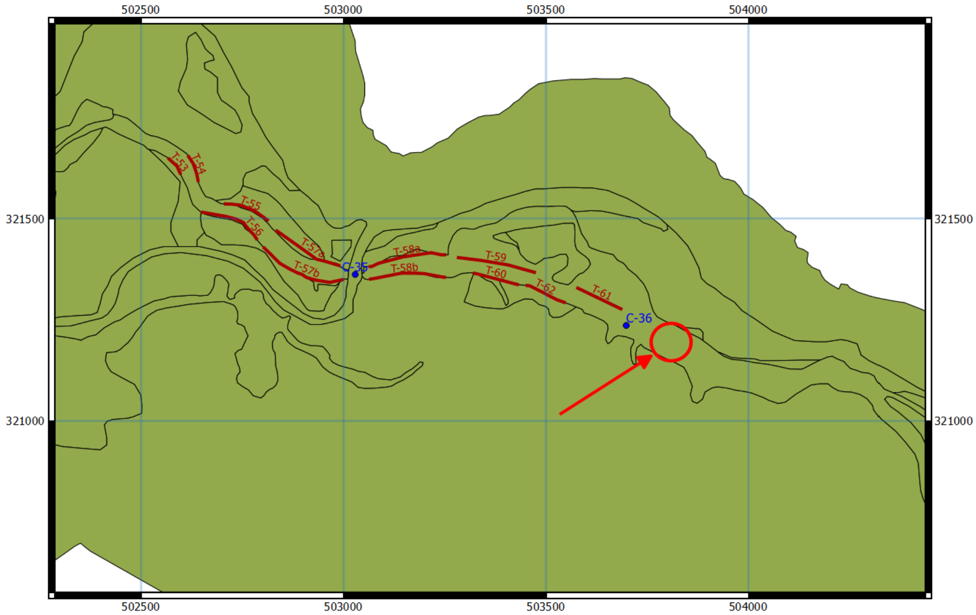


Point T-63

- Name: Infiernito Crucitas
- Location: E506807, N321188
- Description: Contouring of slope, lined ditch, and placement of silt fences. Station 15+400

BEFORE	AFTER
	

- Location on the map:

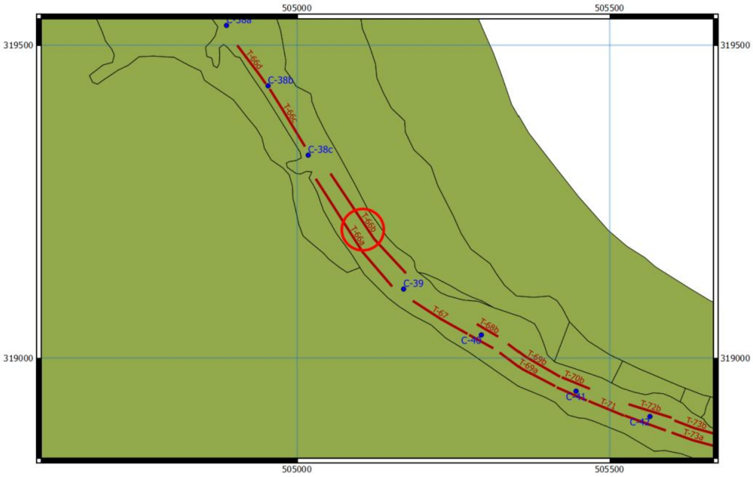


Point T-66a, T-66b

- Name: Caño Venada - Crucitas
- Location: E505112, N319194
- Description: Compaction and contouring of loose filling on slope, construction of verges, placement of coconut fibre.

BEFORE	AFTER
	
	

- Location on the map:

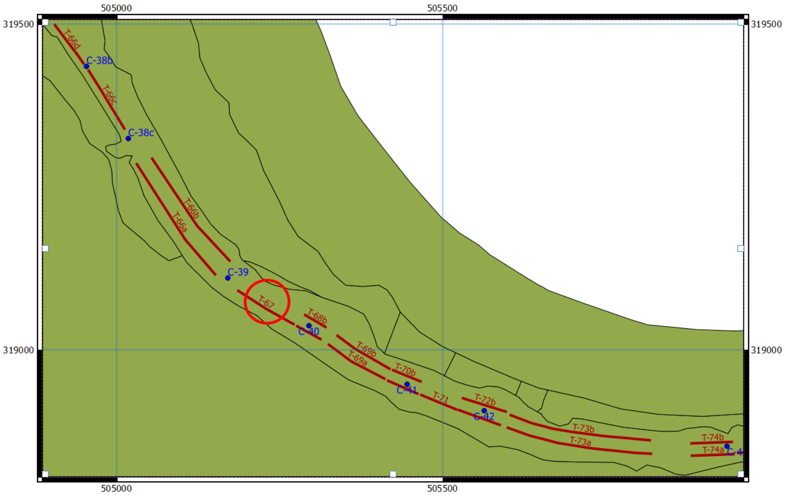


Point T-67

- Name: Caño Venada - Crucitas
- Location: E505258, N319091
- Description: Compaction and contouring of loose filling on slope, construction of verges, placement of coconut fibre.

BEFORE	AFTER
 	

- Location on the map:

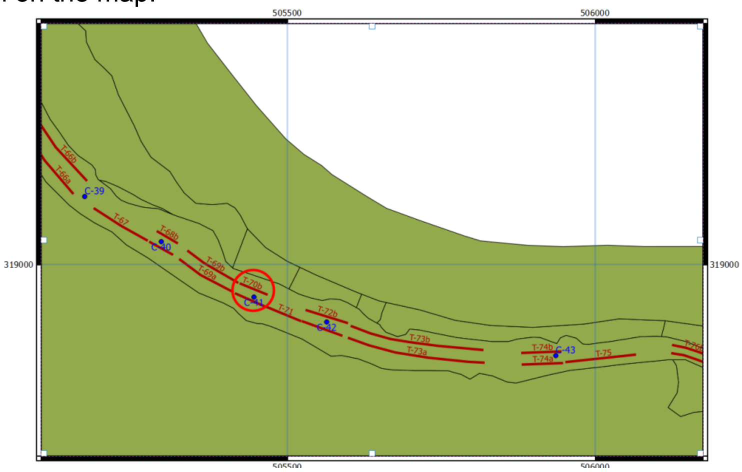


Point T-70b

- Name: Caño Venada - Crucitas
- Location: E505336, N319069
- Description: Compaction and contouring of loose filling on slope, construction of berms, placement of coconut fibre at slope T-70b

BEFORE	AFTER
	
	

- Location on the map:

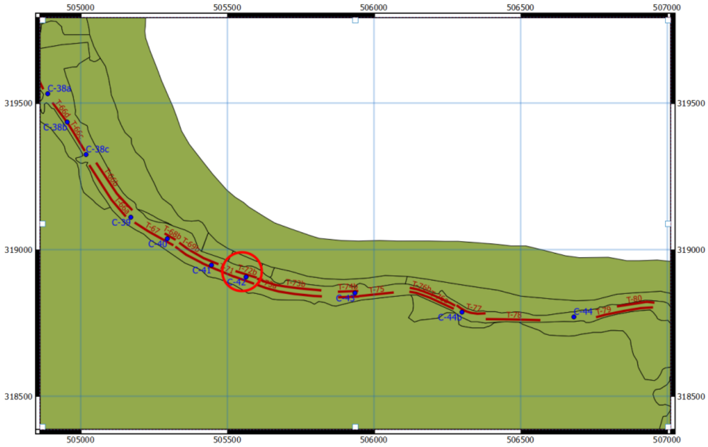


Point T-72b

- Name: Caño Venada - Crucitas
- Location: E505466, N319037
- Description: Compaction and contouring of loose filling on slope, construction of berms at slope T-72b

BEFORE	AFTER
	
	

- Location on the map:

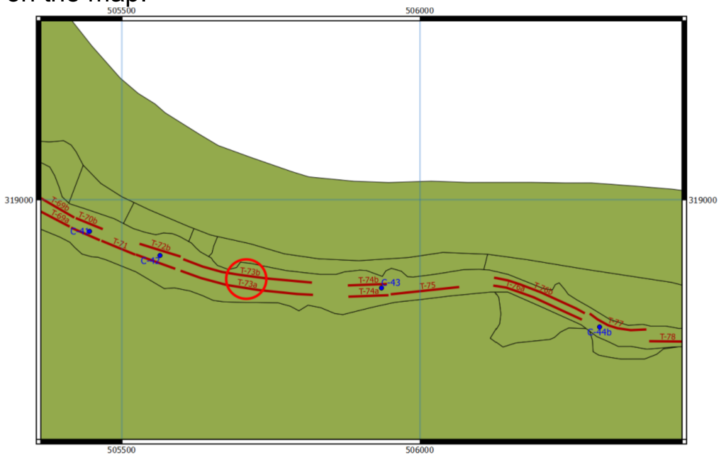


Point T-73a, T-73b

- Name: Caño Venada - Crucitas
- Location: E505698, N319032
- Description: Compaction and contouring of loose filling in slopes and berms, placement of coconut fibre along the length of slopes T-73a and T-73b

BEFORE	AFTER
	
	

- Location on the map:

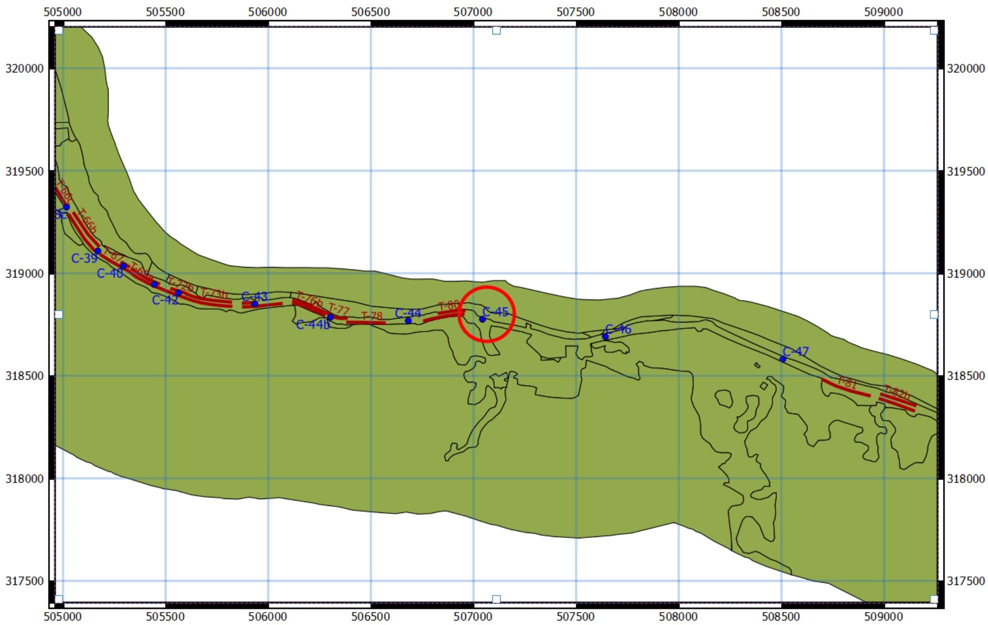


Point C-45

- Name: Caño Venada
- Location: E507041, N318778
- Description: Removal of logs and placement of new bridge over Caño Venada

BEFORE	AFTER
	

- Location on the map:

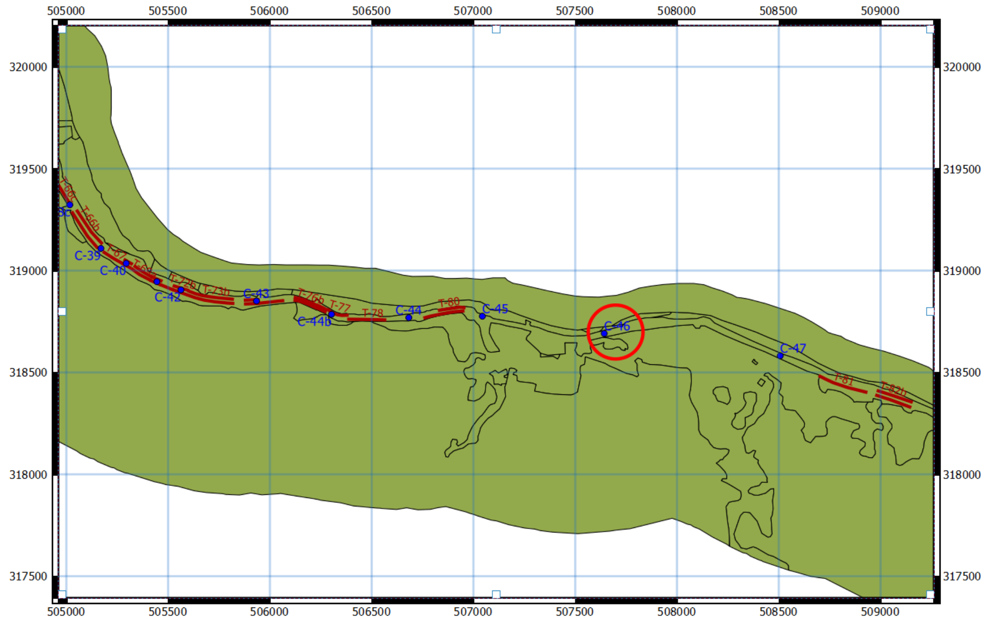


Point C-46

- Name: Caño Venada - Crucitas
- Location: E507408, N318879
- Description: Placement of bridge over creek C-46

BEFORE	AFTER
	

- Location on the map:

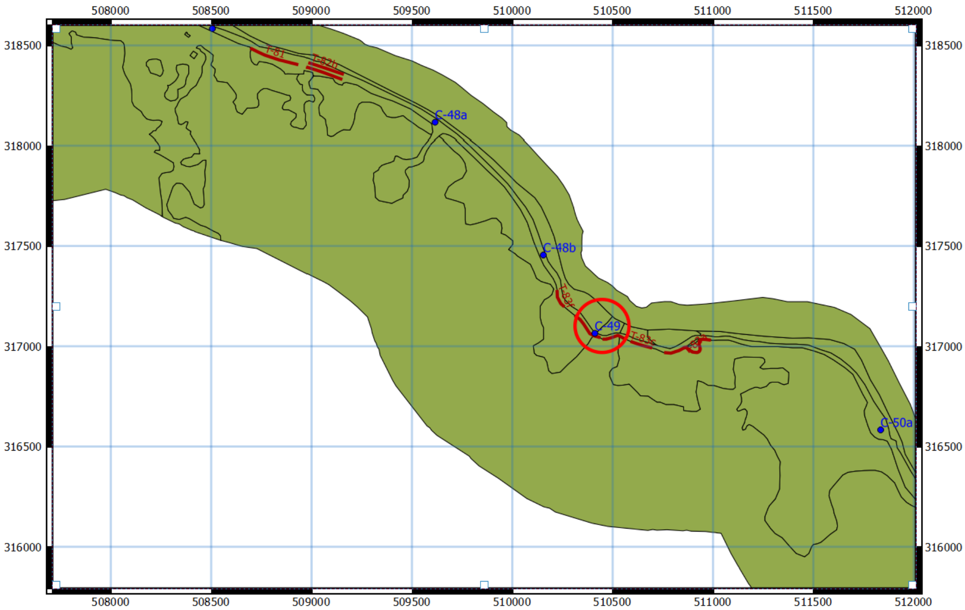


Point C-49

- Name: Caño La Chorrera
- Location: E510406, N317065
- Description: Placement of pedestrian bridge over La Chorrera creek (C-49)

BEFORE	AFTER
	

- Location on the map:

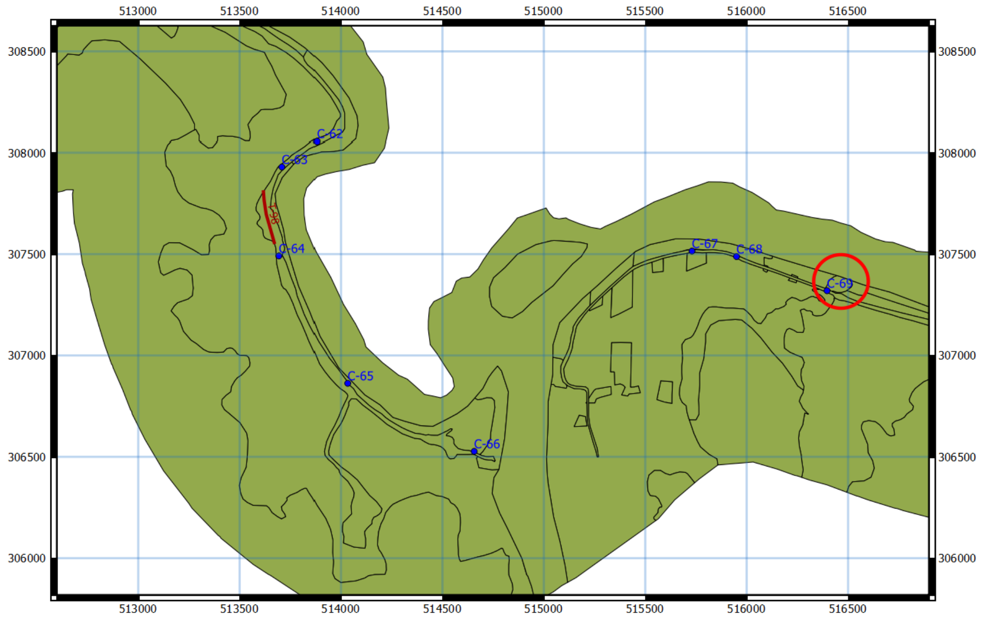


Point C-69

- Name: Quebrada
- Location: Boca San Carlos, E 516386 N307325
- Description: Removal of smooth pipe at collapsed pass and placement of log pass on water course C-69.

BEFORE	AFTER
	
	
	

- Location on the map:

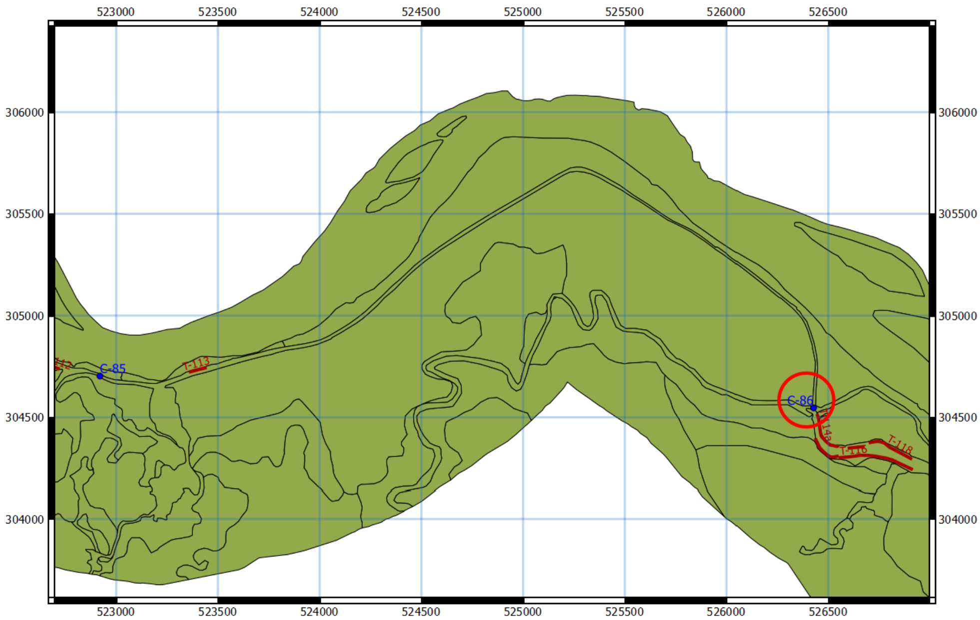


Point C-86

- Name: Caño Cureña
- Location: E 526425, N 304545
- Description: In the process of building two panel-type modular bridges.

BEFORE	AFTER
	

- Location on the map

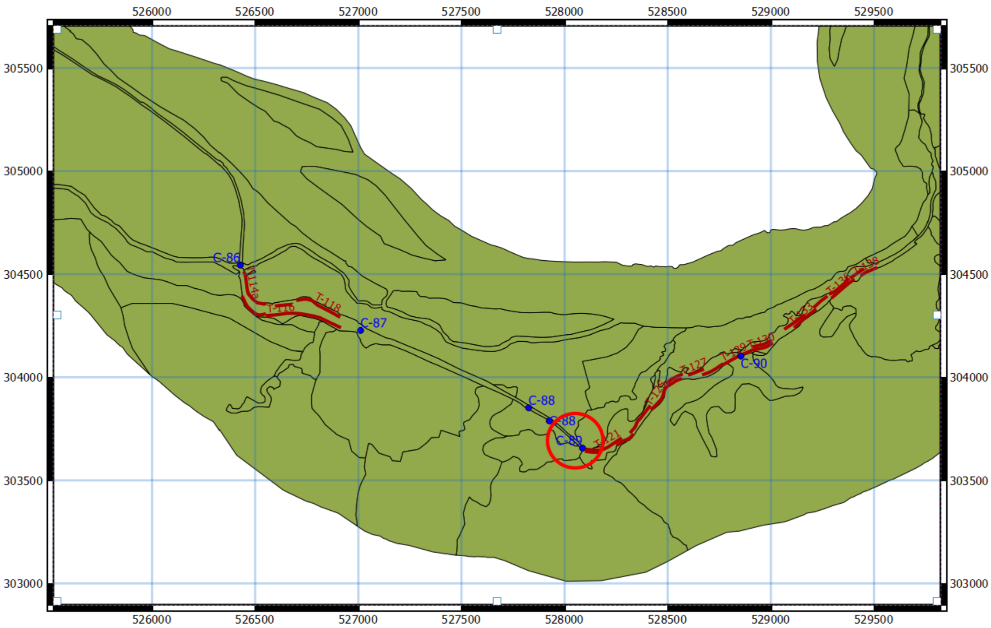


Point C-89

- Name: Caño Cureñita
- Location: E 528087, N 303657
- Description: Removal of logs and placement of new panel-type modular bridge over water course C-89.

BEFORE	AFTER
	

- Location on the map



ANNEX 12

Comisión de Desarrollo Forestal de San Carlos (CODEFORSA)

Restoration and rehabilitation of ecosystems affected by the construction of the Juan Rafael Mora Porras border road, Route 1856. Quarterly Report

November 2014

COMISIÓN DE DESARROLLO FORESTAL DE SAN CARLOS
Corporate ID number: 3-002-066610-06

Telephone: 2460-1055 Fax: 2460-1650
Email: codeforsa@codeforsa.org
Webpage: www.codeforsa.org
P.O. Box 205-4400 Ciudad Quesada, San Carlos

Restoration and rehabilitation of ecosystems affected by the construction of the Juan Rafael Mora Porras border road, Ruta 1856

QUARTERLY REPORT

November 2014

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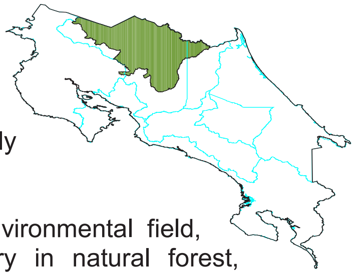
I. INDEX OF APPENDIXES

II. INFORMATION OF THE EXECUTOR

Organization: Asociación Comisión de Desarrollo Forestal de San Carlos (CODEFORSA)
Location: Ciudad Quesada, San Carlos
Address: 800 m. sur de la estación de Bomberos.
Contact information: codeforsa@codeforsa.org, www.codeforsa.org
www.facebook.com/CODEFORSA
Phone number: 2460-1055, 2460-0952.
Fax: 2460-1650
Legal representative: Fabio Rodríguez Camacho
ID number: 2-282-687
Powers: General attorney in fact with no amount limit
Persons to notify:
Executive Director: MSc. Jhonny Méndez Gamboa,
jmendez@codeforsa.org.
Technical manager: Gilberth Solano Sánchez, Eng. gsolano@codeforsa.org.

Comisión de Desarrollo Forestal de San Carlos (CODEFORSA) is a non-governmental organization (NGO), non-profit, established in July 1983, whose actions are aimed at achieving sustainable growth and rendering forestry services and general services for environmental management and conservation.

The area of direct influence of CODEFORSA is mainly the North of Costa Rica, where lowland tropical rainforests predominate. It practically extends from the top of the Central Volcanic and Guanacaste mountain ranges to the border with Nicaragua. The area represents approximately 20% of the national territory.



CODEFORSA has over 30 years of experience in the environmental field, having performed work in the North area of the country in natural forest, commercial reforestation and other environmental field work.

III. Area of study

The area where the works are performed is located between the towns of Tiricias, specifically at the mouth of Infiernito River, and the community of Chorreras, on the right bank of the San Juan River.

According to the first line of the service requested for restoration and rehabilitation of ecosystems in three sectors of the Juan Rafael Mora Porras border road, Ruta 1856, the geographic location of the project is the following:

Project: Restoration and rehabilitation of ecosystems affected by the construction of the Juan Rafael Mora Porras border road, Ruta 1856, located within the Northern Border Corridor Wildlife Refuge (*Refugio de Vida Silvestre, Corredor Fronterizo Norte*).	**Geographic coordinates (CRTM 05)**
Province: Alajuela Canton: San Carlos District: Cutris	83° 39' 58.53"/10°55' 50.88"

IV. AREAS TO INTERVENE:

1. Profile of the land grading

In this area, the border road was built on land covered by forest with slopes varying between 45 and 60 degrees, with cut and fill slopes, as well as areas of deposits of material to soften the slopes in the water courses present on the built road.

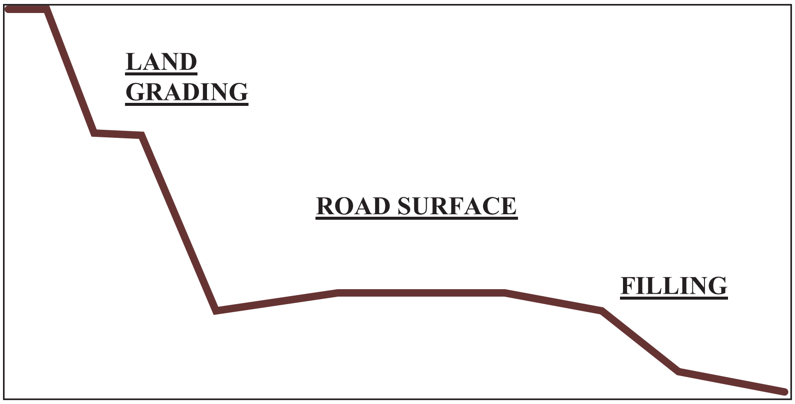


Figure 1. Grading profile for the road.

a) Cut slopes:

Land grading or cut slopes correspond to an exposed area of land on a slope; this grading may occur, depending on the altitude, in a single cut or in terraces.

At these sites six activities are performed, aimed at the protection and restoration of the ecosystems present. These measures include: drains at the base of the cut and on the terraces to divert the runoff, drain over the cut to prevent the water from flowing through the cut due to gravity, sediment traps, either small or large to reduce sediment carried off and finally protection of exposed soil through the placement of saran on the surface and planting of vetiver grass to stabilize the land and native tree species at suitable sites.

b) Road surface

It includes the area where vehicles circulate plus surrounding areas on both sides; road surfaces are between 14 and 20 metres wide.

In these areas work is currently being performed with machinery to lay gravel on the road from Quebrada Venada to Quebrada Crucitas. Channels will be built in these areas to divert the water towards the edges of the road, as well as barriers to slow down water runoff and reduce the sediments carried on the surface of the road.

c) Fill slopes:

Fill slopes for this work correspond to areas of contouring of the road where part of the material from land grading has been deposited, and where there has been loss of soil.

In this area of road contouring soil conservation activities should also be performed. For fill slopes sufficient sediment traps will be placed to slow down water runoff and prevent soil loss, drains will be built at the base of the fill slope to route the disposal of surface water and works will be performed to prevent the carrying of materials in drains. In addition, saran cover will be placed on areas lacking vegetation, vetiver grass will be planted to stabilize the soil and native tree species will be planted at suitable sites.

2. Water courses.

Another factor that is causing soil loss is the watercourses that cross the Ruta 1856.

In most of these sites small culverts were placed, which in some cases became obstructed with branches and trunks, leading to the formation of blockages which due to the amount of rain destroyed the passage built and culverts placed. The most troubling is the carrying of material to the river bank, causing the direct contamination of both the creek and the river at its mouth and downstream.

V. ACTIVITIES PERFORMED:

1. Restoration or compensation measures developed.

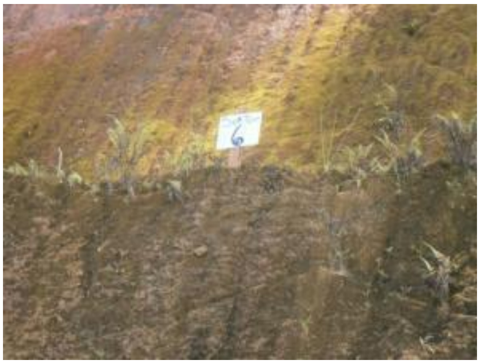
We describe herein the different restoration or compensation measures which are being implemented to reduce or correct the problems of soil loss and sedimentation occurring in the area to be intervened.

The order to begin activities was issued through communication No. SINAC-DE-GDF-300, of 11 September 2014.

Restoration activities were initiated by CODEFORSA, on 17 September 2014, at point 5 of the three points to intervene, since this area presents more problems.

a) Labelling of the areas to be intervened.

The first activity performed was the labelling of the different slopes defined in the contract to keep better control of the activities to be performed.



For this report we are using the numbering of the slopes used by Dr. Andreas Mende in his study.

Currently restoration works are being carried out at the three points defined in the contract. Point 6 is where the most progress has been achieved, with 70% progress in the construction of drains and sediment traps.

b) Drains on cut slopes:

These drains are being built in the upper part of the cut slope. Their function is to prevent runoff water from flowing on the cut slope, directing it instead transversely, descending the slope to an area with sufficient vegetation cover to absorb the water flow.

POINT 4. Construction of drain in the upper part of the cut slope.

Construction of drain in the terraces.

POINT 5.

Upper drain, Slope T66a.

Upper drain, Slope T73a.

Drain on terrace, Slope T75

Drain on road, Slope T75.

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

POINT 6.

Drain at base of cut, Slope T81.

Drain at base of filling, Slope T82b.

Drain on terrace, Slope T81

Drain on upper part of cut, Slope T82a.

c) Cross drains on the road:

These divert runoff water from the surface of the road to prevent it from running freely along the road forming small holes and preventing soil loss.

These drains are not going to be built for now given that there is machinery working in point 5 to enable access from Quebrada Venada to Quebrada Crucitas.

At Point 6 some drains have been built that could work like this type of drain to direct runoff waters from the road surface.

Cross drains built at Slope T82a on the edge of the road.

d) Small sediment traps:

A sediment trap is an artisanal trap placed on the drains in order to filter the passage of sediments downstream and at the same time reduce the speed of run-off water.

This sediment trap is built with logs or wooden stakes lined with saran, on the surface of built drains and natural outlets of rainwater, fulfilling the function of sediment filters and water speed reducers.

To date 263 small sediment traps have been built at the three points on which work is being performed.

Later on we present the percentage of progress for the number of works to be performed for each of the slopes that are being intervened.

Fill Slope T69b. Cut Slope T82a.

Small sediment traps.

e) Large sediment traps:

These have the same function as small sediment traps but are placed to cover more extensive areas of exposed soil and protect more against soil loss.
Their size may range from a few to several metres depending on the size of the area to protect. It is convenient to place several in a row to increase effectiveness.

Large sediment trap, Slope T76b.

Large sediment trap, Slope T66b.

Large sediment trap, Slope T69a.

Large sediment trap, Slope T66a.

These sediment traps are placed in areas where landslides occur.

To date 58 large sediment traps have been built at the three points where work is being performed.

f) Box sediment trap:

This type of trap is being placed at the end of all drains that have been built, either at the top of cut slopes or on terraces.
The dimensions of the box built vary depending on the location of the drain and the space available; however, the measures of the boxes are approximately 1 metre long by 75 cm wide, and 50 cm deep.
To date 148 box sediment traps have been built.


Box sediment traps in gullies and at the end of the drain

g) Coverage of the areas lacking vegetation:

In order to prevent and reduce soil loss due to rain, and to retain soil material in place, all coverage will be placed on all exposed areas of soil at the three points to intervene.

Priority has been given at Point 5 to the placement of coverage material with saran and also the establishment of vegetation cover with the planting of vetiver grass is mainly in the cut slope areas and Sotacaballo trees in the fill slopes.

So far 4.140 m² of slopes have been covered with saran and 910 plantsof vetiver grass and 783 Sotacaballo trees have been planted.

Placement of saran on Slope T76a.

Planting of Vetiver

Planting of Sotacaballo trees

h) Planting of native species of trees:

The planting of trees is a remedial measure that has been implemented in several sites along Ruta 1856 from Delta Costa Rica to the sector of Río Pocosol in Los Chiles, northern border area. This activity has been performed in exposed areas dedicated to livestock where the owners have offered part of the productive areas to perform this activity.

This activity was contemplated only for two specific points on Slopes T64b and T81; however, the planting of trees has already been implemented in all possible areas within the slopes to be intervened, primarily in the fill slopes of each sector.

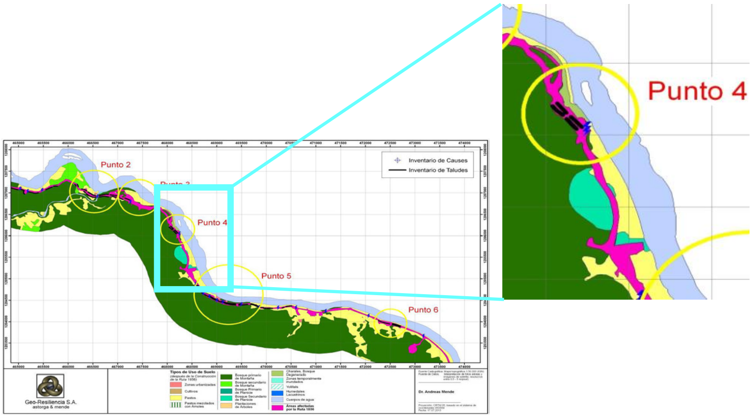
As indicated above, a total of 783 trees have already been planted, mainly on slopes T66b and T76b.

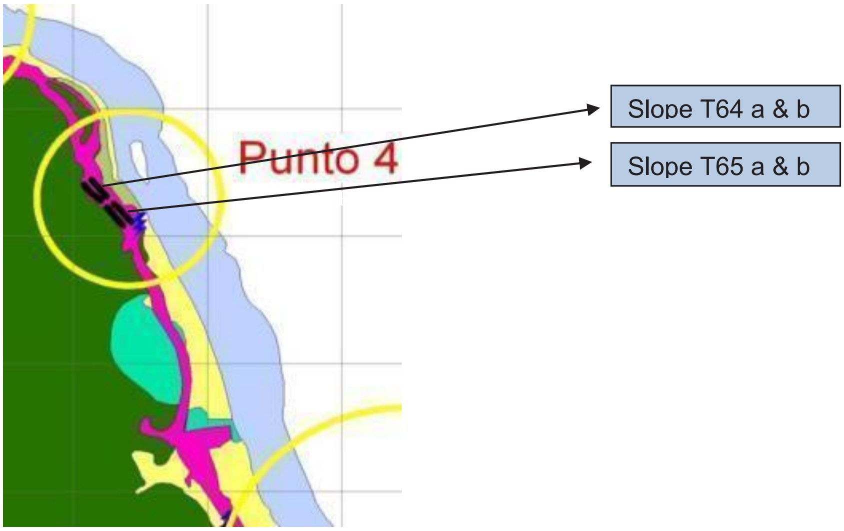
As can be seen in the picture, natural grass is already coming out of the saran, improving the coverage in the fill slope, in this case on Slope T66b. In the upper part of the picture you can see "Lengua de Vaca" plants that were already colonising the fill slope; a hole was made in the saran to let their development process continue in the fill area.

VI. Description of the activities implemented by site.

Below is a breakdown of the reconstruction works carried out in each of the prioritized sites.

1. Point 4 of the areas to intervene. 600 m of slope.





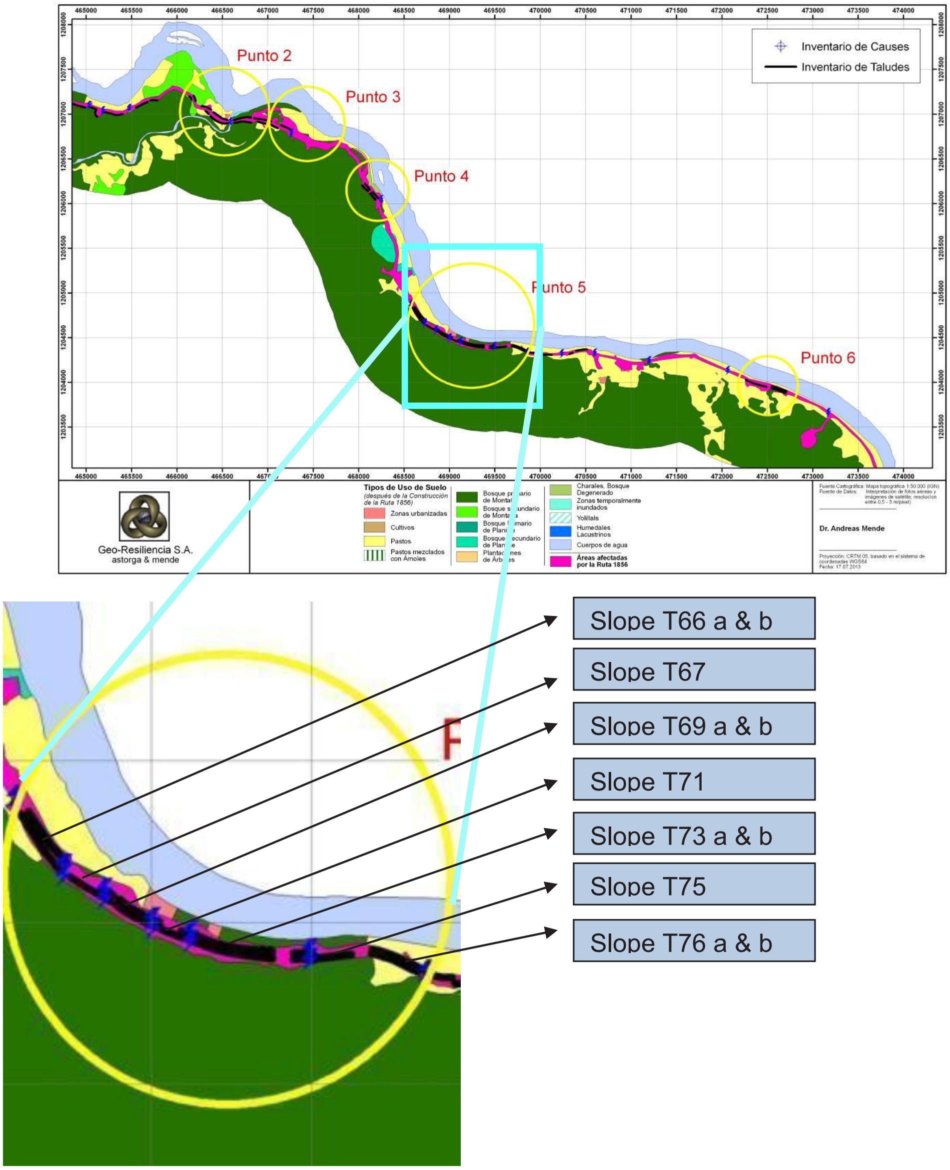
a) **Slope T64 a & b**

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
Cut slopes:	Drains at the base of the cut slope and on the terrace	300 metres	195,4	65,1%
	Small sediment traps at drains	13 units	0	0,0%
	Box sediment traps at the end of the drain	3 units	6	200,0%
	Coverage of areas without vegetation	1.485, 5 m²	0	0,0%
Road surface:	Cross drains to divert waters	100 metres	0	0,0%
Fill slopes:	Drains at the base of the fill slopes	150 metres	190	126,7%
	Small sediment traps.	16 units	0	0,0%
	Box sediment traps	12 units	4	33,3%
	Large sediment traps	10 units	0	0,0%
	Coverage of areas without vegetation	1.372 m²	0	0,0%
	Planting of trees	100 trees	0	0,0%

b) Slope T65 a & b:

Restoration measures to be implemented.		Number of units per activity.	Progress of activities	Percentage %
Cut slopes:	Drains at the base of the cut slope and on the terrace	300 metres	225	75,0%
	Drain in the upper part of the cut slope	150 metres	151,7	101,1%
	Small sediment traps for drains	14 units	0	0,0%
	Box sediment traps at the end of the drain	8 units	7	87,5%
	Coverage of areas without vegetation	3.233 m²	0	0,0%
Road surface:	Cross drains to divert waters	120 metres	0	0,0%
Fill slopes:	Drains at the base of the fill slopes	150 metres	0	0,0%
	Box sediment traps for drains and gullies	38 units	0	0,0%
	Large sediment traps	24 units	0	0,0%
	Coverage of areas without vegetation	1.861 m²	0	0,0%

2. **Point 5 of the areas to intervene 2690 m of slope.**



a) **Slope T66 a & b:**

Restoration measures to be implemented		**Number of units per activity**	**Progress of activities**	**Percentage %**
Cut slopes:	Drains at the base of the cut slope and on the terrace	500 metres	154,5	30,9%
	Drain in the upper part of the cut slope	150 metres	200	133,3%
	Small sediment traps for drains	40 units	33	82,5%
	Box sediment traps at the end of the drain	10 units	17	170,0%
	Large sediment traps (15 m) for landslide area	4 units	9	225,0%
	Coverage of areas without vegetation	5.397 m²	0	0,0%
Road surface:	Cross drains to divert waters	160 metres	0	0,0%
Fill slopes:	Drains at the base of the fill slopes	200 metres	115	57,5%
	Small sediment traps for drains	41 units	9	22,0%
	Box sediment traps for drains and gullies	21 units	33	157,1%
	Large sediment traps (10 m) for gullies	5 units	10	200,0%

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
	Coverage of areas without vegetation	4.562 m²	1200	26,3%
	Planting of trees	0 trees	600	60000,0%

b) Slope T67

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
Cut slopes:	Drains at the base of the cut slope and on the terrace	150 metres	60	40,0%
	Drain in the upper part of the cut slope	50 metres	75	150,0%
	Small sediment traps for drains	18 units	13	72,2%
	Box sediment traps at the end of the drain	8 units	2	25,0%
	Coverage of areas without vegetation	974 m²	880	90,3%
Road surface:	Cross drains to divert waters	160 metres	0	0,0%
	Box sediment traps to intervene gullies	16 units	2	12,5%

c) Slope T69 a & b:

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
Cut slopes:	Drains at the base of the cut slope and on the terraces	600 metres	400	66,7%
	Drain in the upper part of the cut slope	250 metres	250	100,0%
	Small sediment traps for drains	25 units	28	112,0%
	Box sediment traps at the end of the drain	14 units	9	64,3%
	Large sediment traps (15 m) for landslide area	6 units	6	100,0%
	Coverage of areas without vegetation	2.450 m²	1200	49,0%
Road surface:	Cross drains to divert waters	90 metres	0	0,0%
	Box sediment traps to intervene gullies	6 units	0	0,0%
	Small sediment traps.	12 units	0	0,0%

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
	Large sediment traps (15 m) for gullies	4 units	0	0,0%
Fill slopes:	Drains at the base of the fill slopes	100 metres	100	100,0%
	Small sediment traps for drains	25 units	6	24,0%
	Box sediment traps for ditch and gullies	31 units	1	3,2%
	Large sediment traps (15 m) for gullies	5 units	0	0,0%
	Coverage of areas without vegetation	882 m²	0	0,0%

d) **Slope T71**

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
Cut slopes:	Drains at the base of the cut slope and on the terraces	290 metres	200	69,0%
	Drain in the upper part of the cut slope	180 metres	180	100,0%
	Small sediment traps for drains	12 units	19	158,3%
	Box sediment traps at the end of the drain	8 units	7	87,5%
	Large sediment traps (15 m) for landslide area	2 units	0	0,0%
	Coverage of areas without vegetation	1.355 m²	800	59,0%
Road surface:	Cross drains to divert waters	90 metres	0	0,0%
	Box sediment traps to intervene gullies	20 units	0	0,0%
	Small sediment traps.	10 units	0	0,0%

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
Fill slopes:	Drains at the base of the fill slopes	80 metres	80	100,0%
	Small sediment traps for drains	34 units	5	14,7%
	Box sediment traps for drains and gullies	28 units	1	3.6%
	Large sediment traps (15 m) for gullies	8 units	0	0,0%
	Coverage of areas without vegetation	1.094 m²	0	0,0%


e) Slope T73 a & b:

Restoration measures to be implemented		**Number of units per activity**	**Progress of activities**	**Percentage %**
Cut slopes:	Drains at the base of the cut slope and on the terraces	400 metres	405	101,3%
	Drain in the upper part of the cut slope	200 metres	200	100,0%
	Small sediment traps for drains	25 units	18	72,0%
	Box sediment traps at the end of the drain	8 units	3	37,5%
	Large sediment traps (15 m) to surround mounds of soil.	4 units	0	0,0%
	Coverage of areas without vegetation	2.499 m²	2300	92,0%
Road surface:	Cross drains to divert waters	90 metres	0	0,0%
	Box sediment traps to intervene gullies	36 units	13	36.1%

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
	Small sediment traps.	44 units	12	27,3%
	Large sediment traps (15 m)	12 units	6	50,0%
Fill slopes:	Drains at the base of the fill slopes	50 metres	240	480,0%
	Small sediment traps for drains	18 units	5	27,8%
	Box sediment traps for drains and gullies	10 units	5	50,0%
	Large sediment traps (15 m) for gullies and protection	15 units	4	26,7%
	Coverage of areas without vegetation	5.160 m²	0	0,0%


f) Slope T75

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
Cut slopes:	Drains at the base of the cut slope and on the terraces	350 metres	348,5	99,6%
	Drain in the upper part of the cut slope	150 metres	150	100,0%
	Small sediment traps for drains	22 units	22	100,0%
	Box sediment traps at the end of the drain	6 units	5	83,3%
	Large sediment traps (15 m) to surround mounds of soil.	10 units	2	20,0%
	Coverage of areas without vegetation	745 m²	1000	134,2%
Road surface:	Cross drains to divert waters	90 metres	0	0,0%

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
	Box sediment traps to intervene gullies	7 units	8	114,3%
	Small sediment traps.	20 units	20	100,0%
	Large sediment traps (15 m)	4 units	4	100,0%

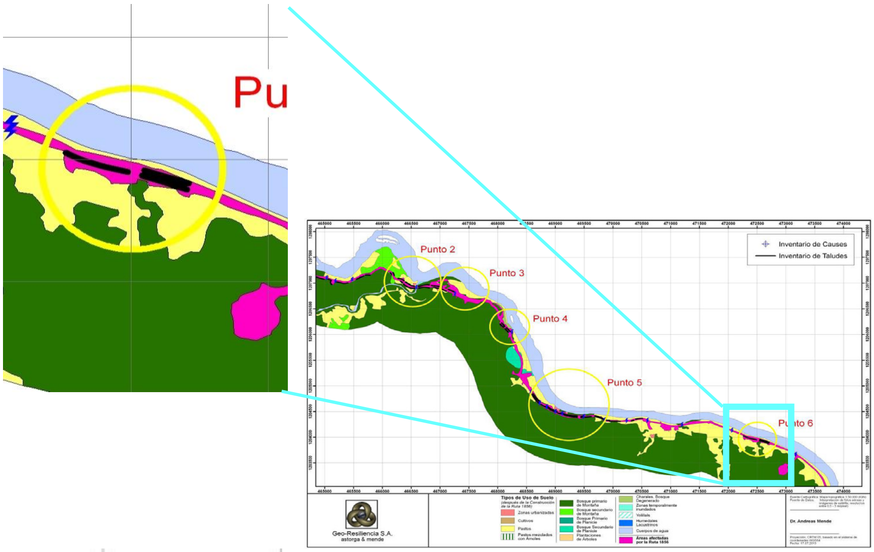


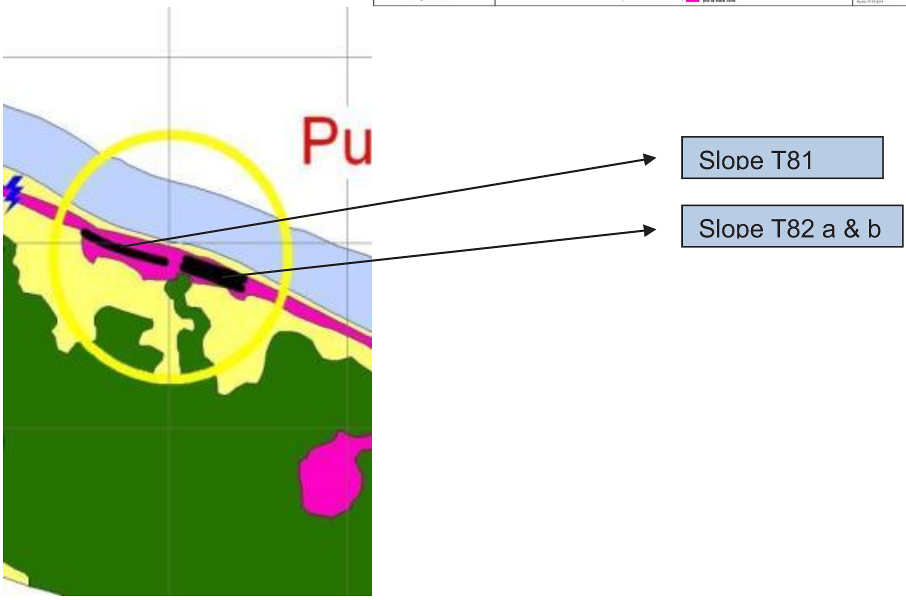
g) Slope T76 a & b:

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
Cut slopes:	Drain at the base of the cut slope	400 metres	400	100,0%
	Drain in the upper part of the cut slope	400 metres	400	100,0%
	Small sediment traps for drains	34 units	34	100,0%
	Box sediment traps at the end of the drain	8 units	5	62,5%
	Large sediment traps (15 m) for landslides	6 units	6	100,0%
	Coverage of areas without vegetation	989 m²	1100	111,2%
Road surface:	Cross drains to divert waters	90 metres	0	0,0%
	Small sediment traps.	10 units	0	0,0%
Fill slopes:	Drains at the base of the fill slopes	200 metres	200	100,0%

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
	Small sediment traps for drains	22 units	22	100,0%
	Box sediment traps for drains and gullies	8 units	9	112,5%
	Large sediment traps (15 m) for gullies and protection	10 units	10	100,0%
	Coverage of areas without vegetation	821 m²	840	102,3%

3. **Point 6 of the areas to intervene 1200 m of slope**





a) **Slope T81**

Restoration measures to be implemented		**Number of units per activity**	**Progress of activities**	**Percentage %**
Cut slopes:	Drains at the base of the cut slope and on the terraces	900 metres	921,3	102,4%
	Drain in the upper part of the cut slope	250 metres	232,6	93,0%
	Small sediment traps for drains	70 units	73	104,3%
	Box sediment traps at the end of the drain	25 units	41	164,0%
	Large sediment traps (15 m) for gullies and landslide areas	10 units	11	110,0%
	Coverage of areas without vegetation	12.463 m²	0	0,0%
	Planting of the trees in the upper part of the cut slope	20 units	100	500,0%
Road surface:	Cross drains to divert waters	90 metres	0	0,0%

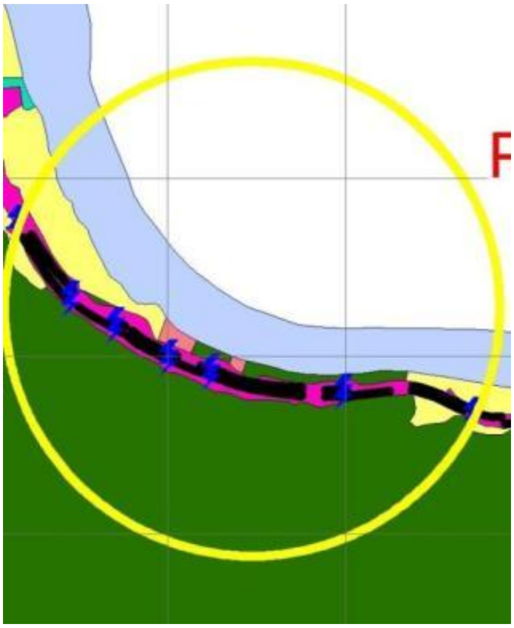
Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
	Small sediment traps.	6 units	0	0,0%
	Drain to direct water from the road drains	300 metres	254	84,7%
Fill slopes:	Small sediment traps for drains	20 units	18	90,0%
	Large sediment traps (15 m) for protection	5 units	4	80,0%

b) Slope T82 a & b:

Restoration measures to be implemented		Number of units per activity	Progress of activities	Percentage %
Cut slopes:	Drains at the base of the cut slope and on the terraces	300 metres	323	107,7%
	Drain in the upper part of the cut slope	150 metres	162	108,0%
	Small sediment traps for drains	16 units	20	125,0%
	Box sediment traps at the end of the drain	4 units	8	200,0%
	Coverage of areas without vegetation	1.678 m²	1700	101,3%
Road surface:	Cross drains to divert waters	90 metres	90	100,0%
	Small sediment traps.	4 units	4	100,0%
Fill slopes:	Drains at the base of the fill slopes	150 metres	175	116,7%
	Small sediment traps for drains	20 units	18	90,0%

Restoration measures to be implemented		**Number of units per activity**	**Progress of activities**	**Percentage %**
	Box sediment traps for drains and gullies	12 units	20	166,7%
	Large sediment traps (15 m) for gullies and protection	6 units	7	116,7%
	Coverage of areas without vegetation	1.379 m²	1379	100,0%

4. **Water courses between slopes at Point 5.**



Two waterfall-type sediment traps were built, of the necessary width in each case, and along the channel of the creeks both upstream from the road passage and along the trajectory between the road and San Juan River to reduce the water speed and also to filter sediments.

Five large sediment traps were built upstream from each of the seven water courses, and after the road passage sediment traps were built up to the mouth on the San Juan River; at least 10 sediment traps were placed in each creek.

All of these works have already been built in the planned areas, and several additional works were built according to the needs of each case.

Restoration measures to be implemented		**Number of units per activity**	**Progress of activities**	**Percentage %**
Creeks	Large sediment traps	105	108	102,9%


Construction of sediment traps downstream from the creek at the end of slope T76 b.

Sediment trap functioning, downstream between slopes T69 and T71.

5. Location of areas to intervene

With the previous report, both digital and physical information was presented of the design of the works to be built and the corresponding blueprints for each of the sites, with the location in the cartographic sheets and in Google Earth. The information was presented both in print and digital, with the locations of each of the slopes with the detail of each of the works to be performed in the field at that time.

Regarding the digital files, these will be presented in SHP format with tracks for each of the works (drains in cut slopes, cross drains and drains in the upper part of the slope as well as in water courses and natural drains), the geo-referenced points for each of the individual works to be performed (small sediment traps, large sediment traps and box sediment traps) and polygons for the coverage of areas without vegetation.

Appendix 1 presents the location with coordinates of the sediment traps built thus far.

6. Characteristics of the materials

Regarding the materials to be used, these are: a) saran, which is the material to be used as a fence for retention of sediment particles of the different traps to be built; b) the vegetative material to be planted at the different sites already specified, which consist of vetiver grass in the areas of the slopes as cover material to prevent erosion on the slope, and the trees to be planted which are located on fill slopes, in addition to the areas indicated in the contracts. This vegetative material is produced directly at the CODEFORSA nursery.

7. Timetable for implementation of the activities.

The following table shows the progress in relation to the timetable for the implementation of activities.

As previously shown, there already is progress in the recovery work at the three points of the contract. At this time the most progress has been achieved at point 6.

Table 1. Schedule of implementation of the activities of restoration and rehabilitation works on Ruta 1856.

Point	**Perform restoration and compensation activities.**																			
	Year 1																			
	Sept 2014		Oct. 2014				Nov. 2014				Dec. 2014		Jan. 2015				Feb. 2015			
	Sem III	Sem IV	Sem I	Sem II	Sem III	Sem IV	Sem I	Sem II	Sem III	Sem IV	Sem I	Sem II	Sem I	Sem II	Sem III	Sem IV	Sem I	Sem II	Sem III	Sem IV
Business day (96)	4	5	5	4	5	5	4	5	5	5	4	5	5	5	5	5	5	5	5	5
Point 4						X											X	X	X	X
Point 5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Point 6					X	X	X	X	X	X										
Water courses			X	X	X	X	X	X												

Implemented | Pending implementation

To date works have been performed during 37 days of the 96 working days required to complete 100% of the activities stipulated in the contract.

There have been some delays related to the weather conditions on the site, which prevent the entrance of materials to the slopes requiring work.

Another important issue is that the work teams of the company MECO, contracted by CONAVI to enable the bridge over Quebrada Venada and the laying of gravel on the access at point 5 of the contract, are conducting stabilization of slopes and fills at point 5, but the weather conditions prevent them from working normally; consequently, the work teams in charge of creating drains and sediment traps are also delayed, given that they must prevent any work from being destroyed by the passing of machinery.

In general terms, the progress of the working days to conduct the works is 33%, and the progress of the execution of the works is at 45% or 50%; therefore, it is expected that all of the contracted works will be executed by the deadline.

Another issue that has delayed the progress of the works is the purchase of materials for the work of covering the exposed areas, specifically saran and metal rods, due to the lack of issuance of the first payment of the contract. To date, 37 business days after the issuance of the order to begin construction of the works, the first payment of the contract has not been made.

8. Maintenance activities

The construction of soil conservation works is just as important as the maintenance that must be provided so that they are truly effective and fulfil the functions for which were implemented.

The timeline of maintenance works includes:

a) Cleaning:

Consists of the elimination of sediment retained by the different traps built and disposal of these sediments in natural trenches or accumulation at sites without risk of erosion, and covered with saran for protection, always applying the planting of vetiver grass for their final disposal. To this end, work teams will perform the cleaning of sediment traps once a month for each work during two years.

The cleaning of sediment traps will be performed manually, and sediment will be moved with carts to a place with protection from the rain to prevent their runoff. Along with the sediment traps, maintenance will also be given to drains and the vegetation cover established.

b) Repair:

The strength of the water current or sediment load can make the traps collapse; therefore the maintenance works contemplate the partial or full repair of the traps and drains in general, built according to the needs of the work.

Sediment trap at creek, slope 66b.

c) Construction of new works:

Apart from the repair of the works, due to destruction or to the identification of new sites where works are required to comply with the protection of the San Juan River from sedimentation from the road, the installation of new works is contemplated, such as sediment traps or drains in the various points proposed. At each maintenance stage we will assess the construction of new works or substitution of works destroyed at each point to visit.

Below is the table with the schedule for implementation of the general maintenance of the built works.

Table 2. Schedule of implementation of the activities of restoration and rehabilitation works on Ruta 1856.

Point	Activities	Maintenance of the works built																							
		Month																							
		oct-14	nov-14	dec-14	jan-15	feb-15	mar-15	apr-15	may-15	jun-15	jul-15	aug-15	sept-15	oct-15	nov-15	dec-15	jan-16	feb-16	mar-16	apr-16	may-16	jun-16	jul-16	aug-16	sept-16
Point 4	Cleaning, repair, and/or construction of works	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Point 5		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Point 6		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Water courses		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Implemented   Pending implementation

To date maintenance work has been performed by work crews to repair damaged sediment traps, mostly on works built on creeks since the force of the water causes the retention material (saran) to break, or even the full destruction of the sediment trap has occurred, and in those cases the work has been repaired or rebuilt. In addition, the cleaning of sediment traps located in built drains has already begun.

9. Follow-up of the project.

For the general monitoring of the project CODEFORSA, through its technical department, has qualified personnel to perform the project monitoring activities, which consist of field visits to verify compliance with the activities programmed and executed, and planning of pending activities.

Table 3. Schedule of technical and administrative monitoring of the project of restoration and rehabilitation of ecosystems in Ruta 1856.

Activities	Technical and administrative monitoring of the project																							
	Month																							
	oct-14	nov-14	dec-14	jan-15	feb-15	mar-15	apr-15	may-15	jun-15	jul-15	aug-15	sept-15	oct-15	nov-15	dec-15	jan-16	feb-16	mar-16	apr-16	may-16	jun-16	jul-16	aug-16	sept-16
Technical monitoring visits to all points	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Presentation of progress reports			X			X			X			X			X			X			X			X

Implemented   Pending implementation

As shown in the picture, technical visits have been performed each week by the person responsible for the contract, Gilberth Solano, Eng. During these visits the works performed are supervised, and the works to be performed for each week are planned, as well as addressing questions or suggestions by the person in charge of the field works on site.

This is the first quarterly report of the project.

VII. APPENDIXES

10. APPENDIX 1: COORDINATES OF LOCATION OF THE SEDIMENT TRAPS BUILT TO DATE.

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
1	Point	4	1	SVC 1	468071,256	1206167,77
2	Point	4	1	SVC 2	468038,249	1206210,68
3	Point	4	1	SVC 3	468046,17	1206196,59
4	Point	4	1	SVC 4	468063,014	1206162,62
5	Point	4	1	SVC 5	468088,154	1206132,18
6	Point	4	1	SVC 6	468040,502	1206190,96
7	Point	4	1	SVR1	468082,038	1206217,11
8	Point	4	1	SVR2	468085,304	1206203,5
9	Point	4	1	SVR3	468091,639	1206198,41
10	Point	4	1	SVR4	468123,972	1206174,26
11	Point	4	2	SVC1	468113,787	1206090,36
12	Point	4	2	SVC2	468192,448	1205996,47
13	Point	4	2	SVC3	468196,012	1205987,41
14	Point	4	2	SVC4	468132,853	1206088,32
15	Point	4	2	SVC5	468172,494	1206047,24
16	Point	4	2	SVC6	468197,374	1206002,54
17	Point	4	2	SVC7	468196,178	1206008,95
18	Point	5	3	SVC1	468567,987	1204825,41
19	Point	5	3	SVC2	468678,546	1204662,02
20	Point	5	3	SVC3	468712,358	1204643,44
21	Point	5	3	SVC4	468697,159	1204684,64
22	Point	5	3	SVC5	468688,644	1204690,97
23	Point	5	3	SVC6	468676,978	1204689,8
24	Point	5	3	SVC7	468672,264	1204684,95
25	Point	5	3	SVC8	468644,059	1204741,62
26	Point	5	3	SVC9	468646,597	1204741,29
27	Point	5	3	SVC10	468637,472	1204742,61
28	Point	5	3	SVC11	468637,358	1204747,28
29	Point	5	3	SVC12	468633,813	1204749,21
30	Point	5	3	SVC13	468637,405	1204758,77
31	Point	5	3	SVC14	468631,772	1204761,03
32	Point	5	3	SVC15	468628,419	1204761,5
33	Point	5	3	SVC16	468627,649	1204770,92
34	Point	5	3	SVC17	468587,309	1204832,39
35	Point	5	3	SPC1	468574,82	1204822,69
36	Point	5	3	SPC2	468584,536	1204816,81
37	Point	5	3	SPC3	468586,755	1204803,49
38	Point	5	3	SPC4	468596,835	1204790,47

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
39	Point	5	3	SPC5	468601,495	1204777,18
40	Point	5	3	SPC6	468609,099	1204766,14
41	Point	5	3	SPC7	468617,474	1204747,5
42	Point	5	3	SPC8	468627,834	1204724,83
43	Point	5	3	SPC9	468631,909	1204712,22
44	Point	5	3	SPC10	468641,488	1204697,16
45	Point	5	3	SPC11	468648,378	1204686,54
46	Point	5	3	SPC12	468652,147	1204680,61
47	Point	5	3	SPC13	468652,392	1204677,6
48	Point	5	3	SPC14	468650,399	1204672,65
49	Point	5	3	SPC15	468653,722	1204660,08
50	Point	5	3	SPC16	468655,699	1204657,11
51	Point	5	3	SPC17	468657,005	1204653,44
52	Point	5	3	SPC18	468658,297	1204653,11
53	Point	5	3	SPC19	468663,676	1204653,72
54	Point	5	3	SPC20	468671,916	1204656,38
55	Point	5	3	SPC21	468677,076	1204658,04
56	Point	5	3	SPC22	468678,974	1204658,96
57	Point	5	3	SPC23	468682,674	1204657,14
58	Point	5	3	SPC24	468690,574	1204658,34
59	Point	5	3	SPC25	468691,966	1204658,03
60	Point	5	3	SPC26	468697,874	1204655,6
61	Point	5	3	SPC27	468701,723	1204646,78
62	Point	5	3	SPC28	468709,362	1204643,47
63	Point	5	3	SPC29	468613,967	1204778,34
64	Point	5	3	SPC30	468609,713	1204785,47
65	Point	5	3	SPC31	468602,176	1204799,44
66	Point	5	3	SPC32	468595,639	1204814,26
67	Point	5	3	SPC33	468591,145	1204829,71
68	Point	5	3	SGC1	468671,422	1204676,11
69	Point	5	3	SGC2	468678,954	1204676,09
70	Point	5	3	SGC3	468693,141	1204669,74
71	Point	5	3	SGC4	468692,333	1204667,91
72	Point	5	3	SGC5	468642,813	1204740,92
73	Point	5	3	SGC6	468638,913	1204745,13
74	Point	5	3	SGC7	468633,888	1204750,18
75	Point	5	3	SGC8	468632,658	1204758,16
76	Point	5	3	SGC9	468629,287	1204769,14

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
77	Point	5	3	SVR1	468612,319	1204843,67
78	Point	5	3	SVR2	468614,94	1204840,57
79	Point	5	3	SVR3	468695,307	1204746,48
80	Point	5	3	SVR4	468688,963	1204742,28
81	Point	5	3	SVR5	468675,403	1204737,21
82	Point	5	3	SVR6	468682,42	1204759,32
83	Point	5	3	SVR7	468618,556	1204849,64
84	Point	5	3	SVR8	468654,27	1204815,87
85	Point	5	3	SVR9	468646,073	1204817,42
86	Point	5	3	SVR10	468675,222	1204777,47
87	Point	5	3	SGR1	468678,477	1204750,92
88	Point	5	3	SGR2	468690,287	1204754,89
89	Point	5	3	SPR1	468618,664	1204848,42
90	Point	5	3	SPR2	468621,607	1204840,12
91	Point	5	3	SPR3	468627,171	1204828,17
92	Point	5	3	SPR4	468636,345	1204818,76
93	Point	5	3	SPR5	468651,975	1204816,42
94	Point	5	3	SPR6	468647,164	1204814,99
95	Point	5	3	SPR7	468651,089	1204804,26
96	Point	5	3	SPR8	468662,333	1204788,21
97	Point	5	3	SPR9	468674,567	1204777,47
98	Point	5	3	SGR3	468702,823	1204742,56
99	Point	5	3	SGR4	468696,722	1204750,39
100	Point	5	3	SGR5	468691,284	1204760,33
101	Point	5	3	SGR6	468711,975	1204744,28
102	Point	5	3	SGR7	468706,404	1204755,16
103	Point	5	3	SGR8	468699,375	1204766,04
104	Point	5	3	SGR9	468693,008	1204776,65
105	Point	5	3	SGR10	468686,376	1204783,94
106	Point	5	3	SVR12	468671,269	1204758,01
107	Point	5	3	SVR13	468672,368	1204764,31
108	Point	5	3	SVR14	468681,006	1204766,85
109	Point	5	3	SVR15	468657,63	1204785,78
110	Point	5	3	SVR16	468653,474	1204783,57
111	Point	5	3	SVR17	468652,277	1204788,77
112	Point	5	3	SVR18	468652,168	1204789,33
113	Point	5	3	SVR19	468655,01	1204789,54
114	Point	5	3	SVR20	468649,331	1204795,3

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
115	Point	5	3	SVR21	468646,707	1204794,2
116	Point	5	3	SVR22	468646,499	1204805,59
117	Point	5	3	SVR23	468637,213	1204812,46
118	Point	5	3	SVR24	468640,825	1204816,54
119	Point	5	3	SVR25	468745,97	1204682,17
120	Point	5	3	SVR26	468748,596	1204684,93
121	Point	5	3	SVR27	468755,475	1204676,19
122	Point	5	3	SVR28	468754,381	1204675,97
123	Point	5	3	SVR29	468749,022	1204672,88
124	Point	5	3	SVR30	468758,747	1204669,22
125	Point	5	3	SVR31	468762,795	1204672,53
126	Point	5	3	SVR32	468769,128	1204664,56
127	Point	5	5	SVR33	468770,011	1204673,3
128	Point	5	4	SVC1	468819,118	1204582,45
129	Point	5	4	SVC2	468754,87	1204615,14
130	Point	5	4	SVC3	468770,615	1204618,33
131	Point	5	4	SVC4	468817,162	1204595,28
132	Point	5	4	SPC1	468817,698	1204584,11
133	Point	5	4	SPC2	468814,856	1204584,33
134	Point	5	4	SPC3	468805,128	1204585,34
135	Point	5	4	SPC4	468801,741	1204587,11
136	Point	5	4	SPC5	468793,986	1204593,64
137	Point	5	4	SPC6	468776,069	1204606,16
138	Point	5	4	SPC7	468764,376	1204610,26
139	Point	5	4	SPC8	468755,417	1204614,92
140	Point	5	4	SPC9	468773,238	1204618
141	Point	5	4	SPC10	468785,37	1204615
142	Point	5	4	SPC11	468798,155	1204610,12
143	Point	5	4	SPC12	468806,239	1204603,81
144	Point	5	4	SPC13	468815,306	1204597,05
145	Point	5	4	SGC1	468752,732	1204626,42
146	Point	5	4	SGC2	468751,565	1204623,68
147	Point	5	4	SVR1	468930,9	1204646,27
148	Point	5	4	SVR2	468945,236	1204662,63
149	Point	5	5	SVC1	468900,781	1204554,28
150	Point	5	5	SVC2	468886,343	1204537,04
151	Point	5	5	SVC3	468982,034	1204511,1
152	Point	5	5	SVC4	468985,113	1204492,77

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
153	Point	5	5	SVC5	468986,921	1204495,69
154	Point	5	5	SPC1	468892,306	1204544,6
155	Point	5	5	SPC2	468886,809	1204535,59
156	Point	5	5	SPC3	468898,254	1204536,41
157	Point	5	5	SPC4	468902,893	1204539,12
158	Point	5	5	SPC5	468912,977	1204535,34
159	Point	5	5	SPC6	468955,203	1204519,45
160	Point	5	5	SPC7	468982,153	1204511,5
161	Point	5	5	SPC8	468984,956	1204491,03
162	Point	5	5	SVR1	469056,5	1204524,16
163	Point	5	5	SPR1	469047,759	1204528,7
164	Point	5	5	SPR2	469043,388	1204530,14
165	Point	5	5	SPR3	469036,393	1204531,48
166	Point	5	5	SPR4	469021,202	1204536,03
167	Point	5	5	SPR5	469015,518	1204536,36
168	Point	5	5	SPR6	469004,803	1204534,82
169	Point	5	5	SVC6	468876,812	1204555,63
170	Point	5	5	SVC7	468949,528	1204460,44
171	Point	5	5	SVC8	468969,016	1204492,17
172	Point	5	5	SVC9	468931,319	1204510,23
173	Point	5	5	SPC9	468877,685	1204553,86
174	Point	5	5	SPC10	468885,002	1204546,11
175	Point	5	5	SPC11	468884,559	1204540,03
176	Point	5	5	SPC12	468884,883	1204535,71
177	Point	5	5	SPC13	468892,299	1204516,68
178	Point	5	5	SPC14	468902,678	1204510,92
179	Point	5	5	SPC15	468914,476	1204501,29
180	Point	5	5	SPC16	468934,691	1204492,64
181	Point	5	5	SPC17	468946,485	1204478,8
182	Point	5	5	SPC19	468948,661	1204467,96
183	Point	5	5	SPC20	468948,77	1204467,96
184	Point	5	5	SPC18	468950,523	1204472,16
185	Point	5	5	SPC21	468948,656	1204462,54
186	Point	5	5	SPC22	468949,638	1204461,1
187	Point	5	5	SPC23	468949,529	1204461,21
188	Point	5	5	SPC24	468949,637	1204460,33
189	Point	5	5	SPC25	468968,585	1204498,36
190	Point	5	5	SPC26	468959,402	1204497,7

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
191	Point	5	5	SPC27	468943,34	1204506,68
192	Point	5	5	SPC28	468935,255	1204510,56
193	Point	5	5	SGC1	468962,234	1204486,86
194	Point	5	5	SGC2	468965,843	1204489,18
195	Point	5	5	SGC3	468969,452	1204490,06
196	Point	5	5	SGC4	468969,995	1204486,86
197	Point	5	5	SGC5	468969,335	1204482,43
198	Point	5	6	SVC1	469082,804	1204419,83
199	Point	5	6	SVC2	468971,502	1204478,45
200	Point	5	6	SVC3	469087,374	1204456,81
201	Point	5	6	SVC4	469078,415	1204459,38
202	Point	5	6	SVC5	469026,198	1204471,86
203	Point	5	6	SVC6	469066,33	1204459,75
204	Point	5	6	SVC7	469039,74	1204471,08
205	Point	5	6	SPC1	469079,677	1204427,16
206	Point	5	6	SPC2	469066,231	1204432,5
207	Point	5	6	SPC3	469055,06	1204431,11
208	Point	5	6	SPC4	469051,646	1204435,33
209	Point	5	6	SPC5	469032,289	1204449,13
210	Point	5	6	SPC6	469019,319	1204454,15
211	Point	5	6	SPC7	469019,394	1204455,94
212	Point	5	6	SPC8	469008,726	1204463,23
213	Point	5	6	SPC9	468989,869	1204463,16
214	Point	5	6	SPC10	468991,012	1204470,64
215	Point	5	6	SPC11	468990,81	1204470,48
216	Point	5	6	SPC12	468990,352	1204470,2
217	Point	5	6	SPC13	469081,968	1204457,04
218	Point	5	6	SPC14	469053,039	1204474,07
219	Point	5	6	SPC15	469041,064	1204475,76
220	Point	5	6	SPC16	469033,416	1204478,25
221	Point	5	6	SPC17	469054,604	1204462,65
222	Point	5	6	SPC18	469051,136	1204467,23
223	Point	5	6	SPC19	469041,216	1204471,09
224	Point	5	6	SVR1	469063,053	1204517,41
225	Point	5	6	SPR1	469113,868	1204498,44
226	Point	5	6	SPR2	469103,593	1204499,67
227	Point	5	6	SPR3	469086,219	1204507,32
228	Point	5	6	SPR4	469073,869	1204510,32

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
229	Point	5	6	SPR5	469066,22	1204514,2
230	Point	5	7	SVC1	469319,705	1204383,97
231	Point	5	7	SVC2	469301,648	1204397,36
232	Point	5	7	SVC3	469269,733	1204376,91
233	Point	5	7	SPC1	469324,297	1204385,96
234	Point	5	7	SPC2	469317,449	1204392,36
235	Point	5	7	SPC3	469306,529	1204394,1
236	Point	5	7	SPC4	469299,157	1204399,16
237	Point	5	7	SPC5	469290,357	1204394,54
238	Point	5	7	SPC6	469273,504	1204392,12
239	Point	5	7	SPC7	469259,466	1204391,64
240	Point	5	7	SPC8	469296,918	1204394,79
241	Point	5	7	SPC9	469282,951	1204392,51
242	Point	5	7	SPC10	469278,355	1204386,37
243	Point	5	7	SPC11	469267,563	1204378,72
244	Point	5	7	SPC12	469250,261	1204375,67
245	Point	5	7	SPC13	469239,096	1204370,95
246	Point	5	7	SPC14	469219,155	1204378,19
247	Point	5	7	SPC15	469202,199	1204383,06
248	Point	5	7	SPC16	469189,766	1204394,3
249	Point	5	7	SPC17	469181,43	1204406,3
250	Point	5	7	SPC18	469177,061	1204407,93
251	Point	5	7	SVR1	469282,5	1204450,51
252	Point	5	7	SVR2	469245,651	1204440,81
253	Point	5	7	SVR3	469169,717	1204485,89
254	Point	5	7	SVR4	469162,73	1204495,52
255	Point	5	7	SVR5	469164,912	1204490,88
256	Point	5	7	SPR1	469184,357	1204476,48
257	Point	5	7	SPR2	469177,034	1204477,7
258	Point	5	7	SPR3	469172,117	1204480,92
259	Point	5	7	SPR4	469170,916	1204482,02
260	Point	5	7	SPR5	469191,243	1204475,15
261	Point	5	7	SGR1	469164,372	1204498,62
262	Point	5	7	SGC1	469471,863	1204412,67
263	Point	5	7	SGC2	469469,258	1204409,45
264	Point	5	7	SGC3	469435,348	1204392,43
265	Point	5	7	SGC4	469440,162	1204395,66
266	Point	5	7	SGC5	469452,018	1204404,65

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
267	Point	5	7	SGC6	469457,591	1204407,08
268	Point	5	8	SVC1	469636,273	1204402,83
269	Point	5	8	SVC2	469524,84	1204399,87
270	Point	5	8	SVC3	469519,905	1204433,75
271	Point	5	8	SVC4	469619,215	1204406,63
272	Point	5	8	SPC1	469623,425	1204401,82
273	Point	5	8	SPC2	469619,768	1204400,63
274	Point	5	8	SPC3	469612,908	1204403,44
275	Point	5	8	SPC4	469597,632	1204401,6
276	Point	5	8	SPC5	469586,652	1204398,37
277	Point	5	8	SPC6	469573,647	1204396,12
278	Point	5	8	SPC7	469561,22	1204393,32
279	Point	5	8	SPC8	469537,592	1204397,33
280	Point	5	8	SPC9	469527,626	1204400,05
281	Point	5	8	SPC10	469519,73	1204433,13
282	Point	5	8	SPC11	469522,493	1204418,4
283	Point	5	8	SPC12	469525,862	1204415,03
284	Point	5	8	SPC13	469550,927	1204419,95
285	Point	5	8	SPC14	469572,159	1204411,53
286	Point	5	8	SPC15	469584,04	1204408,34
287	Point	5	8	SPC16	469596,508	1204405,27
288	Point	5	8	SPC17	469605,801	1204407,46
289	Point	5	8	SVR1	469634,372	1204427,73
290	Point	5	8	SVR2	469472,784	1204409,63
291	Point	5	8	SVR3	469495,867	1204427,86
292	Point	5	8	SVR4	469495,976	1204427,97
293	Point	5	8	SVR5	469496,085	1204427,97
294	Point	5	8	SVR6	469522,76	1204429,82
295	Point	5	8	SVR7	469522,761	1204430,27
296	Point	5	8	SVR8	469522,655	1204434,03
297	Point	5	8	SPR1	469630,766	1204429,61
298	Point	5	8	SPR2	469614,801	1204424,21
299	Point	5	8	SPR3	469584,076	1204417,16
300	Point	5	8	SPR4	469528,32	1204412,56
301	Point	5	8	SPR5	469510,392	1204412,8
302	Point	5	8	SPR6	469490,055	1204408,51
303	Point	5	8	SPR7	469472,893	1204409,74
304	Point	5	8	SPR8	469547,793	1204428,25

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
305	Point	5	8	SPR9	469533,909	1204427,82
306	Point	5	8	SPR10	469508,658	1204429,5
307	Point	5	8	SPR11	469495,32	1204427,86
308	Point	5	9	SVC1	469833,474	1204349,48
309	Point	5	9	SVC2	469661,78	1204420,2
310	Point	5	9	SPC1	469832,705	1204350,07
311	Point	5	9	SPC2	469815,294	1204359,35
312	Point	5	9	SPC3	469797,875	1204358,76
313	Point	5	9	SPC4	469787,429	1204358,3
314	Point	5	9	SPC5	469762,66	1204366,7
315	Point	5	9	SPC6	469754,697	1204376,13
316	Point	5	9	SPC7	469748,531	1204386,31
317	Point	5	9	SPC8	469736,105	1204395,35
318	Point	5	9	SPC9	469726,28	1204402,94
319	Point	5	9	SPC10	469709,565	1204410,54
320	Point	5	9	SPC11	469691,985	1204415,44
321	Point	5	9	SPC12	469676,584	1204417,01
322	Point	5	9	SPC13	469666,956	1204419,34
323	Point	5	9	SGC1	469763,806	1204277,38
324	Point	5	9	SGC2	469764,164	1204277,84
325	Point	5	9	SGC3	469758,95	1204287,06
326	Point	5	9	SGC4	469770,221	1204287,51
327	Point	5	9	SGC5	469758,75	1204299,31
328	Point	5	9	SGC6	469774,552	1204304,37
329	Point	5	9	SVR1	469752	1204430,72
330	Point	5	9	SVR2	469719,114	1204450,66
331	Point	5	9	SVR3	469782,367	1204405,58
332	Point	5	9	SVR4	469784,227	1204406,69
333	Point	5	9	SVR5	469791,55	1204405,36
334	Point	5	9	SVR6	469795,481	1204401,26
335	Point	5	9	SVR7	469796,353	1204397,83
336	Point	5	9	SVR8	469803,02	1204396,72
337	Point	5	9	SPR1	469719,196	1204450,66
338	Point	5	9	SPR2	469713,209	1204448,89
339	Point	5	9	SPR3	469705,776	1204449,23
340	Point	5	9	SPR4	469699,982	1204449,02
341	Point	5	9	SGR1	469724,911	1204454,52
342	Point	5	9	SGR2	469754,515	1204432,04

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
343	Point	5	9	SGR3	469763,035	1204423,63
344	Point	5	9	SGR4	469782,267	1204415,32
345	Point	5	9	SGR5	469794,835	1204411,1
346	Point	5	9	SGR6	469811,886	1204408,88
347	Point	5	9	SGR7	469778,438	1204411,89
348	Point	5	9	SGR8	469769,259	1204416,44
349	Point	5	9	SGR9	469763,794	1204417,22
350	Point	6	10	SVC1	472354,623	1203962,01
351	Point	6	10	SVC2	472350,028	1203978,31
352	Point	6	10	SVC3	472421,008	1203938,73
353	Point	6	10	SVC4	472426,883	1203940,31
354	Point	6	10	SVC5	472311,134	1203981,68
355	Point	6	10	SVC6	472296,991	1204019,71
356	Point	6	10	SVC7	472476,025	1203963,44
357	Point	6	10	SVC8	472513,291	1203957,25
358	Point	6	10	SPC1	472399,413	1203919,14
359	Point	6	10	SPC2	472406,449	1203928,73
360	Point	6	10	SPC3	472407,238	1203940,26
361	Point	6	10	SPC4	472412,226	1203944,18
362	Point	6	10	SPC5	472403,025	1203942,5
363	Point	6	10	SPC6	472388,796	1203944,05
364	Point	6	10	SPC7	472380,019	1203946,32
365	Point	6	10	SPC8	472373,103	1203948,92
366	Point	6	10	SPC9	472358,966	1203961,35
367	Point	6	10	SPC10	472353,927	1203961,9
368	Point	6	10	SPC11	472343,657	1203963,53
369	Point	6	10	SPC12	472335,321	1203967,08
370	Point	6	10	SPC13	472314,594	1203977,68
371	Point	6	10	SPC14	472299,724	1203978,97
372	Point	6	10	SPC15	472292,016	1203966,21
373	Point	6	10	SPC16	472296,908	1203975,33
374	Point	6	10	SPC17	472305,666	1203983,98
375	Point	6	10	SPC18	472313,191	1203986,71
376	Point	6	10	SPC19	472321,283	1203987,81
377	Point	6	10	SPC20	472333,588	1203986,68
378	Point	6	10	SPC21	472348,766	1203981,04
379	Point	6	10	SPC22	472350,677	1203976,86
380	Point	6	10	SPC23	472357,578	1203966,99

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
381	Point	6	10	SPC24	472376,661	1203963,23
382	Point	6	10	SPC25	472398,545	1203955,48
383	Point	6	10	SPC26	472413,491	1203944,77
384	Point	6	10	SPC27	472418,654	1203938,82
385	Point	6	10	SPC28	472426,81	1203940,32
386	Point	6	10	SPC29	472424,616	1203947,07
387	Point	6	10	SPC30	472407,262	1203958,34
388	Point	6	10	SPC31	472382,686	1203968,11
389	Point	6	10	SPC32	472366,738	1203974,52
390	Point	6	10	SPC33	472335,659	1203976,4
391	Point	6	10	SPC34	472324,693	1203978,79
392	Point	6	10	SPC35	472315,504	1203980,57
393	Point	6	10	SPC36	472298,637	1203994,12
394	Point	6	10	SPC37	472283,244	1203994,65
395	Point	6	10	SPC38	472275,071	1203996,22
396	Point	6	10	SPC39	472273,972	1204007,85
397	Point	6	10	SPC40	472268,544	1204013,55
398	Point	6	10	SPC41	472284,215	1204016,3
399	Point	6	10	SPC42	472293,378	1204016,84
400	Point	6	10	SPC43	472297,467	1204019,6
401	Point	6	10	SPC44	472424,106	1203983,55
402	Point	6	10	SPC45	472449,838	1203975,03
403	Point	6	10	SPC46	472475,98	1203964,79
404	Point	6	10	SPC47	472454,855	1203958,81
405	Point	6	10	SPC48	472489,749	1203949,78
406	Point	6	10	SPC49	472476,733	1203954,58
407	Point	6	10	SPC50	472502,749	1203946,82
408	Point	6	11	SVC1	472562,259	1203942,07
409	Point	6	11	SVC2	472600,402	1203916,58
410	Point	6	11	SVC3	472694,348	1203892,6
411	Point	6	11	SVC4	472608,484	1203928,86
412	Point	6	11	SVC5	472599,297	1203923,67
413	Point	6	11	SVC6	472698,211	1203900,03
414	Point	6	11	SVC7	472692,307	1203899,26
415	Point	6	11	SVC8	472560,402	1203950,8
416	Point	6	11	SPC1	472562,598	1203942,1
417	Point	6	11	SPC2	472583,246	1203924,81
418	Point	6	11	SPC3	472598,549	1203914,45

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
419	Point	6	11	SPC4	472609,911	1203914,41
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421	Point	6	11	SPC6	472661,897	1203897,44
422	Point	6	11	SPC7	472626,188	1203921,54
423	Point	6	11	SPC8	472609,795	1203927,86
424	Point	6	11	SPC9	472606,843	1203927,31
425	Point	6	11	SPC10	472600,608	1203922,12
426	Point	6	11	SPC11	472633,504	1203911,58
427	Point	6	11	SPC12	472656,677	1203909,02
428	Point	6	11	SPC13	472678,538	1203905,02
429	Point	6	11	SPC14	472696,572	1203901,36
430	Point	6	11	SPC15	472690,996	1203899,48
431	Point	6	11	SPC16	472675,143	1203897,39
432	Point	6	11	SPC17	472656,998	1203900,5
433	Point	6	11	SPC18	472635,904	1203905,5
434	Point	6	11	SPC19	472602,348	1203911,94
435	Point	6	11	SPC20	472561,385	1203949,8
436	Point	6	11	SVR1	472734,628	1203916,04
437	Point	6	11	SVR2	472728,171	1203908,3
438	Point	6	11	SVR3	472682,048	1203919,73
439	Point	6	11	SVR4	472668,28	1203926,6
440	Point	6	11	SVR5	472659,207	1203927,93
441	Point	6	11	SVR6	472663,474	1203932,02
442	Point	6	11	SVR7	472661,945	1203933,35
443	Point	6	11	SVR8	472659,541	1203935,45
444	Point	6	11	SVR9	472655,386	1203933,36
445	Point	6	11	SVR10	472655,169	1203936,23
446	Point	6	11	SVR11	472650,577	1203934,8
447	Point	6	11	SVR12	472654,077	1203937,01
448	Point	6	11	SGR1	472607,411	1203953,52
449	Point	6	11	SGR2	472735,505	1203919,02
450	Point	6	11	SGR3	472685,548	1203921,5
451	Point	6	11	SGR4	472674,619	1203925,38
452	Point	6	11	SGR5	472661,182	1203935,89
453	Point	6	11	SGR6	472652,331	1203940,44
454	Point	6	11	SGR7	472635,951	1203962,46
455	Point	6	11	SPR1	472614,195	1203960,82
456	Point	6	11	SPR2	472618,894	1203958,49

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460	Point	6	11	SPR6	472659,104	1203935,56
461	Point	6	11	SPR7	472668,282	1203929,58
462	Point	6	11	SPR8	472675,822	1203925,93
463	Point	6	11	SPR9	472686,531	1203921,05
464	Point	6	11	SPR10	472697,68	1203919,16
465	Point	6	11	SPR11	472709,265	1203915,84
466	Point	6	11	SPR12	472722,056	1203916,49
467	Point	6	11	SPR13	472733,862	1203915,93
468	Point	6	11	SPR14	472731,564	1203912,94
469	Point	6	11	SPR15	472726,859	1203907,75
470	Point	5	SECTOR 3	DN1	468688,693	1204918,81
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473	Point	5	SECTOR 3	DN4	468658,731	1204909,1
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475	Point	5	SECTOR 3	DN6	468617,833	1204894,76
476	Point	5	SECTOR 3	DN7	468609,521	1204890,13
477	Point	5	SECTOR 3	DN8	468605,694	1204889,47
478	Point	5	SECTOR 3	DN9	468597,707	1204882,06
479	Point	5	SECTOR 3	DN10	468593,221	1204878,31
480	Point	5	SECTOR 3	DN11	468572,472	1204859,66
481	Point	5	SECTOR 3	DN12	468566,825	1204856,86
482	Point	5	SECTOR 3	DN13	468559,967	1204851,58
483	Point	5	SECTOR 3	DN14	468552,713	1204844,98
484	Point	5	SECTOR 3	DN15	468543,933	1204834,04
485	Point	5	SECTOR 4 & 5	DN16	468909,759	1204600,72
486	Point	5	SECTOR 4 & 5	DN17	468910,638	1204605,92
487	Point	5	SECTOR 4 & 5	DN18	468912,612	1204612,67
488	Point	5	SECTOR 4 & 5	DN19	468912,287	1204615,87
489	Point	5	SECTOR 4 & 5	DN20	468915,243	1204620,3
490	Point	5	SECTOR 4 & 5	DN21	468930,9	1204646,27
491	Point	5	SECTOR 4 & 5	DN22	468945,236	1204662,63
492	Point	5	SECTOR 4 & 5	DN23	468876,487	1204579,41
493	Point	5	SECTOR 4 & 5	DN24	468863,915	1204557,11
494	Point	5	SECTOR 4 & 5	DN25	468860,98	1204543,91

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497	Point	5	SECTOR 4 & 5	DN28	468938,712	1204654,82
498	Point	5	SECTOR 4 & 5	DN29	468926,531	1204640,1
499	Point	5	SECTOR 4 & 5	DN30	468922,471	1204634,52
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501	Point	5	SECTOR 5 & 6	DN32	469002,453	1204466,64
502	Point	5	SECTOR 5 & 6	DN33	469004,897	1204474,73
503	Point	5	SECTOR 5 & 6	DN34	469003,016	1204481,36
504	Point	5	SECTOR 5 & 6	DN35	469011,852	1204483,97
505	Point	5	SECTOR 5 & 6	DN36	469109,746	1204533,18
506	Point	5	SECTOR 5 & 6	DN37	469106,353	1204528,65
507	Point	5	SECTOR 5 & 6	DN38	469094,329	1204529,99
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510	Point	5	SECTOR 5 & 6	DN41	469076,4	1204529,01
511	Point	5	SECTOR 5 & 6	DN42	469053,108	1204520,62
512	Point	5	SECTOR 5 & 6	DN43	469049,718	1204519,74
513	Point	5	SECTOR 5 & 6	DN44	469043,924	1204519,41
514	Point	5	SECTOR 5 & 6	DN45	469036,704	1204514,22
515	Point	5	SECTOR 5 & 6	DN46	469034,079	1204512,46
516	Point	5	SECTOR 6 & 7	DN47	469140,237	1204419,94
517	Point	5	SECTOR 6 & 7	DN48	469141,959	1204419,2
518	Point	5	SECTOR 6 & 7	DN49	469137,743	1204417,46
519	Point	5	SECTOR 6 & 7	DN50	469133,329	1204400,91
520	Point	5	SECTOR 6 & 7	DN51	469103,565	1204437,26
521	Point	5	SECTOR 6 & 7	DN52	469100,707	1204437,89
522	Point	5	SECTOR 6 & 7	DN53	469105,326	1204439,14
523	Point	5	SECTOR 6 & 7	DN54	469098,901	1204436,75
524	Point	5	SECTOR 6 & 7	DN55	469091,445	1204400,92
525	Point	5	SECTOR 6 & 7	DN56	469162,873	1204531,91
526	Point	5	SECTOR 6 & 7	DN57	469152,03	1204509,58
527	Point	5	SECTOR 6 & 7	DN58	469155,632	1204504,05
528	Point	5	SECTOR 6 & 7	DN59	469158,913	1204505,7
529	Point	5	SECTOR 6 & 7	DN60	469158,913	1204505,59
530	Point	5	SECTOR 6 & 7	DN61	469156,937	1204496,64
531	Point	5	SECTOR 6 & 7	DN62	469157,155	1204496,19
532	Point	5	SECTOR 7 Y 8	DN63	469474,539	1204413,58

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
533	Point	5	SECTOR 7 Y 8	DN64	469474,774	1204409,53
534	Point	5	SECTOR 7 Y 8	DN65	469467,487	1204406,69
535	Point	5	SECTOR 7 Y 8	DN66	469461,153	1204404,68
536	Point	5	SECTOR 7 Y 8	DN67	469456,751	1204400,07
537	Point	5	SECTOR 7 Y 8	DN68	469522,999	1204451,94
538	Point	5	SECTOR 7 Y 8	DN69	469544,435	1204461,99
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540	Point	5	SECTOR 7 Y 8	DN71	469527,161	1204460,46
541	Point	5	SECTOR 7 Y 8	DN72	469522,33	1204452,11
542	Point	5	SECTOR 7 Y 8	DN73	469518,193	1204456,15
543	Point	5	SECTOR 7 & 8	DN74	469511,195	1204454,5
544	Point	5	SECTOR 7 & 8	DN75	469503,976	1204449,2
545	Point	5	SECTOR 7 & 8	DN76	469501,788	1204447,98
546	Point	5	SECTOR 7 & 8	DN77	469495,986	1204438,36
547	Point	5	SECTOR 7 & 8	DN78	469492,59	1204430,74
548	Point	5	SECTOR 8 & 9	DN79	469656,68	1204424,56
549	Point	5	SECTOR 8 & 9	DN80	469660,113	1204421,42
550	Point	5	SECTOR 8 & 9	DN81	469662,898	1204410,12
551	Point	5	SECTOR 8 & 9	DN82	469667,944	1204397,95
552	Point	5	SECTOR 8 & 9	DN83	469656,027	1204439,66
553	Point	5	SECTOR 8 & 9	DN84	469649,688	1204440,21
554	Point	5	SECTOR 8 & 9	DN85	469640,728	1204445,2
555	Point	5	SECTOR 8 & 9	DN86	469638,655	1204449,74
556	Point	5	SECTOR 8 & 9	DN87	469633,312	1204464,45
557	Point	5	SECTOR 8 & 9	DN88	469637,248	1204464,89
558	Point	5	SECTOR 8 & 9	DN89	469638,122	1204464,78
559	Point	5	SECTOR 8 & 9	DN90	469650,367	1204466,1
560	Point	5	SECTOR 8 & 9	DN91	469651,658	1204442,76
561	Point	5	SECTOR 9	DN92	469797,764	1204317,28
562	Point	5	SECTOR 9	DN93	469821,024	1204322,33
563	Point	5	SECTOR 9	DN94	469822,054	1204326,48
564	Point	5	SECTOR 9	DN95	469814,489	1204330,56
565	Point	5	SECTOR 9	DN96	469812,453	1204328,18
566	Point	5	SECTOR 9	DN97	469821,786	1204333,46
567	Point	5	SECTOR 9	DN98	469828,658	1204334,09
568	Point	5	SECTOR 9	DN99	469836,57	1204338,09
569	Point	5	SECTOR 9	DN100	469877,997	1204380,06
570	Point	5	SECTOR 9	DN101	469884,67	1204384,7

#	Type of file	POINT	SECTOR	TRAP	COORD. X	COORD. Y
571	Point	5	SECTOR 9	DN102	469885,769	1204391,67
572	Point	5	SECTOR 9	DN103	469895,722	1204397,19
573	Point	5	SECTOR 9	DN104	469909,715	1204397,95
574	Point	5	SECTOR 9	DN105	469913,002	1204406,24
575	Point	5	SECTOR 9	DN106	469916,393	1204408,01
576	Point	5	SECTOR 9	DN107	469924,701	1204408,11
577	Point	5	SECTOR 9	DN108	469936,835	1204407,44

SYMBOLS

SPC: Small sediment trap at cut slope
SVC: Sediment trap with box at cut slope
SGC: Large sediment trap at cut slope
SPR: Small sediment trap at fill slope
SVR: Box sediment trap at fill slope
SGR: Large sediment trap at fill slope
DN: Sediment traps at natural drain

ANNEX 13

Comisión de Desarrollo Forestal de San Carlos (CODEFORSA)

Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road, Report of Contract SINAC-CDE-004-2012

November 2014

COMISIÓN DE DESARROLLO FORESTAL DE SAN CARLOS
Corporate ID number: 3-002-066610-06

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Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road

REPORT OF CONTRACT SINAC-CDE-004-2012

November 2014

Report of the Project

Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road
Direct Contract by Emergency Exception SINAC-CDE-004-2012

I. INDEX OF APPENDIXES

APPENDIX 1: Material prepared for delivery to the participants of the activities and members of public institutions involved.

APPENDIX 2: Maps of the location of the planted areas, FIRST STAGE.

APPENDIX 3: Maps of the location of the planted areas, SECOND STAGE (EXPANSION).

II. THE PROJECT.

Consulting Services for the Development and Implementation of an Environmental Plan for the Border Road Juan Rafael Mora Porras

Direct Contract by Emergency Exception SINAC-CDE-004-2012

Start date: APRIL 2012.
End date of the first stage: APRIL 2014.
Duration of the project: 2 years

Start date of the second stage: DECEMBER 2013.
End date of the second stage: SEPTEMBER 2015.
Duration of the project: 2 years

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1. INTRODUCTION

On 7 March 2011, Executive Decree No. 36440-MP was published in Gazette No. 46, which declared a state of emergency in the cantons bordering with Nicaragua, and authorized the institutions of the State to take the measures necessary to guarantee national sovereignty and the environment.

Within the framework of this decree, the *Sistema Nacional de Áreas de Conservación* (SINAC, National System of Conservation Areas) published the tender entitled "Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road" as part of the actions within its jurisdiction to restore the landscape in the process of construction of *Ruta 1856*.

By means of Tender Award Order SINAC-CDE-004-2012 of 12 April 2012, which was declared final on 19 April 2012, the tender was officially awarded to COMISIÓN DE DESARROLLO FORESTAL DE SAN CARLOS (CODEFORSA, Commission for Forestry Development in San Carlos).

Based on this resolution, CODEFORSA developed a work plan, including a breakdown of the actions to be implemented, schedule of activities to be performed during its execution and maintenance activities, within the deadlines stipulated in the consulting contract.

The work plan consisted in performing institutional administrative coordination, field visits to coordinate with the owners of the area of influence of the project, coordination and planning to locate volunteers to plant trees and the field activities necessary to plant and provide maintenance to 25,000 trees and the management of 12 slopes in the areas surrounding *Ruta 1856* and/or the San Juan River, as part of the implementation of the Environmental Management Plan for the border road.

In this first stage of the contract a total of 26,575 trees were planted, and the total mortality was estimated at 1.5%. During 2013 an extension to the contract was agreed, to plant and provide maintenance to 24,000 new trees. Between December 2013 and July 2014 a total of 24,134 trees were planted in this second stage of the contract.

In total, as part of the Environmental Management Plan for the border road *Ruta 1856*, 50,709 trees were planted trees, aged between 2 months and 28 months, with heights ranging from 50 centimetres to 7 metres, in an area equivalent to 46 hectares of land ceded through an agreement by the holders of these lands adjacent to the border road and/or the San Juan River.

III. PHASES OF THE PROJECT:

The phases presented were carried out for both stages of the project. In the second stage no tree-planting was performed by volunteers, only in the first.

1. PHASE NO. 1. PLANNING AND COORDINATION OF THE ACTIONS CONTAINED IN THE ENVIRONMENTAL MANAGEMENT PLAN FOR RE-VEGETATION.

The success of the implementation of the consulting services' Work Plan was largely due to CODEFORSA's field experience in the work area, in addition to the adequate application of the terms of reference of the consulting work.

Below is a description of how we worked with the areas whose involvement was required by the consulting contract to coordinate the activities.

a) Coordination with the Conservation Areas involved:

During the planning process, coordination was established with the Conservation Areas involved in the portion of *Ruta 1856* that was already built, from Delta Costa Rica to the area of Las Tablillas in Los Chiles.

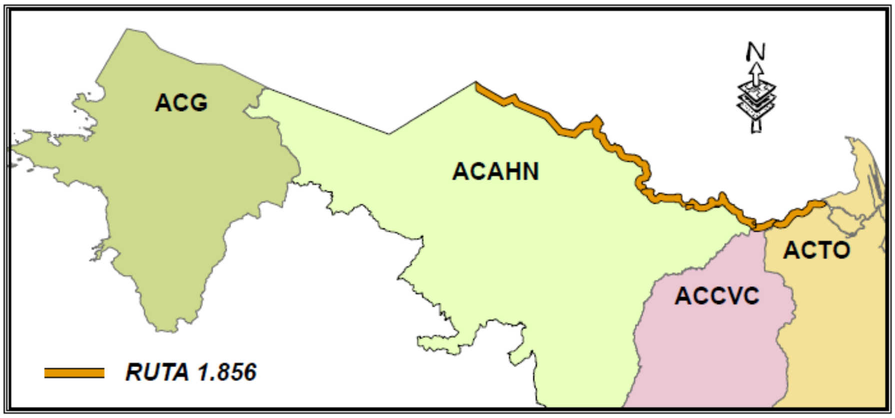

Figure 1. Map of the built portion of *Ruta 1856*

Meetings were held with the three Conservation Areas involved: Área de Conservación Arenal Huetar Norte (ACAHN), Área de Conservación Cordillera Volcánica Central (ACCVC) and Área de Conservación Tortuguero (ACTO), as shown in Figure 1, to present the Work Plan and hear the opinions and suggestions of the State's Forestry Administration.

The number of meetings scheduled with the Conservation Areas of the Sistema Nacional de Áreas de Conservación was determined based on the area of influence of each conservation area. As observable in Figure 1 above, approximately 80% of the total border road area which is in the vicinity of the San Juan River is in ACAHN territory, followed by ACTO and lastly by ACCVC, which has a 7 km area of influence of the border road in the area currently covered by *Ruta 1856*, which goes from the Costa Rican Delta to Los Chiles de Alajuela, with an approximate length of 167 km. In total, 15 meetings were held with the different offices.

Regarding the field visits for supervision of the activities, these were performed after the presentation of each of the quarterly progress reports during the term of both stages of the project. Once each quarterly report was presented to the offices of the technical managers of the project, the field visits were programmed with each of them to verify the information presented in each of the reports.

The technical managers of the conservation areas are:

-Área de Conservación Arenal Huetar Norte: Mr. Carlos Ulate Rodríguez
-Área de Conservación Cordillera Volcánica Central: Mr. José Luis Agüero Barquero
-Área de Conservación Tortuguero: Mr. Erick Herrera Quesada.

The field visits performed with each of the officials of the Conservation Areas are presented in the following table.

Table Nº 1: Meetings with the different Conservation Areas involved.

Conservation Area	**Field visits with Conservation Areas**	
	FIRST STAGE	**SECOND STAGE**
Tortuguero (ACTO)	**7**	**3**
Cordillera Volcánica Central (ACCVC)	**7**	**3**
Arenal Huetar Norte (ACAHN)	**7**	**3**
TOTAL	**21**	**9***

* To date.

b) Coordination with the holders of the lots to obtain their consent for the reforestation

The area where the project was implemented has two characteristics regarding its inhabitants:
a. diverse centres of population located mainly near the access roads, where the holders of the lands and other inhabitants live; and
b. isolated houses along the border road and adjacent to the San Juan River, where the holders and farm workers live further away from the centres of population.

General meetings were held with the inhabitants, with the aim achieving an adequate distribution of the areas and sites to be reforested, which had been previously identified together with the Conservation Areas (CA). In each general meeting the goals of the project were explained as well as the expected results, and their collaboration was requested. This was fundamental to obtain the collaboration required.

2. PHASE NO. 2: IMPLEMENTATION OF THE WORK PLAN

a. Scheduling of the planting events

Once the participation agreements were signed by the inhabitants of the different areas, the activities were scheduled based on the list of agreements. The Work Plan contemplated performing all planting events between June and August; however, due to a delay in the first payment of the consulting work, the planting activities with volunteers for July were suspended. There were 20 planting events in total from June to December 2012.

Table No. 2. Execution of planting events with volunteers during 2012.

Name of the area	**Planting events with volunteer and student groups**														
	Week-Month														
	01-jun	02-jun	03-jun	04-jun	03-ago	04-ago	01-sep	02-sep	04-sep	01-oct	02-oct	03-oct	04-oct	01-dec	**TOTAL**
Delta Costa Rica				1											**3**
Trinidad (Mouth of Sarapiquí River)	1	2	1												**5**
Mouth of San Carlos River			1	1	1		1		1		1	1	1	1	**7**

Tiricias					1	1	1	1		2					**5**
TOTAL	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**20**

b. Availability of trees for planting

CODEFORSA has a certified nursery from which most of the material planted in the project was sourced. As part of the commitments, the trees were transferred to the planting site the day before or on the day of the event in order to prevent damages or theft of trees at the site and to guarantee optimal strength and development conditions of the trees at the time of planting. In addition, we complied with the commitment that all the trees planted were native species.

c. Preparation of the ground and protection of the trees

Once the agreements of participation in the planting of trees were signed with the inhabitants of the different areas, the planning for preparation of the ground at the different sites began.

d. Initial mowing and herbicide spots

In all cases, the preparation of the ground began with a general mowing, tracing and staking of the planting system. Subsequently, herbicide was applied in the spots around each stake, covering a radius of 1 metre, to guarantee that weeds would not compete with the trees to be planted. Finally, holes were dug at the sites so that when the planting events took place the volunteers could focus exclusively on planting the trees.

e. Building of Fences

In some cases it was not necessary to place wire fences for protection since there were previous ones in place, while in others a fence was placed to separate the planting area from the rest of the site. In all cases maintenance will be given to the fences as protection of the planted areas.

f. Planting of the trees

Table 7 shows the date of planting and number of trees planted per site for the first stage of the project. The planting goal of the project was establishing 25,000 trees; however, at the 20 planting events a total of **26,575** trees were planted. The activities began on 5 June 2012 in the Trinidad area (Sarapiquí) and concluded in the Tiricias area. The last planting event was on 4 December 2012.

The trees were planted at **31** sites, with the collaboration of the volunteers who were transported, personnel from public institutions and students from schools and colleges in the neighbouring areas.

Table Nº 3: Actual number of trees planted at the sites with a plantation agreement in the first stage

No.	Name of the party to the agreement	Place	Number of trees planted	Date of planting (year 2012)
1	Félix Hernández Jarquín	Boca La Ceiba (Trinidad)	260	05 june
2	Iglesia Boca La Ceiba	Boca La Ceiba (Trinidad)	225	05 june
3	Segundo Gaitán Mora	Boca Río Sarapiquí	100	12 June
4	Fabio Vargas	Boca La Ceiba (Trinidad)	407	16 and 19 June
5	Escuela Boca La Ceiba	Boca La Ceiba (Trinidad)	117	19 June

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No.	Name of the party to the agreement	Place	Number of trees planted	Date of planting (year 2012)
6	Melis Góngora Moraga	Boca La Ceiba (Trinidad)	252	19 June
7	María Hilaria Miranda Rivas	Boca Las Marías	500	15 July
8	Tito Hernández Ferreto	Delta Costa Rica	366	30 June
9	Escuela Delta Costa Rica	Delta Costa Rica	325	30 June
10	Fredy Ulate Castro	Remolinito	3180	22 September
11	Fabio Cedeño G. (F. San Antonio 1)	Boca Río San Carlos	420	23 June
12	Fabio Cedeño G. (F. San Antonio 2)	Boca Río San Carlos	1180	28 June
13	Fabio Cedeño G. (Saíno)	Boca Río San Carlos	875	04 July
14	Fabio Cedeño G. (Boca Tapada)	Boca Río San Carlos	770	06 September
15	Fabio Cedeño G. (Jóvenes)	Boca Río San Carlos	1000	29 September
16	Olman Quesada Campos	Tiricias	650	25 July
17	Daniel Jiménez B. (El Guabo)	Tiricias	1907	22 August
18	Daniel Jiménez B. (Slopes)	Tiricias	1000	14 August
19	Daniel Jiménez B. (Alonso)	Tiricias	200	16 August
20	Daniel Jiménez B. (Pilo)	Tiricias	950	20 August
21	Daniel Jiménez B. (Bismark)	Tiricias	1280	29 de agosto
22	Marcelo Méndez Morales	Tiricias	1870	27 August
23	William Cortés Madrigal	Tiricias	1460	25 August
24	German Díaz Ruiz	Mojón 2	2570	26 September

No.	Name of the party to the agreement	Place	Number of trees planted	Date of planting (year 2012)
25	German Díaz Ruiz (El Concho)	Mojón 2	668	02 October
26	German Díaz Ruiz (Banderas)	Mojón 2	857	04 October
27	Fabio Cedeño G. (Gastón Peralta)	Boca Río San Carlos	900	11 October
28	Fabio Cedeño G. (Pital)	Boca Río San Carlos	1000	16 October
29	Fabio Cedeño G. (Aguas Zarcas)	Boca Río San Carlos	800	23 October
30	Escuela Delta Costa Rica	Delta Costa Rica	500	01 December
31	Edgar Salazar Ramírez	Tiricias	86	04 December
	TOTAL TREES PLANTED		**26,575**	

Table 4 shows the date of planting and number of trees planted per site for the second stage of the project. The activities were carried out between December 2013 and August 2014, when the last plots were planted.

The trees were planted at **12** sites along the border road, from Delta Costa Rica to Las Delicias de Los Chiles, northern border.

Table Nº 4: Actual number of trees planted at the sites with a plantation agreement in the second stage.

#	Name of the party to the agreement	Place	Trees planted	Date of establishment
1	Fabio Cedeño González (Ochoa)	Boca Río San Carlos	3.100	02 December 2013
2	Melis Góngora Moraga	Boca La Ceiba (Trinidad)	220	20 January 2014
3	Tito Hernández Ferreto	Delta Costa Rica	570	24 January 2014
4	Edwin Segura Retana	Delta Costa Rica	2.610	23 January 2014

#	**Name of the party to the agreement**	Place	Trees planted	Date of establishment
5	Marcelo Méndez Morales	Tiricias	1.345	20 December 2013
6	Eylin Cruz Campos	Los Chiles	3.550	26 December 2013
7	Frits Perera Jiménez (Palo seco)	Cureña	2.500	20 December 2013
8	Porfirio Rodríguez Campos	Delta Costa Rica	920	10 January 2014
9	Fabio Vargas (Chachalaca)	Boca Río San Carlos	4.050	18 December 2013
10	Daniel Jiménez Berrocal (El Almendro)	Tiricias	2.463	15 August 2014
11	Daniel Jiménez Berrocal (La Laguna)	Tiricias	256	30 August 2014
12	Frits Perera Jiménez (Pindongo)	Cureña	2.550	30 de agosto de 2014
		TOTAL	**24.134**	

The species used were:

For protection of the land on the banks of rivers and creeks: *Zygia longifolia* (Sotacaballo).

For humid areas: *Vochysia guatemalensis* (Cebo), *Calophyllum brasiliense* (Cedro María), *Tabebuia rosea* (Roble sabana), *Hyeronima alchorneoides* (Pilón), *Anacardium excelsum* (Espavel).

For high areas: *Vochysia ferruginea* (Botarrama), *Dipteryx panamensis* (Almendro), *Tabebuia ochracea* (Corteza amarilla), *Terminalia amazonia* (Roble coral), *Cordia alliodora* (Laurel), *Delonix regia* (Malinche), *Samanea saman* (Cenizaro) and *Schizolobium parahyba* (Gallinazo).

3. PHASE NO. 3. MAINTENANCE OF THE PLANT COVER

a. Monitoring of planted areas

As of July 2012 follow-up visits to the planted areas are made as part of the commitments of the consulting contract, and also as input for the submission of quarterly progress reports.

During the term of the project, the maintenance work was performed by work crews comprised of people from the areas surrounding the projects, to collaborate with the economy of the area, which is difficult and there are few sources of employment. Four work crews were used for this task, one in the area of Tiricias, another in the mouth of Río San Carlos, another in La Ceiba - Trinidad de Sarapiquí and the fourth in the Delta Costa Rica area.

b. Mowing:

As programmed, a full mowing was performed for each plot, either manually or with a hedge trimmer. There is a variety of weeds in each lot. The one that gave the most problems is called *gamalote* (bullgrass), which grows very aggressively and its roots spread through the ground which makes it difficult to clean.


Mowing of *rotana* grass


Mowing of *gamalote* (bullgrass)

These pictures correspond to the mowing work performed at the plots planted in June and July 2014.

The planted area of each plot was fully mowed five times during the first two years of each project.

c. Spot herbicide treatment around trees:

After the mowing at each plot, a spot herbicide treatment was applied in a circle around each tree to fully eliminate the competition of weeds with the planted trees.

Due to the aggressiveness of bullgrass, at the plots which had this type of grassy weed a full chemical burning of the site was performed with glyphosate, which is a green-label herbicide permitted by international certifiers such as FSC or ISO 14001.

Spot herbicide treatment to the tree. Total burning of the plot.

Similarly, spot herbicide treatments or full chemical burns were applied five times, as visible in the pictures, depending on the type of weeds at the site of each plot.

d. Mortality and replanting:

Within the terms of reference of the consulting contract, the number of trees was established by units and not by area; therefore, the commitment of the contractor, in this case CODEFORSA, was to maintain the number of trees originally planted in each lot planted until the end of the respective contract.

This is why during the entire period of the project, within the maintenance programme (mowing, herbicide spot, etc.), we conducted for each plot a review of mortality and replanting of any trees lost during the term of the project.

For each plot we performed a monthly monitoring visit, and the field visit reports indicated the number of trees to be replaced for each, if necessary, to maintain the initial number of trees planted by plot, meaning that this activity was constant in each of the plots until the end of the project.

Below is the data from the mortality reports of the visits to the projects, performed during 2012, 2013 and 2014 for all plots during both stages of the contract.

Table Nº 5: Mortality report from follow-up visits to all plots planted during both stages of the contract.

FIRST STAGE (26.575 TREES PLANTED)							
NAME OF THE PARTY TO THE AGREEMENT	TOTAL TREES PLANTED	MORTALITY IN 2012		MORTALITY IN 2013		MORTALITY IN 2014	
		N	%	N	%	N	%
Escuela Delta Costa Rica	325	28	8,6%	25	7,7%	0	0,0%
Escuela y Policía	500	0	0,0%	25	5,0%	0	0,0%
Tito Hernández Ferreto	366	14	3,8%	5	1,4%	0	0,0%
María Hilaria Miranda Rivas	500	30	6,0%	20	4,0%	0	0,0%
Felix Hernández Jarquín	260	17	6,5%	15	5,8%	0	0,0%
Fabio Vargas	407	52	12,8%	10	2,5%	0	0,0%
Escuela Boca La Ceiba	117	10	8,5%	5	4,3%	0	0,0%
Melis Góngora Moraga	252	25	9,9%	5	2,0%	0	0,0%
Iglesia Boca La Ceiba	225	30	13,3%	7	3,1%	0	0,0%
Fredy Ulate Castro	3,180	150	4,7%	0	0,0%	0	0,0%
Fabio Cedeño G. (F. Ochoa)	5,345	329	6,2%	345	6,5%	0	0,0%
Fabio Cedeño G. (San Antonio)	1,600	57	3,6%	50	3,1%	0	0,0%
Marcelo Méndez Morales	1,870	75	4,0%	25	1,3%	0	0,0%
Daniel Jiménez Berrocal (El Guabo)	1,907	125	6,6%	30	1,6%	0	0,0%
Daniel Jiménez Berrocal (Alonso)	200	20	10,0%	0	0,0%	0	0,0%
Daniel Jiménez Berrocal (Slopes)	1,000	40	4,0%	20	2,0%	0	0,0%
Olman Quesada Campos	650	26	4,0%	5	0,8%	0	0,0%
Daniel Jiménez Berrocal (Lote Pilo)	950	95	10,0%	4	0,4%	0	0,0%
Daniel Jiménez Berrocal (Bismark)	1,280	78	6,1%	8	0,6%	0	0,0%
William Cortés Madrigal	1,460	150	10,3%	25	1,7%	0	0,0%
German Díaz Ruiz	4,095	274	6,7%	100	2,4%	0	0,0%
Edgar Salazar Ramírez	86	0	0,0%	5	5,8%	0	0,0%
TOTAL	**26,575**	**1,625**	**6,6%**	**734**	**2,8%**	**0**	**0,0%**

SECOND STAGE (24,134 TREES PLANTED)							
NAME OF THE PARTY TO THE AGREEMENT	N TREES PLANTED	MORTALITY IN 2012		MORTALITY IN 2013		MORTALITY IN 2014	
		N	%	N	%	N	%
Fabio Cedeño González (Ochoa)	3,100					150	4,8%
Melis Góngora Moraga	220					5	2,3%
Tito Hernández Ferreto	570					55	9,6%
Edwin Segura Retana	2,610					270	10,3%
Marcelo Méndez Morales	1,345					255	19,0%
Eylin Cruz Campos	3,550					40	1,1%
Frits Perera Jiménez (Palo Seco)	2,500					50	2,0%
Porfirio Rodríguez Campos	920					150	16,3%
Fabio Vargas Vargas (Chachalaca)	4,050					250	6,2%
Daniel Jiménez Berrocal (El Almendro)	2,463					0	0,0%
Daniel Jiménez Berrocal (La Laguna)	256					0	0,0%
Frits Perera Jiménez (Pindongo)	2,550					0	0,0%
TOTAL	**24,134**					**1,225**	**6,0%**

For both stages of the contract, the mortality in the first year of planting did not exceed 6.6%, of which 100% were replanted.

The main causes of mortality in the first year were: dry conditions (several days without rain) immediately after the day when the tree was planted, bad planting technique, high humidity in areas close to point where the tree was planted, entry of ruminants and equines to the planted area and finally poisoning effect of herbicide applied for weed control.

As you can see also, for the second year the mortality was much lower, and by the end of the first stage of the project no dead trees were found within the planted areas. Similar behaviour is expected for 24,134 trees planted in the second stage of the project.

e. Fertiliser application:

Soil improvement activities contemplated in the project were implemented in a satisfactory manner, at each lot planted. One month after the tree-planting an earthing up was performed on all the trees planted, followed by the application of a dose of granulated fertiliser (10-30-10) at a ratio of 60 g per tree.

When the plots reached one year from planting, foliar fertiliser was applied (20-20-20 plus minor elements) as part of the soil improvements scheduled for the plots planted. Whitewashing was also applied when the trees reached one year of age, using 500 g of calcium carbonate ($CaCO_3$) at the base of each tree. This work was carried out after the fourth activity of herbicide spot treatment applied to the plots.

f. Pruning:

This activity has been implemented in all plots to trees that have required it, including *Cebo, Roble Coral* and *Laurel* trees, which have been intervened the most to prevent that due to the effect of wind they fall due to the weight of the canopy, practically the only species that has not required pruning due its growth style is the *sotacaballo*.

Pruning of Project Fabio Cedeño Ochoa.

g. Maintenance of the fences:

According to the approved Work Plan, this activity was scheduled once a year; however, as part of the program of maintenance visits executed at the planted plots, the fences were checked on each visit to prevent the entry of cattle to the site, and this activity was performed whenever necessary. In some cases it was reinforced with more posts, and in others it was replaced with barbed wire.

h. Follow-up visits to the planted areas

Since July 2012 follow-up visits are made to the planted areas. As per the work plan, project visits were made monthly during the first year and bi-monthly during the second year.

After each visit a report was prepared with the corresponding observations and maintenance recommendations that should be applied. All of these reports were presented in the quarterly progress reports of the project, along with photographic records of each plot.

Below is a summary of each plot planted in the first stage of the project, which presents a photographic sequence of the status of the plot at the beginning of the planting and its current state.

Information per plot of the project:

Name of the plot: Félix Hernández Jarquín.

Holder: Félix Hernández Jarquín.

Located: La Ceiba, near the mouth of the Río Sarapiquí

MINAE Office which supervises: A.C.C.V.C., Sarapiquí sub-region.

Number of trees planted: 260 trees.

Planting date: 05 June 2012.

Area of the plot: 0 ha 3433.00 m²

Description of the plot:
This plot was planted with the species *sotacaballo, laurel, malinche, cedro maría, almendro, cebo, roble coral, roble sabana, botarrama* and *pilón*. A fence was built for its protection, 40 metres long and with three wires. The initial cover of the plot was pastures of short grasses.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 3.2 metres, with more development of the *malinche* and *laurel* trees which are approximately 5 metres high.

PLOT FELIX HERNANDEZ JARQUIN


One month from planting


One year from planting


Current Condition (average height 3.2 m)

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

Information per plot of the project:

Name of the plot: Iglesia Boca La Ceiba.

Holder: Adilia Com Hernández (member of the Church council)

Located: Mouth of Caño La Ceiba with the Sarapiquí River.

MINAE Office which supervises: A.C.C.V.C., Sarapiquí sub-region.

Number of trees planted: 225 trees.

Planting date: 05 June 2012.

Area of the plot: 0 ha 1918 m²

Description of the plot:
This plot was planted with the species *cebo, roble coral, cedro maría, laurel, botarrama, malinche, sotacaballo, pilón*. This plot was already surrounded by a wire fence, therefore we only gave it maintenance. The initial cover of the plot was scrubland and a mimosacea called *abacá*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.8 metres, with more development of the *malinche* and *laurel* trees which are approximately 4 metres high.

PLOT IGLESIA BOCA CAÑO LA CEIBA


One month from planting


One year from planting


Current Condition (average height 2.8 m)

Information per plot of the project:

Name of the plot: Fabio Vargas Vargas.

Holder: Fabio Vargas Vargas.

Located: Next to the school of Caño La Ceiba.

MINAE Office which supervises: A.C.C.V.C., Sarapiquí sub-region.

Number of trees planted: 407 trees.

Planting date: 16 June 2012.

Area of the plot: 0 ha 3671 m²

Description of the plot:
This plot was planted with the species *pilón, sotacaballo, roble sabana, cebo, cedro maría, almendro, roble coral*. For this plot 70 metres of fence were built, with three wires, given that the rest was already surrounded by a wire fence. The initial cover of the plot was pastures of short grasses.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.2 metres, with more development of the *cebo* and pilón trees.

PLOT FABIO VARGAS VARGAS


One month from planting


One year from planting


Current Condition (average height 2.2 m)

Information per plot of the project:

Name of the plot: Escuela Boca del caño La Ceiba.

Holder: Area neighbouring the school.

Located: Next to the school of Caño La Ceiba.

MINAE Office which supervises: A.C.C.V.C., Sarapiquí sub-region.

Number of trees planted: 117 trees.

Planting date: 19 June 2012.

Area of the plot: 0 ha 1062 m²

Description of the plot:

This plot was planted with the species *pilón, cebo, roble sabana, roble coral, cedro maría, malinche, gallinazo, almendro, sotacaballo*. This plot was already surrounded by a wire fence, therefore we only gave it maintenance. The initial cover of the plot was pastures of short grasses.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.4 metres, with more development of the *malinche* and *gallinazo* trees which are approximately 3 metres high.

PLOT ESCUELA BOCA CAÑO LA CEIBA


One month from planting


One year from planting


Current Condition (average height 2.4 m)

Information per plot of the project:

Name of the plot: Melis Góngora Moraga.

Holder: Melis Góngora Moraga.

Located: Next to the plot of the school of Caño La Ceiba.

MINAE Office which supervises: A.C.C.V.C., Sarapiquí sub-region.

Number of trees planted: 252 trees.

Planting date: 19 June 2012.

Area of the plot: 0 ha 1975 m²

Description of the plot:

This plot was planted with the following species *cebo, roble coral, cedro maría, malinche, almendro, sotacaballo*. For this plot 70 metres of fence were built, with three wires, given that the rest was already surrounded by a wire fence. The initial cover of the plot was pastures of short grasses.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 3.1 metres, with more development of the *cebo* and *pilón* trees.

PLOT MELIS GONGORA MORAGA

One month from planting

One year from planting

Current Condition (average height 3.1 m)

Information per plot of the project:

Name of the plot: María Hilaria Miranda Rivas.

Holder: María Hilaria Miranda Rivas.

Located: To one side of the mouth of Caño Las Marías.

MINAE Office which supervises: A.C.C.V.C., Sarapiquí sub-region.

Number of trees planted: 500 trees.

Planting date: 15 July 2012.

Area of the plot: 0 ha 5167.12 m²

Description of the plot:
This plot was planted with the species *cebo, sotacaballo, botarrama*. For this plot 316 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was *gamalote*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.5 metres, with more development of the *cebo* and *botarrama* trees, in addition to a natural regeneration of trees of the *cedro amargo* and *jobo* species.

PLOT MARIA HILARIA MIRANDA RIVAS


One month from planting


One year from planting


Current Condition (average height 2.5 m)

Information per plot of the project:

Name of the plot: Tito Hernández Ferreto.

Holder: Tito Hernández Ferreto.

Located: San Antonio, on the road to Delta Costa Rica.

MINAE Office which supervises: A C.To., Gerencia de A.S.P.

Number of trees planted: 366 trees.

Planting date: 30 June 2012.

Area of the plot: 0 ha 3047 m²

Description of the plot:
This plot was planted with the species *cebo, sotacaballo, roble coral, genízaro, cedro maría, pilón, roble sabana*. For this plot 200 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was *gamalote*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 3.2 metres, with more development of the *cebo, pilón* and *genízaro* trees.

PLOT TITO HERNANDEZ FERRETO


One month from planting


One year from planting


Current Condition (average height 3.2 m)

Information per plot of the project:

Name of the plot: Escuela La Esperanza, Delta Costa Rica.

Holder: Area behind the school, land of the institution.

Located: Delta Costa Rica.

MINAE Office which supervises: A.C.To., Gerencia de A.S.P..

Number of trees planted: 325 trees.

Planting date: 30 June 2012.

Area of the plot: 0 ha 3200 m²

Description of the plot:

This plot was planted with the species *cebo, roble coral, genízaro, cedro maría, pilón, roble sabana, sotacaballo*. For this plot 100 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was *gamalote* and grasses.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2 metres, with more development of the *cebo, pilón* and *roble sabana* trees.

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PLOT ESCUELA DELTA COSTA RICA


One month from planting


One year from planting


Current Condition (average height 2 m)

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

Information per plot of the project:

Name of the plot: Escuela La Esperanza- Policía Frontera.

Holder: Area behind the school and to the side of the facilities of the border police.

Located: Delta Costa Rica.

MINAE Office which supervises: A.C.To., Gerencia de A.S.P..

Number of trees planted: 500 trees.

Planting date: 01 December 2012

Area of the plot: 0 ha 4140 m²

Description of the plot:
This plot was planted with the species *sotacaballo, cebo, guanacaste, roble sabana.* For this plot 50 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was *gamalote* and grasses.

The planted trees have had a regular development, with a high mortality rate at the beginning and a replanting during June 2013. All maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 1.8 metres, due to the replanting applied, and that the plot next to the border police mainly has *sotacaballo* trees, which fork and grow relatively low.

PLOT ESCUELA DELTA COSTA RICA- POLICIA FRONTERA

One month from planting

One year from planting

Current Condition (average height 1.8 m)

Information per plot of the project:

Name of the plot: Fredy Ulate Castro.

Holder: Fredy Ulate Castro.

Located: Remolinito de La Cureña

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 3180 trees.

Planting date: 22 September 2012.

Area of the plot: 3 ha 7715.66 m²

Description of the plot:

This plot was planted with the species *cebo, pilón, sotacaballo, almendro, guaba, roble coral, guanábana*. For this plot 1300 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was gamalote.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2 metres, with more development of the *cebo* and *pilón* trees. In addition, there was replanting of *genízaro* and *guaba* trees.

In this plot the average height decreases due to the effect of the *sotacaballo* trees, which represent approximately 50% of the total number of trees planted and have a lateral growth and fork in the shaft at a low height.

PLOT FREDDY ULATE CASTRO

One month from planting

One year from planting

Current Condition (average height 2 m)

Information per plot of the project:

Name of the plot: Fabio Cedeño González (San Antonio).

Holder: Fabio Cedeño González

Located: Boca del río San Carlos.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 1600 trees.

Planting date: 25 June 2012.

Area of the plot: 1 ha 4404 m²

Description of the plot:
This plot was planted with the species *cebo, roble coral, roble sabana, pilón, almendro, laurel, botarrama, sotacaballo*. For this plot 600 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was *gamalote* and grasses.

At this point two of the plots planted with volunteers are joined.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 3 metres, with more development of the *roble coral, laurel* and *roble sabana*, with trees close to 5 metres high.

PLOT FABIO CEDEÑO GONZALEZ (SAN ANTONIO)


One month from planting


One year from planting


Current Condition (average height 3 m)

Information per plot of the project:

Name of the plot: Fabio Cedeño González (Ochoa).

Holder: Fabio Cedeño González

Located: Boca del río San Carlos, Finca Ochoa.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 5.345 trees.

Planting date: September 2012.

Area of the plot: 7 ha 8.450,59 m².

Description of the plot:
This plot was planted with the species *cebo, roble coral, roble sabana, pilón, almendro, espavel, botarrama, sotacaballo, cedro maría, guapinol, cenízaro, guanacaste.* For this plot 8000 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was *gamalote*.

Six of the plots planted with volunteers are joined here.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.2 metres, with more development of the *cebo* and *genízaro* trees, which are over 3 metres high.

PLOT FABIO CEDEÑO GONZALEZ (OCHOA)


One month from planting


One year from planting


Current Condition (average height 2.2 m)

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

Information per plot of the project:

Name of the plot: Olman Quesada Campos

Holder: Olman Quesada Campos

Located: Tiricias, next to caño Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 650 trees.

Planting date: 25 July 2012.

Area of the plot: 0 ha 4678 m²

Description of the plot:
This plot was planted with the following species *roble coral, cedro maría, pilón, laure*l. For this plot 50 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was grasses and *gamalote*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 3.5 metres, with more development of the *laurel* and *roble coral* trees, which are over 4 metres high.

PLOT OLMAN QUESADA CAMPOS

One month from planting

One year from planting

Current Condition (average height 3.5 m)

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

Information per plot of the project:

Name of the plot: Daniel Jiménez Berrocal (El Guabo)

Holder: Daniel Jiménez Berrocal

Located: 2 km east of plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 1907 trees.

Planting date: 22 August 2012

Area of the plot: 2 ha 0443.77 m²

Description of the plot:

This plot was planted with the species *almendro, cedro maría, cebo, pilón, sotacaballo, corteza amarillo, botarrama, guanacaste, roble coral, genízaro*. For this plot it was not necessary to build a wire fence, only maintenance was given to the existing one. The initial cover of the plot was grasses and *gamalote*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 3 metres, with more development of the *almendro* and *cebo* trees.

PLOT DANIEL JIMENEZ BERROCAL (EL GUABO)

One month from planting

One year from planting

Current Condition (average height 3 m)

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

Information per plot of the project:

Name of the plot: Daniel Jiménez Berrocal (Slopes)

Holder: Daniel Jiménez Berrocal

Located: 800 m west of plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 1000 trees.

Planting date: 14 August 2012

Area of the plot: 1 ha 3730 m²

Description of the plot:

The trees planted in this lot are all *sotacaballo* species, given that this area is for the protection of a slope. For this plot it was not necessary to build a wire fence; maintenance was given to the existing one. The initial cover of the plot was grasses, which was maintained most of the time only with mowing so that the slope protected by these trees was maintained with vegetation cover.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 1.8 metres, given that since they are *sotacaballo* trees the growth is mainly lateral due to the typical forking of the tree.

PLOT DANIEL JIMENEZ BERROCAL (SLOPES)


One month from planting


One year from planting


Current Condition (average height 1.8 m)

Information per plot of the project:

Name of the plot: Daniel Jiménez Berrocal (Alonso)

Holder: Daniel Jiménez Berrocal

Located: Next to the plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 200 trees.

Planting date: 16 August 2012

Area of the plot: 0 ha 1584 m²

Description of the plot:
This plot was planted with the species *malinche, pilón, cebo, almendro, sotacaballo, botarrama, guapinol, roble coral*. For this plot 120 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was grasses.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.3 metres, with more development of the *malinche, pilón* and *cebo* trees.

PLOT DANIEL JIMENEZ BERROCAL (ALONSO)

One month from planting

One year from planting

Current Condition (average height 2.3 m)

Information per plot of the project:

Name of the plot: Daniel Jiménez Berrocal (Pilo)

Holder: Daniel Jiménez Berrocal

Located: 1.7 km northwest of plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 950 trees.

Planting date: 04 September 2012.

Area of the plot: 0 ha 8644 m²

Description of the plot:
This plot was planted with the following species *cebo, espavel, sotacaballo, corteza amarillo, cedro maría, roble coral, pilón, botarrama*. For this plot 50 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was grasses and *gamalote* in the areas close to San Juan River.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.8 metres, with more development of the *corteza amarilla, pilón* and *espavel* trees.

Report of the Project

Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road
Direct Contract by Emergency Exception SINAC-CDE-004-2012

PLOT DANIEL JIMENEZ BERROCAL (PILO)

One month from planting

One year from planting

Current Condition (average height 2.8 m)

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

Information per plot of the project:

Name of the plot: Daniel Jiménez Berrocal (Bismark)

Holder: Daniel Jiménez Berrocal

Located: 2 km northwest of plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 1280 trees.

Planting date: 04 September 2012.

Area of the plot: 1 ha 7004 m²

Description of the plot:
This plot was planted with the species *botarrama, cebo, sotacaballo, almendro, malinche, cedro maría, guapinol*. This plot did not require fencing, we only gave maintenance to the existing one. The initial cover of the plot was grasses and *matones*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.1 metres, with more development of the *malinche* and *cebo* trees.

PLOT DANIEL JIMENEZ BERROCAL (BISMARK)

One month from planting

One year from planting

Current Condition (average height 2.1 m)

Information per plot of the project:

Name of the plot: Marcelo Méndez Morales

Holder: Marcelo Méndez Morales

Located: 5.8 km northwest of plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 1870 trees.

Planting date: 27 August 2012

Area of the plot: 2 ha 1216 m²

Description of the plot:
This plot was planted with the species *almendro, pilón, cedro maría, botarrama, cebo, genízaro, guanacaste, corteza amarillo, sotacaballo, roble coral, espavel*. For this plot 715 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was grasses and *matones*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.4 metres, with more development of the *cebo, botarrama* and *almendro* trees.

PLOT MARCELO MENDEZ MORALES

One month from planting

One year from planting

Current Condition (average height 2.4 m)

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

Information per plot of the project:

Name of the plot: William Cortéz Madrigal

Holder: William Cortéz Madrigal

Located: 4.5 km northwest of plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 1460 trees.

Planting date: 25 August 2012

Area of the plot: 1 ha 6099 m²

Description of the plot:
This plot was planted with the species *roble sabana, espavel, pilón, sotacaballo, cedro maría, cebo, roble coral, corteza amarillo, botarrama*. For this plot 550 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was grasses and *matones*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.1 metres, with more development of the *roble sabana* and *cebo* trees.

PLOT WILLIAM CORTEZ MADRIGAL

One month from planting

One year from planting

Current Condition (average height 2.1 m)

Information per plot of the project:

Name of the plot: German Díaz Ruíz

Holder: German Díaz Ruíz

Located: 5.5 km northwest of plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 4095 trees.

Planting date: 02 October 2012.

Area of the plot: 4 ha 2401.58 m²

Description of the plot:
This plot was planted with the *species espavel, sotacaballo, cedro maría, cebo, corteza amarillo, botarrama*. For this plot 360 metres of fence were built, with three wires, to protect the planted area. The initial cover of the plot was grasses and *matones*.

Three of the plots planted with volunteers are joined here.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 2.1 metres, with more development of the *cebo* trees.

PLOT GERMAN DIAZ RUIZ


One month from planting


One year from planting


Current Condition (average height 2.1 m)

Information per plot of the project:

Name of the plot: Edgar Salazar Ramírez

Holder: Edgar Salazar Ramírez

Located: 1 km northwest of plaza de deportes de Tiricias.

MINAE Office which supervises: A.C.A.H.N., Gerencia de Manejo Forestal.

Number of trees planted: 86 trees.

Planting date: 04 December 2012

Area of the plot: 0 ha 0774 m²

Description of the plot:
This plot was planted with the following species *Roble coral, cedro maría, pilón, guaba, cebo* and fruit trees. For this plot it was not necessary to build a wire fence. The initial cover of the plot was grasses and *matones*.

The planted trees have developed well since the beginning, and all maintenance proposed in the Work Plan has been applied.

Below is a photo sequence of the development of the plantation from newly planted, to one year and the current state of the trees, which have an average height of 1.8 metres, with more development of the *maría* trees.

PLOT EDGAR SALAZAR RAMIREZ

One month from planting

One year from planting

Current Condition (average height 1.8 m)

Tel: (506) 2460-1055 Fax: (506) 2460-1650 Webpage: www.codeforsa.org

4. SLOPES

a. Recovery of slopes

Regarding the recovery of slopes, as part of the project's commitments, after walkthroughs of the areas of influence of the project we found that the Tiricias area has the most pronounced terrain cuts. Therefore, most of the recovery of slopes was performed in that area.

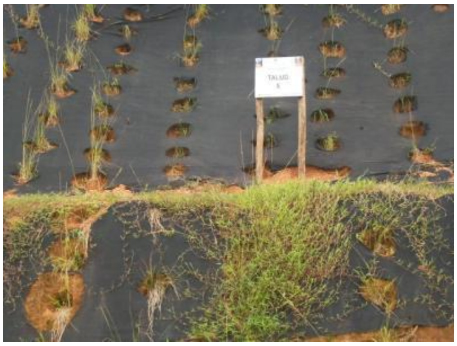
We identified a total of 9 slopes in the area of Tiricias, which were sown with *vetiver* grass, digging rows on the slope (as can be seen in the photo). The vegetation material was reproduced in the nursery of CODEFORSA and taken to the field in a plastic bag, similar to the production of timber trees. This is to promote a good amount of "adobe" composed of fertile soil in the area of roots of the vegetation material, since the slopes are areas with little fertile soil, rather, they correspond to the deeper layers of soil with very little ability to provide nutrients to planted material.

Design of the sowing of grass at each slope.

Once the different slopes were intervened, they were labelled for identification and subsequent management and maintenance.

At some of the intervened slopes in the area of Tiricias, they were covered by saran, which had been placed during the process of construction of the border road. However, in many cases the saran was stolen from the site, so we decided to break it with the planting of the vegetation material to take advantage of its effect of reducing the impact of rain on the exposed soil of the slope and thus promote the decrease in sediment erosion and pollution of waters and finally so it would not to be removed from the site.

View of planting of vegetation on Slope No 5



Signs placed on the slopes.

To complete the number of slopes to be intervened, work was performed on three slopes in the area of the mouth of San Carlos River, with the numbers 10, 11 and 12. In total there were nine slopes in the Tiricias area and three in the area of the mouth of San Carlos River.

View of Slope No. 10

Signs placed at the slopes.

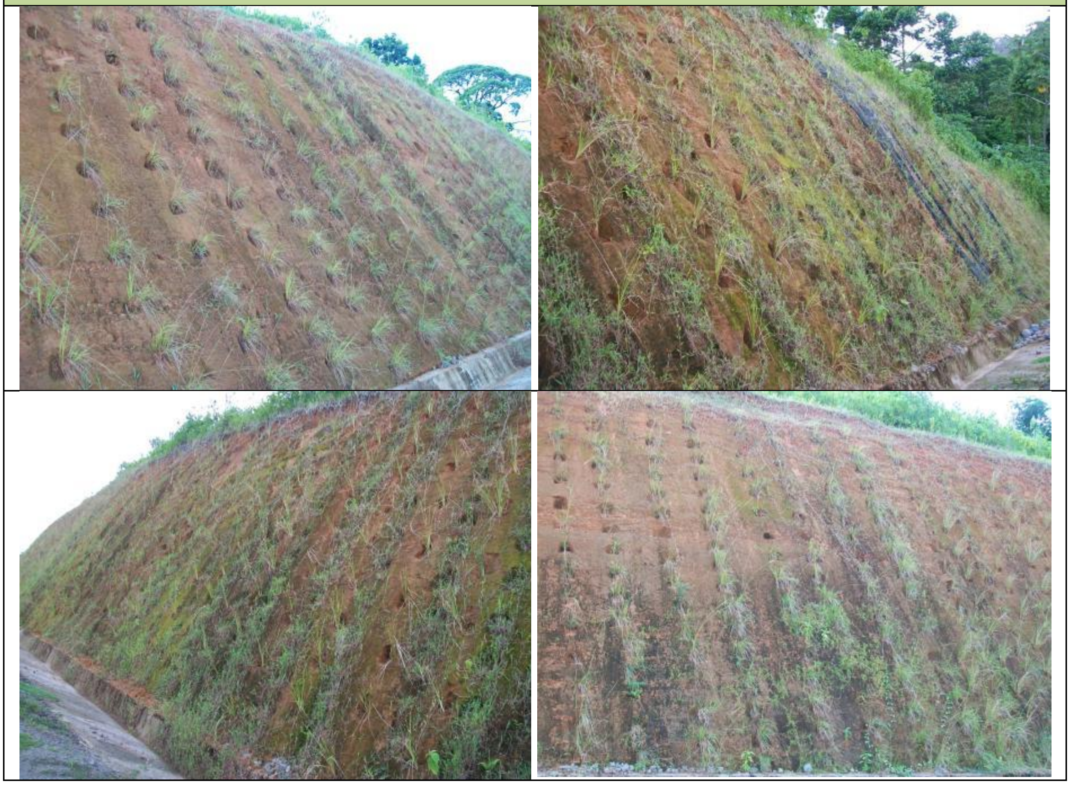
Below are photographs of the state of the slopes in February 2014. The photographs presented correspond to the visit made in February 2014.

The cover has suffered the impact of the dry season and shows a yellowing in the stumps; however, once the first rains fall this situation will normalize.

SLOPE 1

SLOPE 2	
	
	

SLOPE 3



SLOPE 4	
	
	

SLOPE 5




SLOPE 6	
	
	

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SLOPE 7	
	
	

SLOPE 8	
	
	

SLOPE 9	
	
	

SLOPE 10	
	
	

SLOPE 11




SLOPE 12

b. Maintenance of plant cover on slopes:

The maintenance work on the slope cover consisted of applying foliar fertiliser to the planted material to favour the establishment of the cover, improve the amount of nutrients available and ensure the cover of the slope with vegetation.

Foliar fertiliser applications at each of the slopes and the indicated repetitions were performed as described in table 16. In total, four applications of foliar fertiliser were applied to the twelve treated slopes.

In addition to the vegetation material established on the site, in most of the slopes the vegetation seeds from the site re-sprouted, helping to repopulate the cover, which enhances both recovery in the affected area and the improvement in the landscape surrounding the border road.

Foliar fertilisation lower part of the slope.

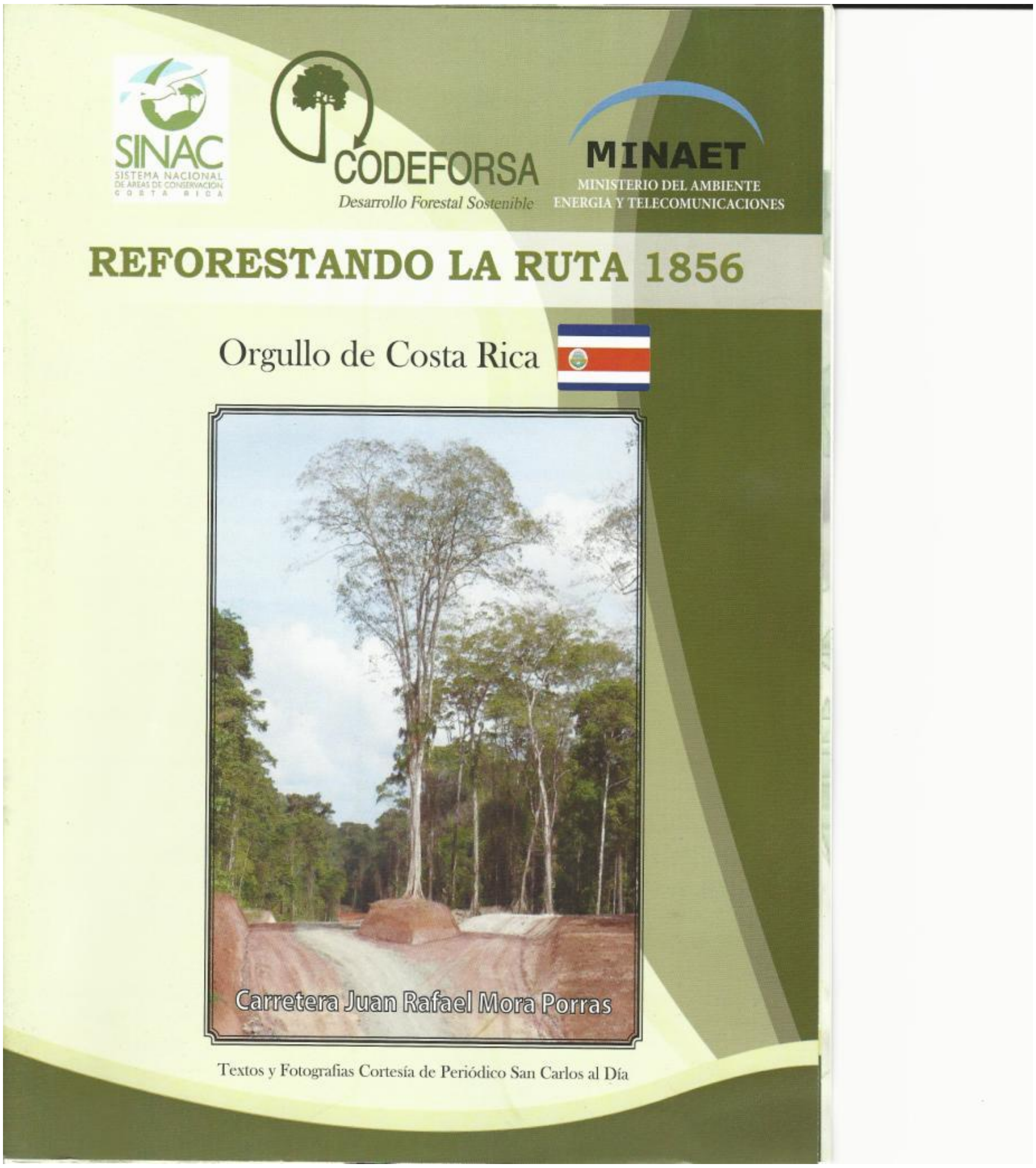
Foliar fertilisation higher part of the slope.

Foliar fertiliser applications were carried out using a back pump with an adaptation or extension of the hose and the rod to ensure that the fertiliser reached all of the material established on each slope.

IV. APPENDICES

APPENDIX 1: MATERIAL PREPARED FOR DELIVERY TO THE PARTICIPANTS OF THE ACTIVITIES AND MEMBERS OF PUBLIC INSTITUTIONS INVOLVED.

8-PAGE MAGAZINE GIVEN TO EACH VOLUNTEER AT THE PLANTING EVENTS.



POSTER WITH INFORMATION AND MAPS OF THE PLANTED SITES DELIVERED TO EACH VOLUNTEER AT THE PLANTING EVENTS

El plan de trabajo consiste en la ejecución de actividades para mitigar los impactos producidos por la construcción de la carretera en dos áreas específicas que son:

SIEMBRA DE ÁRBOLES.

El proyecto contempla la siembra de 25.000 árboles de especies nativas en los sectores a orilla del río San Juan y en áreas aledañas a la ruta 1856.

A Octubre de 2012 se han plantado 26.249 árboles en tres sectores de la Ruta 1.856, a saber: Delta Costa Rica y Trinidad (2.712 árboles); Boca del Río San Carlos, Cureña y Remolinito (10.125 árboles) y Boca Río Infiernillo, Tiricias, Mojón 2 (13.412 árboles). Se han realizado un total de 19 eventos de siembra con la participación de 733 voluntarios de varias zonas del país, los cuales descubrieron las bellezas de esta poco conocida zona de Costa Rica.

Las especies de árboles utilizadas son:

Como amarre del terreno en bordes del ríos y quebradas: *Zygia longifolia* (Sotacaballo).

Para zonas húmedas: *Vochysia guatemalensis* (Cebo), *Calophyllum brasiliense* (Cedro María), *Tabebuia rosea* (Roble sabana), *Hyeronima alchorneoides* (Pilón), *Anacardium excelsum* (Espavel).

Para zonas altas: *Vochysia ferruginea* (Botarrama), *Dipteryx panamensis* (Almendro), *Tabebuia ochracea* (Corteza amarilla), *Terminalia amazonia* (Roble coral), *Cordia alliodora* (Laurel), *Delonix regia* (Malinche), *Samanea saman* (Cenizaro) y *Schizolobium parahyba* (Gallinazo).

RECUPERAR COBERTURA EN TALUDES.

En cuanto a la recuperación de la cobertura vegetal en los taludes de la ruta 1.856, se ha trabajado en la siembra de material vegetal, el cual se ha sometido a un proceso de fertilización constante para asegurar su establecimiento y que rápidamente cubra los sitios tratados para evitar la erosión y arrastre se sedimentos principalmente en lo más fuerte de la época lluviosa en los mese de octubre a diciembre.

De 12 taludes planeados ya se han completado los trabajos en 8 de ellos con la siembra y fertilización foliar de la cobertura establecida.

Todas estas actividades se ha realizado por medio de una estrecha coordinación con las autoridades del las Áreas de Conservación involucradas, las comunidades aledañas a la Ruta 1.856 y la sociedad civil.

SINAC — CODEFORSA Desarrollo Forestal Sostenible — MINAET

REFORESTANDO LA RUTA 1856

La construcción de la Ruta 1.856 parte de una necesidad del Gobierno Costarricense, de proteger la soberanía y resguardar la seguridad de los habitantes de toda la frontera con Nicaragua, que han tenido por siempre como vía de comunicación el Río San Juan.

Dicha construcción inicia a mediados del año 2.011 con un camino de lastre que inicia en la localidad de Delta Costa Rica en el cantón de Sarapiquí y se extiende por 160 kilómetros hasta la comunidad de Las Tablillas en Los Chiles, Frontera Norte.

Esta carretera se desarrolla en una zona de difícil acceso con topografías y suelos variados y zonas sin acceso terrestre en donde también se tuvo que habilitar rutas de acceso a la margen del Río San Juan.

Los pobladores de estas zonas que antes tenían sus casas construidas con frente al Río San Juan, ahora cambiaron las fachadas con frente a la nueva carretera.

Junto con el acceso a sus viviendas por vía terrestre, los pobladores de estas zonas han tenido acceso también a la corriente eléctrica y la facilidad de introducir equipos para facilitar las labores de campo como máquinas de ordeño, enfriadores, maquinaria para preparación del terreno, etc.

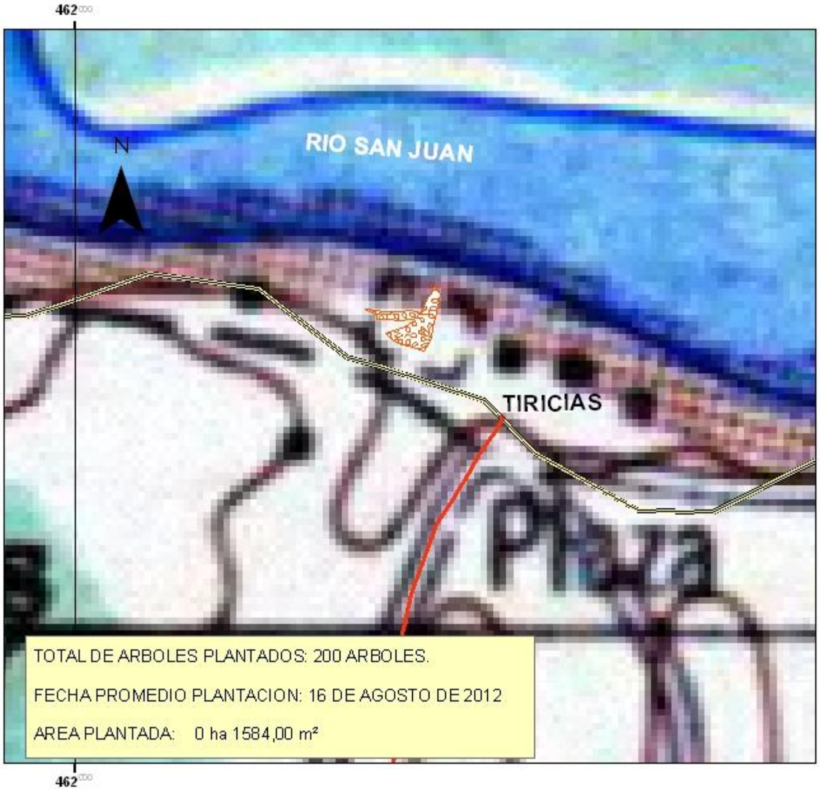
COMPROMISO AMBIENTAL EN LA RUTA 1856

El Sistema Nacional de Áreas de Conservación (SINAC) como encargado de velar por la protección y vigilancia de los recursos aledaños al Río San Juan, por localizarse dentro del Corredor Biológico Froenterizo, sacó a concurso la consultoría denominada *"Consultoría para el desarrollo de un plan de gestión ambiental en el camino Fronterizo Juan Rafael Mora Porras"* la cual fue otorgada a la Comisión de Desarrollo Forestal de San Carlos (CODEFORSA) para que se encargue de ejecutar el Plan de Gestión Ambiental para la Ruta 1856.

APPENDIX 2: MAPS OF THE LOCATION OF THE PLANTED AREAS, FIRST STAGE.

UBICACION DE LAS AREAS PLANTADAS

LOTE: DANIEL JIMENEZ (ALONSO), TIRICIAS.

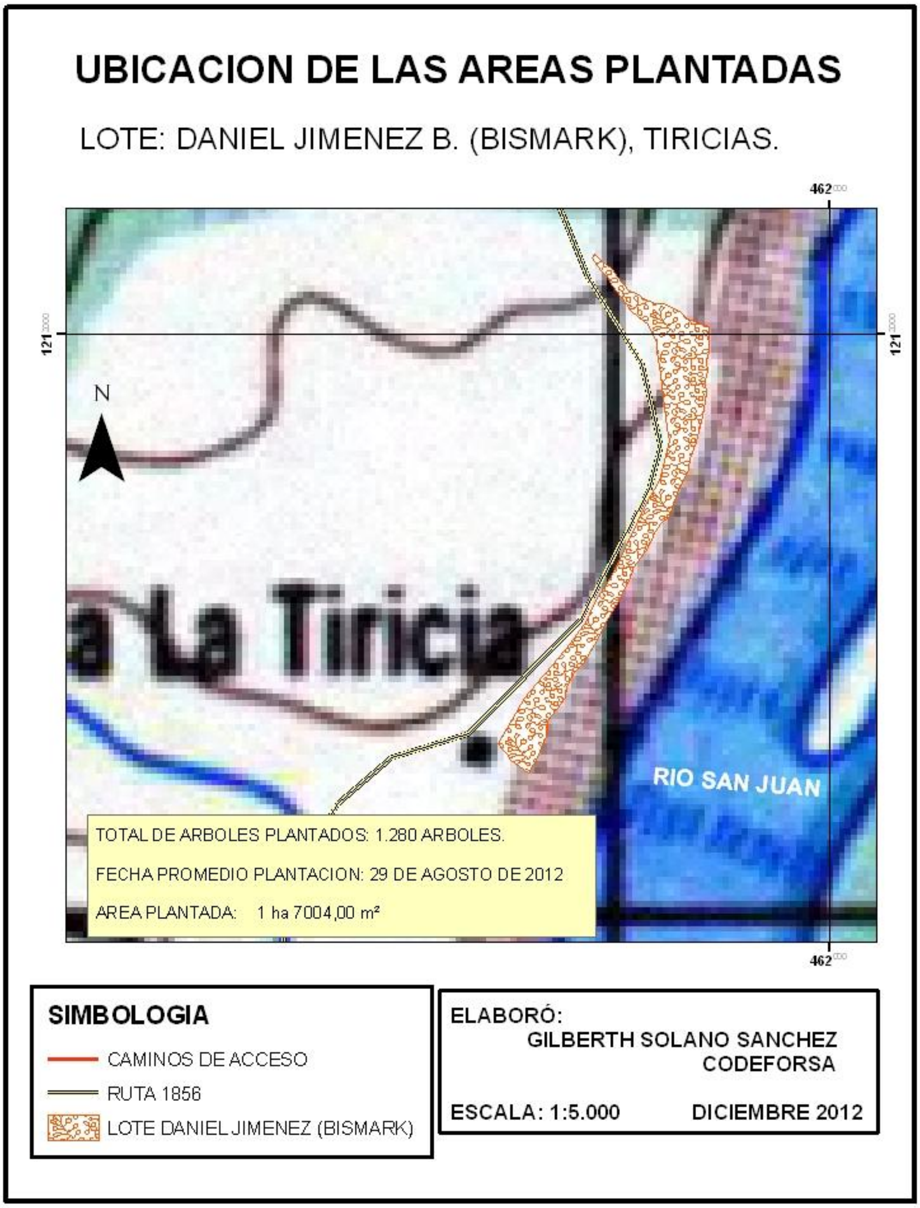


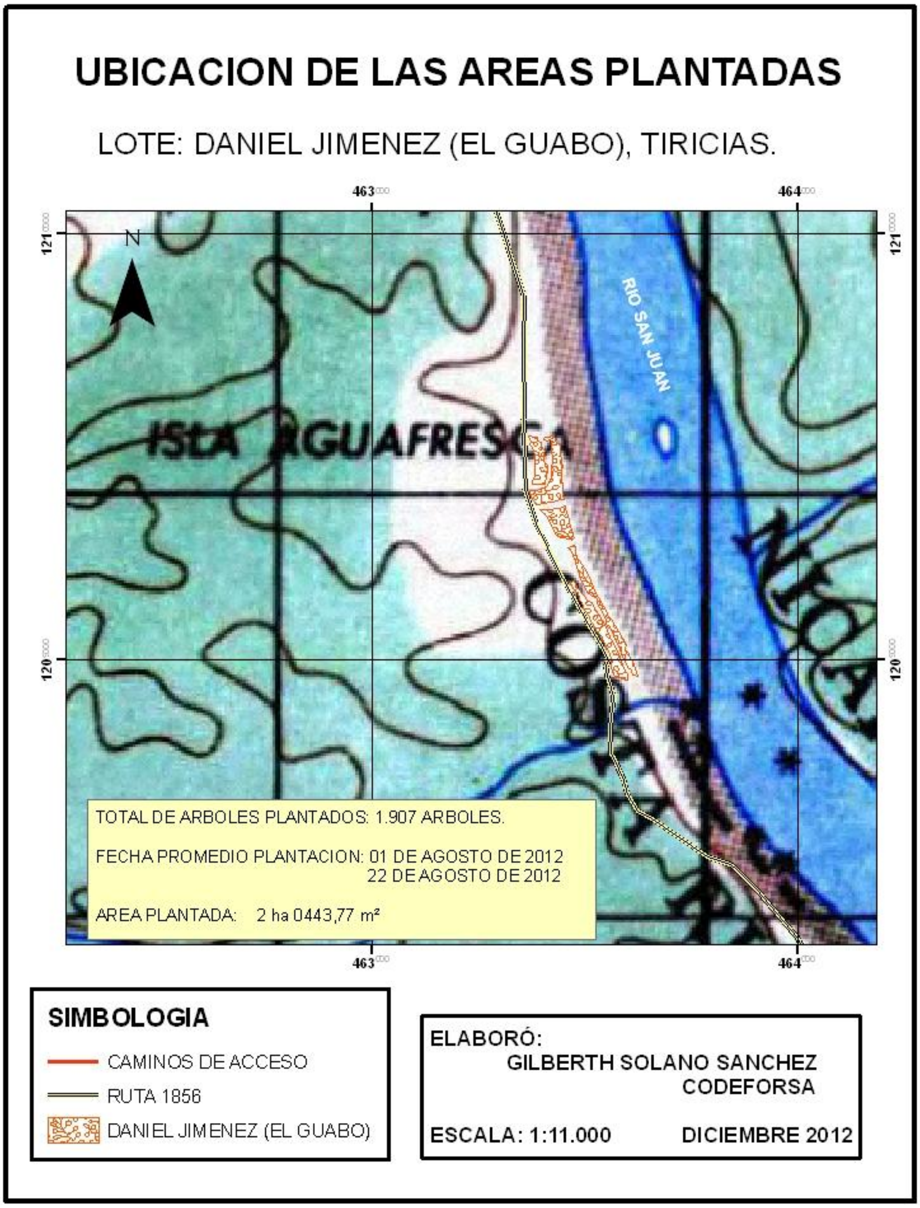
SIMBOLOGIA

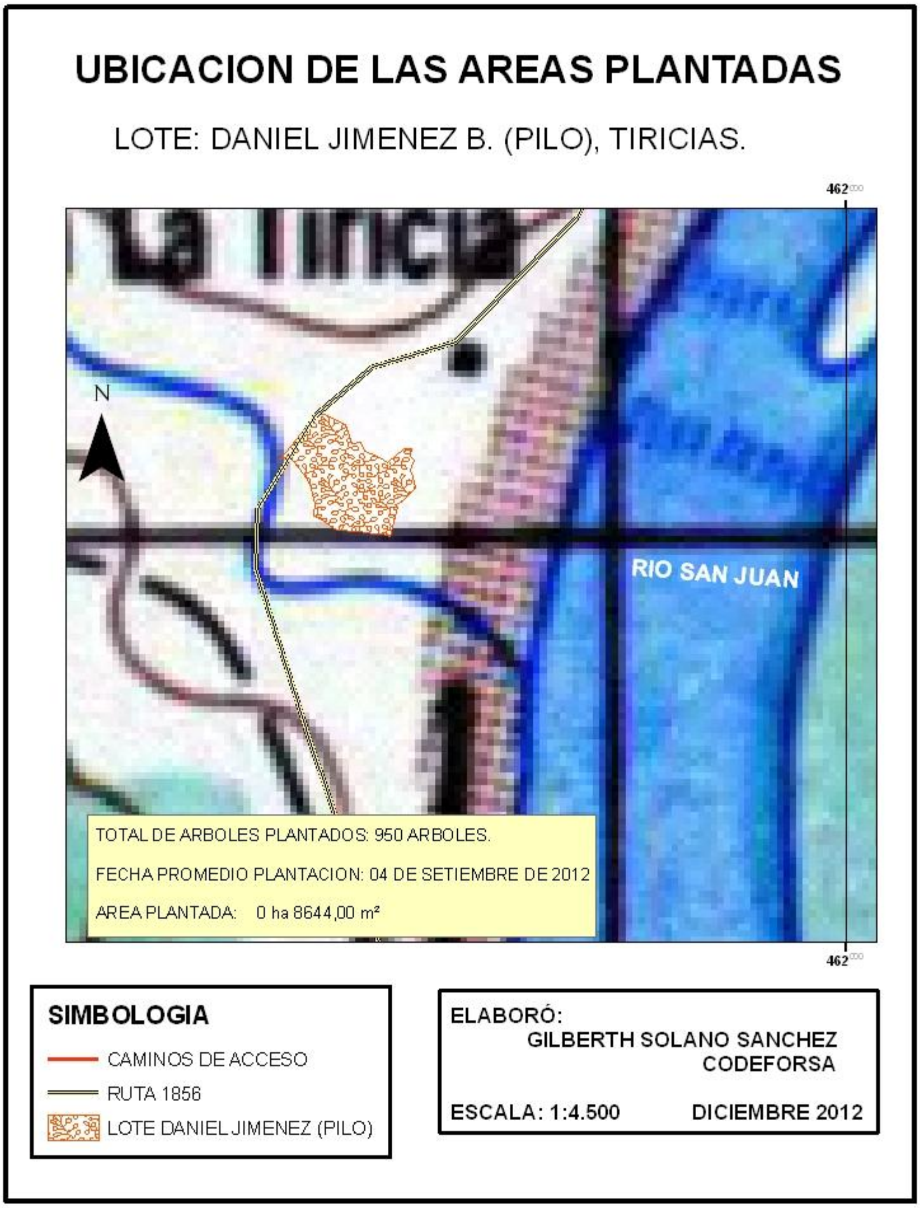
- CAMINOS DE ACCESO
- RUTA 1856
- LOTE DANIEL JIMENEZ (ALONSO)

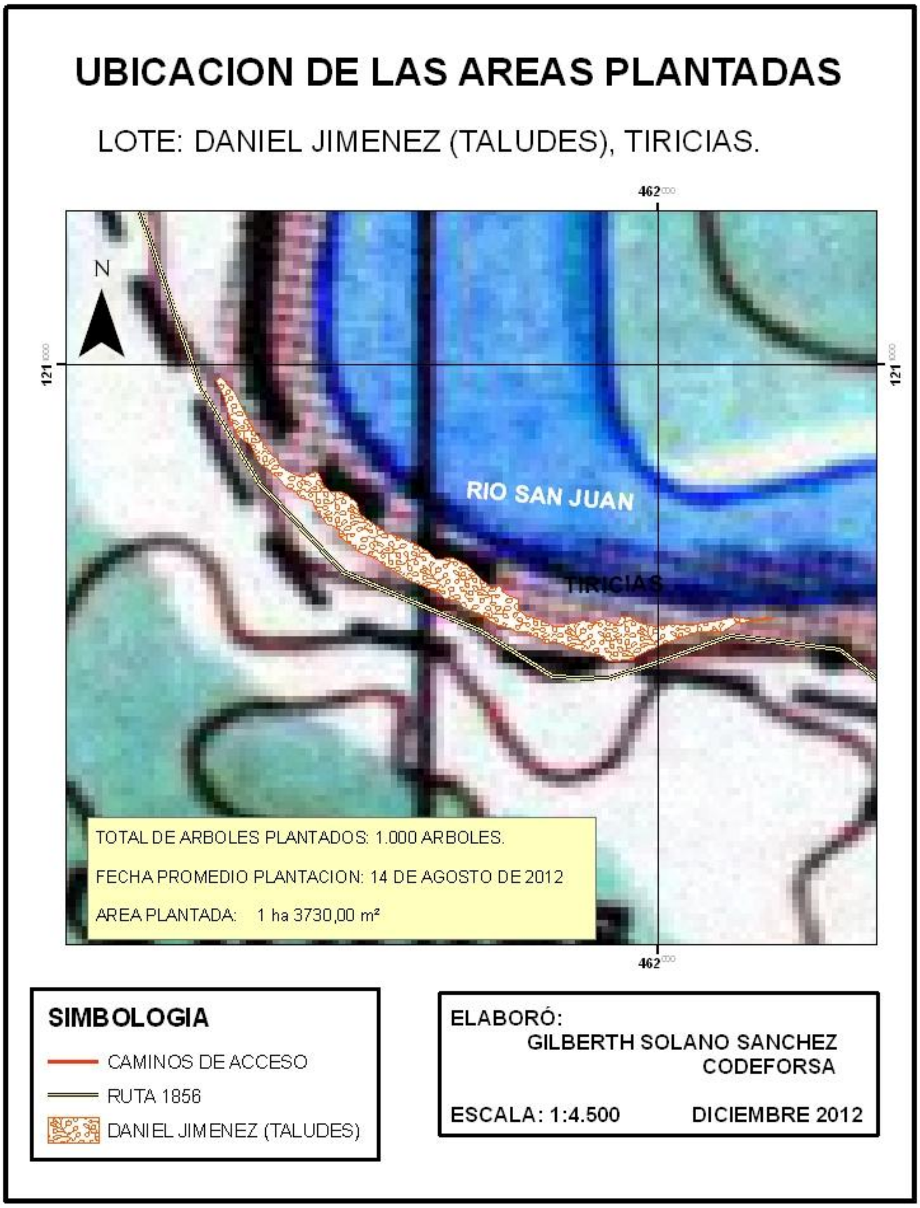
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA

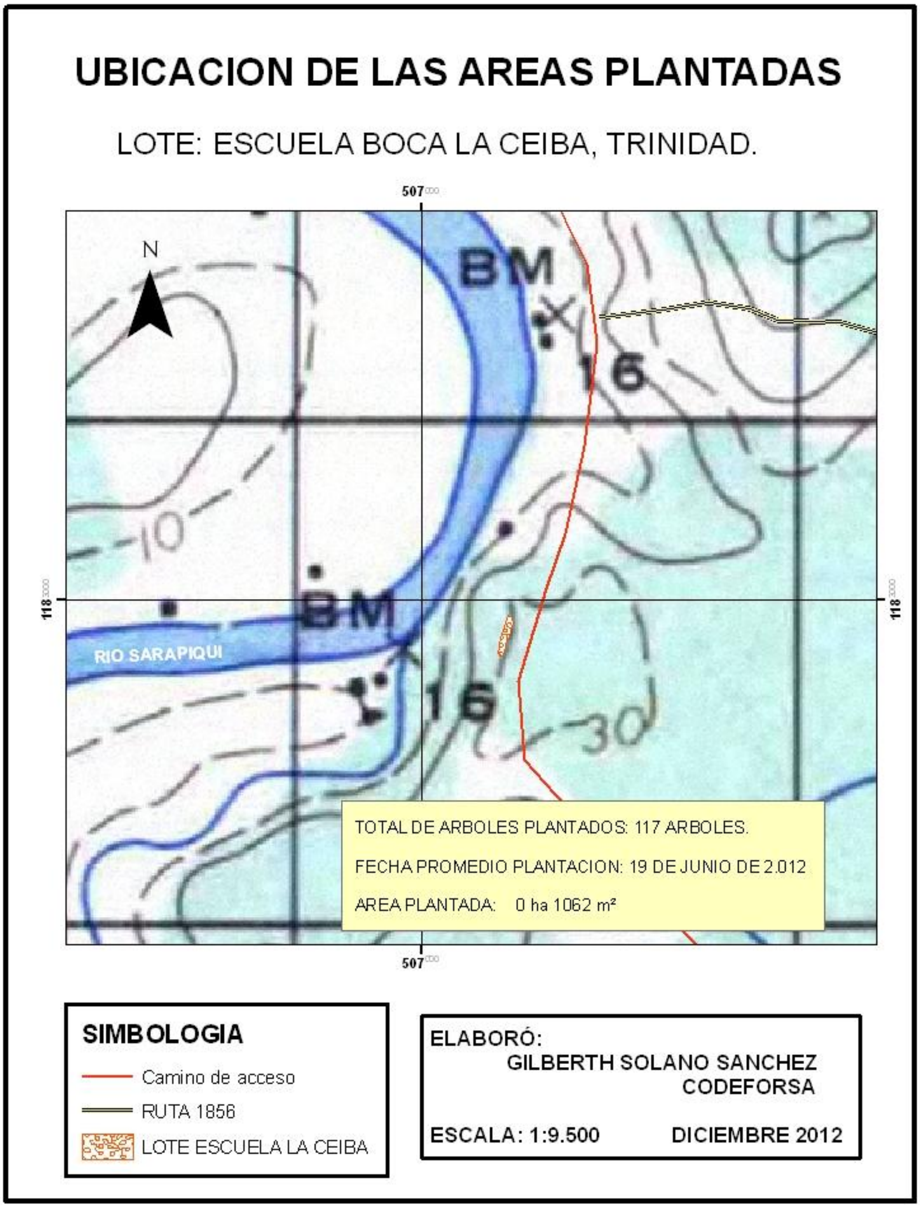
ESCALA: 1:4.500 DICIEMBRE 2012

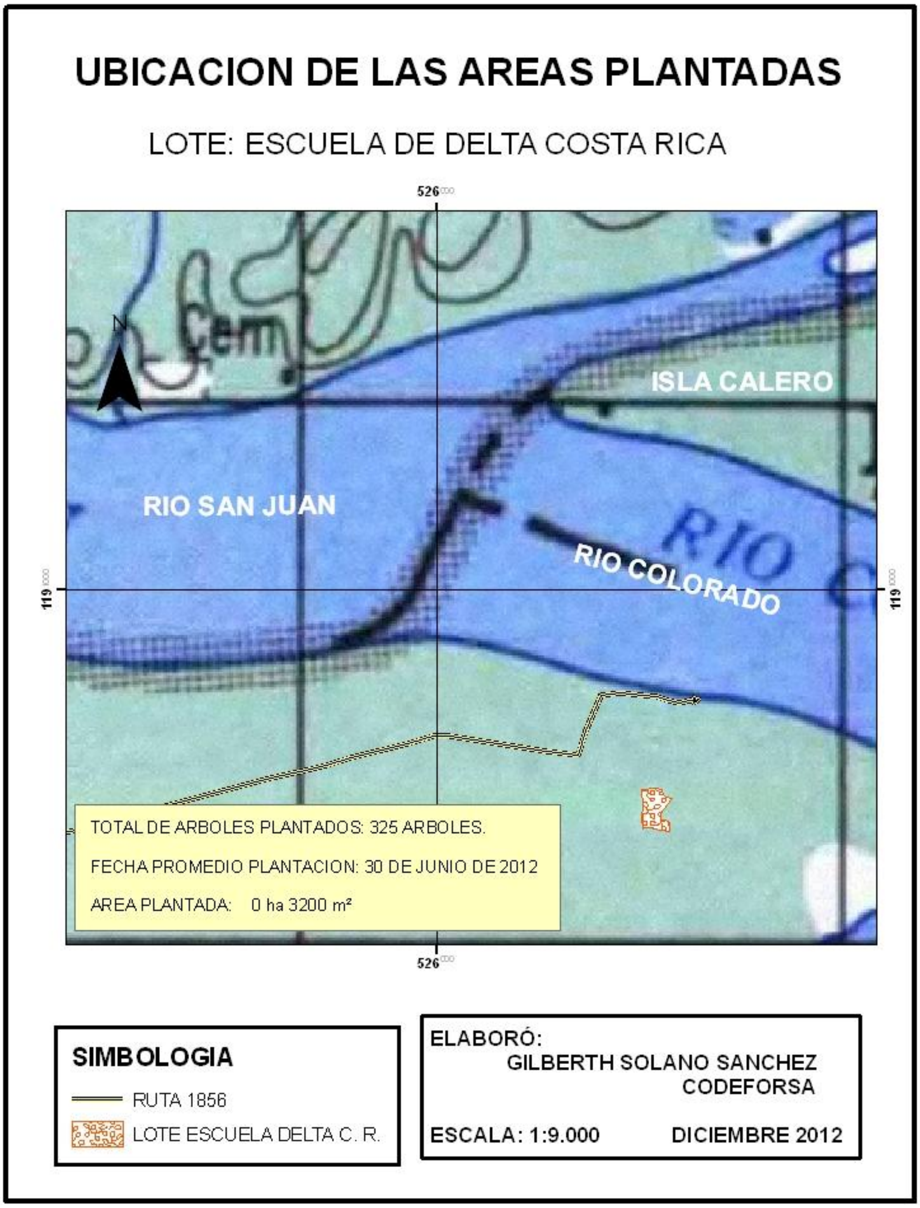

UBICACION DE LAS AREAS PLANTADAS
LOTE: DANIEL JIMENEZ B. (BISMARK), TIRICIAS.
462
121
121
N
La Tiricia
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 1.280 ARBOLES.
FECHA PROMEDIO PLANTACION: 29 DE AGOSTO DE 2012
AREA PLANTADA: 1 ha 7004,00 m²
462
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE DANIEL JIMENEZ (BISMARK)
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:5.000
DICIEMBRE 2012

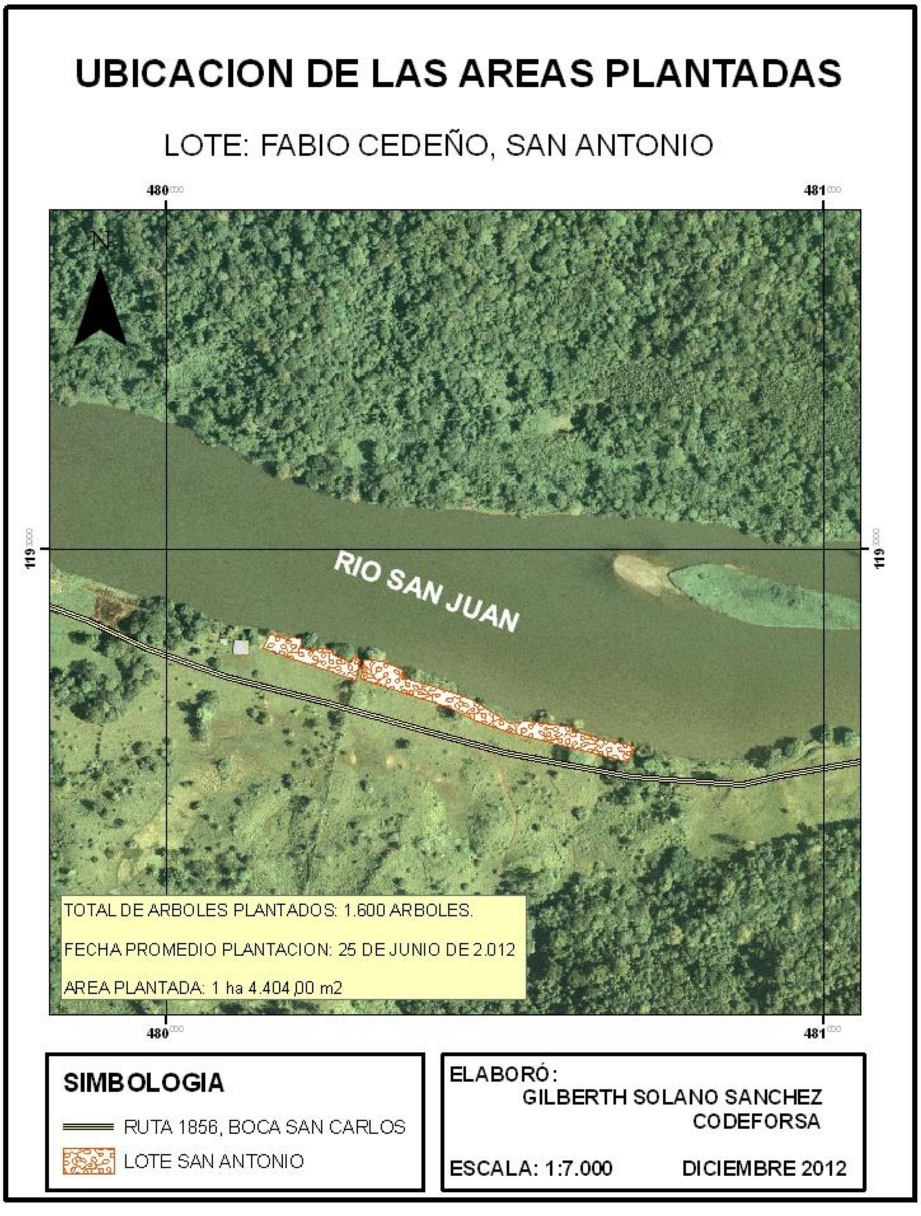

UBICACION DE LAS AREAS PLANTADAS
LOTE: DANIEL JIMENEZ (EL GUABO), TIRICIAS.
463
464
121
120
N
RIO SAN JUAN
ISLA AGUAFRESCA
TOTAL DE ARBOLES PLANTADOS: 1.907 ARBOLES.
FECHA PROMEDIO PLANTACION: 01 DE AGOSTO DE 2012
22 DE AGOSTO DE 2012
AREA PLANTADA: 2 ha 0443,77 m²
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
DANIEL JIMENEZ (EL GUABO)
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:11.000
DICIEMBRE 2012

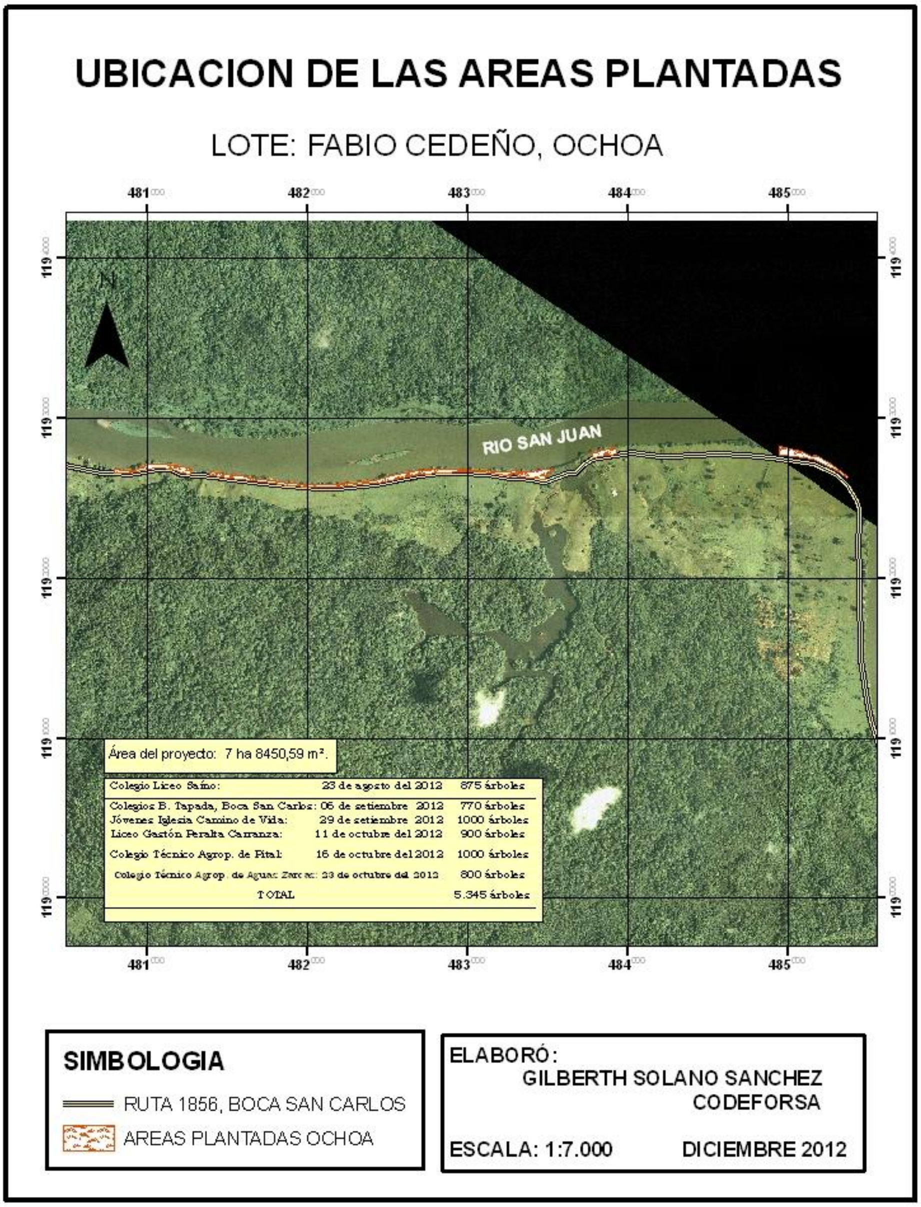

UBICACION DE LAS AREAS PLANTADAS
LOTE: DANIEL JIMENEZ B. (PILO), TIRICIAS.
462
N
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 950 ARBOLES.
FECHA PROMEDIO PLANTACION: 04 DE SETIEMBRE DE 2012
AREA PLANTADA: 0 ha 8644,00 m²
462
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE DANIEL JIMENEZ (PILO)
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:4.500
DICIEMBRE 2012

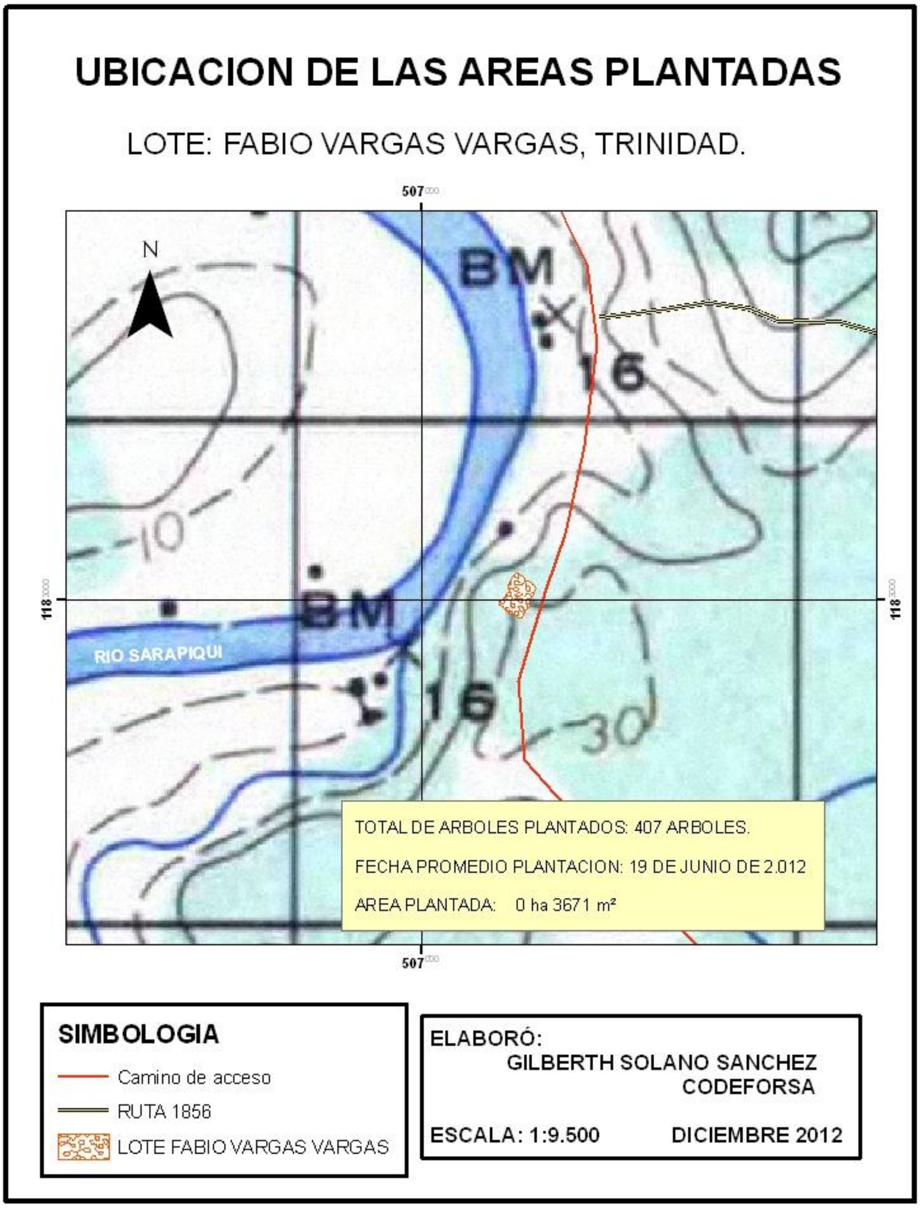

UBICACION DE LAS AREAS PLANTADAS
LOTE: DANIEL JIMENEZ (TALUDES), TIRICIAS.
462
121
N
RIO SAN JUAN
TIRICIAS
TOTAL DE ARBOLES PLANTADOS: 1.000 ARBOLES.
FECHA PROMEDIO PLANTACION: 14 DE AGOSTO DE 2012
AREA PLANTADA: 1 ha 3730,00 m²
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
DANIEL JIMENEZ (TALUDES)
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:4.500
DICIEMBRE 2012

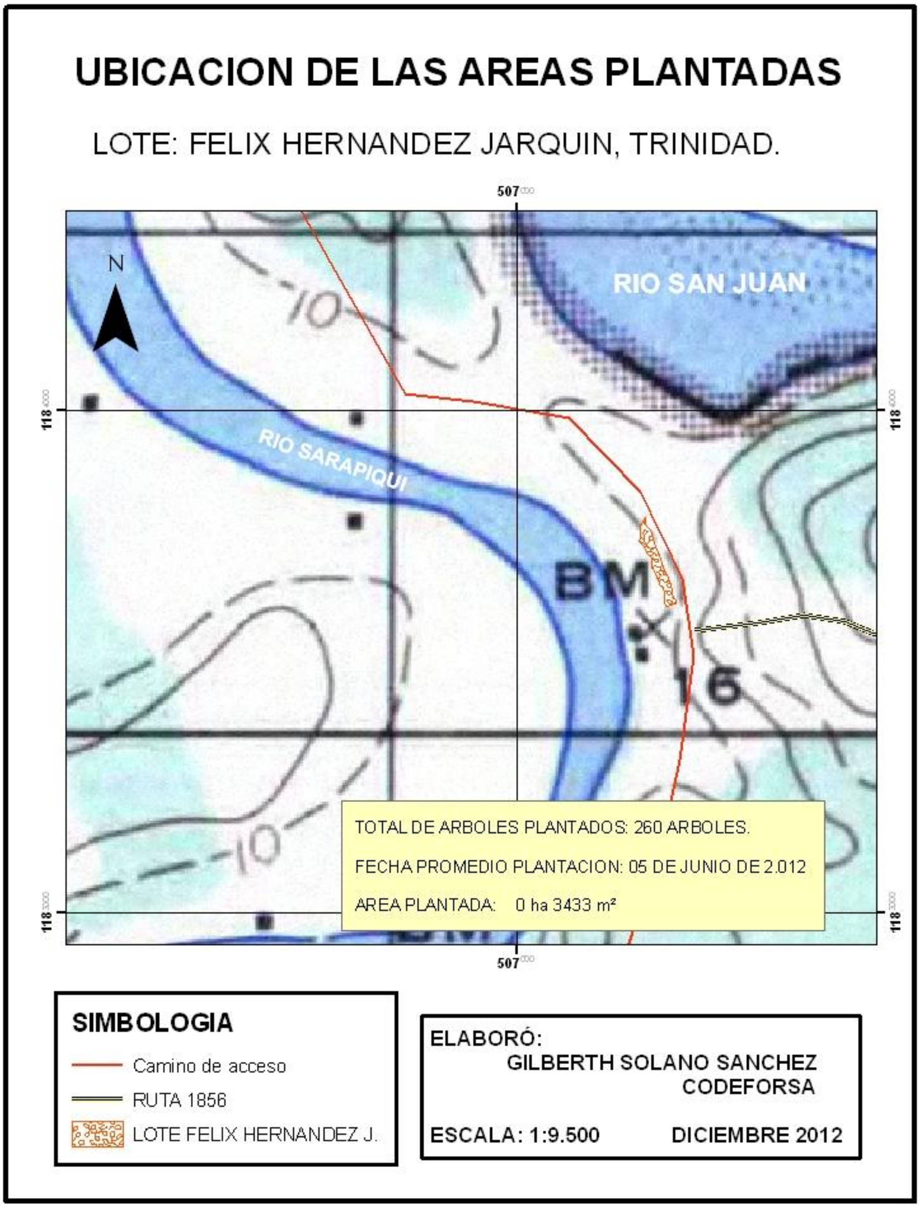

UBICACION DE LAS AREAS PLANTADAS
LOTE: ESCUELA BOCA LA CEIBA, TRINIDAD.
507
N
BM
16
10
118
RIO SARAPIQUI
BM
16
30
TOTAL DE ARBOLES PLANTADOS: 117 ARBOLES.
FECHA PROMEDIO PLANTACION: 19 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 1062 m²
507
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE ESCUELA LA CEIBA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

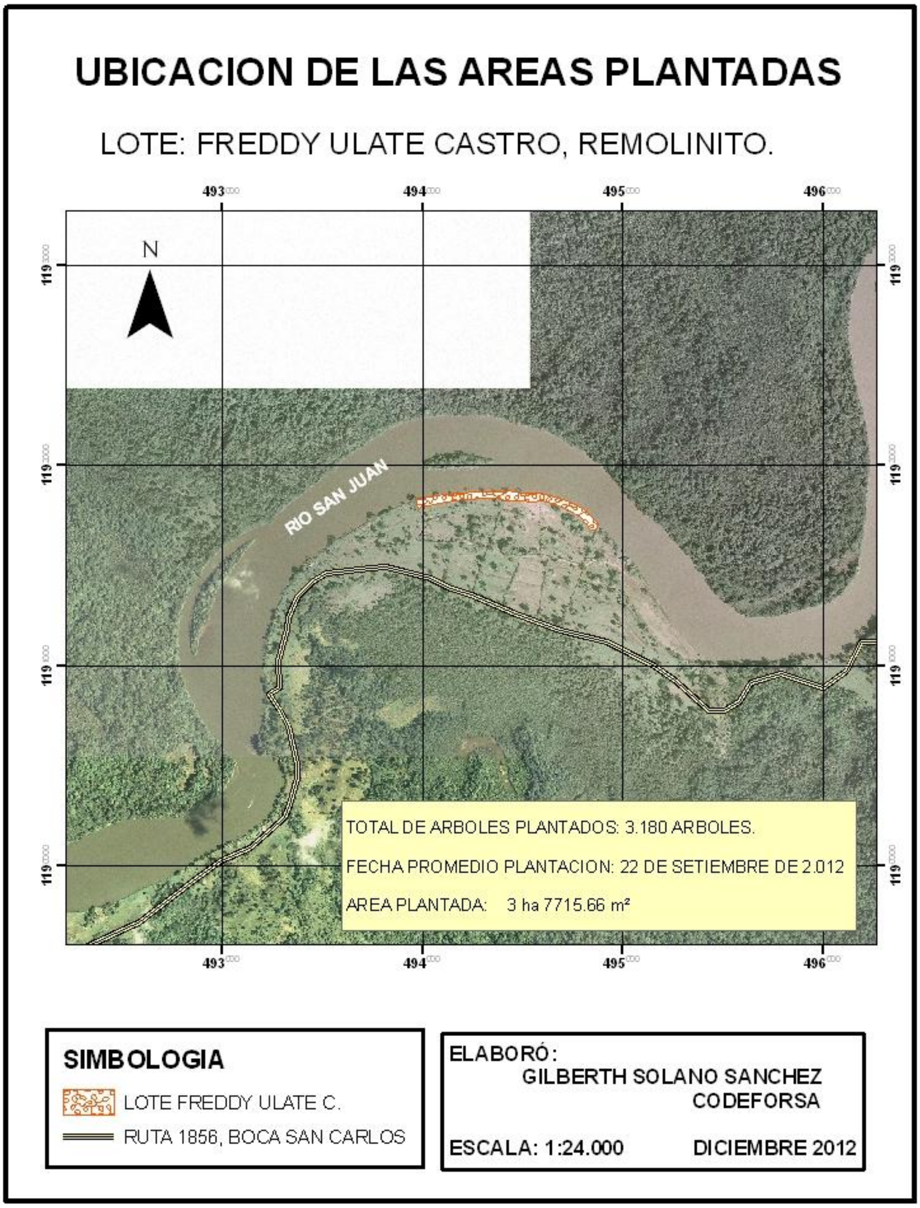

UBICACION DE LAS AREAS PLANTADAS
LOTE: ESCUELA DE DELTA COSTA RICA
526
N
ISLA CALERO
RIO SAN JUAN
RIO
RIO COLORADO
119
119
TOTAL DE ARBOLES PLANTADOS: 325 ARBOLES.
FECHA PROMEDIO PLANTACION: 30 DE JUNIO DE 2012
AREA PLANTADA: 0 ha 3200 m²
526
SIMBOLOGIA
RUTA 1856
LOTE ESCUELA DELTA C. R.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.000
DICIEMBRE 2012

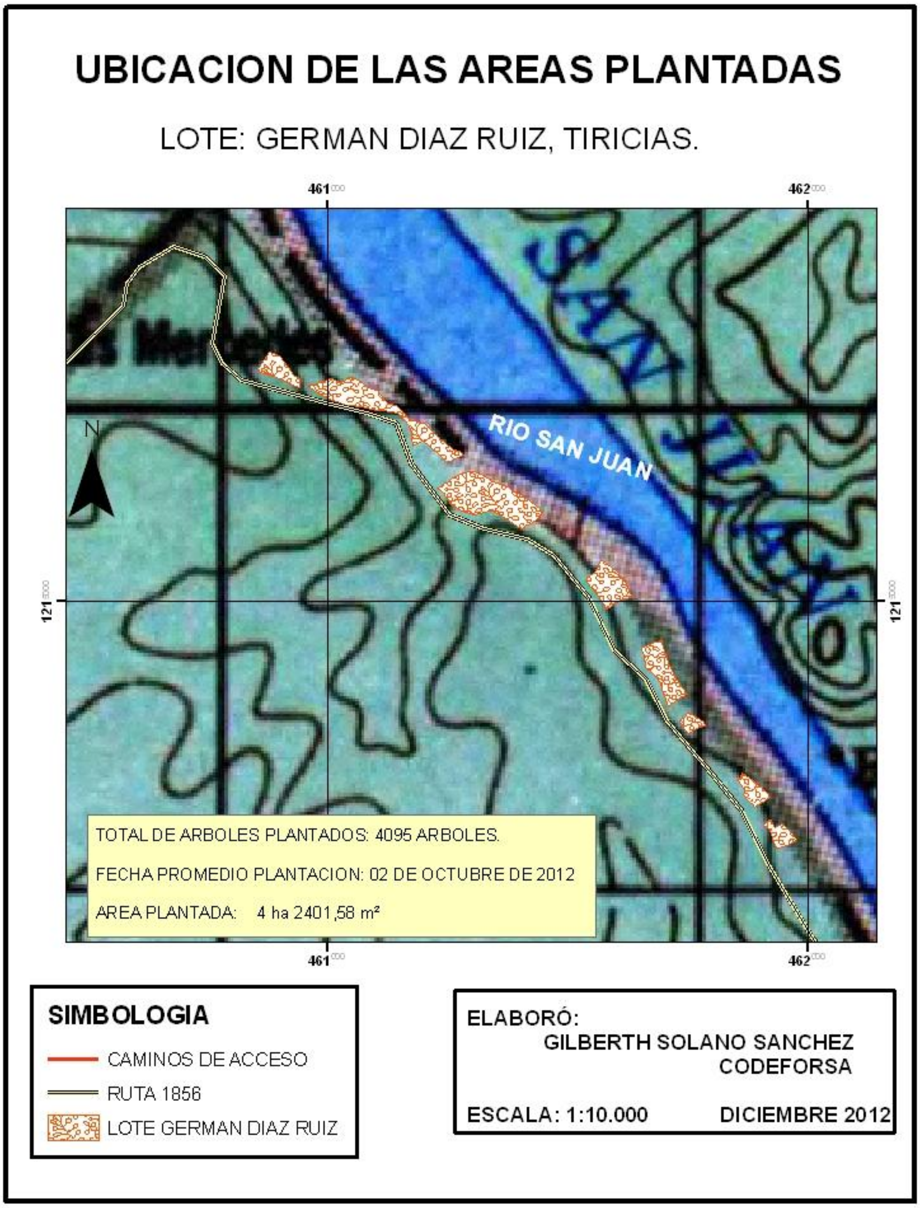

UBICACION DE LAS AREAS PLANTADAS
LOTE: FABIO CEDEÑO, SAN ANTONIO
480
481
119
N
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 1.600 ARBOLES.
FECHA PROMEDIO PLANTACION: 25 DE JUNIO DE 2.012
AREA PLANTADA: 1 ha 4.404,00 m2
SIMBOLOGIA
RUTA 1856, BOCA SAN CARLOS
LOTE SAN ANTONIO
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:7.000
DICIEMBRE 2012

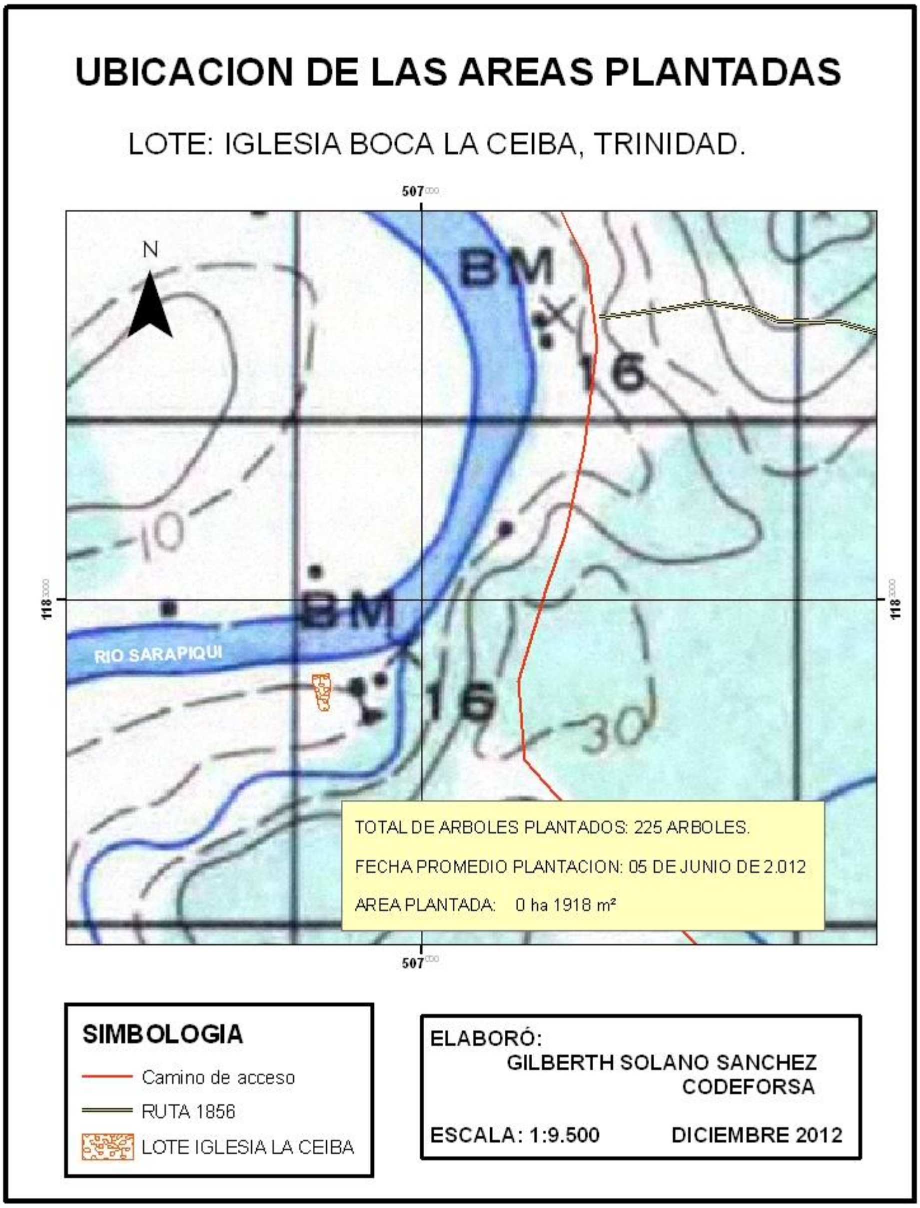

UBICACION DE LAS AREAS PLANTADAS
LOTE: FABIO CEDEÑO, OCHOA
481
482
483
484
485
119
N
RIO SAN JUAN
Área del proyecto: 7 ha 8450,59 m².
Colegio Liceo Saíno: 23 de agosto del 2012 875 árboles
Colegios B. Tapada, Boca San Carlos: 06 de setiembre 2012 770 árboles
Jóvenes Iglesia Camino de Vida: 29 de setiembre 2012 1000 árboles
Liceo Gastón Peralta Carranza: 11 de octubre del 2012 900 árboles
Colegio Técnico Agrop. de Pital: 16 de octubre del 2012 1000 árboles
Colegio Técnico Agrop. de Aguas Zarcas: 23 de octubre del 2012 800 árboles
TOTAL 5.345 árboles
SIMBOLOGIA
RUTA 1856, BOCA SAN CARLOS
AREAS PLANTADAS OCHOA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:7.000
DICIEMBRE 2012

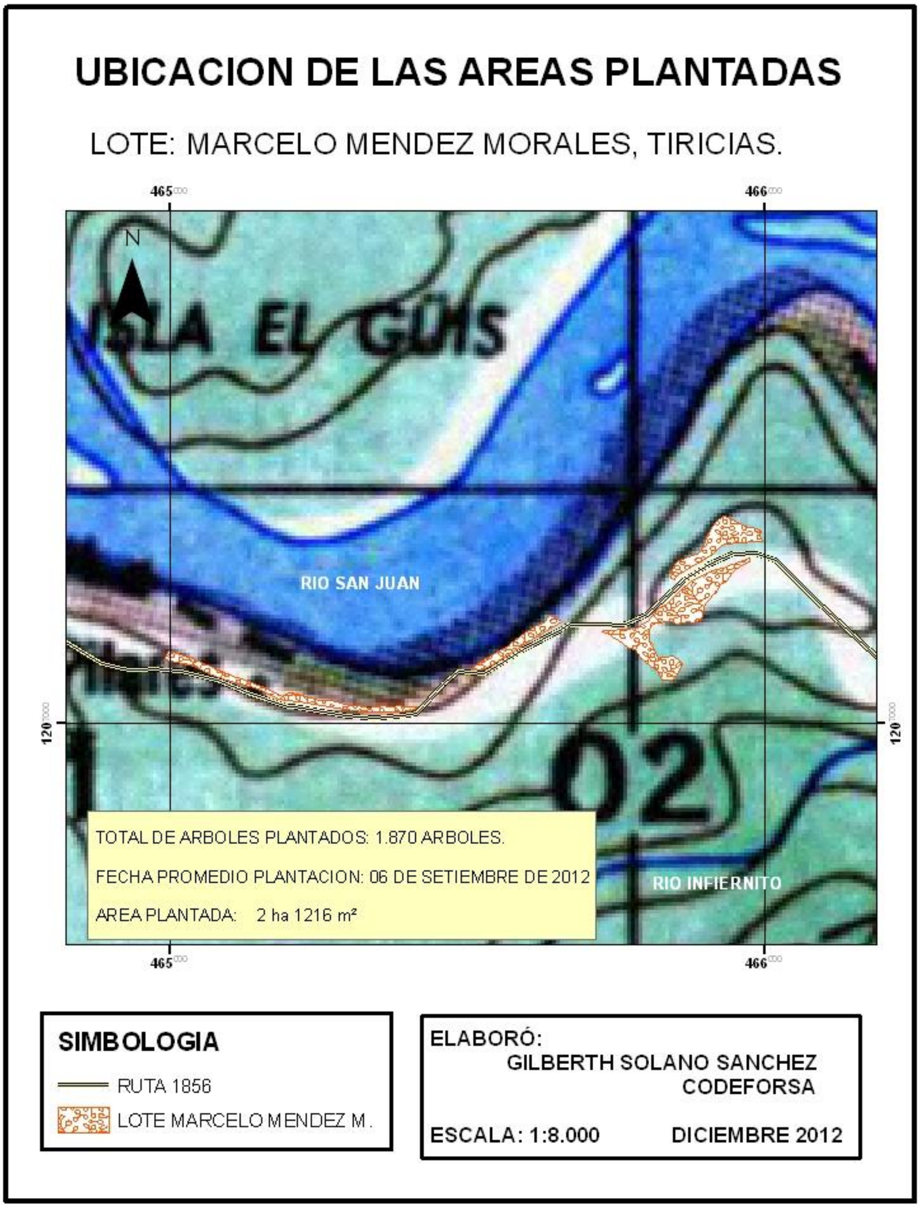

UBICACION DE LAS AREAS PLANTADAS
LOTE: FABIO VARGAS VARGAS, TRINIDAD.
507
N
BM
16
10
BM
RIO SARAPIQUI
16
30
118
118
TOTAL DE ARBOLES PLANTADOS: 407 ARBOLES.
FECHA PROMEDIO PLANTACION: 19 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 3671 m²
507
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE FABIO VARGAS VARGAS
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

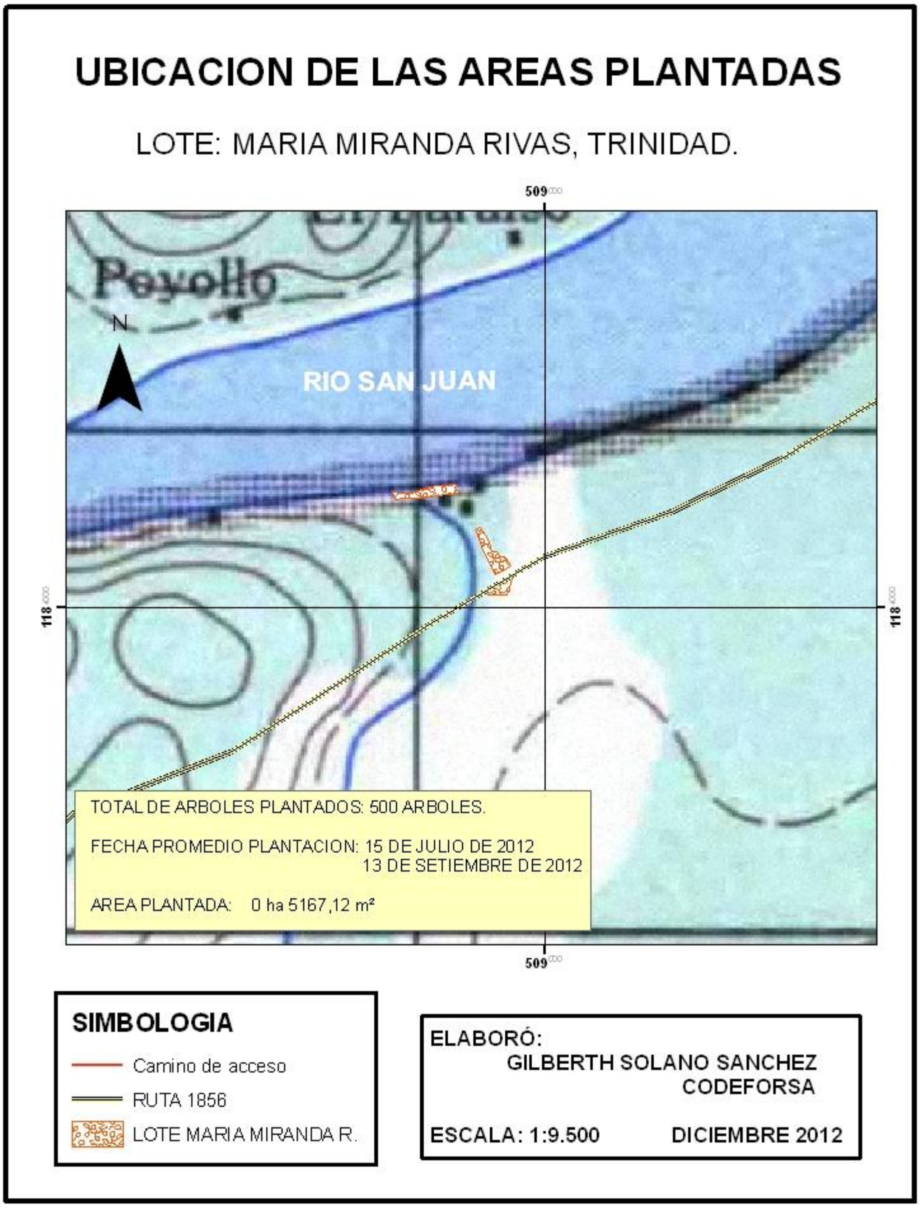

UBICACION DE LAS AREAS PLANTADAS
LOTE: FELIX HERNANDEZ JARQUIN, TRINIDAD.
507
N
RIO SAN JUAN
RIO SARAPIQUI
118
BM
16
10
TOTAL DE ARBOLES PLANTADOS: 260 ARBOLES.
FECHA PROMEDIO PLANTACION: 05 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 3433 m²
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE FELIX HERNANDEZ J.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

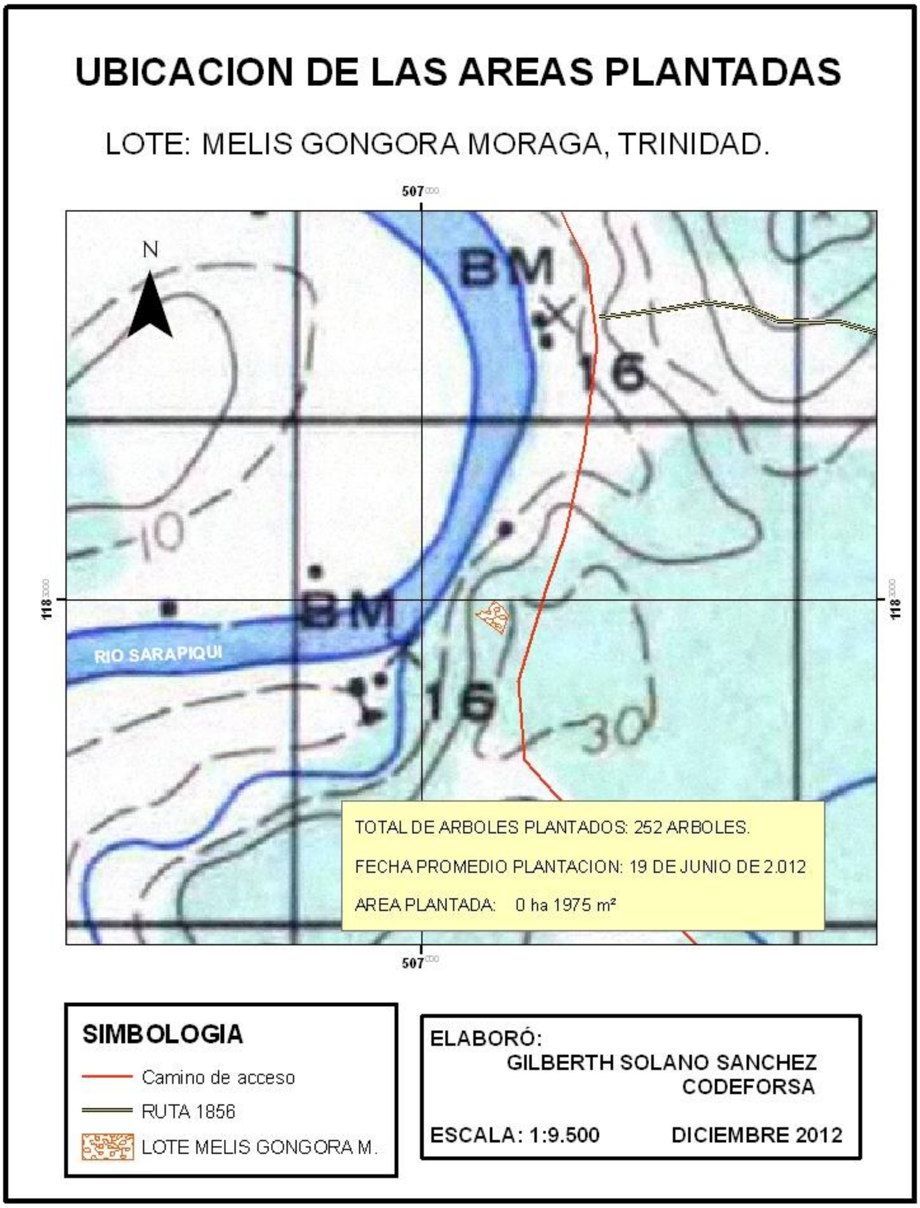

UBICACION DE LAS AREAS PLANTADAS
LOTE: FREDDY ULATE CASTRO, REMOLINITO.
N
RIO SAN JUAN
493
494
495
496
119
TOTAL DE ARBOLES PLANTADOS: 3.180 ARBOLES.
FECHA PROMEDIO PLANTACION: 22 DE SETIEMBRE DE 2.012
AREA PLANTADA: 3 ha 7715.66 m²
SIMBOLOGIA
LOTE FREDDY ULATE C.
RUTA 1856, BOCA SAN CARLOS
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:24.000
DICIEMBRE 2012

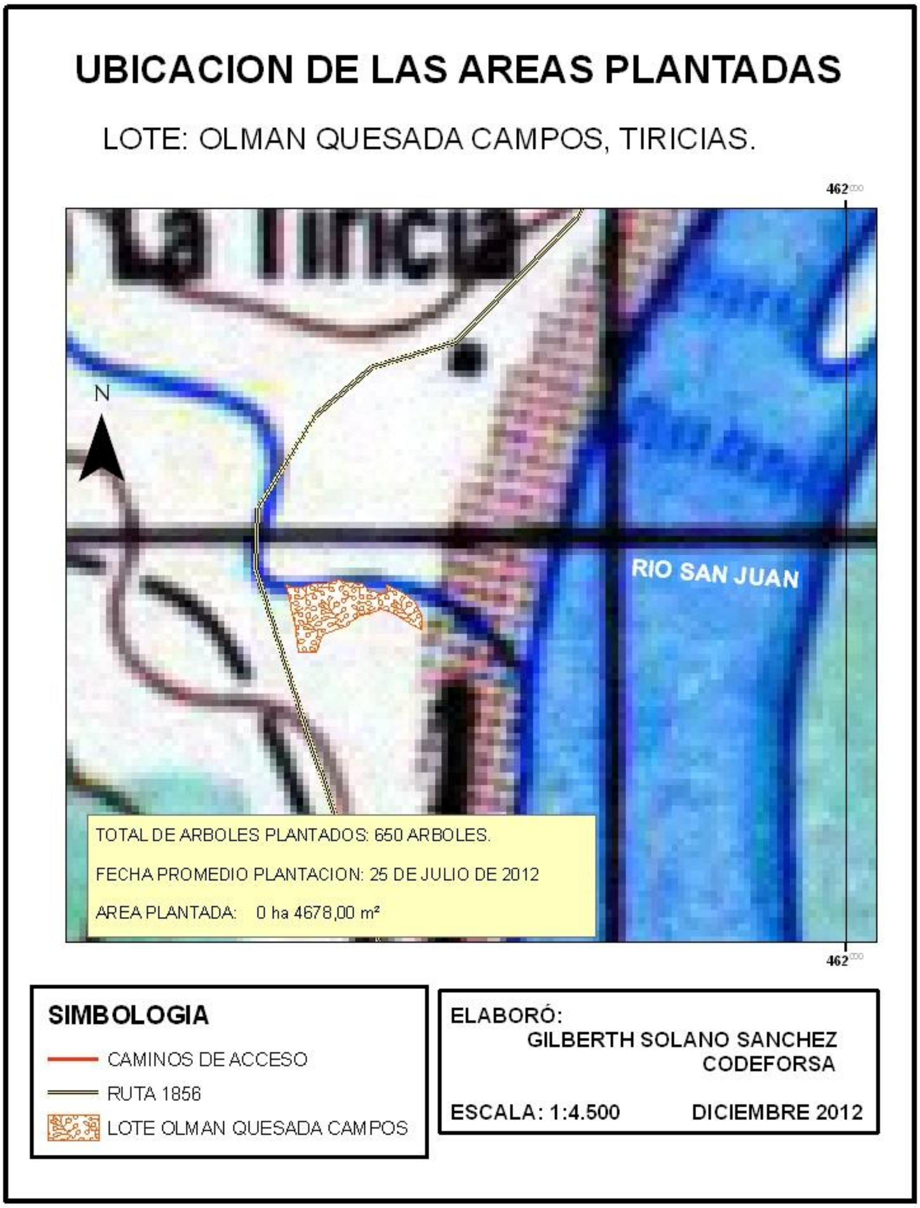

UBICACION DE LAS AREAS PLANTADAS
LOTE: GERMAN DIAZ RUIZ, TIRICIAS.
461
462
121
RIO SAN JUAN
SAN JUAN
N
TOTAL DE ARBOLES PLANTADOS: 4095 ARBOLES.
FECHA PROMEDIO PLANTACION: 02 DE OCTUBRE DE 2012
AREA PLANTADA: 4 ha 2401,58 m²
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE GERMAN DIAZ RUIZ
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:10.000
DICIEMBRE 2012

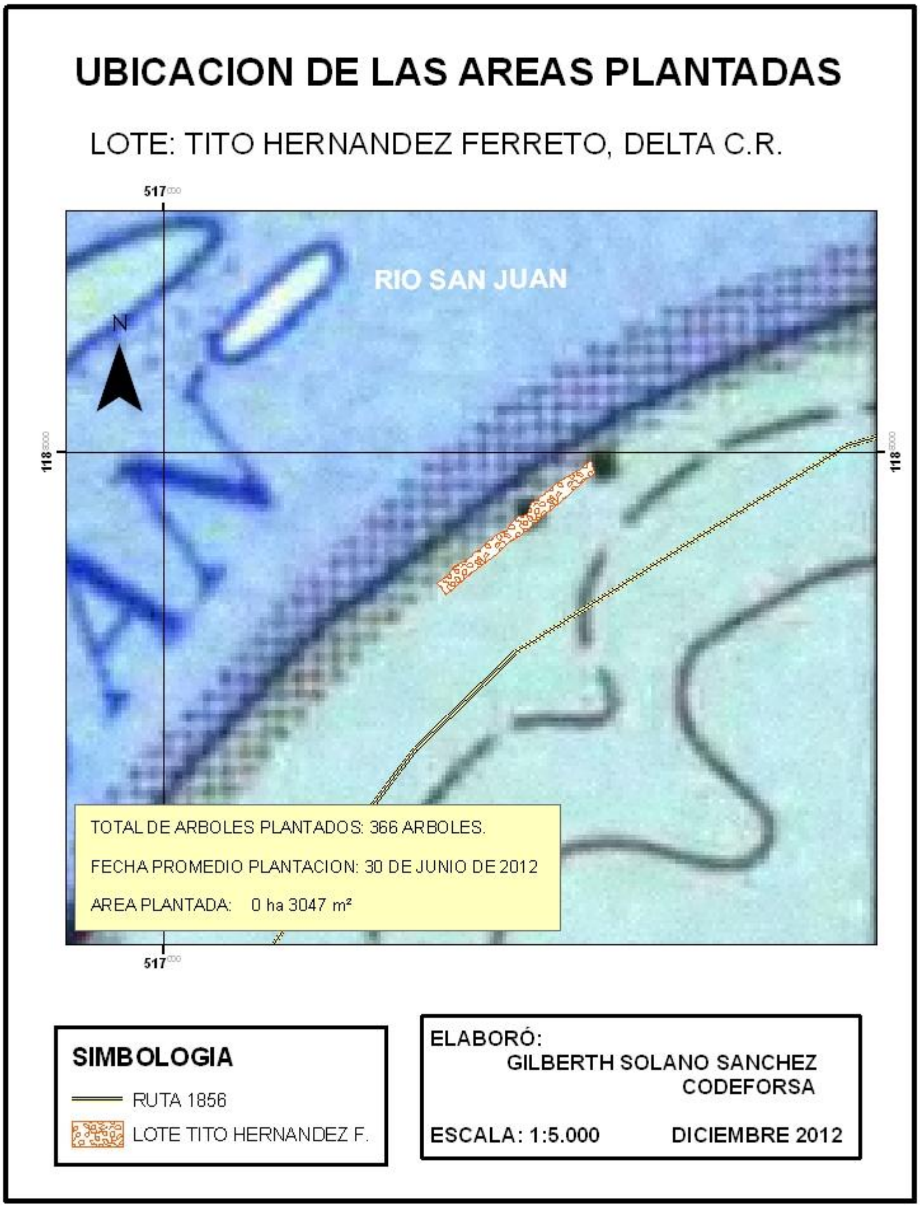

UBICACION DE LAS AREAS PLANTADAS
LOTE: IGLESIA BOCA LA CEIBA, TRINIDAD.
507
N
BM
16
10
BM
118
RIO SARAPIQUI
16
30
TOTAL DE ARBOLES PLANTADOS: 225 ARBOLES.
FECHA PROMEDIO PLANTACION: 05 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 1918 m²
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE IGLESIA LA CEIBA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

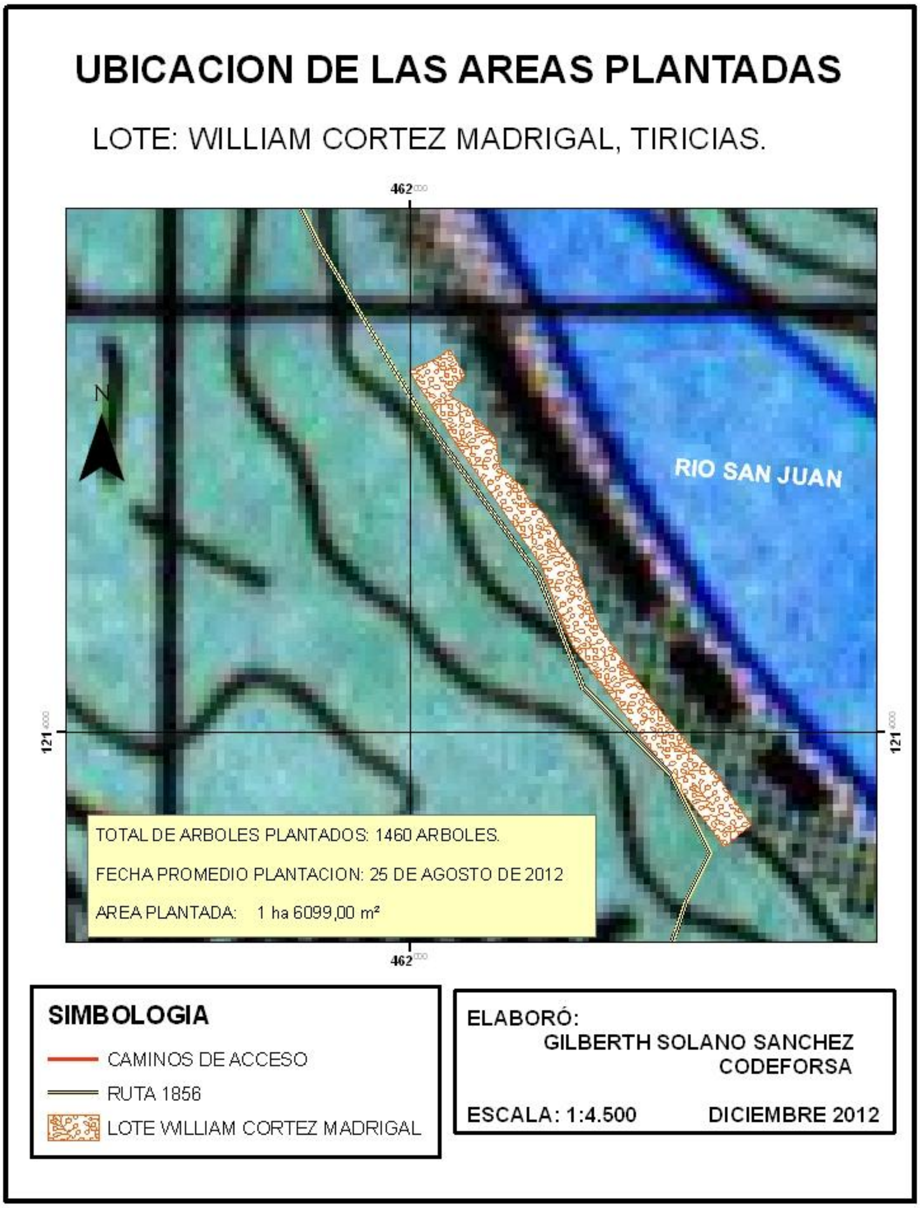

UBICACION DE LAS AREAS PLANTADAS
LOTE: MARCELO MENDEZ MORALES, TIRICIAS.
465
466
120
N
ISLA EL GUIS
RIO SAN JUAN
02
RIO INFIERNITO
TOTAL DE ARBOLES PLANTADOS: 1.870 ARBOLES.
FECHA PROMEDIO PLANTACION: 06 DE SETIEMBRE DE 2012
AREA PLANTADA: 2 ha 1216 m²
SIMBOLOGIA
RUTA 1856
LOTE MARCELO MENDEZ M.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:8.000
DICIEMBRE 2012


UBICACION DE LAS AREAS PLANTADAS
LOTE: MARIA MIRANDA RIVAS, TRINIDAD.
509
Peyollo
N
RIO SAN JUAN
118
118
TOTAL DE ARBOLES PLANTADOS: 500 ARBOLES.
FECHA PROMEDIO PLANTACION: 15 DE JULIO DE 2012
13 DE SETIEMBRE DE 2012
AREA PLANTADA: 0 ha 5167,12 m²
509
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE MARIA MIRANDA R.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

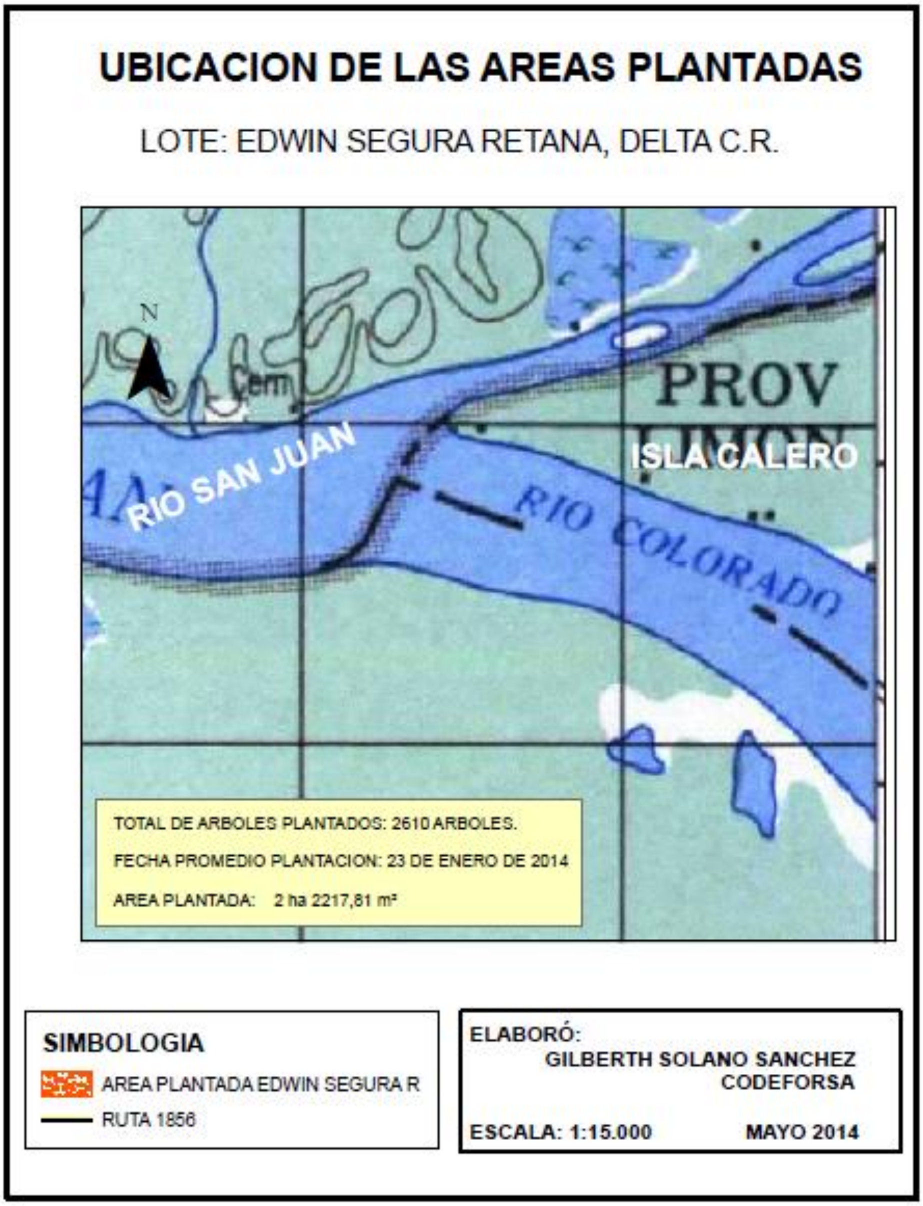

UBICACION DE LAS AREAS PLANTADAS
LOTE: MELIS GONGORA MORAGA, TRINIDAD.
507
N
BM
16
10
BM
118
RIO SARAPIQUI
16
30
118
TOTAL DE ARBOLES PLANTADOS: 252 ARBOLES.
FECHA PROMEDIO PLANTACION: 19 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 1975 m²
507
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE MELIS GONGORA M.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

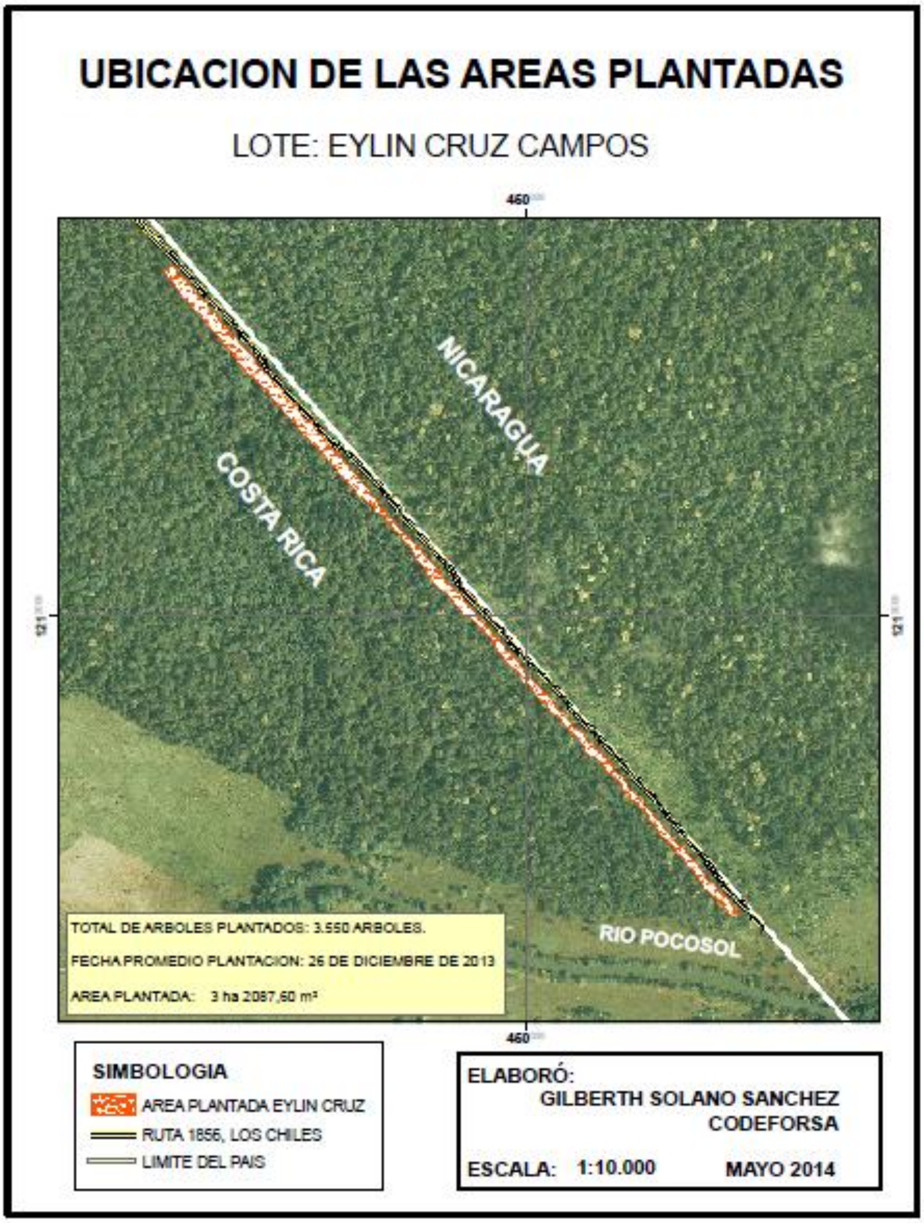

UBICACION DE LAS AREAS PLANTADAS
LOTE: OLMAN QUESADA CAMPOS, TIRICIAS.
462
La Tiricia
N
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 650 ARBOLES.
FECHA PROMEDIO PLANTACION: 25 DE JULIO DE 2012
AREA PLANTADA: 0 ha 4678,00 m²
462
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE OLMAN QUESADA CAMPOS
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:4.500
DICIEMBRE 2012

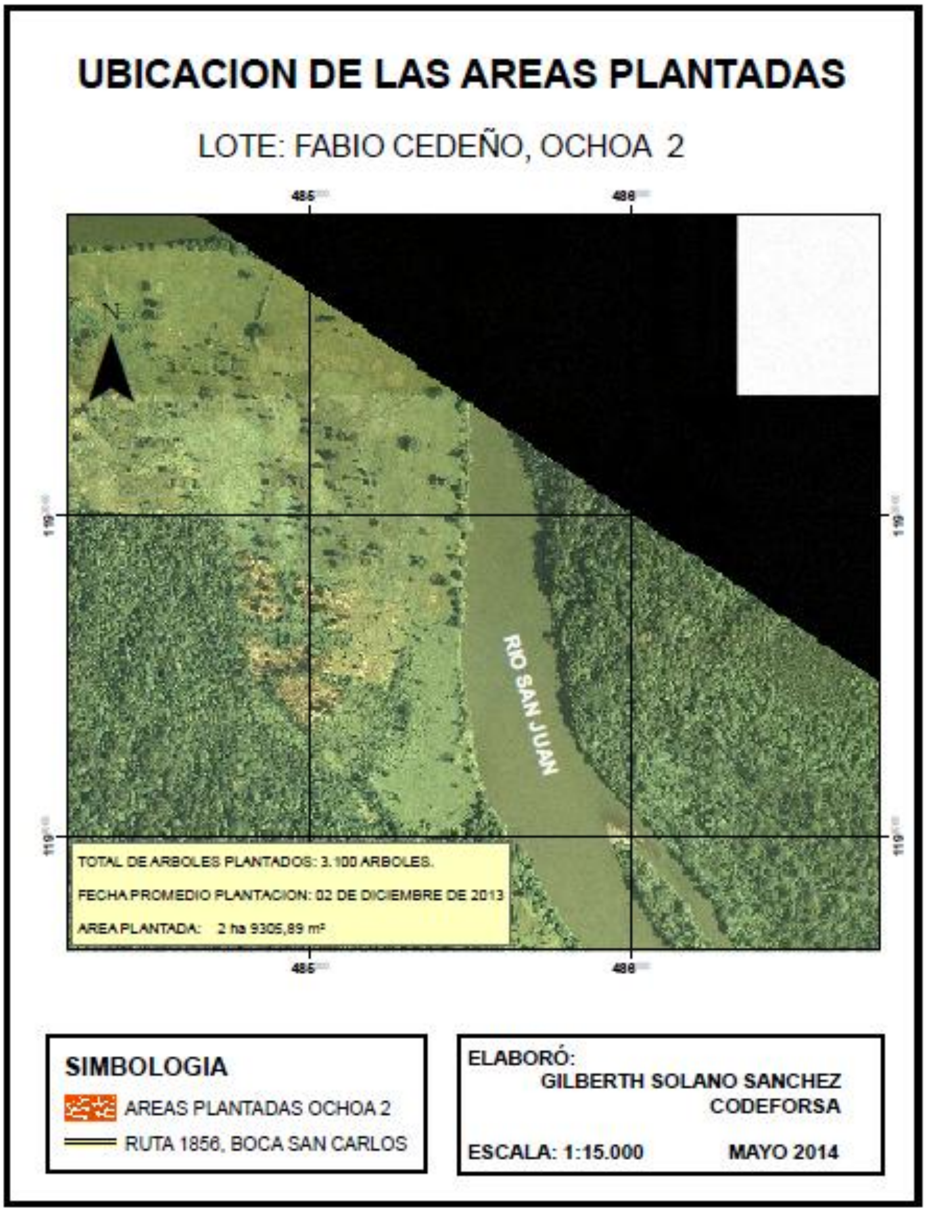

UBICACION DE LAS AREAS PLANTADAS
LOTE: TITO HERNANDEZ FERRETO, DELTA C.R.
RIO SAN JUAN
N
TOTAL DE ARBOLES PLANTADOS: 366 ARBOLES.
FECHA PROMEDIO PLANTACION: 30 DE JUNIO DE 2012
AREA PLANTADA: 0 ha 3047 m²
SIMBOLOGIA
RUTA 1856
LOTE TITO HERNANDEZ F.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:5.000
DICIEMBRE 2012

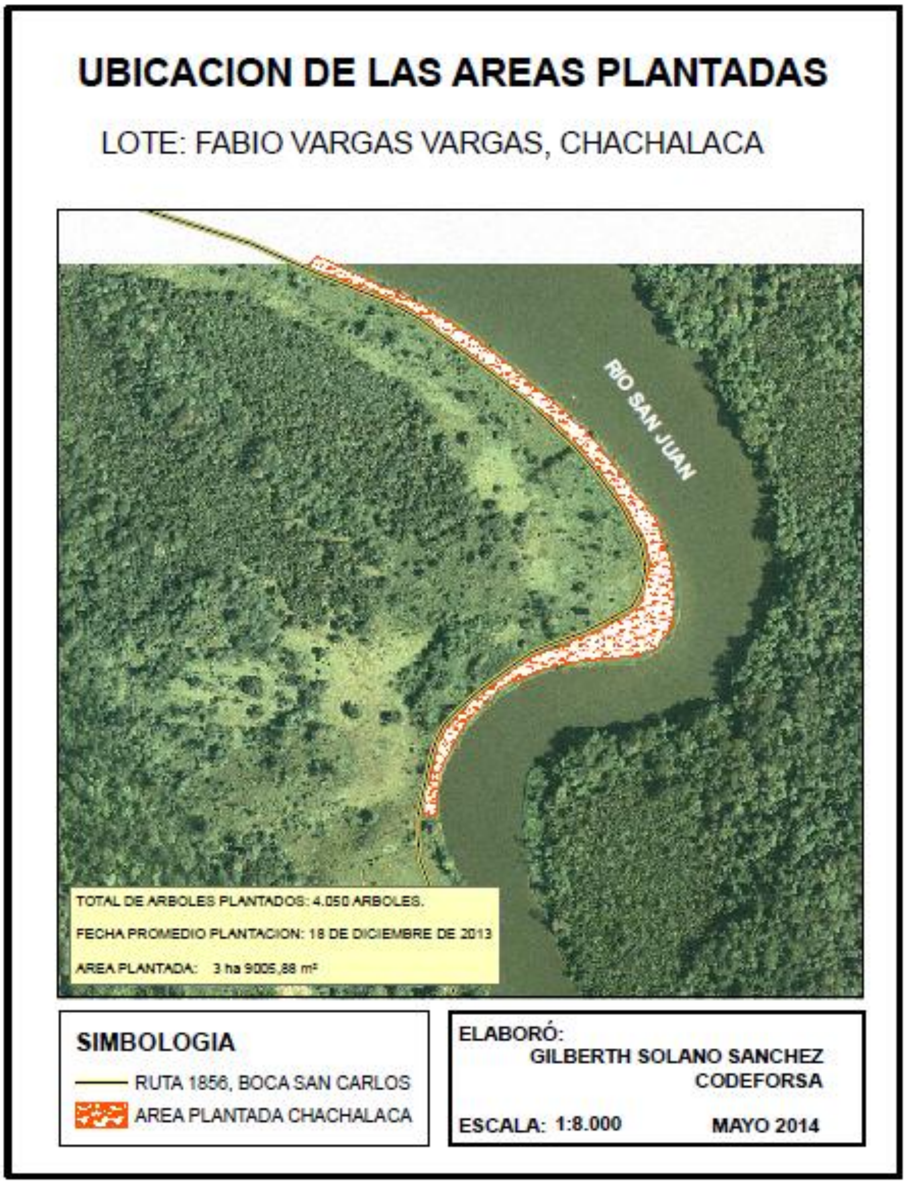

UBICACION DE LAS AREAS PLANTADAS
LOTE: WILLIAM CORTEZ MADRIGAL, TIRICIAS.
462
N
RIO SAN JUAN
121
121
TOTAL DE ARBOLES PLANTADOS: 1460 ARBOLES.
FECHA PROMEDIO PLANTACION: 25 DE AGOSTO DE 2012
AREA PLANTADA: 1 ha 6099,00 m²
462
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE WILLIAM CORTEZ MADRIGAL
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:4.500
DICIEMBRE 2012

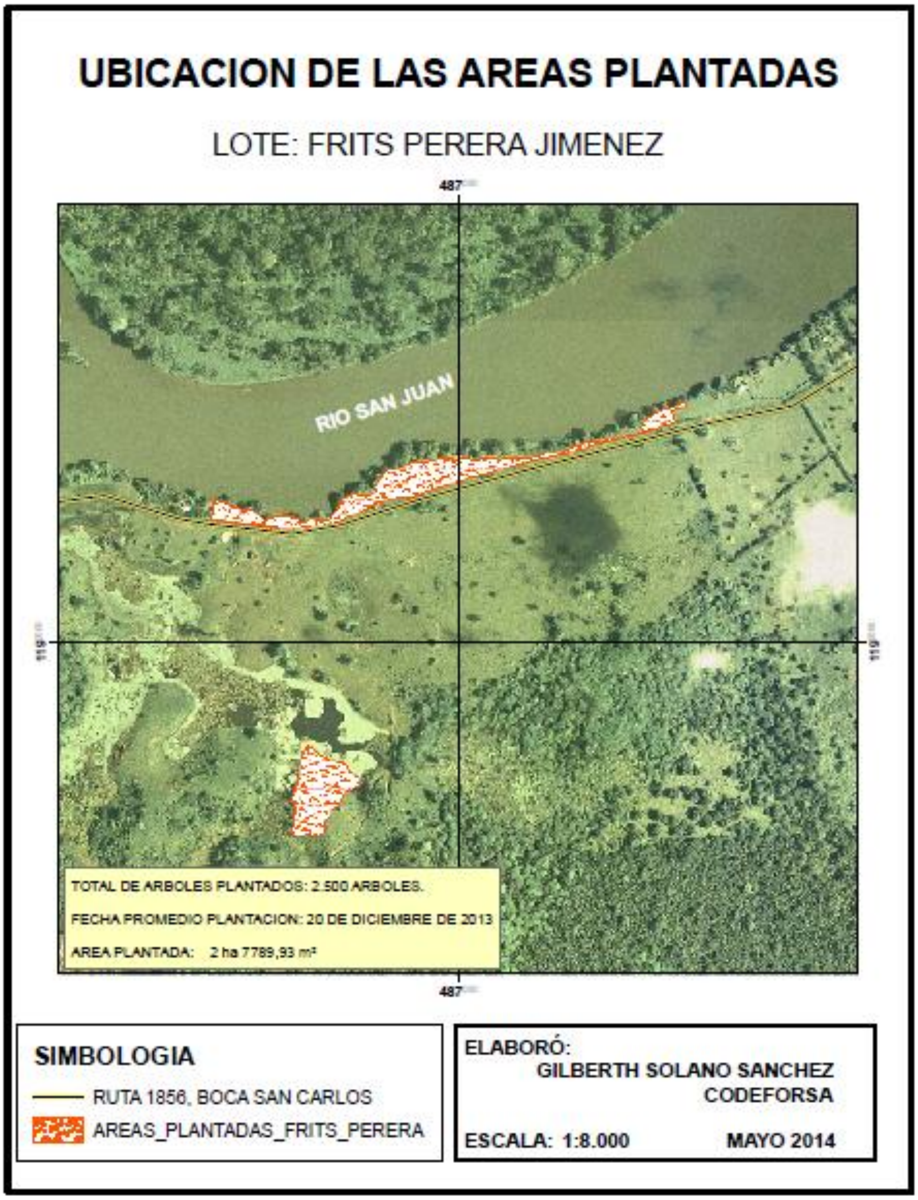
APPENDIX 3: MAPS OF THE LOCATION OF THE PLANTED AREAS, SECOND STAGE (EXPANSION).

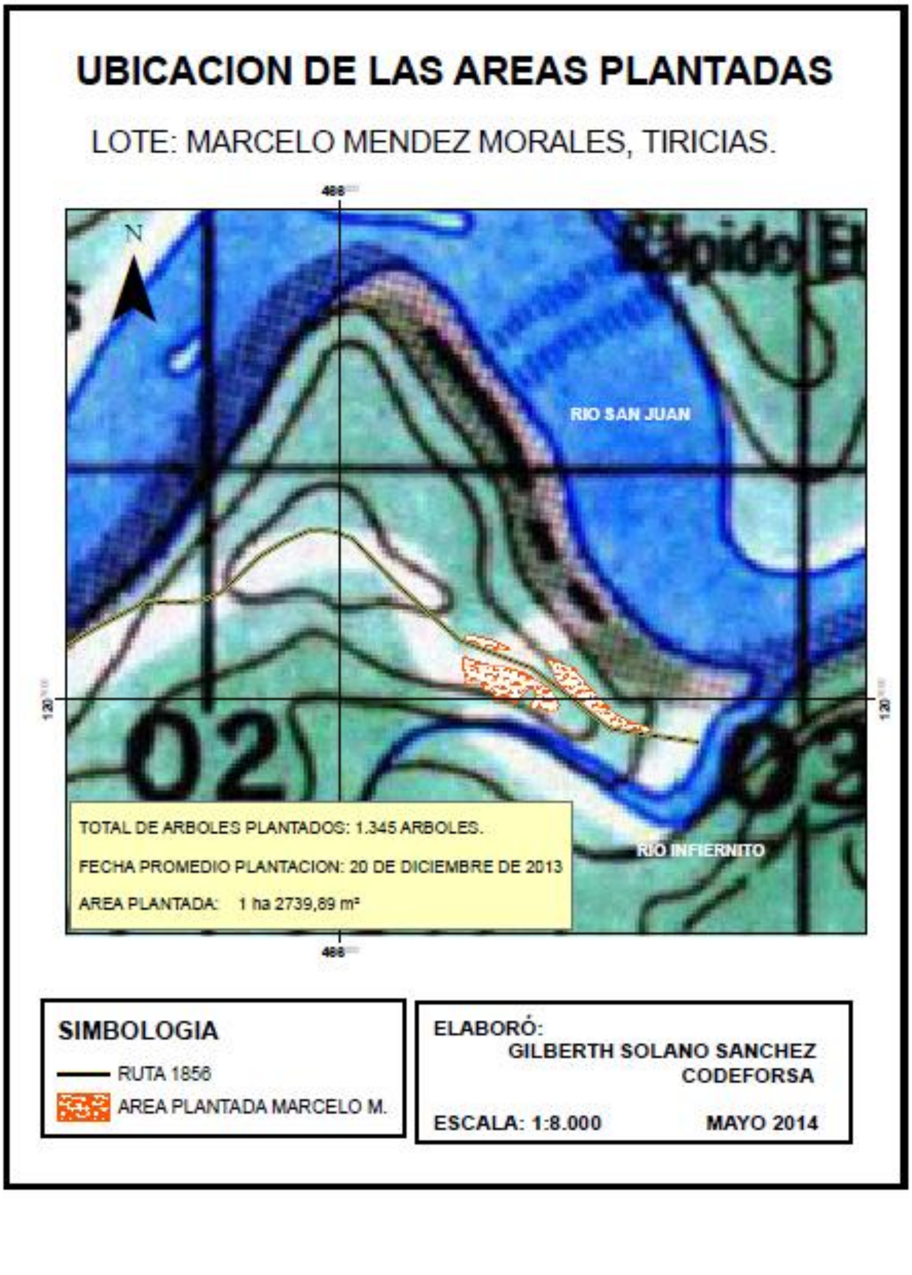

UBICACION DE LAS AREAS PLANTADAS
LOTE: EDWIN SEGURA RETANA, DELTA C.R.
N
RIO SAN JUAN
PROV
ISLA CALERO
RIO COLORADO
TOTAL DE ARBOLES PLANTADOS: 2610 ARBOLES.
FECHA PROMEDIO PLANTACION: 23 DE ENERO DE 2014
AREA PLANTADA: 2 ha 2217,81 m²
SIMBOLOGIA
AREA PLANTADA EDWIN SEGURA R
RUTA 1856
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:15.000
MAYO 2014

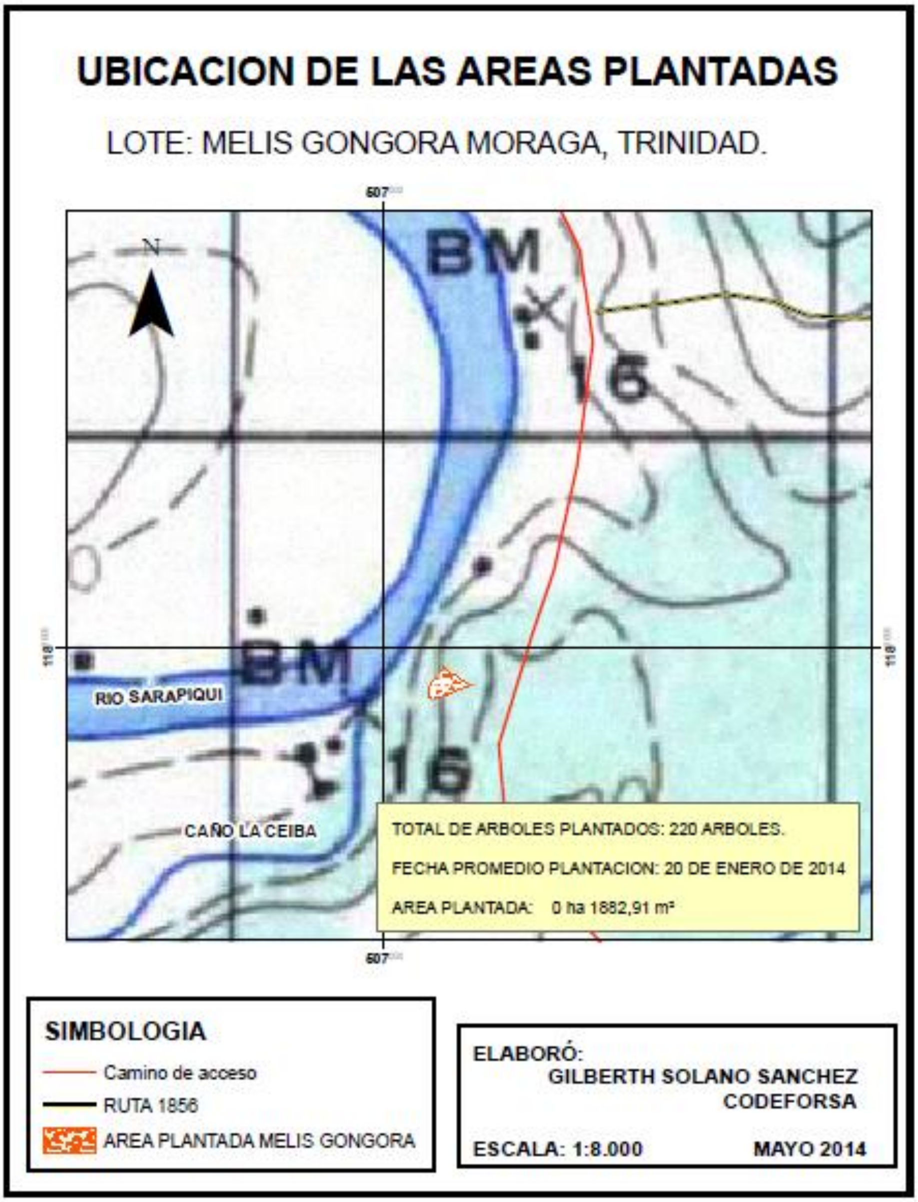

UBICACION DE LAS AREAS PLANTADAS
LOTE: EYLIN CRUZ CAMPOS
460
NICARAGUA
COSTA RICA
121
121
RIO POCOSOL
TOTAL DE ARBOLES PLANTADOS: 3.550 ARBOLES.
FECHA PROMEDIO PLANTACION: 26 DE DICIEMBRE DE 2013
AREA PLANTADA: 3 ha 2087,60 m²
460
SIMBOLOGIA
AREA PLANTADA EYLIN CRUZ
RUTA 1856, LOS CHILES
LIMITE DEL PAIS
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:10.000
MAYO 2014

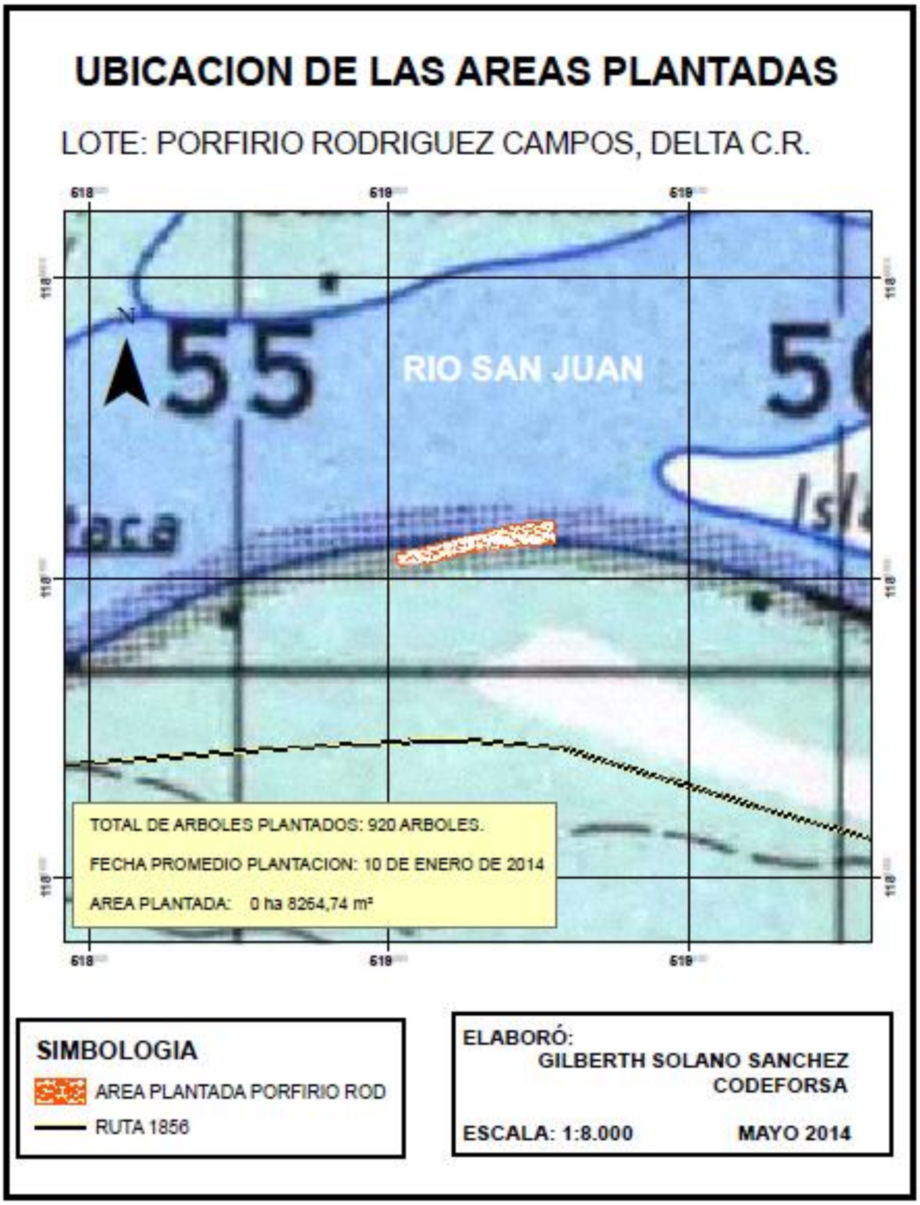

UBICACION DE LAS AREAS PLANTADAS
LOTE: FABIO CEDEÑO, OCHOA 2
N
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 3.100 ARBOLES.
FECHA PROMEDIO PLANTACION: 02 DE DICIEMBRE DE 2013
AREA PLANTADA: 2 ha 9305,89 m²
SIMBOLOGIA
AREAS PLANTADAS OCHOA 2
RUTA 1856, BOCA SAN CARLOS
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:15.000
MAYO 2014

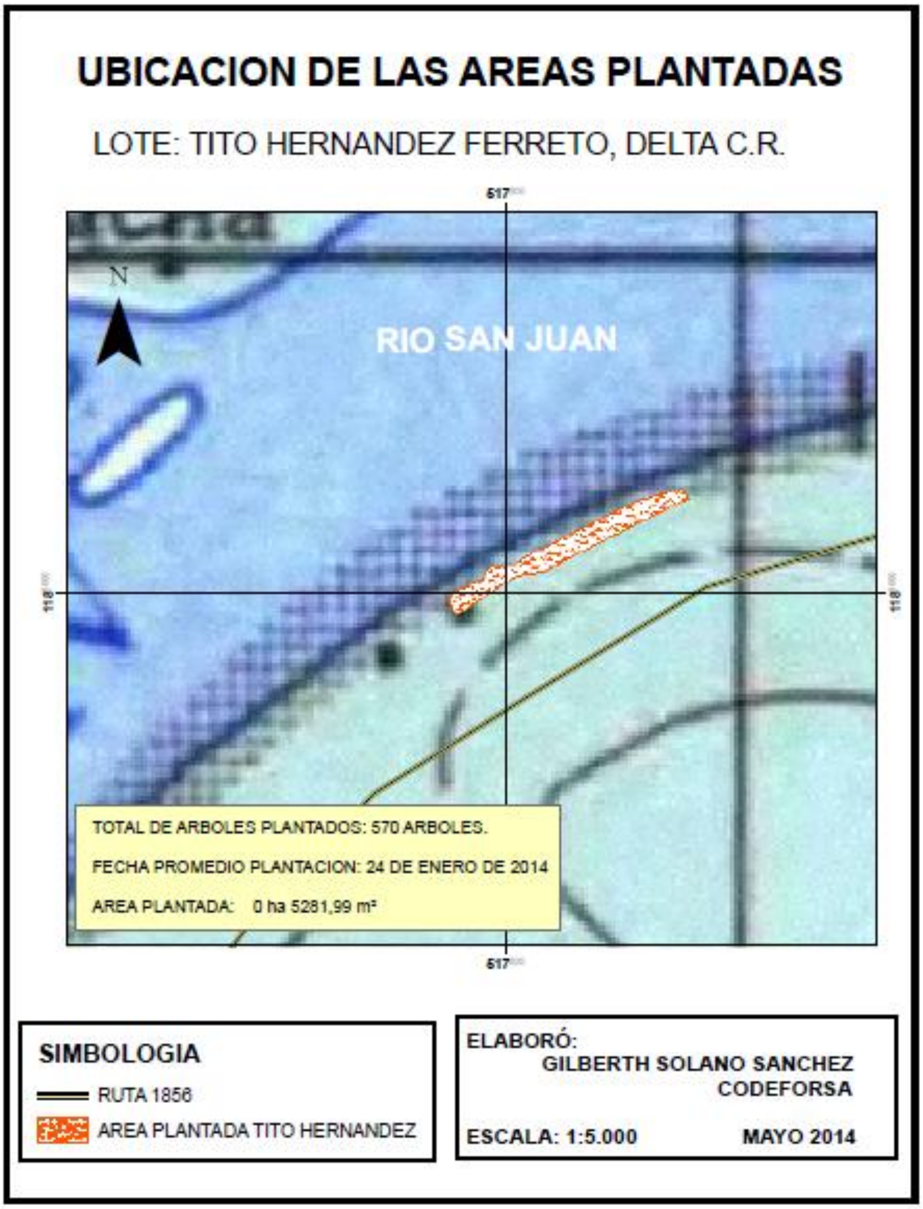

UBICACION DE LAS AREAS PLANTADAS
LOTE: FABIO VARGAS VARGAS, CHACHALACA
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 4.050 ARBOLES.
FECHA PROMEDIO PLANTACION: 18 DE DICIEMBRE DE 2013
AREA PLANTADA: 3 ha 9005,88 m²
SIMBOLOGIA
RUTA 1856, BOCA SAN CARLOS
AREA PLANTADA CHACHALACA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:8.000
MAYO 2014


UBICACION DE LAS AREAS PLANTADAS
LOTE: FRITS PERERA JIMENEZ
487
RIO SAN JUAN
119
TOTAL DE ARBOLES PLANTADOS: 2.500 ARBOLES.
FECHA PROMEDIO PLANTACION: 20 DE DICIEMBRE DE 2013
AREA PLANTADA: 2 ha 7789,93 m²
SIMBOLOGIA
RUTA 1856, BOCA SAN CARLOS
AREAS_PLANTADAS_FRITS_PERERA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:8.000
MAYO 2014


UBICACION DE LAS AREAS PLANTADAS
LOTE: MARCELO MENDEZ MORALES, TIRICIAS.
N
RIO SAN JUAN
02
RIO INFIERNITO
TOTAL DE ARBOLES PLANTADOS: 1.345 ARBOLES.
FECHA PROMEDIO PLANTACION: 20 DE DICIEMBRE DE 2013
AREA PLANTADA: 1 ha 2739,69 m²
SIMBOLOGIA
RUTA 1856
AREA PLANTADA MARCELO M.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:8.000
MAYO 2014


UBICACION DE LAS AREAS PLANTADAS
LOTE: MELIS GONGORA MORAGA, TRINIDAD.
N
BM
16
BM
RIO SARAPIQUI
16
CAÑO LA CEIBA
TOTAL DE ARBOLES PLANTADOS: 220 ARBOLES.
FECHA PROMEDIO PLANTACION: 20 DE ENERO DE 2014
AREA PLANTADA: 0 ha 1882,91 m²
SIMBOLOGIA
Camino de acceso
RUTA 1856
AREA PLANTADA MELIS GONGORA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:8.000
MAYO 2014


UBICACION DE LAS AREAS PLANTADAS
LOTE: PORFIRIO RODRIGUEZ CAMPOS, DELTA C.R.
N
55
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 920 ARBOLES.
FECHA PROMEDIO PLANTACION: 10 DE ENERO DE 2014
AREA PLANTADA: 0 ha 8264,74 m²
SIMBOLOGIA
AREA PLANTADA PORFIRIO ROD
RUTA 1856
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:8.000
MAYO 2014


UBICACION DE LAS AREAS PLANTADAS
LOTE: TITO HERNANDEZ FERRETO, DELTA C.R.
517
N
RIO SAN JUAN
118
118
TOTAL DE ARBOLES PLANTADOS: 570 ARBOLES.
FECHA PROMEDIO PLANTACION: 24 DE ENERO DE 2014
AREA PLANTADA: 0 ha 5281,99 m²
517
SIMBOLOGIA
RUTA 1856
AREA PLANTADA TITO HERNANDEZ
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:5.000
MAYO 2014

ANNEX 14

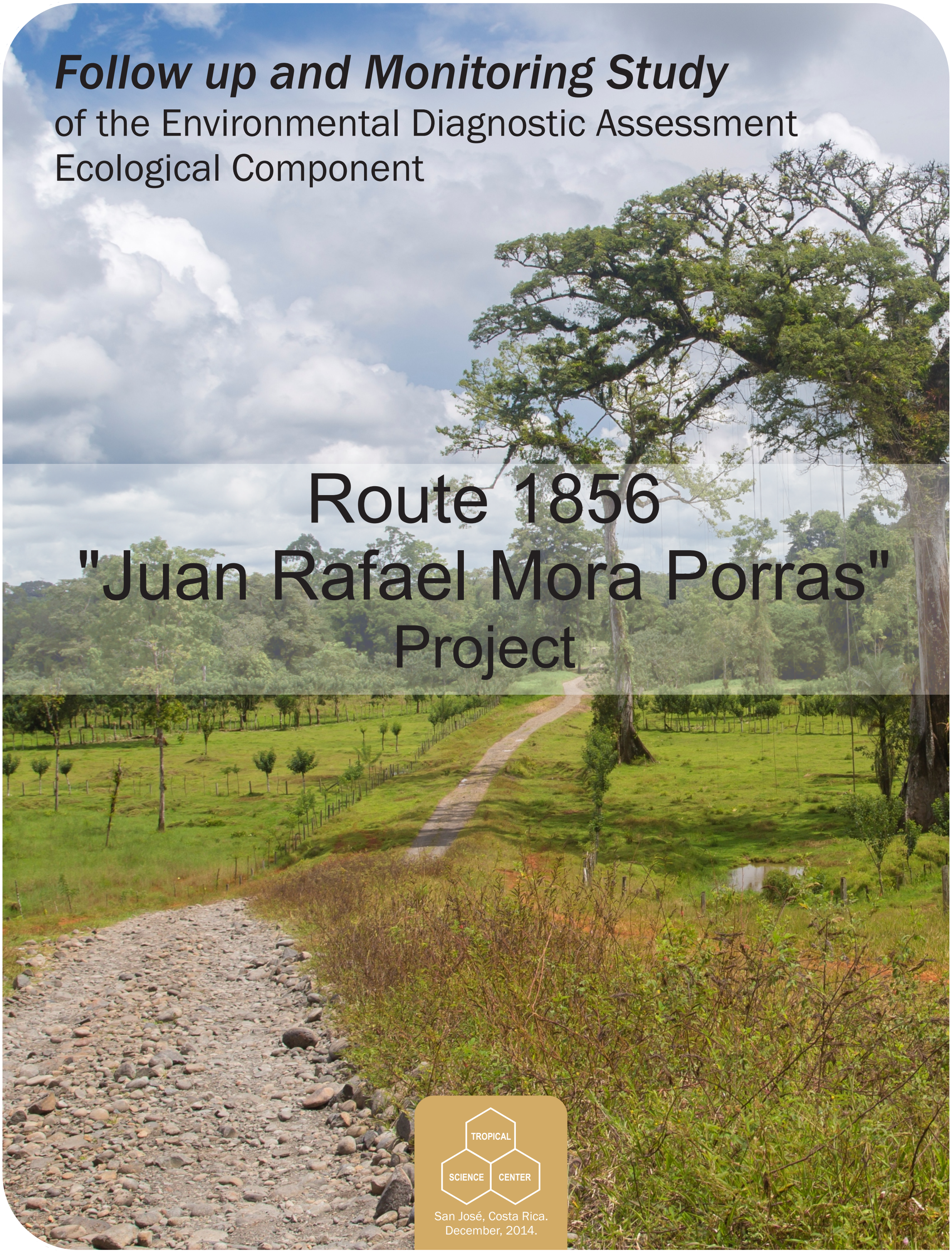
Centro Científico Tropical (CCT)

Follow-up and Monitoring Study Route 1856 Project- EDA Ecological Component

January 2015

Follow up and Monitoring Study
of the Environmental Diagnostic Assessment
Ecological Component

Route 1856
"Juan Rafael Mora Porras"
Project



TROPICAL SCIENCE CENTER

San José, Costa Rica.
December, 2014.

i. Professional team participating in Follow-up and Monitoring Study of the Environmental Diagnostic Study- Ecological Component, Route 1856.

This document was coordinated and prepared by the TROPICAL SCIENCE CENTER, with the participation of the following professional specialists:

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Olivier Chassot Labastrou, Ph.D.	Natural Sciences for Development and Environmental Management Technical Coordinator	Colegio: 1967 SETENA: CI-157-12	________________
Ana Luisa Báez Rojas	Sustainable Tourism	Colegio: 1202	________________
Guisselle Monge Arias, Ph.D.	Biology and Natural Resources Management	Colegio: 844 SETENA: CI-146-13	________________
Rafael Bolaños Montero	Forestry and Land Use	Colegio: CIA-4377 SETENA: CI-001-98	________________
Bernald Pacheco Cháves	Aquatic Biology	Colegio: 1695 SETENA: CI-214-08	________________
Andreas Mende, Ph.D.	Digital Cartography and Geographic Information Systems	CGCR: 382 SETENA: CI-173-14	________________

ii. General Index

Table Index

Map Index

Photo Index

Glossary

Agarradores: "clingers", organisms found in bodies of water with strong currents, which often have features (long, strong claws nails, hooks, suction cups) enabling them to hold onto their surroundings.

Altered primary forest: primary forest that has been previously subject to some form of human intervention, such as logging and land clearing below the canopy level.

Auto-trophs: organisms that have the ability to synthesize all elements essential to their metabolic needs based on non-organic substances, such that they do not need other living organisms for their nourishment.

Bailey bridge: portable pre-fabricated metal bridge, designed primarily for military use, which is used in many countries as a provisional bridge whilst a permanent structure is being built.

Bentonic: relative to the community formed by organisms that inhabit the bottom of aquatic ecosystems.

Bentonic macro-invertebrate: non-vertebrate animal that lives all or part of its life cycle in the bottom or in the substratum of the bottom layer in bodies of fresh water, whose body size allows direct visual observation without the use of instruments.

Bio-indicator: organism selected for its degree of sensibility or tolerance to diverse types of contamination or its effects. It measures or quantifies the magnitude of stress and degree of ecological response to it.

Biological Corridor: a territory that offers connectivity among landscapes, eco-systems and habitats, natural or modified, assuring the presence of biological diversity and ecological processes.

Boundary marker or landmark: artificial structure used commonly to define the limits of properties and territories.

Branchiae: gills, respiratory organs of aquatic animals which allow extraction of oxygen diluted in the water, and transference of carbon dioxide (CO_2) to the environment.

Caudal: current, quantity of water that moves through a section of a river during a given unit of time.

Caño: channel, water course that runs through muddy, flooded terrain, or through palustrine or lacustrine wetlands, whose depth and appearance change as a function of the level of water.

"Climbers": organisms that live in the submerged part of aquatic plants.

Collectors: organisms that collect fine particles deposited in water surfaces.

Community: group of organisms of all species that co-exist in a defined space called a biotope which offers the required environmental conditions for their survival.

Density: number of organisms in an area or defined volume.

Detriment: slight or partial destruction of something.

Detritus: residues, generally solid and permanent, that result from the decomposition of organic sources (vegetal and animal); dead matter.

Diversity: related to the number or richness of species, as well as the equality or relative abundance of individuals between species.

Divers: organisms that dive and swim to feed themselves; often they spend time holding onto submerged objects.

Egg-laying: fish, reptiles and amphibians which release eggs into the environment.

Endemic Species: taxon that is limited to a reduced geographic area, not found in a natural state anywhere else in the world.

Epi-lithic: organism that develops on the surface of hard substrata.

Extinction: disappearance of all the individuals of a species or a taxonomic group; a species is extinguished when the last individual of the species dies.

Filters: organisms that feed off particulate, fine, and very fine organic matter in suspension, which are collected by the organism with the use of mouth brushes or silk nets.

Forest: natural vegetation of a forest ecosystem of an extension greater than 2 hectares.

Forested: a section covered by natural tree vegetation, with variable surfaces, whether smaller or larger than 2 hectares.

Fragmenters: organisms that chew large pieces of vascular plants to feed themselves.

Habitat: area where organisms live and grow in a natural way.

Interstitial Space: space or crevice between two bodies or between parts of a body.

Lacustrine: organisms that exist or develop in waters of little or no movement.

Lentic: system of stagnant continental waters with little movement and exchange, for example, lakes formed by emerging waters, lakes, ponds, swamps and marshes.

Monitoring: systematic use of biological responses to evaluate changes in the environment for the purpose of implementing conservation and control programs.

Morbility: proportion of organisms the health of which declines in a site over a specified period of time.

Mortality: number of individuals within a population that die within a specified period of time.

Palustrine: referring to stagnant or slow moving shallow waters with emergent vegetation at least in 30% of the area.

Phytoplancton: group of aquatic organisms that are plankton auto-thropic, have photosynthetic capacity and live dispersed in water.

Plancton: group of organisms, mainly microscopic, that inhabit salty or fresh waters, whose movement is passive.

Population: group of organisms, or individuals of the same species that co-exist in a given space and time, and share certain biological properties which produce a high reproductive and ecological cohesion in the group.

Predators: herbivores and other organisms that feed on other organisms.

Richness: number of species that are part of a community.

River: natural course of water that flows continuously has a defined stream, constant throughout the yearly cycle, that flows into the sea, a lake, or another river (in which case it is considered an affluent or tributary course).

"Scrapers": organisms that feed on peri-phyton algae and microbes that adhere to rocks and other substrata.

Sediment: solid accumulated material on the terrestrial surface (lithosphere) derived from the action of phenomena and processes that act on the atmosphere, hydrosphere and biosphere (winds, temperature variations, meteorological precipitations, circulation of surface or underground waters, displacement of masses of water in marine or lacustrine environments, chemical agents or the action of live organisms.

Slope: slanting surface, inclined surface of land or artificial inclined structure that is part of an engineering work.

Skaters: organisms that live in the aerial phase on the surface film of water and skate on this surface.

"**Sprawlers"**: organisms that live in habitats, or micro-habitats with less current and which crawl on the surface of the bottom substratum, on rocks, sediment, leaves and wood.

Swimmers: organisms that live in permanent submersion and are capable of swimming with movements such as those of fish; organisms spend time holding on to rocks, roots of aquatic plants and other submerged objects.

Taxa: plural of taxon.

Taxon: any unit, category or group used in the science of biological classification, such as phylum, order, family, genus or species.

Tributary (or affluent): body of water that does not run its course to the sea, but empties into a river, at a point known as the confluence of both.

Trophic level: each one of the group of species or organisms of an eco-system that coincide by the place they occupy in the system of energy and circulation of nutrients; those that occupy an equivalent place in the food chain.

Wetland: area covered with water generally containing natural and semi-natural vegetation and very often rich in diversity of organisms.

“Yolillal” patch or extension: basal tropical eco-system that generally grows close to the coasts and is frequently inundated, and is dominated by the palm known as ”Yolillo” (Raphia taedigera).

Abbreviations

RNVSMM: Refugio Nacional de Vida Silvestre Mixto Maquenque (Maquenque National Wildlife Refuge)

DBH: Diameter at Breast Height (1.30 meters)

TSC: Tropical Science Centre

BBC: Border Biological Corridor

ICE: Costa Rican Electrical Institute

IGN: National Geographic Institute

RSJ: San Juan River, on the Costa Rica- Nicaragua border

UCR: University of Costa Rica

1 OVERVIEW

This study is responsive to various statements made by the Government of Nicaragua in the case concerning *Construction of a Road in Costa Rica along the San Juan River (Nicaragua v. Costa Rica)* (‘*Road* case’) regarding purported impacts on its territory allegedly caused by the construction of the 1856 Route in Costa Rica.

Following the issue of proceedings in the *Road* case, the Costa Rican Ministry of Foreign Affairs and Worship commissioned an exhaustive assessment of conditions of the Route and its potential environmental impacts. This led to the study entitled “Environmental Diagnostic Assessment - Ecological Component” of Route 1856 (‘EDA’), completed in November of 2013, one of a number of studies commissioned by Costa Rica in the context of the *Road* case.

The Ministry of Foreign Affairs and Worship of the Government of Costa Rica commissioned the services of the Tropical Science Center (‘TSC’) to carry out the EDA, based on its well-known reputation, technical expertise concerning the topics under study and more than 20 years of experience conducting research projects in the area.

One year after the completion of the EDA, the Government of Costa Rica commissioned the TSC to conduct a Follow-up and Monitoring Study to the EDA, which was completed in December 2014 (‘Follow-up Study’), the results of which are set out in this report. The Follow-up Study reviewed the environmental measures recommended in the EDA required to attain an environmental equilibrium for the works and activities executed, and it compared new samples with samples assessed in the EDA in order to evaluate potential changes that might have taken place over a one-year period.

The project description also clarifies that this Follow-up Study is not a new assessment of the Route project, but rather an analysis of the actual state of Route 1856, and of the technical and environmental recommendations that have been put into effect over the past 12 months.

The general objective of this Follow-up Study is “[t]o formulate an environmental follow-up document which repeats the methodology applied during the [EDA] of Route 1856, for comparison and further evaluation of current environmental conditions of the same, and of the effectiveness of corrective environmental measures that have been applied in the Project area.”

This general objective finds expression in four specific objectives that define with greater precision the activities that are proper to this study in areas such as field verification of current physical and biological conditions, a synthesis of the environmental conditions identified in the EDA, and review and adjustment of environmental measures established in the EDA.

The methodology established for this study is also presented in some detail as it describes with precision the steps taken to collect the field information, and its analysis.

It must be pointed out that even though this Follow-up Study is not a repetition of the EDA, it does take into account as a reference base general aspects of the EDA, such as geographic location, description of the project works, influence area, description of the activity under study, environmental aspects analysed and the environmental risk control system evaluated.

This Follow-up Study presents the environmental diagnostic study with the description of the potential environmental impacts identified in the EDA, and the current environmental conditions with the results obtained in the new sampling and field verifications.

It also comprises an assessment of the alleged environmental impacts and corrective measures, with specification of the methodology employed for such assessment and the characterization of evaluation criteria.

It presents both the EDA data of 2013 alongside follow-up and monitoring data of 2014 in the Matrix of Importance of Environmental Impact (MIIA), in order to conduct the comparative assessment of the results of the two years being evaluated.

Further, environmental control measures are updated for the impacts identified, specifying and describing the environmental measures executed and proposing the environmental measures to be put into effect.

In this manner the assessment of impacts and updating of corrective measures are used as inputs for the formulation of an Environmental Action-Environmental Restoration Plan, which presents the environmental aspect considered, the environmental aspect identified, the corrective or compensatory measure with its corresponding environmental goals and respective environmental indicators; its location, the interpretation and feedback, the entity responsible for its execution and the degree of compliance.

This plan for the Correction and Environmental Action is updated according to the results of the assessment, to ensure monitoring and follow-up. It includes a chapter of conclusions and recommendations which contains the conclusions for the current situation and the updated recommendations. Maps are included with the spatial distribution of the sampling points and tables with illustrative photographs and coordinates for the same.

Annexes contain data and indexes that support the aquatic and terrestrial environmental analysis conducted in this Follow-up Study.

2 INTRODUCTION

2.1 Background

As a result of allegations made by the Government of Nicaragua concerning purported impacts on the territory of Nicaragua allegedly caused by the construction of Route 1856, the Ministry of Foreign Affairs and Worship of Costa Rica commissioned an exhaustive evaluation of the Route and the potential environmental impacts allegedly caused by it. This led to the EDA, which was completed in November 2013.

The Ministry of Foreign Affairs and Worship of Costa Rica commissioned the TSC to conduct the EDA, given its well-known reputation, technical knowledge of the topics in question and more than 20 years of experience in research projects in the study area. The EDA was principally focused on impacts on Costa Rican territory although it sought to incorporate an element of potential transboundary impact. However, the TSC's work in this respect was inevitably limited because the Nicaraguan authorities did not permit measurements or assessments to be carried out by the technical personnel of the TSC on Nicaraguan territory (i.e. to sample or monitor the Rio San Juan, where the impacts are said to have been felt).

One year after the completion of the EDA, the Government of Costa Rica commissioned the TSC to conduct this Follow-up Study, which was completed in December 2014. This Follow-up Study reviews the recommended environmental measures of the EDA which were deemed necessary to attain environmental equilibrium of the activities and works conducted, and it evaluates new samples of the same points assessed in the EDA, as it compares these with samples assessed in the EDA in order to determine potential changes taking place over a period of one year.

2.2 Scope

This Follow-up Study fulfils the objective of conducting a monitoring study based on scientific criteria of current environmental conditions in the same area where the EDA sampling was conducted.

The purpose of the present Follow-up Study is to verify the present state of Route 1856, and the effectiveness of the technical and environmental recommendations that have been applied over the last 12 months.

This Follow-up Study constitutes a new analysis of the area of the project. It involved carrying out a field verification of the environmental conditions, in addition to the execution of 10 aquatic sampling studies in the same riverbeds analysed in the EDA.

This Follow-up Study is not a further EDA. Rather, it is a means by which to monitor the environmental conditions previously identified, and to update the mitigation measures proposed in the EDA.

2.3 Objectives

2.3.1 General

To formulate an environmental follow-up document applying the same methodology employed in the EDA, in order to compare the matters presented in the EDA with those analysed in the present Follow-up Study, and to further evaluate the current environmental conditions and effectiveness of the corrective environmental measures which have been implemented.

2.3.2 Specific Objectives

a. To carry out a field verification of the current physical and biological conditions of the ecosystems in the area, specifically from Border Marker 2 to the site known as Delta 7 (Delta Costa Rica).

b. To conduct a synthesis of environmental conditions identified in the EDA of the area where Route 1856 is located.

c. To formulate a comparative analysis of potential environmental impacts identified in the EDA, resulting from the construction activities related to the Route, and the current conditions of the same.

d. To review and adjust, if and where necessary, the environmental measures established in the EDA, based on the environmental conditions analysed in the present Follow-Up Study, and providing technical-scientific bases to guide decision-making by the Government of Costa Rica regarding design and construction works of the Route.

2.4 METHODOLOGY

The EDA was used as a base line for the Follow-up Study. In addition, a methodological verification (by means of sampling the aquatic environments), an updated version of the bibliography of studies and research conducted in the past by the authors and colleagues of the TSC in the region, and the results of five field visits were used to validate aspects of the characterization of the local ecosystems and the potential environmental factors purportedly impacted by Route 1856.

This Follow-up Study benefited from the experience gained over the last 15 years from field work carried out by experts Guisselle Monge and Olivier Chassot, who form part of the Lapa Verde Program which the TSC has developed in the area, which allowed field verification with respect to information contained in the literature. This Follow-up Study also benefited from the experience of consultants from relevant disciplines acquired during the preparation of the EDA.

On the basis of information on ecosystems set out in the EDA, field assessments were carried out on different sites purportedly impacted along the Route, with particular focus on natural associations. Work was based on maps of the associations, forest cover of the Route area, as well as quantification of the alleged environmental impacts and their evaluation in the MIIA, and the conclusions and recommendations given.

For the sampling study of macro-invertebrates, several visits were conducted in the project area established in the EDA, during the periods of 8-10 August, 5-7 and 19-21 September, and 20

October 2014. The collection of macro-invertebrates in the field was undertaken using the same methods employed in the EDA, with the purpose of allowing an effective comparison between the results obtained in 2013 and those obtained in the context of the present Follow-up Study. Macro-invertebrates were selected as bio-indicators of the quality of the aquatic habitat.

The criteria used for the selection of the sampled sites, were:

a. Geographic location;
b. Land use;
c. Type of land cover;
d. Access, size and depth;
e. Type of current; and
f. Availability of substrata.

The analysed tracts were prioritised for the possible existence of environmental impacts due to the construction works of Route 1856.

The collection method was based on that described by Ramirez (2010), namely a qualitative method of direct collection in the field (see photograph 1), which uses a net of type D of 500 um of net light to trap organisms and material from the body of water (see photograph 2). The organisms and material are placed together in a white plastic tray to which water is added. Separation is achieved using entomological pincers designed for this task, and the macro-invertebrates are then conserved in sealed vials filled with 70% alcohol, and labelled with information of each site, written in waterproof ink on scroll paper.

In order to standardise the sampling process, a total of one hour was dedicated to each point under study (that is: one hour upstream from the Route and one hour downstream). In the water quality analysis of the aquatic ecosystem, the BMWP index was utilised, adapted to Costa Rica, with the sensibility scores in line with those specified in the Rules for the Evaluation and Classification of the Bodies of Superficial Waters (MINAET-S, 2007).

This index assigns sensibility scores to macro-invertebrates found in a body of water, which are used as bio-indicators, and most sensitive macro-invertebrates are given high scores while the more tolerant ones are assigned a low score.

This index takes into account the presence or absence of different taxa, but not their relative abundance. Finally, once the macro-invertebrates families have been scored, the scores are added, the total score is compared with a series of categories in order to define where the total fits, and the study site is assigned a value that ranges from excellent to very poor water quality.

The organisms collected are conserved, labelled, and taken to a laboratory where they are identified using specialised optical equipment (stereoscope and micro-scope) inside petri dishes, by reference to available taxonomic keys (Merritt *et al.*, 2008; Springer *et al.*, 2010; Pacheco Chaves, 2010; Oceguera-Figueroa and Pacheco-Chaves, 2012, among others). The organisms are then separated into taxonomic groups, preserved in 70% alcohol in cotton-topped vials, labelled and placed inside large glass containers with 70% alcohol and their respective informative label.

The preserved collection, with labels, is deposited in the Aquatic Entomology Collection of the Zoology Museum of the University of Costa Rica. The program 'Past' was used to calculate additional indexes for the analysis, including: Dominance, Jacquard Equity and Shannon-Wiever Diversity (In).

Photo 1: Direct collect of macro-invertebrates in the field.

Photo 2: Net used for macro-invertebrate collection.

The structure and guidelines of the present Follow-up Study are based on the EDA, which in turn is based on the Technical Guide for the EDA, established by the National Environmental Technical Secretariat (SETENA) of MINAE, based on Resolution No. 2572-2009 SETENA of 2 November 2009.

2.5 Duration of Follow-up Study

The Follow-up Study was conducted from July to November 2014. This work included incorporation of new bibliographical data and 6 field trips to the project area. The present report was completed in December 2014.

2.6 Geographical Scope of Follow-up Study

Results of the Follow-up Study are limited to the section of the Route that starts at Marker 2, in the vicinity of Tiricias de Cutris de San Carlos, and runs to Delta Costa Rica, at the bifurcation of the Colorado and San Juan Rivers.

As was the case with the formulation of the EDA in 2013, it was not possible to enlarge the study area due to the Nicaraguan Government's refusal to allow scientists in the study team to enter the San Juan River. For this reason, it was not possible to sample the San Juan River or the waters in the mouths of the rivers and channels, which would have provided valuable information for analysis of the environmental conditions of the River.

2.7 Criticisms by Nicaragua

A number of experts commissioned by the Government of Nicaragua presented observations, mostly criticisms, on the work conducted by the TSC in relation to the EDA. The TSC wishes to state the following general observations in response to those criticisms.

The EDA is an environmental assessment instrument regulated by the laws of the Republic of Costa Rica. As such, the TSC undertook to fulfil those requirements. While the TSC's evaluation of impacts has taken place on Costa Rican territory, at the request of the Government of Costa Rica, the TSC tried to incorporate an element of the potential transboundary effect of the construction of the Route. However, as noted above, the Nicaraguan authorities did not permit measurements or assessments be carried out by the technical personnel of the TSC.

Furthermore, most criticisms directed at the work of TSC concerned the size of the areas sampled and methodology, yet, as stated before, the TSC carried out all assessments fulfilling the requirements of Costa Rican law. In this respect, just with respect to this second report, we have put together a team of professionals that, together, carried out field work spanning 5 months, and hundreds of hours were spent assessing the environmental conditions of the road on site.

The TSC has carried out an objective and comprehensive environmental assessment, yet, some criticism was made by individuals that spent little time on the San Juan River, or no time at all, and clearly without any knowledge of the requirements set forth by Costa Rica in its legislation regarding EDA.

The TSC stands fully by its findings set out in the 2013 EDA. This Follow-Up Study shows the consistency and strength of those findings, and confirm that the methods and assessments made by the TSC reflect objectively and truthfully the conditions of the border road.

3 GENERAL INFORMATION ON THE PROJECT

3.1 Geographic Location

Route 1856 is located in the northern territory of Costa Rica, in the provinces of Alajuela and Heredia. The area that corresponds to the study area is located between the following points:

Start: Border landmark 2 (Marker 2), 1215724 North and 526412 East.

End: Site known as Delta 7 or Delta Costa Rica, between coordinates 1190664 North and 460768 East (See map 1).

The design of the Route is contained in four topographical sheets at a scale of 1:50,000 by the National Geographic Institute (IGN), which are labelled from northwest to southeast from Marker 2 to Delta Costa Rica as follows: Pocosol 3348-IV, Infiernito 3348-III, Cutris 3348-II and Trinidad 3448-III.

3.2 Political and Administrative Location

Relevant internal boundaries within Costa Rica, at the provincial, county and district levels, were identified for the purpose of coordination, decision-making, and environmental technical follow-up, as follows:

Alajuela (Province 02): San Carlos County and Pocosol, Cutris and Pital districts

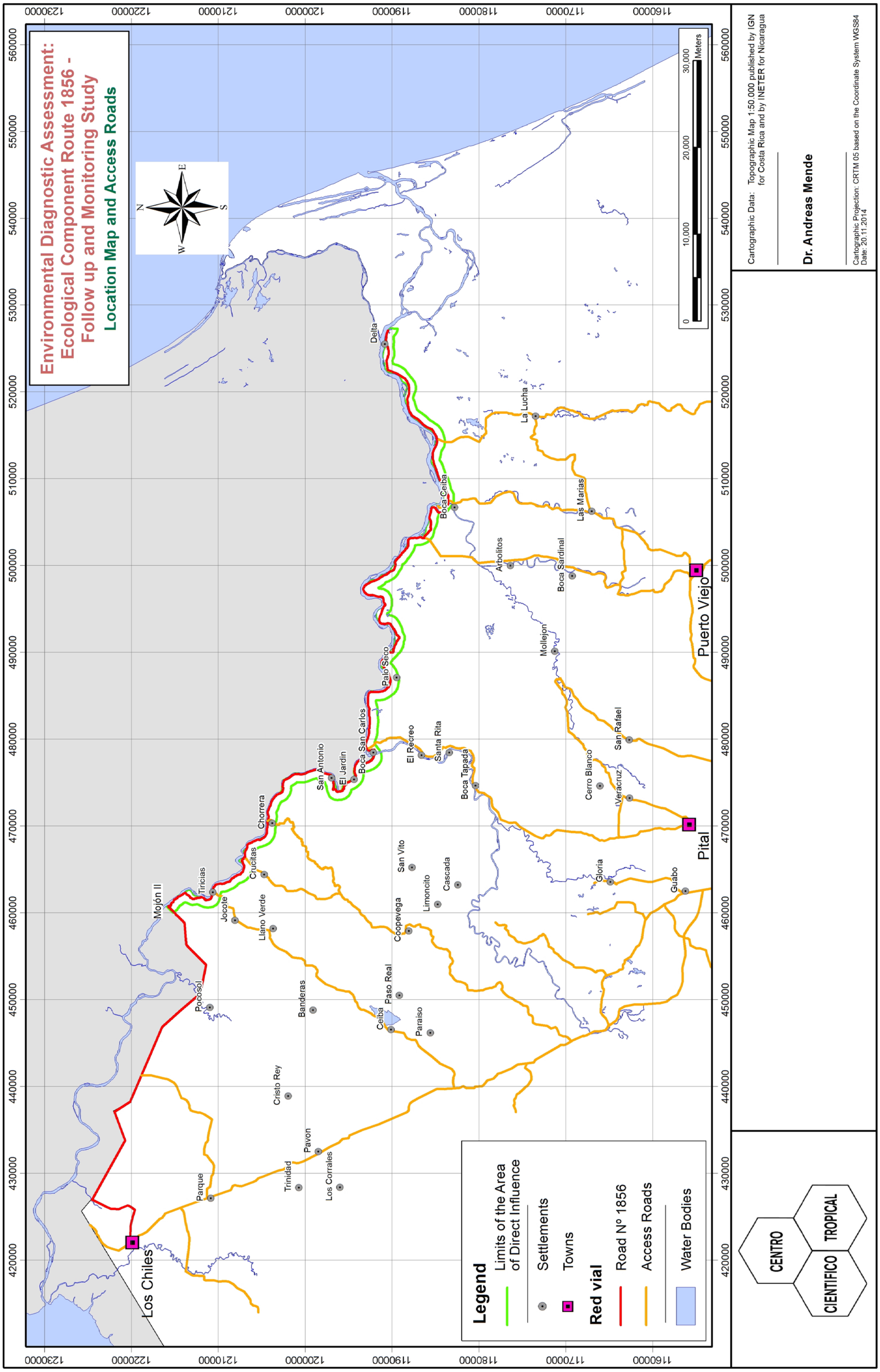
Heredia (Province 04): Sarapiquí County and the Cureña, Puerto Viejo and Llanura del Gaspar districts.

3.3 Area of the Follow-up Study and Impacted Areas

It was determined that the study area for the Follow-up Study would correspond exactly to the area assessed in the 2013 EDA. This area includes an important segment of tropical evergreen broad-leaf forest and swampy broad-leaf forest (World Bank and CCAD 2001; Vreugdenhill *et al.* 2002), with different degrees of human intervention evident, as well as different agriculture and livestock systems in place, in the Northern Caribbean watershed of Costa Rica. These ecosystems are characterised by perhumid forests, with dense tree cover, epiphytes and palm trees, and which have an average annual rainfall between 1500 and 3500 mm (Hartshorne 2002; Chassot *et al.* 2006a). The territorial framework of the study is determined by the conceptual reference known as the Water and Peace Biosphere Reserve (Moreno and Muller 2007) and the Biological Corridor San Juan-La Selva (Chassot *et al*. 2006a).

The study area covers part of the San Carlos and Sarapiquí counties, both of them demonstrating the largest extension of natural land cover on the northern Caribbean territory of Costa Rica. Such areas constitute a mosaic of lands in a natural state, some of which show signs of human intervention, and other areas of anthropic use that act as buffer zones for areas in a natural state (Chassot, 2010).

The terrestrial buffer zone includes landscaped areas that defend the protected wild lands from threats originating outside the protected areas and also include human communities that cause some types of direct impact on protected wild lands (Groom et al, 1999, Vilhena *et al.*, 2004).


Environmental Diagnostic Assessment: Ecological Component Route 1856 - Follow up and Monitoring Study
Location Map and Access Roads
Legend
Limits of the Area of Direct Influence
Settlements
Towns
Red vial
Road Nº 1856
Access Roads
Water Bodies
Los Chiles
Pital
Puerto Viejo
Delta
La Lucha
Boca Ceiba
Las Marias
Arbolitos
Boca Sardinal
Mollejon
Palo Seco
Boca San Carlos
San Rafael
El Recreo
Santa Rita
San Antonio
El Jardin
Boca Tapada
Cerro Blanco
Veracruz
Chorrera
San Vito
Cascada
Limoncito
Gloria
Guabo
Crucitas
Tiricias
Jocote
Mojón II
Llano Verde
Coopevega
Paso Real
Ceiba
Paraiso
Pocosol
Banderas
Cristo Rey
Pavon
Trinidad
Los Corrales
Parque
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10,000
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Cartographic Data: Topographic Map 1:50.000 published by IGN for Costa Rica and by INETER for Nicaragua
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 20.11.2014
CENTRO CIENTIFICO TROPICAL

Due to the physical and biological characteristics of the region of Route 1856, the ecological analyses contain terrestrial as well as aquatic components. Taking into account the influence of the road works conducted during the construction of the Route, as well as the national legislation on the matter, the Project Area (AP) has been identified as encompassing 50 metres inland of the Route.

On the other hand, the Direct Influence Area (DIA) has been defined as the first 1000 metres inland from the right margin of the San Juan River (see Map 1).

As it was determined in the initial EDA, the Indirect Influence Areas (AII) of the Follow-up Study has no uniform extension but is defined by the physical and biological conditions as estimated by each professional member of the team, and, where possible, the conditions of San Juan River were assessed, subject to the access limitations mentioned above.

4 The 2013 EDA

4.1 Description of activities assessed in EDA

The Route 1856 project consisted of the construction of a gravel road starting at the site known as San Jerónimo de Los Chiles and continuing to the site called Delta 7 (Delta Costa Rica). The road is 159.7 km. in length, with approximately 63.6% (101.5 km.) of the Route's extension made up of pre-existing roads and connections that have been used for over 30 years. The remaining 35.9% (57.4 km.) are new roads that were built to connect the existing pathways.

The EDA conducted in 2013 analysed that section of the Route that runs parallel to the San Juan River, which represents 108.2 km. of the total Route.

The main purpose of the Route was the consolidation of a new terrestrial pathway that would communicate all settlements located between Marker 2 and Delta Costa Rica. This project took advantage primarily of the network of existing roads that run parallel to the San Juan River and built a smaller percentage of new, short road sections required to provide continuity to the network.

The improvement of existing roads and the construction of new connecting pathways that allowed the network to be consolidated represented the development of several secondary actions. Land clearing and cleaning, establishment of retention slopes, placement of drains and water conduits, and laying the Route's base and rolling surface were the main works executed.

Table 4-1 shows the main and secondary components conducted during the construction of Route 1856, which were identified and analyzed in the EDA 2013.

Table 4-1 :Activities conducted during the Project´s construction stage.

Nº	Activity	Description
1	Clearing and cleaning of new sites	At specific sites along the right of way of the Route.
2	Land movement, retention slopes and land fills	In sections of the right of way where topography and the slope did not permit normal traffic. This was done with the use of heavy machinery (backhoes, heavy trucks, excavators, etc.)
3	Erosion control measures	Installation of systems to control the speed of superficial runoff and sediment control structures.
4	Installation of drainage systems and temporal bridges	Drainage systems and temporal bridges were placed on most rivers and ducts along the Route
5	Road filling, base layer and rolling surface	Commonly needed on any road to permit the transit of vehicles.

As described in the EDA, the following were the environmental components identified as associated with the activities conducted during the construction of Route1856:

1. Clearing and cleaning of land on sites of road design: this activity is related to the elimination of forest or plant cover along some sections of the Route where no roads were present.
2. Soil movements, building of retention slopes and fills: this activity could generate instability of slopes in some sites where the degree of slope is high. Likewise with the generation of increased surface runoff, placing of sediments close to bodies of water and the impact on the scenery in some sections of the Route.
3. Installation of drainage systems and temporary bridges: this activity could be associated to the affectation of aquatic ecosystems on isolated, specific points and the modification of natural drainage systems in the area.
4. Placement of landfills, sub-surface layers and rolling surface: this activity is associated with the possible laying of sediments in some bodies of water close to the Route.

4.2 Environmental impacts identified in the 2013 EDA

The following is a review of the environmental impacts initially identified in the 2013 EDA. These were organised according to the environmental factors affected.

4.2.1 Terrestrial flora and fauna

a. Logging in the Route´s path and adjacent areas

According to the evaluation of the plant cover along the length of the Route, the EDA had estimated that 14,9 hectares of secondary forest and 68,3 hectares of altered primary forest were cut down to clear the land where the design of the road was outlined; these correspond to 4,2% and 19,5% respectively of the area affected by the road design.

In addition, some 2,3 hectares of natural wetland systems had been altered. It was then determined that the Route was constructed mostly in open areas without forest cover (74%). In cases where trees were cut down, this occurred in areas where there were no open areas through which the path of the Route could pass.

b. Partial sedimentation of wetland edges near Route 1856

During field visits in 2013, it was observed that the majority of wetlands along the Route had not been affected by sedimentation, since most of them were located on plains or flat terrain where no significant soil movements occurred, with the exception of filling done on the road surface.

However, in two wetland sites that were located next to a hilly terrain, some sediment had been accumulating leading to a slight obstruction of sites near to the path of the natural drainage system of these wetlands. Even though no loss of tree or palm vegetation was observed it was possible that this loss was affecting ecosystems near the Route, with some alteration or natural substitution of native vegetation.

Besides, the lacustrine wetland Remolinito Grande was affected by the filling of the Route, although alteration of this site had been occurring for years prior to the Route construction; previous alterations included the substitution of aquatic vegetation with pasture and the building of a drainage system to allow the wetland to be used for cattle grazing. Specific, one-off impacts were located in the section between the mouths of the San Carlos and Sarapiqui rivers.

c. Elimination of trees and shrubs on river banks due to flooding

In the section between Border Marker 2 and the Infiernito River there were some sites with small streams that during rainy season in 2013 showed an accumulation of water, forming small reservoirs on the riparian vegetation. This was a consequence of the collapse of culverts or drainage tubes that were initially placed, causing the flooding of ecosystems an area estimated at 100 to 200 square metres per site. This flooding led to the loss of vegetation according to what was observed in 2013.

d. Landslides and slope erosion that affected the forest edge along the Route

At the site of land cuts adjacent to the Route, and where there was forest vegetation on the margins of the cut, laminar erosion of the ground of such cuts was observed, which generally caused the small trees (also two large trees were observed) to be uprooted due to the displacement of soil in their radicular system, which caused them to fall onto the Route.

In similar way, but to a lesser extent, landslides were observed to have occurred at several sites with steep slopes on the side of the Route, carrying with them the edges of the adjacent forest, including some small and large trees that had fallen and obstructed the Route. Field observations in 2013 determined that this was accentuated by the surface runoff which took place above the slopes.

This phenomena generally occurred at the sites with steeper slopes, which were also often covered by forest, causing damage to the vegetation on slopes that run down past the Route. This impact was located at specific points mostly between the sector close to the Infiernito River and the sector known as Chorreras. This alteration occurred after the opening of the Route and could may reoccur as it generally does in these topographic settings and with soil types that are susceptible to erosion.

e. Alteration of the wetland ecosystem (due to drainage and landfills)

This corresponded to alterations caused to wetlands by drainage and construction of artificial landfills in small areas along the path of the Route. This impact was very specific, located at certain very limited points along the Route.

In the case of Yolillo palm patches, the ecosystem had presented a loss of 0.7 hectares due to drainage, burning or the construction of artificial landfills. As indicated in the 2013 EDA, the "Yolillal" is difficult to recover through reforestation and the only alternative was natural regeneration. In terms of landscape, the impact was minimal and localised.

f. Impact on structural connectivity

Loss of structural connectivity had been identified as a result of the elimination of forest cover in forests along some sections of the Route.

The identification of connectivity routes and important connectivity areas along the landscape of the study area demonstrated that these are not related to the Route, despite the fact that the Route is located in the area of greatest forest cover in the study area. Given the reduced extension of natural ecosystems impacted (83.2 hectares), it was determined that the Route had not generated a significant impact on the structural connectivity of the landscape studied.

4.2.2 Aquatic flora and fauna

g. Potential alteration of the aquatic habitat

Possible alterations of the aquatic habitat were identified as a consequence of the drainage system and the laying of cement structures where gutters and drains were located. This could have affected some of the aquatic organisms by homogenization of the substratum at a local level in sites where the Route cuts across the bodies of water, affecting the re-colonization of the aquatic ecosystem by macro-invertebrates given that these organisms prefer heterogeneous substrata (Williams and Felmate 1992).

h. Potential alteration of the micro-habitats and substrata of the aquatic macro-invertebrates due to filling of interstices with sediments

Some sedimentary material in the water and the decrease in the contribution of vegetal matter to the aquatic means, along with decrease in shade, could have caused the filling in of cavities and modification of the substratum where aquatic macro-invertebrates normally live.

i. Potential alteration of taxonomic abundance and richness

Similarly to the previous impact, taxonomic richness could have been diminished by sediments in the water, a decrease in vegetal matter in the aquatic environment, and a decrease in shade.

j. Potential alteration of water quality due to turbidity

The contribution of sediments on the stream of water could have affected the water quality due to the turbidity in some rivers as a consequence of the construction works of the Route.

4.2.3 Landscape

k. Landscape Alteration due to construction works

The exposed surfaces of slopes and road cuts at some specific sites along the tracing of the Route, contrasted with the forest, pastures and dominant farming field landscapes. These visible points were located mainly along Marker 2 and the vicinity of the mouth of the San Carlos River.

5 ENVIRONMENTAL CONDITIONS OF ROUTE 1856 IN 2014

5.1 Update of environmental impacts according to 2014 field observations

The following is an update of the impacts identified and described in the 2013 EDA. This update considers the current conditions of Route 1856 assessed during the months of August to November 2014.

It was further supplemented with observations and field surveys made by the team that conducted this Follow-Up Study, as well as lab analyses and bibliographic revision.

5.2 Environmental impacts updated to observed conditions in 2014

5.2.1 Terrestrial flora and fauna

a. Logging in the Route's path and adjacent areas

Logging was performed only for clearing a path for some sections of Route 1856. The cutting of more trees has not been necessary. This situation was verified during field visits in 2014, during which no extensions of the existing path of the Route or further tree cutting was identified.

Many of these areas where tree cutting was necessary exhibit a successful natural recovery process and are also included in the reforestation program implemented by CODEFORSA, which has planted more than 50,000 trees in an area of over 51 ha.

b. Partial sedimentation of wetlands edges near Route 1856

The impact was not observed during the current Follow-up Study due to the works for the improvement in natural conditions of drainages that were partially affected by the Route. Specifically, the lacustrine wetland Remolinito Grande located in the sector between Boca San Carlos and Boca Sarapiqui exhibited a natural, undisturbed condition.

c. Removal of trees and shrubs located on river banks due to flooding

The action that caused this impact was corrected in full, notably by improving the natural conditions of drains in the area. Adequate placement of culverts and heads have prevented the formation of reservoirs that could affect surrounding riparian vegetation.

d. Landslides and slope erosion affecting the forest edge along the road

Slope stabilization works developed in the last 10 months by CONAVI have been notably effective as unstable slopes are not observed. In addition, the reforestation works by CODEFORSA through the planting of trees and vetiver grass that favour soil consolidation have been effective and noticeable along Route 1856. The improvement in the physical conditions of slopes is evidence of the success of the works implemented, which also help avoid falling trees on its banks. Another factor influencing the improved condition is the channelling of surface runoff water, which promotes proper rainwater drain and its uptake in systems that prevent sediment flow into streams and rivers nearby.

e. Alteration of the wetland ecosystem (due to drainage and landfills)

The 2013 EDA identified a loss of approximately 0.7 ha of yolillal wetland due to drainage and construction of artificial landfills in small areas along the Route. This impact was identified at specific locations and not generalized. During field visits in 2014, no further alteration of such areas was identified. Although the affected area remains the same in extension, drains were improved to allow yolillal areas to return to its original condition by natural regeneration.

f. Impact of structural connectivity

As described in the 2013 EDA, landscape connectivity routes and important connectivity areas are not linked to the Route project. The extension of natural ecosystems altered as a consequence of the construction of the Route is considered reduced at the landscape level (83.2 ha), for which reason the impact on structural connectivity is not a significant impact.

5.2.2 Aquatic flora and fauna

g. Potential alteration of the aquatic habitat

As for 2013, there is a possibility of some alteration as a consequence of the drainage systems etc. Significant improvements in the existing culverts were observed such as re-adequacy of drainages and placement of sediment traps. Such improvements could have a positive impact on the aquatic habitat and biodiversity and so reducing the possibility of the affected conditions to occur.

h. Potential alteration of the micro-habitats and substrata of the aquatic macro-invertebrates due to filling of interstices with sediments

The conditions observed in 2014 were very similar to those in 2013. Mitigation works conducted to avoid sediment flow into streams and rivers and recovery of forest cover have been significant and successful.

i. Potential alteration of taxonomic abundance and richness

Current conditions remain very similar to those identified in 2013. However, the mitigation works focused on preventing sediment input to the streams have been successful, which could be expected to improve taxa abundance and richness conditions.

j. Potential alteration of water quality due to turbidity

Improvements in the conditions of slopes and infrastructure related to sediment containment are excellent. Most slopes are being protected with geo-textiles and reforestation techniques that have been successful, which directly effects the reduction of sediment contribution to water bodies.

5.2.3 Landscape

k. Landscape affected by the works

The current conditions remain similar to those identified in 2013. However, the mitigation work focused on the recovery of vegetation cover has been significant and successful by CODEFORSA. For obvious reasons, the reforestation process will require at least 4 or 5 years.

5.3 Description of Environmental Characteristics

5.3.1 Terrestrial Environment

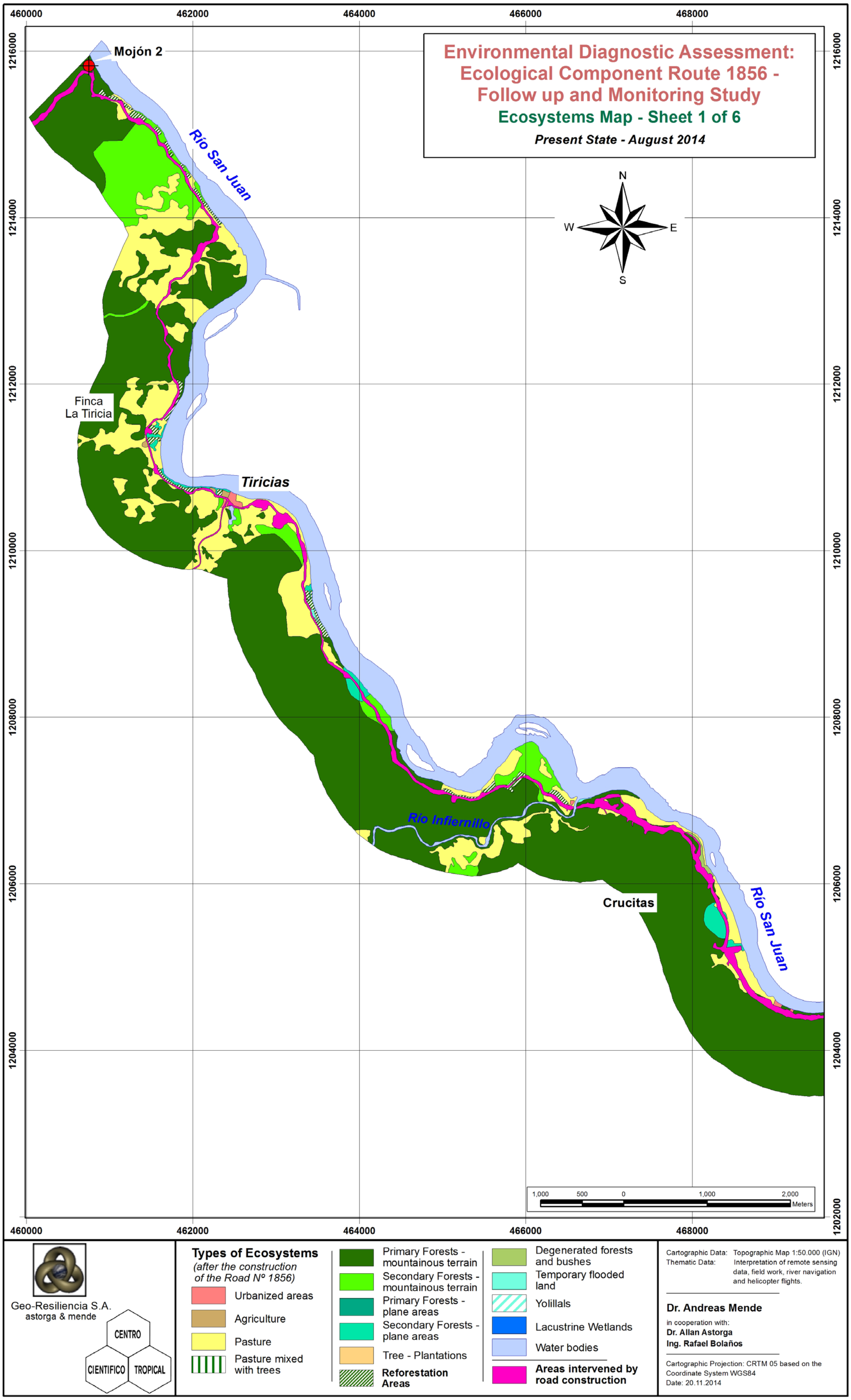
The area adjacent to the San Juan River, on its right margin, has been a territory known for its intermittent migratory and colonization processes. Until 1950, the dominant land use in the current Route area was subsistence agriculture or domestic use. Weak agricultural production was meant local inhabitants also relied on fishing and hunting. Poor soil quality have frustrated attempts to develop land productivity. The few successful agricultural products require the use of large quantities of fertilisers (general chemical fertilisers) that have proven to pose a high risk for the health of the workers who apply them, consequently such agriculture has proven to be a less than profitable alternative (Chassot and Monge, 2002).

Currently, the main productive activities in the area are cattle-raising and pineapple production, both of them extensively practised. The latter creates erosion problems due to the production method. Other activities are the growing of basic grains, tubers, palm and citrus. During the last two decades, large cattle farms have begun to change into extensive monoculture plantations of exotic species (mainly *Melina* and *Teca* trees).

All activities and events mentioned previously have occurred within the National Wildlife Refuge Border Corridor through the years. Families living within the area for over 40 years have worked the land according to their proprietary rights (Chassot *et al*. 2006)

During the Follow-up Study surveys of the area were carried out, and more fauna has been observed. However, this could be due to the season during which the visits were conducted. In order to assess the state of wildlife populations, it is necessary to conduct more extensive monitoring of the region.

There has been significant progress in the reforestation program along Route 1856. Areas clearly in the process of regeneration were identified. The following are the updated versions of ecosystem maps provided in the 2013 EDA (see Map 2 through Map 7). Reforestation areas have been delimited on these maps, mainly areas where more than 50,000 trees native to the area have been planted. These efforts cover a total area of 51 ha.


Environmental Diagnostic Assessment:
Ecological Component Route 1856 -
Follow up and Monitoring Study
Ecosystems Map - Sheet 1 of 6
Present State - August 2014
Mojón 2
Río San Juan
Finca
La Tiricia
Tiricias
Río Infiernillo
Crucitas
Río San Juan
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468000
1216000
1214000
1212000
1210000
1208000
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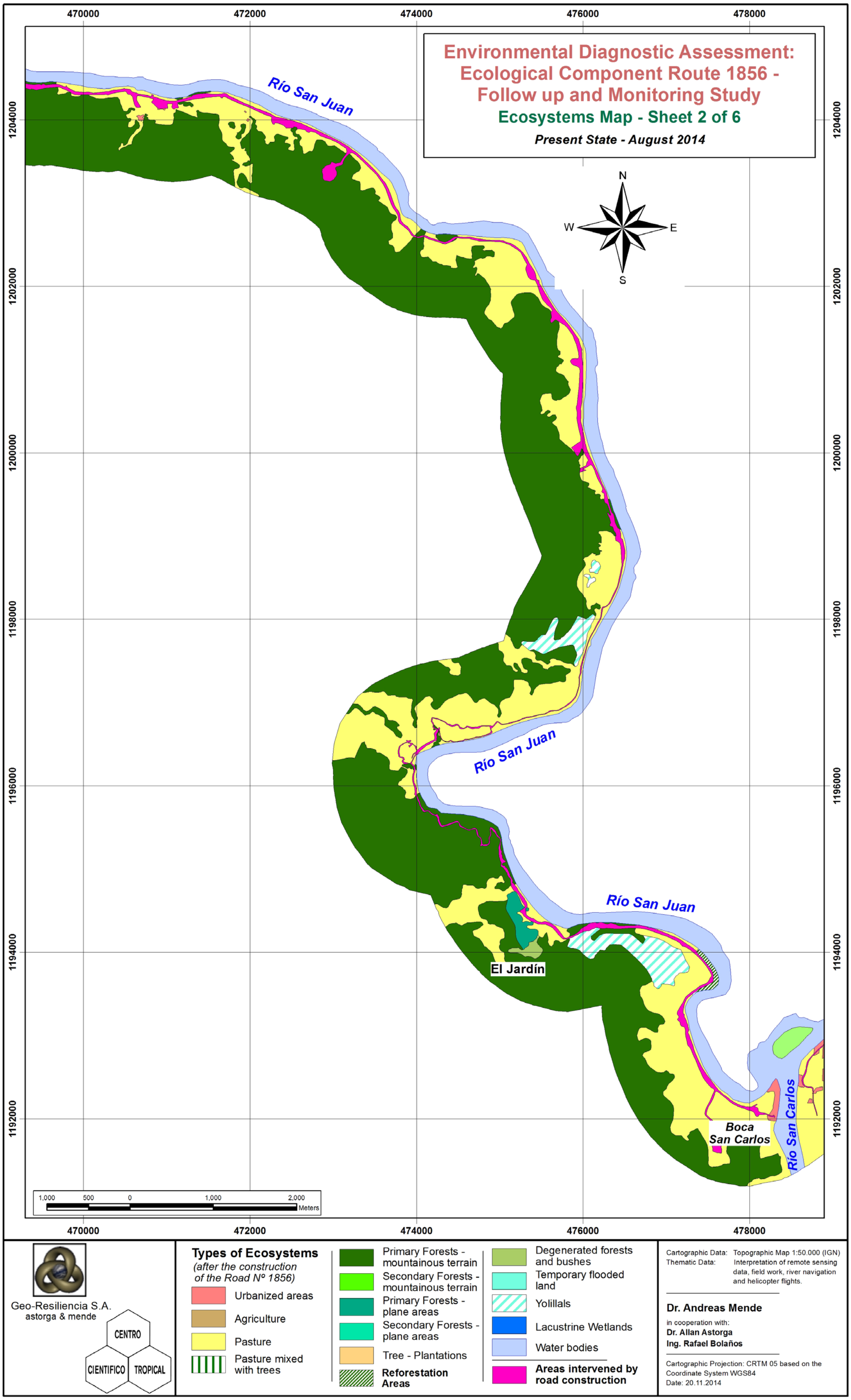
2,000
Meters
Geo-Resiliencia S.A.
astorga & mende
CENTRO
CIENTIFICO
TROPICAL
Types of Ecosystems
(after the construction
of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed
with trees
Primary Forests -
mountainous terrain
Secondary Forests -
mountainous terrain
Primary Forests -
plane areas
Secondary Forests -
plane areas
Tree - Plantations
Reforestation
Areas
Degenerated forests
and bushes
Temporary flooded
land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by
road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 20.11.2014



Environmental Diagnostic Assessment:
Ecological Component Route 1856 -
Follow up and Monitoring Study
Ecosystems Map - Sheet 2 of 6
Present State - August 2014
470000
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Río San Juan
Río San Carlos
El Jardín
Boca
San Carlos
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Meters
Geo-Resiliencia S.A.
astorga & mende
CENTRO
CIENTIFICO
TROPICAL
Types of Ecosystems
(after the construction
of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed
with trees
Primary Forests -
mountainous terrain
Secondary Forests -
mountainous terrain
Primary Forests -
plane areas
Secondary Forests -
plane areas
Tree - Plantations
Reforestation
Areas
Degenerated forests
and bushes
Temporary flooded
land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by
road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing
data, field work, river navigation
and helicopter flights.
Dr. Andreas Mende
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Dr. Allan Astorga
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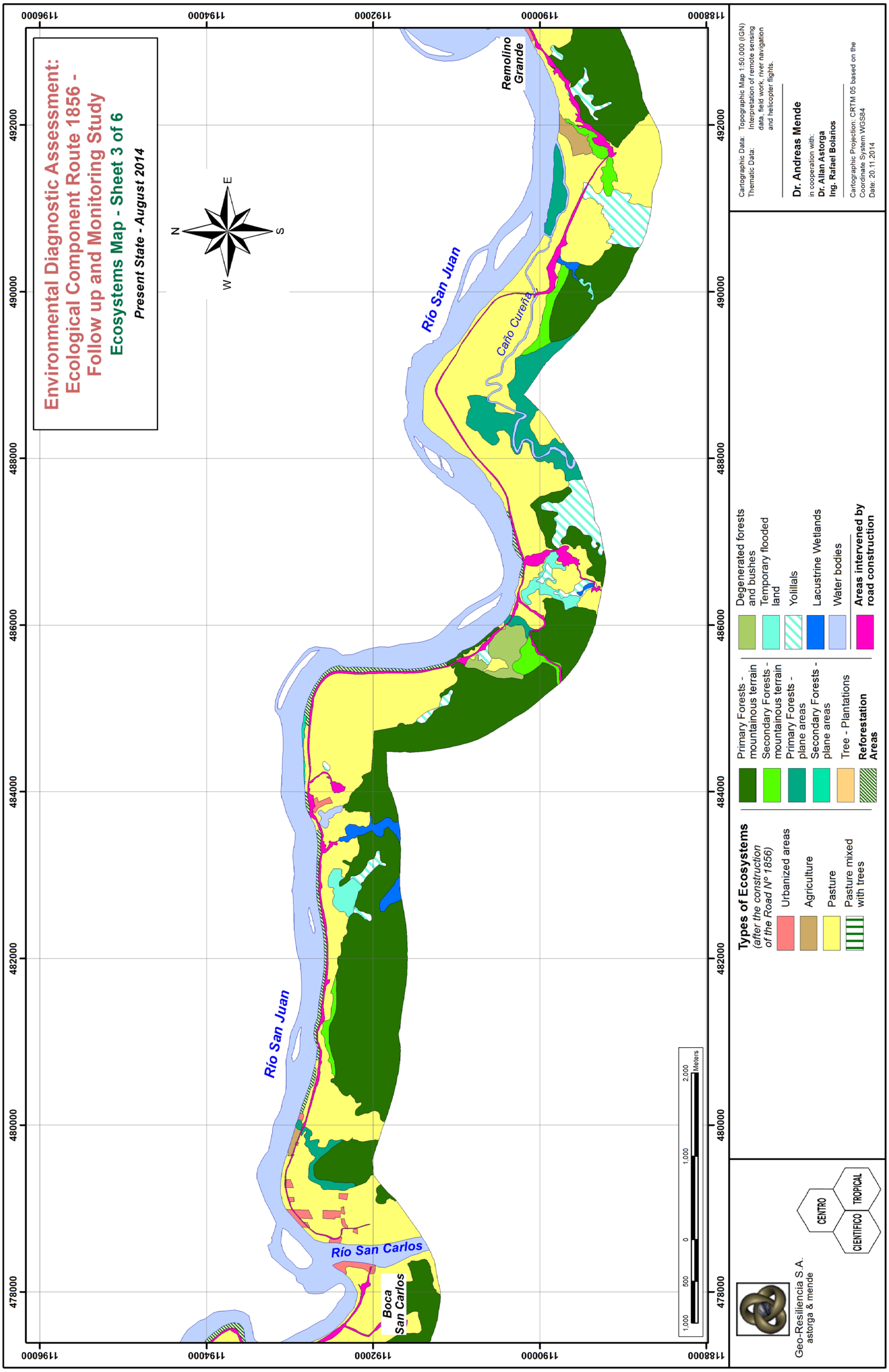
Cartographic Projection: CRTM 05 based on the
Coordinate System WGS84
Date: 20.11.2014


Environmental Diagnostic Assessment: Ecological Component Route 1856 - Follow up and Monitoring Study
Ecosystems Map - Sheet 3 of 6
Present State - August 2014
N
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Río San Juan
Río San Juan
Río San Carlos
Boca San Carlos
Remolino Grande
Caño Cureña
Types of Ecosystems
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Reforestation Areas
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 20.11.2014
Geo-Resiliencia S.A.
astorga & mende
CENTRO CIENTIFICO TROPICAL
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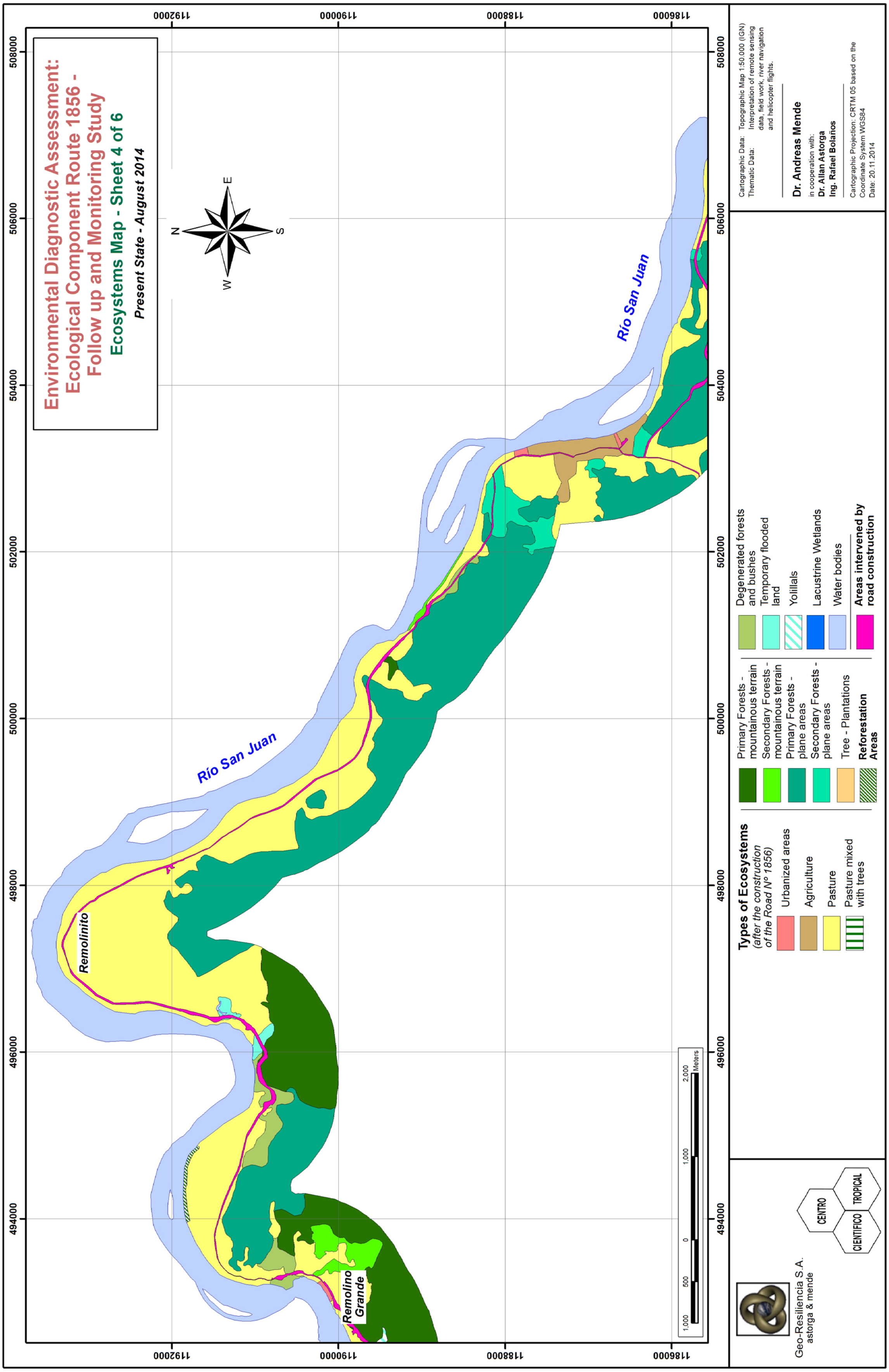
Environmental Diagnostic Assessment: Ecological Component Route 1856 - Follow up and Monitoring Study
Ecosystems Map - Sheet 4 of 6
Present State - August 2014
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Río San Juan
Remolinito
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Types of Ecosystems
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Reforestation Areas
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Geo-Resiliencia S.A.
astorga & mende
CENTRO CIENTIFICO TROPICAL
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
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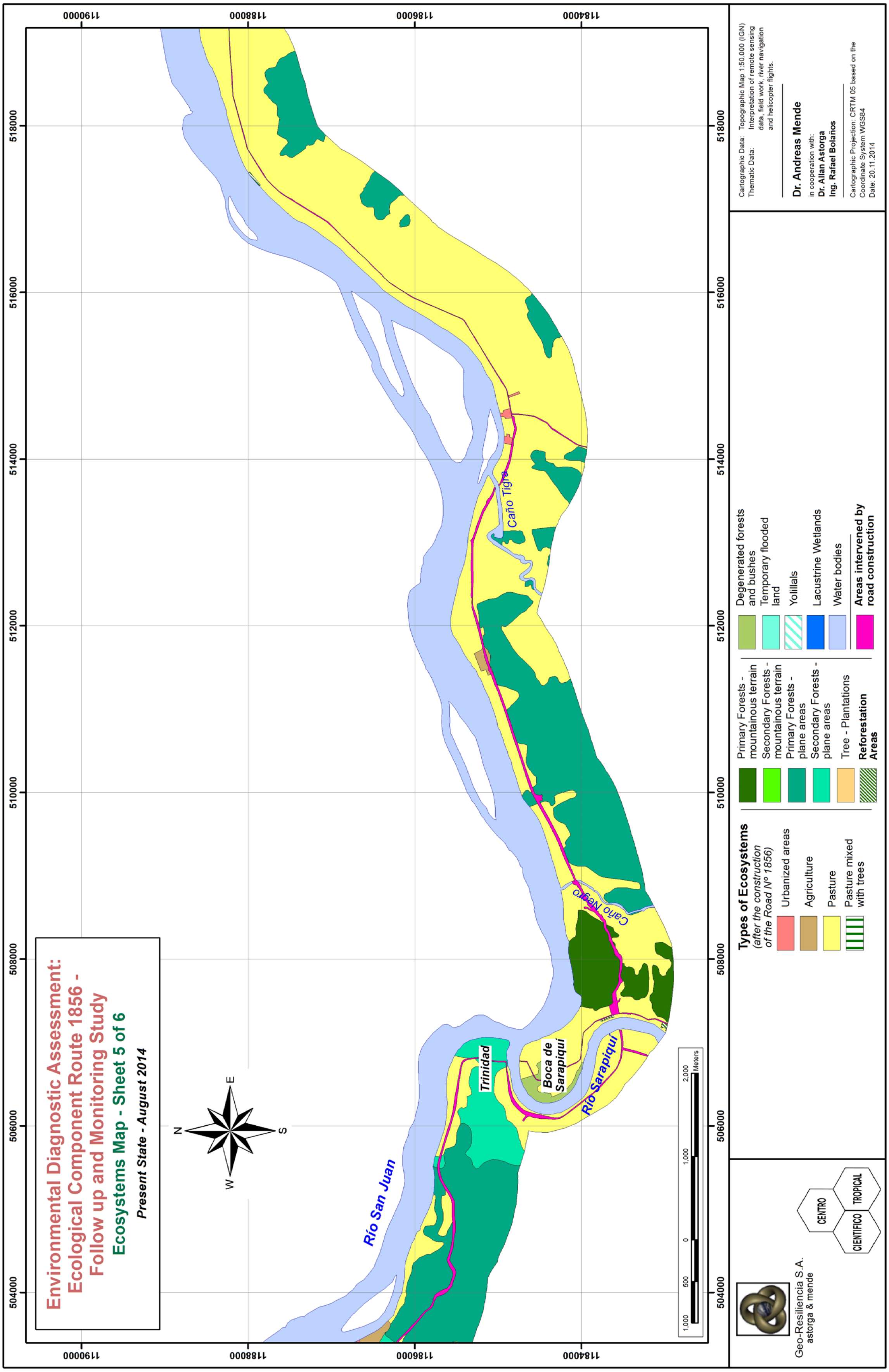
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 20.11.2014


Environmental Diagnostic Assessment:
Ecological Component Route 1856 -
Follow up and Monitoring Study
Ecosystems Map - Sheet 5 of 6
Present State - August 2014
N
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Río San Juan
Trinidad
Boca de Sarapiquí
Río Sarapiquí
Caño Negro
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Types of Ecosystems
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Reforestation Areas
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 20.11.2014
Geo-Resiliencia S.A.
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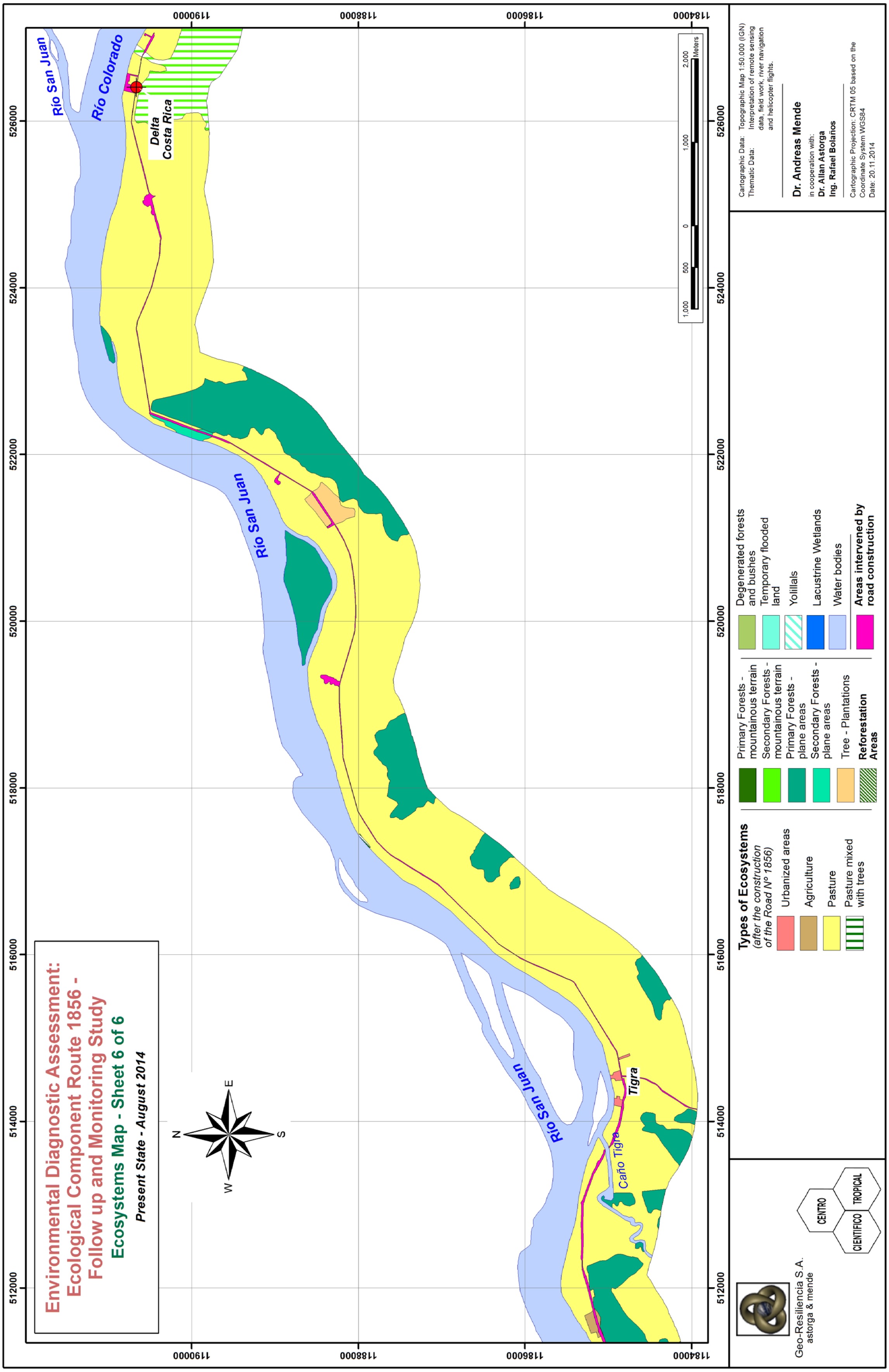
Environmental Diagnostic Assessment:
Ecological Component Route 1856 -
Follow up and Monitoring Study
Ecosystems Map - Sheet 6 of 6
Present State - August 2014
N
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Río Colorado
Delta Costa Rica
Río San Juan
Río San Juan
Tigra
Caño Tigra
Types of Ecosystems
(after the construction of the Road N° 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Reforestation Areas
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Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
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Date: 20.11.2014
Geo-Resiliencia S.A.
astorga & mende
CENTRO CIENTIFICO TROPICAL
1,000 500 0 1,000 2,000 Meters
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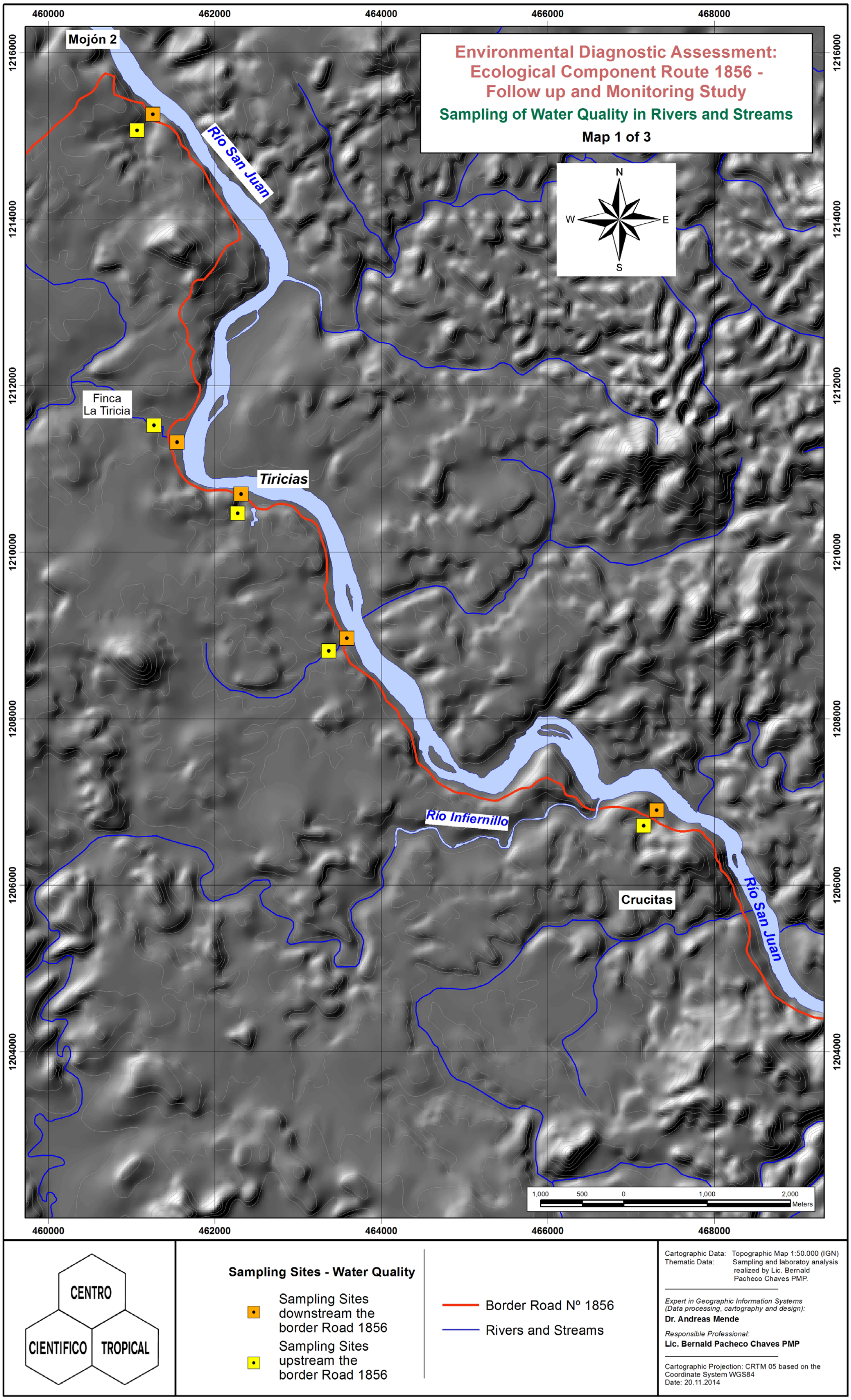
5.3.2 Aquatic Environment

5.3.2.1 Sampling Sites

In addition to the sampling of macro-invertebrates in various bodies of water in the area of the Route, the area was visually surveyed by foot and in vehicle along the length of the Route with a particular focus on bodies of water.

The sampling sites correspond to those where the EDA 2013 was performed. The sampling in those sites was repeated in order to conduct a comparison of results obtained in 2013 with those of 2014.

In total, 10 bodies of water that are traversed by Route 1856 were sampled (see Map 8) both downstream from the Route (above, direct influence site) as well as upstream (below, "white" site, without direct influence), This allowed analysis of any potential effect of the construction works of the project on the aquatic ecosystem. The characteristics of the sample sites at the moment of sampling are described in Table 5.1.


Environmental Diagnostic Assessment: Ecological Component Route 1856 - Follow up and Monitoring Study
Sampling of Water Quality in Rivers and Streams
Map 1 of 3
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Finca La Tiricia
Tiricias
Río Infiernillo
Crucitas
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CENTRO
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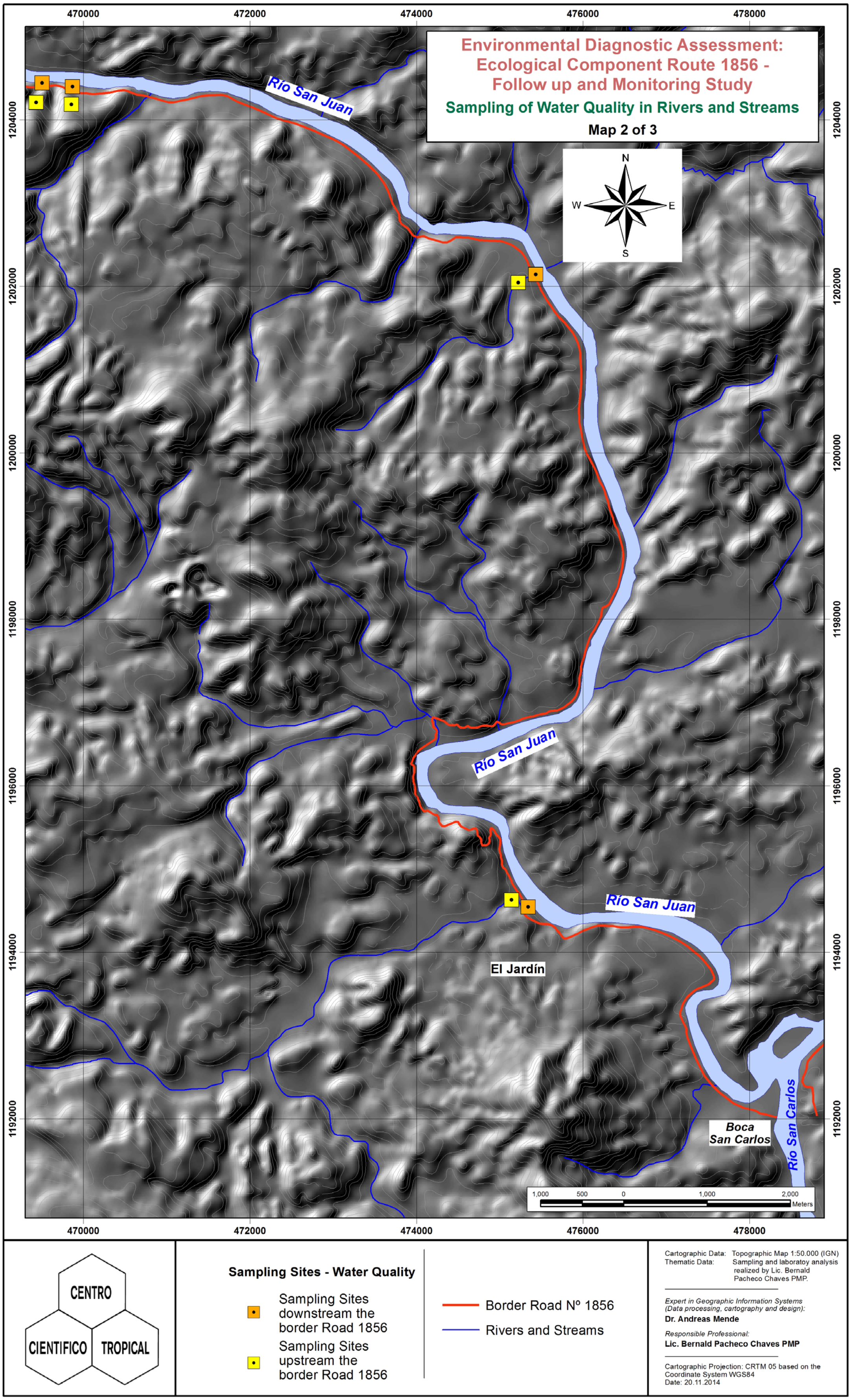
Sampling Sites - Water Quality
Sampling Sites downstream the border Road 1856
Sampling Sites upstream the border Road 1856
Border Road Nº 1856
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Sampling and laboratoy analysis realized by Lic. Bernald Pacheco Chaves PMP.
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 20.11.2014


Environmental Diagnostic Assessment:
Ecological Component Route 1856 -
Follow up and Monitoring Study
Sampling of Water Quality in Rivers and Streams
Map 2 of 3
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Río San Juan
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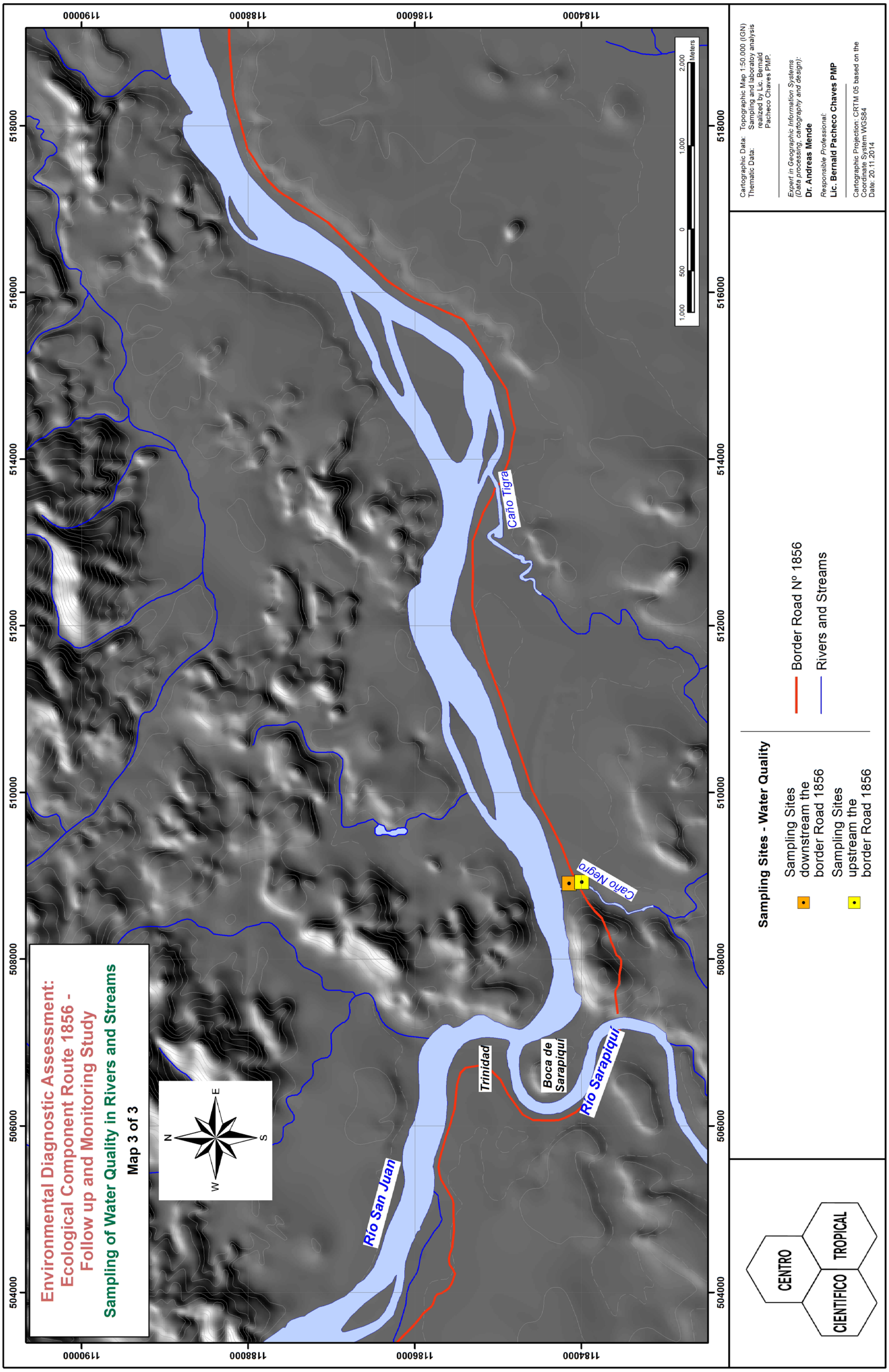
TROPICAL
Sampling Sites - Water Quality
Sampling Sites downstream the border Road 1856
Sampling Sites upstream the border Road 1856
Border Road Nº 1856
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Sampling and laboratoy analysis realized by Lic. Bernald Pacheco Chaves PMP.
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 20.11.2014



Environmental Diagnostic Assessment:
Ecological Component Route 1856 -
Follow up and Monitoring Study
Sampling of Water Quality in Rivers and Streams
Map 3 of 3
Río San Juan
Trinidad
Boca de Sarapiquí
Río Sarapiquí
Caño Negro
Caño Tigra
Sampling Sites - Water Quality
Sampling Sites downstream the border Road 1856
Sampling Sites upstream the border Road 1856
Border Road Nº 1856
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Sampling and laboratoy analysis realized by Lic. Bernald Pacheco Chaves PMP.
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 20.11.2014
CENTRO CIENTIFICO TROPICAL

Table 5-1: Description of Sampling Sites and Points along Route 1856 (2014).

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
1	Above		10,98939°N, -84,35498°O, 35 msnm	A: 2,5 m P: 0,5 m	Moderate	Mud, clay	100% exposure	Presence of fish, leaves, submerged roots. Transparent water color Bushes and pasture on both sides. with flooded pastures. Clouded.
	Below		10,99007°N, -84,35464°O, 36 msnm	A: 3 m P: 0,5 m	Slow	Mud	Large open spaces	Presence of fish, leaves, submerged roots. Transparent water color Bushes and pasture on both sides, with flooded pastures. Clouded.

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
2 Caño Trinidad	Above		10,95466°N, -84,35317°O, 29 msnm	A: 30 m P: >1 m	Moderate	Clay	Large clearings	Presence of fish, leaves, submerged roots. Transparent water color With flooded pastures. Pastures and trees on both sides Clouded.
	Below		10,95486°N, -84,35281°O, 40 msnm	A: 25 m P: >1 m	Moderate	Clay	100% Exposed	Presence of fish, leaves, submerged roots. Transparent water color Bushes and pasture on both sides, with flooded pastures. Clouded.

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
3	Above		10,94813°N, -84,34488°O, 32 msnm	A: 1,5 m P: 0,25 m	Fast Moderate	Clay and mud	100% Exposed	Presence of fish, leaves, submerged roots. Transparent water color Pasture on both sides, with flooded pastures. Clouded.
	Below		10,94830°N, -84,34493°O, 31 msnm	A: 2 m P: 0,25 m	Fast Moderate	Rounded rock, Stone and clay	100% Exposed	Presence of fish, leaves, submerged roots. Transparent water color Pasture on both sides, with flooded pastures. Clouded.

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
4	Above		10,93293°N, -84,33364°O, 26 msnm	A: 3 m P: 0,5 m	Moderate Slow	Mud	Shade with windows	Presence of fish, leaves, submerged roots. Transparent water color Forest on both sides, with flooded pastures. Clouded.
	Below		10,93294°N, -84,33337°O, 33 msnm	A: 3 m P: 0,5 m	Slow-stagnant	Rounded rocks, stones, clay, mud,	Shade with windows	Presence of fish. Cloudy waters. Sediment on rocks. Secondary growth and pasture lands on both sides Sunny.

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
5	Above		10,91335°N, -84,29953°O, 31 msnm	A: 2m P: 0,15m	Fast Moderate	Stone and mud	Shade with windows	Presence of fish, leaves, trunks and branches, submerged branches and roots. Forests on both sides. Cloudy.
	Below		10,91358°N, -84,29939°O, 29 msnm	A: 1 m P: 0,15 m	Fast	Rounded rocks, stones and mud	100% exposed	Presence of fish, leaves, submerged roots. Transparent water color Flooded pastures and bushy vegetation on both sides. Clouded.

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
6	Above		10,89144°N, -84,27994°O, 17 msnm	A: 1,5 m P: 0,20 m	Fast	Rounded rocks, stones and mud	Shade with windows	Presence of fish, leaves, submerged roots. Clean rock surfaces. Transparent water color Forests on both sides. Clouded.
	Below		10,89238°N, -84,27893°O, 22 msnm	A: 1 m P: 0,15 m	Fast	Rounded rocks, stones and mud	Shade with windows	Presence of leaves and trunks, submerged branches. Sediment on rock surfaces. Transparent water. Secondary growth on both sides. Clouded.

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
7	Above	 	10,89171°N, -84,27746°O, 55 msnm	A: 1 m P: 0,10 m	Fast	Rounded rocks, stones and mud	Shade with windows	Presence of leaves, submerged trunks and branches. Transparent water color. Clean rock surfaces. Forests on both sides. Clouded.
	Below	 	10,89233°N, -84,,27780°O, 30 msnm	A: 1 m P: 0,20 m	Fast	Rounded rocks, stones and mud	Large clearings	Presence of fish, leaves, submerged roots. Transparent water color With flooded pastures. Pasture and bushes on both sides Clouded.

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
8	Above		10,87121°N, -84,22561°O, 30 msnm	A: 15 m P: > 1 m	Slow	Mud	100% Exposed	Presence of fish, leaves, submerged roots. Turbid water Pasture on both sides, with flooded pastures. Sunny.
	Below		10,87136°N, -84,22531°O, 35 msnm	A: 10 m P: > 1 m	Slow	Mud	100% Exposed	Presence of fish, leaves, submerged roots. Turbid water Pasture on both sides, with flooded pastures. Sunny.

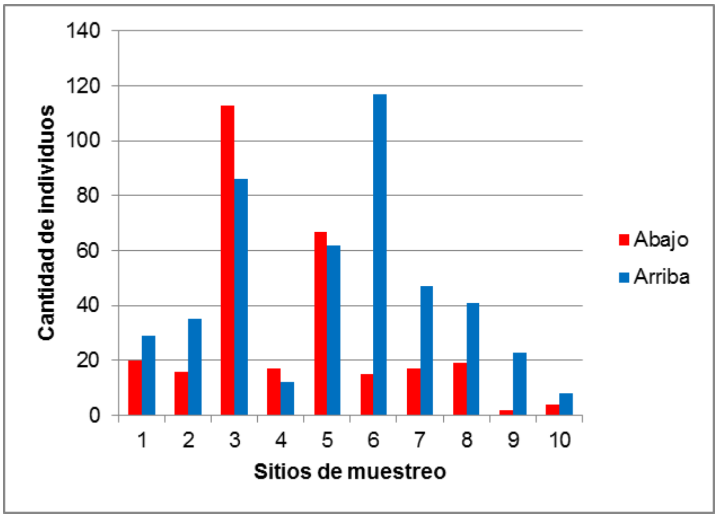
Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
9	Above		10,80299°N, -84,22599°O, 31 msnm	A: 4 m P: 0,5 m	Fast Moderate	Mud	Shade with windows	Presence of fish. Leaves, branches and roots submerged. Transparent water color Forests on both sides Clouded.
	Below		10,80269°N, -84,22574°O, 27 msnm	A: 3 m P: > 1 m	Slow	Mud	Shade with windows	Presence of fish, leaves, submerged roots. Turbid water Pasture on both sides, with flooded pastures. Sunny.

Site	Location	Photographs	Coordinates/Altitude	Width/Depth	Speed	Substrate	Sun Exposure	Observations
10 Río Marías	Above		10,70774°N, -83,91811°O, 26 msnm	A: 20 m P: > 1 m	Moderate Slow	Mud	Large clearings	Presence of fish, leaves, submerged roots. Turbid water Flooded pastures. Trees and pastures on both sides. Clouded
	Below		10,70854°N, -83,91824°O, 36 msnm	A: 25 m P: > 1 m	Moderate Slow	Mud	Shade with windows	Presence of fish, leaves, submerged roots. Turbid water Pasture on both sides, with flooded pastures. Sunny.

In 2014, macro-invertebrates sampling in the field resulted in a total of 751 individuals collected, distributed among 17 orders, 48 families, and at least 80 taxa (see Annex 9-1). Sampling of 2013, on the other hand, offered greater abundance with 957 individuals, distributed among 21 orders, 58 families, but with 73 taxa, a lesser number than found in 2014 (see Annex 9-4).

When observing abundance among the sampling sites, there seems to be a tendency for greater abundance and richness of taxa in the sites above Route 1856, with 7 sites that present greater abundance as well as greater richness in the point above as compared to the point below (see Map 8). The 2013 sampling showed a more balanced tendency with 5 sites that presented greater abundance in the point above the Route, and 5 sites that present greater abundance in the site below the Route; in the case of richness of taxa in the same year, there were 6 sites with greater richness in the point above, and 4 sites with greater richness at the point below. Such changes have occurred at the micro level, and are a temporary response to changes in the environment. We do not consider them as a pointer towards long term significant impacts. (see Graphs 1, 2, 3, and 4).

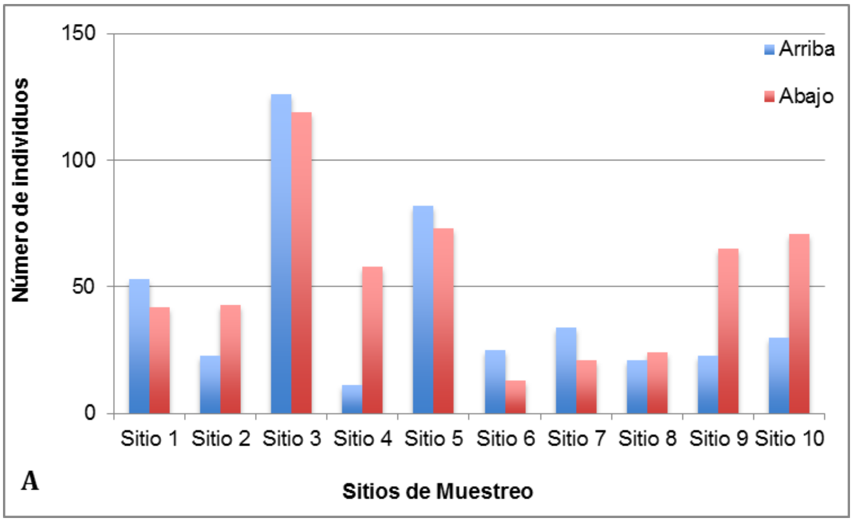
Graph 1: Abundance of Macro-Invertebrates at Sampling Sites along Route 1856 (2014).



Cantidad de individuos = number of individuals
Sitios de muestreo = sampling sites

Abajo = Below, downstream
Arriba = Above, upstream

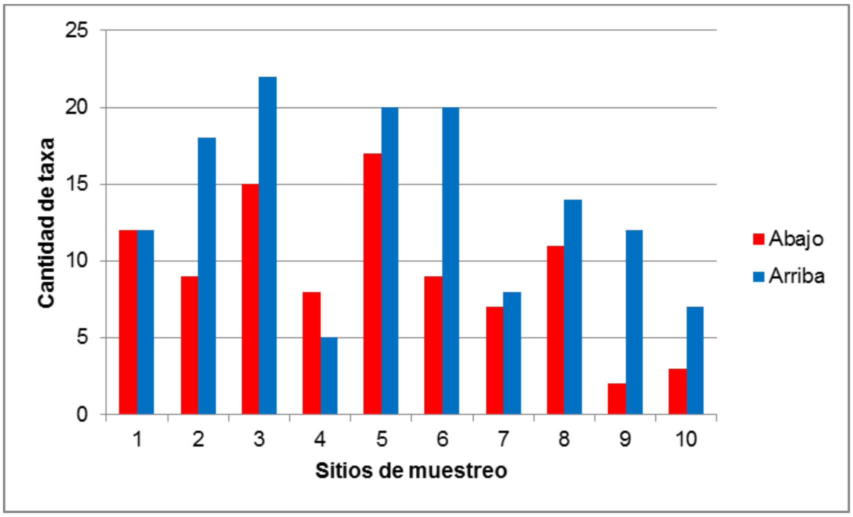
Graph 2: Abundance of Macro-Invertebrates at Sampling Sites along Route 1856 (2013).



Cantidad de individuos = number of individuals
Sitios de muestreo = sampling sites
Sitio = Site

Abajo = Below, downstream
Arriba = Above, upstream

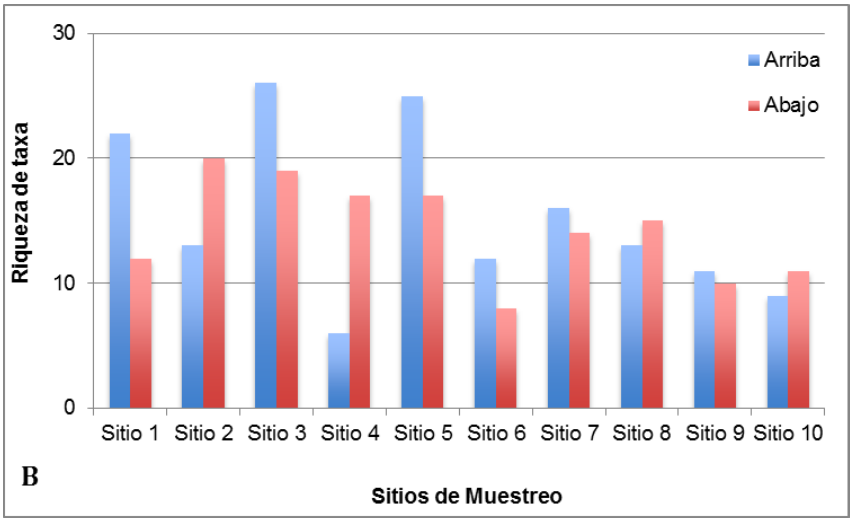
Graph 3: Richness of Macro-Invertebrates at Sampling Sites along Route 1856 (2014).



Cantidad de taxa = number of taxa
Sitios de muestreo = sampling sites

Abajo = Below, downstream
Arriba = Above, upstream

Graph 4: Richness of Macro-Invertebrates at Sampling Sites along Route 1856 (2013).



Riqueza de taxa = Richness of taxa
Sitios de muestreo = sampling sites
Sitio = Site

Abajo = Below, downstream
Arriba = Above, upstream

A general view of the results of the Shannon diversity index for the 2014 sampling does not offer a very clear trend, with 4 sites showing greater diversity values at the downstream site and 6 sites presenting greater diversity at the upstream site. Regarding the dominance index, it was found to be greater at the upstream point in 5 of the sampled sites, and greater at the downstream site of the Route in 5 sampled sites; and the equity index was greater for the sites below the Route at 7 of the sampled sites, and greater at upstream sites in 3 of the sampled sites (see Annex 9-2).

In 2013 the diversity index was greater for the upstream points in 5 sites, and smaller in 5 sites, while the dominance index was greater for the points upstream at 5 sites and less in the other 5 sites; and finally the equity index was greater for the points upstream at 7 sites and 2 were equal, and one was smaller (see Annex 9-2).

These indexes generally do not present a clear tendency but are divided between both points of the sampled sites (upstream and downstream), for both sampling dates (2013-14), with the exception of the equity index, which seems to show a tendency towards greater equity at the downstream points for both sampling years.

For the present sampling, the quality of water according to the BMWP-CR index led to classifications of very poor to regular quality, with the majority of sites obtaining very poor to poor quality. Regarding the effect of Route 1856 on the aquatic habitat, it has been possible to observe that in 7 of 10 sampled sites, the quality was lower at points with direct influence (downstream) in comparison with points at which no direct influence is expected (upstream), or "white" sites (sites 1, 2, 3, 8 and 10), with a difference of one category between points, and in sites 6 and 9 in which the quality differed in 2 categories of the index.

Sites 4, 5 and 7 presented the same water quality, both at the upstream and the downstream site. Of these 7 sampling sites, 3 are found in the so-called "critical section" from Infiernito River to the mouth of the San Carlos River, and 3 are in the section from Marker 2 to Infiernito River. From a comparison of the results of the BMWP-CR index of the present year, with those obtained in 2013, it is possible to observe that the difference in the quality of water at the sampling sites was more evident in the current year, since in 2013 there were 4 sites that presented lower quality at the downstream point (with influence) in comparison to the upstream point (without influence) in comparison to 7 sites in 2014 (see Annex 9-2).

Despite the fact that a tendency was found towards obtaining a lesser quality of water at the sites with direct influence on the Route, only in 2 of the sampled sites was there a difference of 2 categories in the index, while the remainder of the sites that differed between up and downstream of the Route only did so in one category, and no extreme difference of two categories was observed in the BMWP-CR in any of the sampled sites.

Considering the comparison of results of the BMWP CR index, the differences in the condition of water quality remain very similar between 2013 and 2014.

In general terms, after visual inspection of Route 1856 during the field visits in 2014, the conditions of the bodies of water traversed by the Route look very similar to those observed in 2013. Most of the length of the Route 1856 lies on flat terrain, with gravel roads and bridges in good condition, and there does not appear to be major threats to the aquatic habitats. Where minor changes have occurred, these may relate to the temporary impact as a result of mitigation works that are being carried out in the so called "critical section". The "critical section" is a section of the road that could not be finished due to suspension of the road works in 2012. The term "critical" describes those areas where Costa Rica has concentrated most of the mitigation works.

Outside this area, most bodies of water that are intersected by Route 1856 seem to not have a significant impact as a result of the works related to it, at least at a visual level since most of the Route stretches over flat terrain with not much slope, in agricultural lands where no deforestation is evident and where sedimentation processes do not seem evident as a result of the construction of the Route.

This is different in the section that runs from Infiernito River to Boca San Carlos, where sedimentation processes seem to be active in some of the slopes associated with the bodies of water that traverse the Route.

Endemic Species with Limited or At-risk Populations

No species of macro-invertebrates were detected that could be considered threatened in any way according to the Regulations of the Wildlife Conservation Law (MINAE, 2005), CITES Appendix or the red list of the IUCN. Nevertheless, it is necessary to point out that in the case of aquatic macro-invertebrate studies, these are done mostly at a taxonomic level of class, due to the fact that for most of them identification at the level of species can only be done with flying adults (mostly terrestrial). For practical purposes, there is no information with respect to the distribution and state of conservation of the different macro-invertebrate aquatic species in the country.

Consequently, information on the state of populations is insufficient, nor are they found in the lists of threatened species, with the exception of some of the dragonfly genera (i.e. Odontata order, except those of the *Agriogomphus* genera), river lobster (i.e. Palaemonidae family), and beetles (i.e. *Dystiscus* genera) that were found in the present Follow-up Study and which have species in the IUCN red list, but the majority of sweet water macro-invertebrates have not been evaluated yet with respect to their conservation status.

Even though some of these genera were found, it was not possible to identify the species to which they belong, either because they were ninfae or larvae (immature states) or due to taxonomic keys at the level of species for these groups in the Tropic, and due to the fact that identification at the level of speciae in macro-invertebrates requires a very high degree of taxonomic specialization. It is possible that some belong to some of these species.

Some of the aquatic macro-invertebrate genera found in this study could be considered uncommon or of restricted distribution (data based on material from the Aquatic Entomology Collection of the Zoology Museum of the University of Costa Rica) among these: *Dystiscus, Gyretes, Callibaetis, Moribaetis, Caenis, Cabecar, Terpides, Ranatra, Martarega, Notonecta, Enallagma, Agriogomphus, Elga, Macrothemis, Micrathyria, Neocordulia, Heteragrion, Thaumatometra, Perissolestes, Centromacronema, Helobdella cf. triserialis, Helobdella elongata and Placobdella ringuleti.* Also, in 2013 some taxa were found that could be considered uncommon or of restricted distribution (Annex 9-4).

6 Evaluation of Environmental Impacts and Corrective Measures

6.1 Methodology

Starting with an analysis conducted on the potential impacts identified in the 2013 EDA, this Follow-up Study evaluated each of the same impacts, in order to determine the environmental changes that had occurred after one year. In order for the changes to be comparable, the assessed impacts are the same, as were the procedures which were applied.

Starting with this analysis and in accordance with the method applied, the Environmental Impact Evaluation was done for each one of the factors identified.

Each one of the participating professionals, offered technical criteria as a function of an expected impact, based on the guidelines offered by the Conceptual Guide for the Formulation of Environmental Impact Studies ("OCE") that the National Environmental Technical Secretariat ("SETENA") has recommended since 1998 and the modifications presented in Executive Decree No 32967 of May 4, 2006: Manual of Technical Instruments for Environmental Impact ("EIS Manual"), Part IV, Annex 2, Instructions Manual for the Evaluation of Environmental Impacts.

Conceptual definitions were used to facilitate an understanding of the Matrix of Importance of Environmental Impacts (MIIA), which summarises the analysis of expected or potential environmental impact of the project on the environment. The definitions relied upon are set out below, as follows:

a. Impacted Environmental Factor: included under this denomination are factors or elements of the environment (biological component) that can be affected by the development of the project, or one of its activities. Elements which have been chosen for purposes of the environmental evaluation are those considered to be potentially related to the activities developed by the Project.

b. Impacting Action: at a specific level, actions, activities or project components are established that exert an impacting relationship over one or more of the environmental factors presented in the previous point. The impacting action may be associated with the constructive phase or the operative phase of the Project.

c. Impact: indicates the expected effect on each of the impact possibilities identified by the team professionals, if the expected impact is water contamination, then the cause of this impact is defined, along with the source of the contamination and the phase of the project in which the impact potentially occurs.

d. Evaluation of impact: corresponds to the qualitative scoring of the environmental impact, with the value based on the criteria presented in the Leopold Matrix (modified) and which, in Costa Rica have become tropicalized through the application of the MIIA of SETENA and made official by Executive Decree No. 32966-MINAE (Manual of Technical Instruments for the Environmental Impact Process (EIS Manual)- Part IV).

According to what is established in Decree No. 32967, the importance of an impact or effect of a given action on an environmental factor is represented by a number obtained through the proposed model, as a function of the value assigned to the previously considered symbols.

$$I = \pm [IN + 2\,EX + MO + PE + PV + SI + AC + EF + PR + MC]$$

The importance of the impact takes on values between 13 and 100, according to the expected potential impact for each element or factor and presents intermediate values (between 40 and 60) when one of the following conditions is present:

- Total intensity and minimal affectation of the remaining symbols
- Very high, or high, intensity, and high, or very high, affectation of the remaining symbols
- High intensity, unrecoverable effect, and very high affectation of some of the remaining symbols
- Medium or low intensity, unrecoverable effect and very high affectation of at least two of the remaining symbols.

Therefore, the importance of impacts is given by the following values:

- Importance of less than **25** means irrelevant impacts
- Importance between **25** and **50** means moderate impacts
- Importance between **50** and **75** indicates severe impacts
- Importance greater than **75** indicates critical impacts

In those boxes that correspond to the more important impacts, or that happen in critical places or moments, and which are impossible to correct, which will lead to the larger scores in the importance chart, then the Alert or Red Banners are superimposed, to call attention to the effect and search for alternatives in the productive processes of the activity, work or project, so as to eliminate the cause or change it for another of less harmful effects.

6.2 Assessment of Identified Environmental Impacts and Updating of Environmental Control Measures

6.2.1 Control Measures for Terrestrial Flora and Fauna

a. Partial Cutting of Forest in Path of the Route and Neighbouring Areas

Sources of Impact/ Risk

Due to the clearing of vegetation on the path of Route 1856, it was necessary to remove some of the trees in some sections in the path of the Route, specifically in places where no roads existed previously.

The number of trees removed was determined by the specific needs in each section and the existing vegetation. This was the case because in most of the Route, at least 74% of the Route's path occurred in open areas that had no vegetation cover. For this reason, in most of the length of the Route 1856, it was not necessary to cut down trees. Nevertheless, it is necessary to establish medium and long term environmental measures to prevent deforestation along the Route.

Impact Assessment

Since tree cutting was performed only at the beginning of the construction of Route 1856, this impact is assessed as ***Negative***, with: ***Medium*** Intensity (-2), ***Spot*** extension (-1), time

Immediate (-4), persistence ***Permanent*** (-4), reversibility ***Permanent*** (-4) ***No Synergistic*** (-1), ***Simple Accumulation*** (-1), ***Direct*** effect (-4), intervals ***Continuous*** (-4) and ***Partial and Mitigating*** recoverability (-4); for a **total** of **-34**, which is rated as ***Moderate***.

Environmental Measures Applied

Even though prior to the formulation of the 2013 EDA, CODEFORSA and MINAE had implemented a mitigation plan to reduce the impact of deforestation, it was evident that species used for reforestation were not very diverse.

It was noted that in new reforestation sites the tree species being planted are increasingly more diverse, although the need to increase diversity remains, and rare species are not being used.

Environmental Measures to be Taken

1. To strengthen the present reforestation plan with planting of trees at sites where no additional road cuts are necessary, use of rare native species to reforest areas, also threatened, endemic species, and avoid planting exotic species, or those not present in the area. It is also advisable to mix species in a proportion approximating 50% of species once common but now decimated such as Manú, Cocobolo and Jícaro. The other 50% may include species that are commonly used in reforestation efforts throughout the area. Prioritization is advised of sites with undulating, or strongly undulating slopes and in the protected zone of the San Juan River, or in other rivers and streams of the Route.
2. To allow the natural regeneration of secondary vegetation in places where it grows aggressively, avoiding cutting to replace it, or using pioneering tree species that provide shade cover to support species that do not tolerate sun, or that grow better under the shade in its early stages, such as Manú, Pinillo, or Almendro de Montaña. In sites with very sharp slopes, it is suggested that secondary vegetation be allow to establish itself, where possible. Given that the total forest cover lost extends over approximately 83 ha, it is suggested that a similar size area be allowed to recover naturally with natural secondary vegetation, in lands next to the path of the Route, giving priority to the more hilly areas along San Juan river, as a way to compensate the native eco-system, since common reforestation efforts do not propitiate ecosystems similar to those required, to maintain native bio-diversity. With the purpose of verifying the existence of tree species under threat of extinction within the right-of-way of the Route, it is suggested that a tree inventory be established of these species along the Route.
3. Establish a protection and maintenance plan for the trees identified along the Route.
4. Periodic monitoring should be conducted along the Route to avoid the presence of squatters.
5. To promote the identification of different sections and ecosystems along the Route that might have touristic potential.
6. It is recommended that once abundant but presently scarce forest species be used along the Route, especially those that have been decimated by over-exploitation, but these should be mixed with others such that reforestation resembles to some degree the present natural ecosystems.
7. Furthermore it is suggested that responsible government institutions exert a greater control on the natural forest cover along the Route.

b. Partial Sedimentation of Wetland Borders along Route 1856

Source of Impact/ Risk

Soil movements, slope construction and land fills generated instability of some of the hillside slopes at some points where the slope gradient is strong, as well as the increase in the surface runoff, the sedimentation of some wetland borders nearby and the affectation of some sectors of the Route.

This impact corresponds with a specific, one-off impact of the Route, where, at some nearby points small amounts of sediment accumulate.

In the 2013 EDA, two wetland sites were identified lying next to hillside terrain with sedimentation that had accumulated which led to slight filling of sites close to the drainage channels of these wetlands.

Presently, neither site has been subjected to corrective measures, nor have road maintenance activities taken place partly because there is no access by vehicles to that section of the road because of the absence of gravel. On the other hand, it was observed that the process of sedimentation of these wetlands, which was taking place last year, due to erosion of the road cuts, tends to be stabilizing, so that there is no increase in the affected area, and, better yet, the area filled last year is now being covered naturally by herbaceous vegetation.

Impact Assessment

This impact has only been identified in specific points along the Route 1856, where sediment accumulations are little. For this reason, the impact was assessed as ***Negative***, with: ***Low*** Intensity (-1), ***Partial*** extension (-1), time ***Immediate*** (-4), persistence ***Temporal*** (-2), ***Temporal*** reversibility (-2) ***No Synergistic*** (-1), ***Simple Accumulation*** (-1), ***Indirect*** effect (-1), ***Periodic*** intervals (-2) and ***Partial and Mitigating*** recoverability (-4); for a **total** of **-22**, which is rated as ***Irrelevant***.

Environmental Measures to be Taken

1. Accumulated sedimentation material should be cleared to allow water to travel down natural drainage gutters. When the road cuts into a wetland, as is the case of Remolinito Grande Lake, the obstruction of free flowing waters must be avoided, so that by the use of gutters or other means, the water that usually flows into the wetland can freely circulate on both sides of the road.

2. Improvements in the fills and drainage structures should be undertaken, in order to avoid risk of sediment entering into bodies of water.

3. Continue with works for the protection of the surface of slopes through the placement of geo-textiles, improvement of slant of the slope and drains.

c. Loss of Trees and Bushes located on river banks due to Flooding

Source of Impact/ Risk

During 2013 it was determined that in the section between Marker 2 and Infiernito River there were some sites with small riverbeds that accumulated waters forming a kind of dam over the forest vegetation on the banks, leading to decay of the flooded vegetation.

Presently maintenance work is being carried out on the Route and this anomaly is being corrected (as recommended in the EDA), through the placement of the proper gutters, improving drainage and placing roadside curbs.

In the same sense, it was noted that with the corrective works, the waters are flowing normally, so that the artificial pools have been drained which had resulted from the stoppage of creeks along the path of the Route, as was recommended (see Photo 3)

Photo 3: Improvement of drainage conditions in flooded areas

Since this problem could appear at any point, if inadequately prepared bridges or drains collapse, this aspect should continue to be monitored to avoid a repetition of the problem and to correct it immediately should it recur.

Impact Assessment

Improvements in the areas where this impact was identified have been satisfactory. Drainages have been improved and returned to its natural conditions, exhibiting natural run off. For this reason, this impact was assessed as ***Negative***, with: ***Low*** Intensity (-1), ***Punctual*** extension (-1), time ***Short term*** (-2), persistence ***Temporary*** (-2), ***Temporary*** reversibility (-2) ***No***

Synergistic (-1), ***Simple Accumulation*** (-1), ***Indirect*** effect (-1), ***Periodical*** intervals (-2) and ***Immediate*** recoverability (-2); for a **total** of **-18**, which is rated as ***Irrelevant***.

Environmental Measures to be Taken

1. To favour good drainage in the sites mentioned through the placement of an adequate drainage system or by lowering the level of drains to avoid the accumulation of water and the affectation of the Route itself. Once the excess waters have been drained at the sites, it is suggested that the area be allowed to recover naturally through the secondary regeneration of the local vegetation.

d. Landslides and Slope Erosion Affecting the Forest Borders of the Route

Sources of Impact/ Risk

Due to the road cuts along the path of the Route, forest vegetation alongside the cuts is subjected to sheet erosion of the soil, which generally causes small trees to fall on the road due to loss of the radicular system through soil removal.

Impact Assessment

Improvements in the stability and protection as well as the implementation of reforestation and grass planting activities on slopes have prevented trees falling as a consequence of eroding terrain. For these reason, the impact was assessed as ***Negative***, with: ***Low*** Intensity (-1), ***Low*** extension (-1), time ***Mid Term*** (-2), persistence ***Temporary*** (-2), ***Temporary*** reversibility (-2) ***No Synergistic*** (-1), ***Accumulative*** (-4), ***Indirect*** effect (-1), ***Periodical*** intervals (-2) and ***Partial and Mitigating*** recoverability (-4); for a **total** of **-24**, which is rated as ***Irrelevant***.

Environmental Measures Taken

During recent months actions have been taken to protect existing slopes on the Route, as well as the improvement of drainage systems on the same, to avoid the occurrence of landslides.

Environmental Measures to be Taken

1. Continue to carry out work to protect the surface of slopes through the placement of geo-textiles, improving the angle of the slopes and placing drainage systems.
2. To evaluate the technical possibility of modifying the path of Route 1856 at the site of Infiernillo, to use local roads built with less slant, tracing a deviation of some kilometres to the south, where some settlements and open areas are found and topographical conditions are more favourable to the presence of the road.

e. Affect on the Wetland Ecosystem (due to Drainage, Fills and Fire Clearing)

Sources of Impact/Risk

Due to the placement of drainage, landfills, road base and rolling surface for the Route. This corresponds with the affect on the ecosystem at some points along the path of the Route, due to the contribution of sediments and the draining of some wetlands next to them.

On the other hand, the loss of "yolillal" was observed due to fire clearing at several points along the Route 1856. This was favoured by the presence of a summer season that was dryer than normal. Even though this affect covers a small area, it is taken into account given the very small presence of this type of ecosystem in the study area.

Impact Assessment

The loss of small "yolillal" areas, as well as the impact on some specific points with wetland ecosystems along the Route, have made this impact to be assessed as ***Negative***, with: ***Low*** Intensity (-1), ***Punctual*** extension (-1), time ***Immediate*** (-4), persistence ***Temporary*** (-2), ***Temporary*** reversibility (-2) ***No Synergistic*** (-1), ***Simple Accumulation*** (-1), ***Direct*** effect (-4), ***Continous*** intervals (-4) and ***Partial y Mitigating*** recoverability (-4); for a **total** of **-28**, which is rated as ***Moderate***.

Environmental Measures to be Taken

1. Conduct improvements in the drainage structures and fills to avoid their affect (this is already ongoing)
2. Allow the natural recuperation of the ecosystems
3. Establish a monitoring plan along the Route with the purpose of verifying the recovery of wetlands and avoid the cutting down of "Yolillal" and other tree species associated with wetlands by the local inhabitants.
4. Implement vigilance and control by the state agency SINAC, to prevent deforestation activities and alteration of natural ecosystems along the Route, since presently this control is very sporadic.

f. Impact on Structural Connectivity

Sources of Impact/Risk

Due to the clearing of land and arboreal cover at some sites along the path of the Route, it was necessary to eliminate some trees along specific sections within the right of way, in areas were no roads existed.

This loss of vegetation cover at some specific sites could generate an alteration of the structural connectivity as a result of the removal of trees.

Impact Assessment

According to the analysis, the status of structural connectivity along the Route was assessed as ***Negative***, with: ***Low*** Intensity (-1), ***Punctual*** extension (-1), time ***Long term*** (-1), persistence ***Temporary*** (-2), ***Temporary*** reversibility (-2) ***No Synergistic*** (-1), ***Simple Accumulation*** (-1), ***Indirect*** effect (-1), ***Irregular, random and discontinuous*** intervals (-1) and ***Partial and Mitigating*** recoverability (-4); for a **total** of **-18**, which is rated as ***Irrelevant***.

Environmental Measures Executed

In recent months a reforestation plan has been developing by CODEFORSA with more than 50,000 planted along both sides of the Route as a mitigation measure proposed by MINAE. This plan is resulting in a good growth process and proper tree maintenance, which has involved local communities in the planting and protection process.

Environmental Measures to be Taken

1. Continue reforestation activities with native species of the area.
2. Promote the natural regeneration and ecological restoration to improve the connectivity among populations, species and communities.
3. Establish a monitoring plan along the path of the Route with the purpose of establishing the recovery of connectivity.

6.2.2 Aquatic Flora and Fauna

g. Potential Affect to the Aquatic Habitat

Sources of Impact/Risk

The construction of drainage works and the covering of some riverbeds with cement where some bridges are located, at different points in the path of the Route. This impact was identified in very few points.

Impact Assessment

Given that there is some sediment delivery from specific points along the Route, this impact was assessed as ***Negative***, with: ***Low*** Intensity (-1), ***Punctual*** extension (-1), time ***Immediate*** (-4), persistence ***Permanent*** (-4), ***Temporary*** reversibility (-2), ***Moderate Synergy*** (-2), ***Accumulative*** (-4), ***Direct*** effect (-4), ***Continuous*** intervals (-4) and ***Midterm*** recoverability (-2); for a **total** of **-31**, which is rated as ***Moderate***.

Environmental Measures to be Taken

1. Consolidate the civil engineering works along the Route, at these sites (this is already ongoing).
2. Avoid placing cement structures on riverbeds under drains and bridges.
3. Carry out a monitoring plan of the aquatic habitat conditions in riverbeds under drains and bridges.

h. Potential Affect to the Micro-habitats and Substrata of Aquatic Macro-Invertebrates due to the Filling of Interstices by Sediment

Sources of Impact/Risk

Movements of soil, formation of slopes and landfills generated instability in slopes along some sites where the slant is strong, with an increase in surface runoff and the contribution of sediments in some nearby bodies of water, in some sections of the Route.

The previous conditions create filling by sediments of the rock cavities and modify temporally the substrata where aquatic macro-invertebrates normally reside.

Impact Assessment

Because the sediment delivery is minimum and environmental measures are being developed in order to mitigate the impact, this is assessed as ***Negative***, with: ***Low*** Intensity (-1), ***Punctual*** extension (-2), time ***Midterm*** (-2), persistence ***Temporary*** (-2), ***Temporary*** reversibility (-2) ***Moderate Synergy*** (-2), ***Accumulative***(-4), ***Indirect*** effect (-1), ***Irregular, random and discontinuous*** intervals (-1) and ***Midterm*** recoverability (-2); for a **total** of **-24**, which is rated as ***Irrelevant***.

Environmental Measures Taken

During recent months, a reforestation plan has been developed with the planting of thousands of trees along both sides of the Route, as a mitigation measure proposed by the Ministry of the Environment (MINAET). This plan is showing progress in terms of an adequate growth process and maintenance of trees which involves local communities.

Environmental Measures to be Taken

1. Consolidate civil works to stabilize the slopes and improve drainage systems as soon as possible, especially with unstable slopes, to avoid contributing sediment to the aquatic environment.
2. Continue reforestation activities with native species of the area.
3. Promote natural regeneration and the ecological restoration of the riverbeds.
4. Establish a monitoring plan along the path of the Route with the purpose of verifying the status of riverbed substrata.

i. Potential Affect to Taxonomic Abundance and Richness

Sources of Impact/Risk

This is generated by the contribution of sediments to the water, the decrease of contribution of vegetal material to the aquatic medium, and the decrease of shade that cause an affect to the abundance of species in the bodies of water.

Impact Assessment

Improvements in the current conditions of this impact and mitigating environmental measures being implemented such as reduction in sediment delivery from slopes, this impact is assessed as ***Negative***, with: ***Medium*** Intensity (-2), ***Partial*** extension (-2), time ***Immediate*** (-4), persistence ***Temporary*** (-2), ***Temporary*** reversibility (-2) ***Moderate Synergy*** (-2), ***Accumulative*** (-4), ***Indirect*** effect (-1), ***Continuous*** intervals (-4) and ***Midterm*** recoverability (-2); for a **total** of **-30**, which is rated as ***Moderate***.

Environmental Measures Implemented

During recent months, a reforestation plan has been developed with the planting of thousands of trees along both sides of the Route, as a mitigation measure proposed by the Ministry of the Environment (MINAET). This plan is showing progress in terms of an adequate growth process and maintenance of trees which involves local communities.

Environmental Measures to be Taken

1. Consolidate civil works to stabilize the slopes and improve drainage systems as soon as possible, especially with unstable slopes, to avoid contributing sediment to the aquatic environment (this is ongoing).
2. Continue reforestation activities with native species of the area.
3. Promote natural regeneration and the ecological restoration of the river banks.
4. Establish a monitoring plan along the path of the Route with the purpose of verifying the status of species.

j. Potential Affect on the Quality of Water due to Turbidity

Sources of Impact/ Risk

Soil movements, slope formation and landfills generated an increase in surface runoff and contributed sediments to some bodies of water close to some sections of the Route.

This corresponds with the impact on some ecosystems along points of the path of the Route due to the contribution of sediments to the nearby bodies of water.

Impact Assessment

The decrease in the sediment delivery due to improvements in slope stability, as well as hillside protection through tree and grass planting activities, make this impact to be assessed as ***Negative***, with: ***Very high*** Intensity (-4), ***Partial*** extension (-2), time ***Immediate*** (-4), persistence ***Fleeting*** (-1), ***Fleeting*** reversibility (-1) ***Moderate Synergy*** (-2), ***Simple Accumulation*** (-1), ***Direct*** effect (-4), ***Periodical*** intervals (-2) and ***Midterm*** recoverability (-2); for a **total** of **-33**, which is rated as ***Moderate***.

Environmental Measures Implemented

During recent months, a reforestation plan has been developed with the planting of thousands of trees along both sides of the Route, as a mitigation measure proposed by the Ministry of the Environment (MINAE). This plan is showing progress in terms of an adequate growth process and maintenance of trees which involves local communities.

Environmental Measures to be Taken

1. Consolidate civil works to stabilize the slopes as soon as possible, especially with unstable slopes, to avoid contributing sediment to the aquatic environment (this is ongoing).
2. Continue reforestation activities with native species of the area.
3. Promote natural regeneration and the ecological restoration of the river banks.
4. Establish a monitoring plan along the path of the Route with the purpose of verifying the status of riverbed substrata.

6.2.3 Landscape

k. Landscape Affect in Some Sections of the Route due to Construction Works

Sources of Impact/Risk

Due to the clearing of vegetation and forest cover at some sites along the Route, it was necessary to eliminate some trees along the right-of-way, specifically in sections where no roads existed.

Despite the fact that the Route is located mostly (54%) in a region that contains roads and the terrain has minimal sloping conditions, at some specific points, the exposed surface of slopes and road cuts is observable, mainly between Marker 2 and close to the mouth of the San Carlos river.

Impact Assessment

Given that the reforestation activities along the Route have been successful with more tan 50.000 trees planted, exhibiting fast growing and low mortality conditions, this impact is assessed as ***Negative***, with: ***Low*** Intensity (-1), ***Spot*** extension (-1), time ***Immediate*** (-4), persistence ***Temporary*** (-2), ***Temporary*** reversibility (-2) ***No Synergistic*** (-1), ***Accumulative*** (-4), ***Direct*** effect (-4), ***Irregular, random and discontinuous*** intervals (-1) and ***Midterm*** recoverability (-2); for a **total** of **-25**, which is rated as ***Irrelevant.***

Environmental Measures Implemented

During recent months, a reforestation plan has been developed with the planting of thousands of trees along both sides of the Route, as a mitigation measure proposed by the Ministry of the Environment (MINAE). This plan is showing progress in terms of an adequate growth process and maintenance of trees which involves local communities.

Environmental Measures to be Taken

1. Continue to reforest in front of all road cuts visible from the right margin of the San Juan River, using several species per site, planting them in rows that are parallel to the road cut, starting along the River edge or the area next to the slope and upwards, according to the specific circumstances, using low species with broad canopy in the lower part of the terrain, such as “Sotacaballo” or “Balsam” (low density planting is appropriate to keep a broad canopy), followed by trees of a medium size, such as “Guabillo” or “Balsa” and other species of high profile, such as “Cebo“, “Botarrama“, “Roble Corral“, in such manner that the density of the trees leads to the desired end of creating foliage from a few metres off the ground to 30 metres high.
2. Continue to stimulate the growth of grasses on the surface of slopes. Along the Route it was observed that native and naturalized species of graminae such as “Sainillo” (*Axonopus sp*) and “Rotana” (*Ischaemun indicum*) are covering efficiently a good part of the area that has low altitude road cuts, avoiding rainfall directly on the slopes.
3. Promote the identification of landscapes and ecosystems along different sections of the Route as touristic attractions.

Table 6-1 corresponds to the Matrix of Importance of Environmental Impacts (“MIIA”) defined with the criteria established by the Technical Instruments Manual for the Environmental Impact Evaluation Process (EIA Manual)-Part IV (SETENA 2004). Taking into account the importance of each, according to their characteristics, environmental aspects and effects they generate.

It should be noted that such a matrix shows the evaluation of 2014 based on the follow-up and monitoring conducted for this report. Furthermore, Annex 7-5 contains a comparative table of the evaluated conditions for the 2013 EDA, incorporating the results of the present analysis for the Follow-up and Monitoring study.

It further should be noted that the findings and assessments presented in this table considers exclusively the territory of Costa Rica, and, as stated in EDA 2013, impacts are local in character, meaning that there are no evidence of transboundary impact outside their localized scope.

Table 6-1: Matrix of the Importance of Environmental Impact (MIIA) for the Project Route 1856, in Costa Rica (2014).

Matrix of Importance of Environmental Impact (MIIA) of Project Route 1856 in Costa Rican Territory.															
			Impact Characteristics												
No.	Environmental Factor	Impact	+/-	IN	EX	MO	PE	RV	SI	AC	EF	PR	MC	I	Value
														2014	
1	Terrestrial Flora and Fauna	a.Cutting down forests in right-of-way and surrounding areas.	-	2	1	4	4	4	1	1	4	4	4	-34	Moderate
		b. Partial sedimentation of wetland borders along Route 1856.	-	1	1	4	2	2	1	1	1	2	4	-22	Irrelevant
		c. Elimination of trees and bushes located along riverbanks, due to flooding.	-	1	1	2	2	2	1	1	1	2	2	-18	Irrelevant
		d. Landslides and slope erosion that affect the forested edges of the Route.	-	1	1	2	2	2	1	4	1	2	4	-24	Irrelevant
		e. Affectation of the wetland ecosystem (due to drainage, landfill and burning)	-	1	1	4	2	2	1	1	4	4	4	-28	Moderate
		f. Affectation of structural connectivity	-	1	1	1	2	2	1	1	1	1	4	-18	Irrelevant
2	Aquatic Flora and Fauna	g. Affectation of aquatic habitat	-	1	1	4	4	2	2	4	4	4	2	-31	Moderate
		h. Potential affectation of the micro-habitats and substrata of aquatic macro-invertebrates due to filling of interstitial spaces with sediment	-	1	2	2	2	2	2	4	1	1	2	-24	Irrelevant

		i. Potential decrease in taxonomic abundance and richness	-	2	2	4	2	2	2	4	1	4	2	-30	Moderate
		j. Potential affectation of the quality of water due to turbidity caused by sediments	-	4	2	4	1	1	2	1	4	2	2	-33	Moderate
3	Landscape	k. Landscape affectation due to construction works	-	1	1	4	2	2	1	4	4	1	2	-25	Irrelevant
	Total	**Environmental Impacts Residuals**												**-287**	

Taking into account the results of values established in Table 6-1, the following results were obtained:

1. In the evaluation of the 2013 EDA, 8 irrelevant impacts were identified and 3 of moderate level. The updating of values identified 6 irrelevant impacts and 5 of moderate level.
2. With respect to impacts that shifted from irrelevant to moderate, the increase occurs within a maximum range of 10 units.
3. The total sum of total importance increases by 12 units.
4. All impacts show a low or medium intensity level on the environment.
5. All impacts have a uniform value, within the range of -18 and -34, which indicates there is homogeneity in the low incidence of impacts along the Route.

Even though it was found that the identified environmental impacts are of a localized nature, it was also considered necessary to evaluate if the conditions identified previously had produced any impact at all on the territory of Nicaragua, where a similar analysis might have been conducted regarding each one of the activities that might generate a potential impact to determine if these could affect the San Juan River.

As stated at the beginning of this Report, it was not possible to conduct such analysis due to the fact that the Government of Nicaragua did not allow the scientific team conducting this study to enter the San Juan River to sample the bodies of water as they entered the River. For this reason, like the 2013 EDA, this Follow-up Study could not verify the existence of environmental impacts in the San Juan River by following an exact, scientific methodology. However, it can be said that the assessment of impacts on Costa Rican territory does not suggest the existence of significant impacts on Nicaraguan territory.

6.3 Environmental Action Plan- Environmental Adaptation Plan (EAP)

As was the case with the 2013 EDA, the present Environmental Adaptation Plan ("EAP") summarises all aspects developed in previous chapters for each of its thematic components and for this purpose it is presented as a Summary Table for ease of reference. The EAP seeks to build on the environmental progress made in 2014 in the design of Route 1856.

In Table 6-2 the updated Adaptation Plan for Route 1856 is presented.

The entity responsible for the execution of environmental measures is the National Roadways Council ("CONAVI") in cooperation with the MINAE and other governmental institutions assigned to the construction and supervision of the Route 1856 project.

Table 6-2: Environmental Adaptation Plan.

Follow-up Study Route 1856 Project Environmental Adaptation Plan (EAP)							
Environmental Aspect	**Environmental Impact**	**Corrective-compensatory Measure**	**Environmental Goals**	**Environmental Performance Indicators**	**Location and Frequency of Sampling**	**Interpretation and Feedback**	**Responsible for Execution**
Clearing and cleaning of some sections along the right-of-way of the Route	Partial cutting of forests in the right-of-way and adjacent roads	Strengthen the existing reforestation with tree planting at sites where road cuts are not present, reforesting with native species that are scarce, threatened, endemic, or in danger of extinction, and not using any exotic species, nor species not found in the area. Species should be mixed to simulate the diversity of the forests and these should include an approximate proportion of 50% of species otherwise common but presently decimate such as Manu, Cocobolo and Jícaro. The other 50% could include species that are commonly planted in reforestation plans in the area. It is suggested that sites with strong undulating slopes, or very undulating slopes, be prioritized, in the buffer zone of the San Juan River, or other sites along rivers and creeks in the Route area. Allow natural recovery of secondary vegetation where it grows naturally and aggressively, , otherwise using pioneering tree species as shade to favor species that are intolerant to sun or which grow better under shade in their early stages, such as Manu, Pinillo or Almendro de Montaña, for example. At sites with very slanted hillsides it is suggested that secondary vegetation be allowed to grow, where possible. Given that the total loss of forest cover was quantified at 83 ha., it is recommended that a similar sized area be allowed to recover its natural secondary forest vegetation, in an area close to the Route but placing priority on the more hilly terrain adjacent to the San Juan river, as a way to compensate the native ecosystem, since reforestation programs do not propitiate ecosystems such as those required, in order to maintain native biodiversity. With the purpose of verifying the existence of endangered tree species within the right-of-way of the Route, it is suggested that a forest inventory be conducted of the presence of these species along the Route. Establish a maintenance and protection plan for the trees identified as threatened by extinction or under seasonal protection. Conduct periodic monitoring along the path of the Route to avoid squatter incursions in the area of the road. Promote the identification of different sections and ecosystems along the path of the Route, as a tourism incentive.	Guarantee the protection of existing trees in the right-of-way (50 m) of the Route Natural vegetation recovery along the Route Improvement of scenic beauty along the path of the Route	Quantity of trees planted Forest Inventory along the path of the Route Results of the Follow-up and Monitoring Plan. Photographic Registry with signs along the path	Along the path of the Route. Every 6 months.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE
Earth movements, slope and landfills	Partial sedimentation of the wetland edges adjacent to Route 1856	Clean materials accumulated due to sedimentation to allow the free flow of water through natural drainage systems. In cases where the roadway approaches a wetland area, as is the case at the Remolinito Grande Lagoon, obstruction of free flowing waters should be avoided, allowing through the use of culverts or similar means for the water that enters the body of water to circulate freely down both sides of the road. Make improvements in the drainage structures and fills with the objective	Start a process of sediment cleaning and construction works to avoid sedimentation of wetlands. .	Photographic register of the works performed. Report of the verification of the efficiency of works.	At identified sites such as the wetlands along the path of the Route. These must be implemented during the process of improvement of civil works along the Route in the short term.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application	CONAVI - MINAE

Follow-up Study
Route 1856 Project
Environmental Adaptation Plan (EAP)

Environmental Aspect	Environmental Impact	Corrective-compensatory Measure	Environmental Goals	Environmental Performance Indicators	Location and Frequency of Sampling	Interpretation and Feedback	Responsible for Execution
		of avoiding affectation of wetlands.				will be defined.	
		Continue with civil Works for the protection of surfaces of slopes through the placement of geo-textiles, improvement of slope angles and drainage systems.					
Placement of some drainage systems and temporary bridges	Loss of trees and bushes located on the banks of rivers and streams, due to flooding	Promote the adequate drainage of water at these sites, through the placement of an adequate drainage system, or lowering the level of drains to avoid the accumulation of water and the affectation of the road. Once the excess water has been drained at the site, the area should be allowed to recover naturally though regeneration of native secondary vegetation.	Avoid the loss of trees due to flooding in areas of poor natural drainage. Start a process of improvement of drainage systems along the path of the Route.	Report of the improvements and construction of drainage and bridge works.	At the sites where water accumulation has been identified and loss of trees along the path of the Route These must be performed during the process of improvement of civil works along the Route, in the short term	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE
Earth movements and formation of slopes	Landslides and erosion of slopes that affect the forest edges along the path of the Route	Continue with civil works for the protection of surfaces of slopes through the placement of geo-textiles, improvement of slope angles and drainage systems.	Prevent the generation of landslides in sections with strong slopes. Guarantee the conservation of forest cover that surrounds slopes and road cuts.	Report on the number of slopes altered and works performed.	At sites where unstable slopes were identified along the path of Route 1856 These must be performed during the process of improvement of works for the construction of drainage systems, bridges and slopes along the Route, in the short term.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE
Soil removal, placement of drains, landfills, sub-base and Rolling Surface of the road.	Affectation of the ecosystem of the wetlands (due to drainage and landfill)	Make improvements in the drainage structures and landfills in order to avoid their affectation. Allow the natural recovery of the ecosystems. Establish a monitoring plan along the Route, with the purpose of verifying the recovery of wetlands and prevent local inhabitants from cutting down wetland vegetation.	Vegetation recovery along the Route. Improvement of aesthetic appreciation Begin a process of sediment cleaning and construction of civil works to avoid sedimentation in wetlands.	Photographic register of the works performed. Report of the verification of the efficiency of the works.	At sites identified as wetlands along the path of the Route. These must be performed during the process of improvement of the civil works along the Route, in a short term.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE

Follow-up Study
Route 1856 Project
Environmental Adaptation Plan (EAP)

Environmental Aspect	Environmental Impact	Corrective-compensatory Measure	Environmental Goals	Environmental Performance Indicators	Location and Frequency of Sampling	Interpretation and Feedback	Responsible for Execution
Vegetation clearing and cleaning in some sections of the right-of-way of the Route	Affectation of structural connectivity	Continue with reforestation activities using native species of the area. Promote the natural regeneration and ecological restoration to improve the connectivity among populations, species and communities. Establish a monitoring plan along the path of the Route, with the purpose of verifying the recovery of connectivity.	Start a reforestation process that allows the improvement of connectivity among different systems along the Route.	Quantity of trees planted. Forest Inventory of the path of Route 1856. Results of the Monitoring plan.	Along the path of the Route. Every 6 months.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE
Placement of some drainage systems and temporary bridges	Potential affectation of the aquatic habitat	Consolidation of civil engineering works at sites along the Route Avoid cementation of the riverbeds under drainage systems and bridges. Implement a monitoring plan of aquatic habitat conditions in the riverbeds under drainage systems and bridges.	Improvement in the conditions of river and stream beds.	Photographic registry of the works performed. Report on the Verification of the efficiency of the works.	Along the path of the Route. Every 6 months.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE
Earth movements, slope and landfill formation	Potential affectation of the micro-habitats and substrata of aquatic macro-invertebrates due to filling of interstices with sediment	Consolidate civil works to stabilize slopes as soon as possible, especially of slopes considered unstable to avoid the contribution of sediments to aquatic environments. Continue reforestation activities with native species from the region. Promote the natural regeneration and ecological restoration of banks of rivers and streams. Establish a monitoring plan along the Route path, with the purpose of verifying the state of substrata of the riverbeds that were monitored in this study.	Avoid sedimentation of river beds by the Route construction works.	Photographic registry of the works performed. Report on the Verification of the efficiency of the works. Number of trees Report on the Verification of the efficiency of works. Number of trees planted. Results of the Monitoring plan.	At sites where unstable slopes have been identified along the path of the Route. These should be implemented during the process of improving the civil works involving drainage systems, bridges and slopes along the Route, in a short term.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE
Soil movements, slope formation, clearing of vegetation	Potential decrease in taxonomic abundance and richness	Consolidate civil works to stabilize slopes as soon as possible, specially of slopes considered to be unstable, to avoid sedimentation of aquatic environments. Continue with reforestation activities using species native to the area. Promote the natural regeneration and ecological restoration of banks	Avoid sedimentation of river beds by the Route construction works.	Photographic register of works performed. Report on the Verification of the efficiency of works.	At sites where unstable slopes have been identified along the path of the Route. These should be implemented during the process of improving the civil works involving	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply	CONAVI - MINAE

Follow-up Study Route 1856 Project Environmental Adaptation Plan (EAP)							
Environmental Aspect	**Environmental Impact**	**Corrective-compensatory Measure**	**Environmental Goals**	**Environmental Performance Indicators**	**Location and Frequency of Sampling**	**Interpretation and Feedback**	**Responsible for Execution**
		along waterways. Establish a monitoring plan along the path of the Route, with the purpose of verifying the state of the substrata of the riverbeds monitored in this study.		Number of trees planted. Results of the Monitoring plan	drainage systems, bridges and slopes along the Route, in a short term.	measures, these will be justified and new deadlines for application will be defined.	
Soil movements, slope formation, clearing of vegetation	Potential affectation of the quality of water due to turbidity caused by sedimentation	Consolidate civil works to stabilize slopes as soon as possible, especially of slopes considered unstable to avoid the contribution of sediments to aquatic environments. Continue with reforestation activities using species native to the area Promote the natural regeneration and ecological restoration of banks along waterways. Establish a monitoring plan along the path of the Route, with the purpose of verifying the state of the substrata of the riverbeds and solids in suspension.	Avoid sedimentation of river beds by the Route construction works.	Photographic register of works performed. Report on the Verification of the efficiency of works. Number of trees planted. Results of the Monitoring plan	At sites where unstable slopes have been identified along the path of the Route. These should be implemented during the process of improving the civil works involving drainage systems, bridges and slopes along the Route, in a short term.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE
Soil movements, slope formation, clearing of vegetation	Landscape affectation due to the works	Continue with reforestation in front of all road cuts visible from the right margin of the San Juan river, through the cultivation of several species per site, but placed in parallel rows in front of the cuts, starting at the river edge, or at the area adjacent to the slope upwards, dependent on the case, with lower species of broad canopy in the lower part of the terrain, such as Sotacaballo or Bálsamo (planted in low density to allow for a broad canopy) , followed by medium profile trees such as Guabillo or Balsa, and behind them other high profile species such as Cebo, Botarrama, Roble Corral, in such a manner that the density of the trees reaches a desired point of covering with foliage from a few meters high, all the way to a height of 30 meters. Stimulate the growth of grass on the surface of slopes. It was observed all along the Route that native and naturalized species of graminae such as Sainillo (Axonopus sp.) and Rotana (Ischaemun indicum) are covering a good part of the area of road cuts of small height, in an efficient manner, preventing direct impact of rain on the slopes. Promote the identification of diferent sections and ecosystems along the Route as tourism incentives.	Improvement of scenic beauty along the path of the Route. Natural vegetation recovery along the Route.	Number of trees planted. Results of the Monitoring and Maintenance Plan Photographic register with signs along the path of the Route.	Along the path of the Route. Every 6 months.	A register will be established with collegiate reports to the MINAET of the results obtained In case of failure to apply measures, these will be justified and new deadlines for application will be defined.	CONAVI - MINAE

Note: information on the cost of measures is omitted due to the fact that some of the measures have already been implemented in recent months. Likewise, another factor that interferes with quantification is that the design of the final path of the Route and its bridges is still in process of adjudication by the Government of Costa Rica.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 General Conclusions

1. The Route 1856 project consists of the construction of a gravel road starting at the site of San Jerónimo de los Chiles, all the way to the locality known as Delta 7 (better known as Delta Costa Rica). Route 1856 has a total length of 159.7 km. An extension of 63.6% of the route (101.5 km) is made up of roads and access byways that have existed in the area for over 30 years. The remaining 35.9% (57.4 km) comprises new roads that were established in order to join the existing ones. However, the present Follow-up Study includes the follow-up and monitoring of the Route only in the section that runs parallel to the San Juan River, namely a section that is 108.2 km of the total length of the Route.
2. For the construction of Route 1856, as is common in these types of projects, it was necessary to execute several important secondary tasks. Among them were the clearing of the terrain, the construction of slopes, the placement of gutters and drains, as well as the laying of a sub-base and rolling surface for the road. However, it must be noted that initial works on this project were carried out as a matter of emergency.
3. Considering the emergency nature of the preliminary works, and where and when circumstances permit, the environmental aspects of these activities are:
   a. Clearing of vegetation and removal of waste at some sites along the Route. This is associated with the elimination of vegetation along some sections of the Route where no roads were previously in existence.
   b. Land movements, slope formation and landfill. This could generate instability of slopes at some sites where the slope gradient is strong, as well as generation of increased surface runoff, contribution of sediments to some bodies of water close to the Route and the affectation of the landscape in some sections of the Route.
   c. Installation of some drainage systems and temporary bridges. This factor could be associated with the punctual affectation of aquatic ecosystems and the modification of natural drainage systems in the area.
   d. Placement of landfills, sub-base and rolling surface for the road. This activity, if not properly mitigated and controlled, could be associated with the potential contribution of sediment to some bodies of water close to the Route.

7.1.1 Terrestrial Biology

1. The study area contains two life zones: a very humid pre-montane forest in basal transition and a very humid tropical forest. The very humid tropical forest is the most representative life zone in the northern part of Costa Rica, adding up to more than 61% of the lowlands of the region of Sarapiquí and San Carlos. It is the life zone that is the main habitat that connects the Atlantic watershed of southern Nicaragua to the Central Volcanic Mountain Range of Costa Rica.

2. In the project area several ecosystems or ecological associations were identified, among them: forest associations (primary, secondary and cropped forests), wetland systems, riparian systems and palm tree associations (Yollilal: *Raphia taedigera*).
3. In recent years and due to the growth of the agricultural frontier, many of the primary forest ecosystems in the border area have been altered to become secondary forests. Even so, these forests present a very high floristic diversity.
4. With respect to wetland systems, the area has an important number of rivers, creeks, channels and lakes that have a vegetation that is typical of lacustrine and palustrine wetlands.
5. Based on aerial photography taken before and after the construction of Route 1856, it was determined that the project area covered a total of 10,475.2 ha, but the project only partially altered or had an impact on 4,921.3 ha, equivalent to 47% of the area.
6. The assessment of the vegetation cover along the length of the project indicates that, for the purposes of land clearing along the path of the Route, 14.9 ha of secondary forest were cut down and 68.3 ha of primary forests were disturbed, which corresponds to 4.2% and 19.5% respectively, of the area that was altered by the path of the Route.
7. Similarly, some 2.3 ha of land that was not forest but natural wetland ecosystems was disturbed. It was determined by field observations that the road was built mostly in areas without forest cover (74%). In cases where forests were cut down, no open areas were available to allow tracing the road design through open terrain.

Specific Observations

The operation of most sections of the path of Route 1856 has offered and opportunity for regional migration processes to occur, which could favour larger land use changes. Currently, such phenomenon is evidenced by the construction of at least 4 huts with small subsistence orchards.

One year after the EDA, a few new settlements along the Route were observed,; this situation requires strengthening adequate control and surveillance processes in areas such as the Border Corridor Wildlife Refuge. Such measures would prevent uncontrolled demographic growth due to the opening of new access roads in the area.

The construction of Route 1856 required the felling of trees in in the path of the Route only, thereby partially affecting the forest cover. It was observed that in the case of wetlands and palm trees that were affected during road construction, they are showing significant recovery, due to the good recovery rate that characterizes the ecosystems of the area.

The lists of species of fauna remain the same given that over a one-year period it is difficult to observe significant changes in populations or in the presence of species. It is necessary to establish long term monitoring to permit estimates or changes in these species.

It is clear that important works to improve the road infrastructure in some sections have been carried out. The natural conditions in the area have been adversely affected in some sections of Route 1856, particularly in terrains with strong slopes, where work on the

Route has not been finished. These sections are presently subject to mitigation works and impacts are likely to be of short duration.

With respect to the impact in the formation of lakes due to stoppage of creeks along the Route, it was possible to observe work being done on the western side of the Route and the problem has been corrected in this section.

New forest plantations were identified along the Route, over an area of some 51 ha and representing more than 50,000 native trees planted. Certain degree of mix between species is observed in the reforested areas, in accordance to what was recommended in 2013. However, reforestation efforts could be improved by using rare and threatened tree species.

It was a recommendation in the 2013 EDA to reforest the area with native species as well as grass planting on slopes. In 2014 field visits, significant improvements have been observed including thriving reforestation areas and plots. It is important to continue with the environmental and ecological connectivity restoration efforts, including the aforementioned reforestation with native tree species.

Reforestation activities have not yet been implemented at some specific sites in order to mitigate the visual impact of works undertaken there. However, it is worth noting that reforestation efforts in general along the Route demonstrate a good growth process, as well as good survival rate and, in general terms, there is good maintenance of these. The suggestion of Nicaragua's expert that most replanted trees have died is simply incorrect.

In the section of the Boca San Carlos and Infiernito River, a similar situation was observed to that of the previous year, where no regular vehicular transit is possible. Some of the road cuts have tended to stabilise and are being covered by native vegetation.

In November 2014, CONAVI (together with CODEFORSA) made a significant intervention in this part of Infiernito-Boca San Carlos and Chorreras, developing a series of stabilisation activities on slopes as well as erosion control, thereby improving the environmental quality of the area (see Photo 4 to Photo 13). Specific activities undertaken in this section include the following:

Drains on land cuts: These drains are being built on top of the cutting area and their function is to prevent runoff water flowing through the soil and cutting transversely, rather than being directed down the slope toward an area with sufficient vegetation cover to absorb the water flow.

Cross drains on the road: These are deviations from runoff from the road surface, to avoid the water running freely and forming small grooves, and thereby to prevent soil loss.

Sediment traps: These consist of a craft trap which is placed over the drain in order to filter out sediment downstream whilst reducing the speed of runoff. So far, 263 sediment traps have been built.

Large sediments collector: These have the same function as the small sediment traps but cover larger areas of exposed soil, and protect soil loss.

Sediment trap with drawer: This type of trap is placed at the end of all drains that have been built either on top of land cuts or on the terraces. The constructed drawer varies in size depending on the location of the drain and the available space; however, measures of the drawers are 1 metre long, 75 cm wide, 50 cm deep. So far, 148 sediment traps with drawers have been built.

Covering of areas without vegetation: In order to reduce and further avoid the loss of soil from laminar and pluvial run off, covering of all exposed soil areas has been carried out. To date, 4,140 m² of slopes have been covered with saran, 910 strains of vetiver grass and 783 sotacaballo trees have been planted.

Planting of native trees: Planting trees as a compensatory measure has been implemented in several places along Route 1856 from Delta Costa Rica to the sector Pocosol river in Los Chiles northern border. This activity was conducted in open areas dedicated to livestock where owners have given part of the production areas to implement this activity.

Photo 3: Sedimentation mitigation measures in section Infiernito river-Boca San Carlos.

Photo 4: Sedimentation mitigation measures in section Infiernito river-Boca San Carlos.

Photo 5: Sedimentation mitigation measures in section Infiernito river-Boca San Carlos.

Photo 6: Slope contention in section Infiernito river-Boca San Carlos.

Photo 7: Slope contention in section Infiernito river-Boca San Carlos.

Photo 8: Slope contention in section Infiernito river-Boca San Carlos.

Photo 9: Slope contention in section Infiernito river-Boca San Carlos.

Photo 10: Sotacaballo trees planted on saran-covered slopes in Chorreras sector

Photo 11: Sedimentation mitigation measures in the Chorreras sector.

Photo 12: Sedimentation mitigation measures in the Chorreras sector.

In the same section between Boca San Carlos and Infiernito River, which is the section of the Route with the most forest cover, it was noted once again how important it is for wildlife. There are no human settlements in this area, which has very colourful wildlife such as Scarlet Macaws, observed in large numbers, Great Green Macaws in lesser numbers, monkeys, badgers, an eagle and tapir hoof prints.

In the section of Caño El Jardín, there is an area of forest close to Route 1856 that is being cleared under the canopy level and there is a small palm oil plantation of 2 ha in extension in an area where agriculture production has been absent.

From Boca San Carlos towards the west, there are alluvial plains along the path of the Route, which have poor drainage and local settlers claim these are prone to occasional flooding, and at some points they showed researchers where the waters of the San Juan River rise to an estimated height of some two metres above the level of the Route.

The situation of some wetlands that had been affected the previous year has now stabilised with some grassy vegetation covering landfill areas, but at some points there continues to be sediment entering, although in lesser proportion that before, suggesting that the growth of grasses on the slopes and road cuts is diminishing the process of erosion.

The section of the Route between Remolinito and Tambor continues to be open to vehicular traffic, even during the rainy months, but the presence of settlers and homes along the sector is noticeable, probably due to the fact that electricity is provided along this section.

7.1.2 Aquatic Biology

1. In order to assess the effect of the construction of the Route on aquatic ecosystems that traverse the road and empty into the San Juan river, ten lotic bodies of water were selected (creeks, channels and rivers), the structure of their biotic communities was characterized and the quality of the water was evaluated by estimating the BMWP-CR (MINAE-S, 2007) index, using the aquatic macro-invertebrates group as indicator species.
2. In each of the bodies of water, two sampling points were selected: one upstream (without direct influence) where the road intersects the body of water, and the other downstream (with direct influence), for a total of 20 sampling points.
3. In general, the aquatic community of the majority of sites sampled had very low diversity and richness of taxa. This result is probably due to three reasons: the current, the turbidity- sedimentation ratio, and the type of substrate.
4. With the values of abundance and richness of taxa obtained for the control sites (above the Route) and the sites with influence (below the Route), in half of cases it is possible to say that bio-indicators did not offer an evident response that would indicate an impact on the community of macro-invertebrates, since the values were very variable.
5. This result could be attributed to the following two factors: (1) degradation in the quality of the habitat as a consequence of some of the activities conducted during the construction of the Route, such as the movement of earth and the cutting of river bank vegetation, and (2) the sedimentation processes that take place in rivers, due to slopes and areas of unstable fills that suffer erosion due to rain. Where degradation was found to exist, it was also concluded that this was localized and of a temporary nature.
6. An aquatic environment, once altered, is subject to periods of re-colonizing that may vary from a few days to weeks or months, depending on the nature and reach of the disturbance. The response of bio-indicators to the effects of the construction of the Route on the aquatic ecosystems could be imperceptible in some of the sampled sites possibly because the aquatic communities have already recovered.

7. The field sampling was performed approximately one year and a half after the works on Route 1856 were conducted and it is likely that during this period the communities were able to stabilise. It is also important to consider that these bodies of water are in low lying areas which receive large quantities of sediment throughout the year coming from the watershed, so that it is expected that aquatic fauna is adapted to high levels of sediments in the water.
8. Therefore, the quantity of sediment contributed by Route 1856 is not sufficient to cause a significant impact on the bio-indicators studied at the sampling sites.
9. The presence of groups which are sensitive to aquatic habitat alterations is a good sign, since these indicators often disappear when there is a strong alteration of the aquatic habitat, especially if the effect is persistent since it does not permit for sensitive taxa to re-colonize the bodies of water. The finding of sensitive families in practically all the sampling sites, both upstream and downstream, can be interpreted as a positive sign of recovery and of the lack of any serious impact by the road works on the environmental conditions of the points under study. Only two sites did not have macro-invertebrates considered sensitive.
10. It should also be noted that the sampling for bio-indicators was performed in bodies of water that flow into the San Juan River. The impacts detected caused by the works on Route 1856 to the bodies of water, such as the modification of substrata and sedimentation, are local effects.
11. The impacts, such as they are, should not transfer to the San Juan River since this river is of a superior order, with a stream volume much larger than those of the bodies of water in the study. The section of the San Juan River that runs parallel to the Route is located in the lower part of the watershed where the quantities of sediment are naturally high, so that any impacts of the Route construction on the organisms that inhabit the San Juan river would be expected to be minimal and very diffuse, given the volume of water that this river carries as a receptor body.
12. In order to be able to evaluate with any greater certainty if the Route works led to a level of sedimentation that could affect the aquatic fauna of the San Juan River and the tributary rivers in the area under study, it would be necessary, first, to determine and validate the thresholds of sedimentation that could affect the species found in these rivers, since there is no information on aquatic organisms in the study area.
13. It would thus be necessary to determine and validate the thresholds of mortality and morbidity for the species found in these rivers as well as the tolerance levels for sedimentation, since there is no information for aquatic organisms in the study area. In order to determine these values it would be necessary to conduct periodic analyses on a long term basis that evaluate the tolerance capacity of fish and macro-invertebrates to different quantities of sediments to be able to determine at what point aquatic organisms begin to die off or their relative abundance and richness is diminished.

Specific Observations

1. In 2014 there seems to be a tendency towards greater abundance and taxonomic richness at the points upstream of the Route, compared to points downstream. Since it is the downstream points that receive a direct influence from the project, it could be that the Route works might be causing a decrease at the downstream points. This tendency was not evident in 2013.
2. In both years, the diversity and dominance indexes do not seem to present a clear trend while the equity index seems to show higher values at the sites downstream of the Route. This could suggest a greater heterogeneity, meaning that the quantity of macro-invertebrates is distributed more evenly among the different taxa.
3. In the case of the BMWP-CR index, in 2014 a decrease was noted in the quality of water at the downstream sites in comparison to the upstream sites at 7 of the 10 sampled sites, as opposed to 4 sites in 2013. Even so, there has not been a decrease of more than 2 categories of the index in any of the sampled years. It is likely that the change in micro-habitats in the bodies of water, resulting from the works on the Route, could be the cause of the localised decrease in the quality of water, especially due to sedimentation processes.
4. Upon visual inspection of the Route 1856, it was possible to determine that most of the Route does not present a great threat to aquatic environments, since most of the Route lies along flat terrain, where no deforestation occurred and no unstable slopes are evident, except for the section between Infiernito river- Boca San Carlos, which exhibits active sedimentation processes. However, CONAVI is intensively developing slope and sediment containment works.
5. It was not possible to find threatened species in the CITES lists, or the red list of the IUCN and the Wildlife Conservation Law, although most of the macro-invertebrates collected were not identifiable at the taxonomic level of species, given their immature state (larvae and nymphae), and the absence of taxonomic keys for many of these at the level of species, in the Tropic. But in the present Follow-Up Study, at least 23 taxa were found that could be considered uncommon or of restricted distribution.
6. The effect of the works of the Route that should be addressed carefully is the liberation of sediment. In this regard, mitigation measures during the construction phase of the Route must be maintained to control the process, such measures include engineering control techniques and mitigation of sedimentation, such as sediment traps, unstable slopes stabilisation, among others.

7.1.3 Tourism

1. The area under study does not offer, nor has it ever been a touristic development area. To date, the touristic offer in the section Marker 2 to Delta Costa Rica, does not have any type of touristic facility on the Costa Rican side

of the River. The only available site is Delta Cabins, with facilities mostly for national visitors. Towards the extremes of the river, infrastructural conditions and facilities improve, concentrating in San Carlos, which is the capital of the province of Rio San Juan and at the Caribbean town of San Juan del Norte.

2. The River, particularly along the study area, only provides transportation services from point to point. This is a very limited tourism offer involving 3.54% of the national tourism offer (PNDTS 2011-2020). The San Juan River is among the poorest provinces in Nicaragua and therefore has a minimal offer in terms of tourism services.
3. The city of San Carlos is the tourism distribution centre for San Juan River (El Castillo, Sábalo, Islas de Solentiname) but it does not offer visitors the touristic base necessary to satisfy all needs. Visitation in this section does not reach beyond an estimated 10,000 visitors per year, a number that is too low to be considered competitive and consolidated.
4. Some lodgings that have adequate infrastructure, of a medium level, well integrated to the environment, are developing tourism services oriented towards international tourists with an eco-touristic perspective: bird watching, visits to protected areas, specialized trail hiking, fishing, etc. However, some are not able to consolidate a visitation level that allows them to break even, so that they often have to offer seasonal services.
5. Touristic services and products concentrate in the observation of nature, walks, boat tours and fishing, mainly. The same take place in areas neighbouring Sábalo, El Castillo, and Biological Preserve Indio Maiz, and not in the area of the area from Marker 2 to Delta Costa Rica.
6. Even though sports fishing is widely offered in the San Carlos region, and neighbouring areas such as El Castillo and Sábalo, no commercial fishing or tourism in the River is documented within the study area. Fishing activities along the area from Marker 2, to Delta Costa Rica, comprise sporadic subsistence fishing.
7. The potential for tourism in the area could serve as a justification to attract international tourists, however, infrastructural conditions, access roads, services and products available, quality of touristic offer, weak image and incipient information and commercial services are not sufficiently satisfactory to attract larger numbers than at present.
8. The previously mentioned factors, in addition to the unstable and unsafe image generated for the area by continuous border disputes between Costa Rica and Nicaragua, do not favour private investment efforts that could strengthen the region.
9. Nevertheless, Nicaragua in its PNDTS 2011-2020 points strongly to the region of the province of Rio San Juan as one of the priority destinations to strengthen

and promote nature tourism. Presently, no significant changes have been identified regarding the number of tourists in the area. Any visual impacts of the Route are confined to short stretches.

10. Visitation in the area of San Carlos, Nicaragua, could increase slightly due to the opening of the new road that links this locality with Managua, which has decreased travel time to 4.5 hours. However, this access points to national tourism and backpackers.
11. Aquatic tourism is conducted mainly with the use of public service boats which run at pre-established schedules and at very low cost. Otherwise the cost of private boats for long stretches is very high and not common.
12. The touristic profile for those visiting the San Juan region is mainly one of a backpacker willing to pay little and expect very basic services.
13. There continues to persist the need to make additional payment for the use of the San Juan River on the part of Costa Rica vessels and they must report travel to authorities in San Carlos. This in addition to the less-than-friendly treatment to tourists, which, along with the hostile atmosphere, does not create a sense of safety and trust to promote organized visitation outside of Costa Rica.
14. The effect of the construction of the Route does not have a direct impact on the touristic movements of recent years.

7.1.4 Ecological Connectivity

1. Analysis of the structure of the landscape in the area makes evident a number of weaknesses in the biodiversity and ecosystems conservation goals for the Atlantic Watershed of Costa Rica. This is a dynamic and heterogeneous landscape, characteristics which can have an impact on processes such as ecological succession, adaptation, maintenance of diversity of species, stability of communities, competence, interaction among predators and prey, parasitism, epidemics and other stochastic events.
2. Identification of connectivity routes and the important connectivity areas in the landscape of the area under study shows that these are not related to the pathway of the Route, despite the fact that this access route is located in the area of greatest forest cover in the area of the study. Likewise, it is possible to say that Route 1856, because of the reduced extension of natural ecosystems affected, has not generated a significant impact on the connectivity structure of the landscape under study.

7.1.5 Impacts Identified

Based on the assessment of the activities conducted by the Route project, a series of activities have been identified, as follows:

- Cutting of trees in the right-of-way and contiguous areas.
- Partial sedimentation along the borders of wetlands neighbouring the Route.
- Loss of trees and bushy vegetation located on the banks of streams, due to flooding.
- Landslides and erosion of slopes affecting the forested areas alongside the Route.
- Affect to the wetland ecosystem (due to drainage, landfill and burning).
- Affect to structural connectivity.
- Potential and localised affect to aquatic habitat.
- Potential and localised affect to micro-habitats and substrata of aquatic macro-invertebrates due to filling of interstitial spaces with sediment.
- Potential localised decrease in taxonomic abundance and richness.
- Landscape affect due to the road works.

Furthermore, in lands near the section of Remolinito Grande de Sarapiquí, an area of 0.5 ha showed signs of burning of the wetland ecosystem, probably during the abnormally dry summer. This procedure is applied by the settlers to change the natural use of pastures to raise cattle.

Taking into account the results of the evaluations of the MIIA (see table 4-3), the following results were identified:

1. In the evaluation conducted by the 2013 EDA, 8 irrelevant impacts were identified and 3 of a moderate level. In the updating of the evaluation of impacts, 6 irrelevant impacts were defined, and 5 of the moderate level.
2. For those impacts that changed from irrelevant to moderate, the increase takes place within a maximum range of 10 units.
3. The sum of the total importance of impacts increases 12 units.
4. All impacts show a low to medium degree of intensity on the environment of Costa Rica.

All impacts have a uniform value between the range of -18 and -34, which indicates homogeneity in the low incidence of impacts along the Route.

7.2 Recommendations

Once the environmental conditions previously identified have been analysed, a series of recommendations are formulated that have been presented previously in this study, but which are presented below in summary, accompanied by the suggestion of a number of activities to be executed as part of the prevention and mitigation measures in the area of the path of Route 1856.

1. To strengthen the existing reforestation plan with the planting of trees at other sites where it is not necessary to cover road cuts, and to reforest with scarce native species, threatened or endemic, or in danger of extinction and not using exotic species, nor those not present in the area. It is recommended that species be mixed, simulating the arboreal diversity of the forests and that the proportion of species be approximately 50% of species that used to be common but which have been decimated such as “Manu”, “Cocobolo” or “Jicaro”. The other 50% could include species that are commonly planted by reforestation programs in the area. Sites with undulating and very undulating slopes should be prioritized within the protection area of the San Juan River, and other streams and rivers in the Route area.
2. Allow the natural regeneration of secondary vegetation where it emerges aggressively, avoiding cutting it down to plant other vegetation, or otherwise use pioneering species of trees as shade to favour the growth of species that do not tolerate the sun or grow better under shade, such as “Manu”, “Pinillo” or “Almendro de Montaña”. At sites with strong slopes, it is suggested that the natural secondary vegetation be allowed to recover, if possible. Since the total of forest cover lost was quantified at 83 ha, it is suggested that an area of similar size be allowed to recover naturally with secondary growth, in terrain next to the Route, giving priority to the most hilly terrain close to the San Juan River, as a way to compensate the native system, since common reforestation efforts do not propitiate ecosystems similar to those required to maintain native biodiversity. With the purpose of verifying the existence of tree species that are threatened by extinction within the Route´s right-of-way, it is recommended that a forestry inventory be established of species found along the Route.
3. Establishment of an integrated land use plan with the region.
4. Establishment of a protection and maintenance plan of the trees identified as being threatened by extinction or under seasonal protection.
5. Identification of different sections and ecosystems along the Route as tourism incentives.
6. To clean accumulated sedimentation materials to allow the free flow of water along natural drainage systems.
7. Where the Route approaches a wetland, as is the case of Laguna Remolinito Grande, obstruction of the free flow of waters should be avoided by the use of gutters or similar means, for the water that usually flows into the wetland to circulate freely on both sides of the way.
8. Perform improvements in the drainage structures and landfills with the purpose of avoiding any impact to local wetlands.
9. Continue remediation works aimed at the protection of slopes through the use of geo-textiles, improvement of the angle of slant and use of drainage systems.

10. Ensure the adequate drainage of waters at these sites, through the placement of an adequate system of gutters, or lowering the level of the drains to avoid accumulation of water affecting the Route itself. Once the excess water is drained, it is suggested that the area be allowed to recover naturally through the secondary regeneration of local vegetation.
11. Establish a monitoring plan along the path of the Route with the purpose of verifying the recovery of the wetlands and preventing the cutting down of vegetation by local inhabitants, as well as avoiding the presence of squatters along the Route.
12. Establish a monitoring plan along the path of the Route in order to verify any required maintenance to be carried out on the Route.
13. Avoid cementing of river and streambeds under drains and bridges.
14. Conduct a monitoring plan of the conditions of aquatic habitats in riverbeds under drainage systems and bridges, in order to monitor the state of the substrata of the riverbeds monitored in this study, and take any necessary action.
15. Consolidate the road works in order to stabilise slopes as soon as possible, especially unstable slopes, to avoid the possibility of contributing sediment to the aquatic environment.
16. Promote natural regeneration and ecological restoration along riverbanks.
17. Consolidate vegetation cover as a means to prevent the poor historical practices in the land use prior to the construction of the Route reoccurring, particularly along the bank of the San Juan River, thereby ensuring respect for the margin in the future.
18. Even though the reforestation work carried out by CODEFORSA uses species native to the area, it is recommended that fast growing species be kept in mind to act as buffers of visual impacts in the short term. This process of reforestation should also include species that can cover vertical spaces to serve as integral visual barriers from the first 60 centimetres upwards.
19. It is of basic importance that the effort at amelioration of the area be an integral process that includes local community participation, and for this purpose it would be advisable to develop environmental education, civic education, entrepreneurship, and self-development programs. The purpose is not just reforestation, but also that in this area more than others, a commitment be made evident, and the vision of a country that struggles for its sustainability, and, thus, for an integrated and visionary work.
20. Improvement of the presence and conditions of safety in the area for inhabitants and tourists alike.

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9 ANNEXES

Anexx 9-1: Taxa richness and individual abundance of aquatic macro-invertebrates collected at the study sites along Route 1856, Juan Rafael Mora Porras Road, August - October, 2014. Downstream (Dwn) y Upstream (Ups) from the Route. (*) least common taxa or with limited distribution in the country, taken as reference material deposited in the Zoology Museum, UCR.

Order / group	Family / group	Genus / group	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
			Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Blattaria	Blattelidae	gen. indet.									1	1				1						
	Blattidae	gen. indet.												2	1							
Coleoptera	Carabidae	gen. indet.									1											
	Dryopidae	gen. indet.									2											
	Dytiscidae	Dytiscus *	1																			
	Elmidae	Heterelmis												1	1							
		Phanocerus														1						
	Gyrinidae	Gyretes*				1																
	Limnichidae	gen. indet.						1			1						2					
	Noteridae	Hydrocanthus															1					
		gen. indet.															1					
	Scirtidae	gen. indet.																				1
		Scirtes*		1																		
	Staphylinidae	gen. indet.			1						1					1		2				1
Collembola	fam. indet.	gen. indet.						1									1	1				
Diptera	Ceratopogonidae	Ceratopogoninae		1				2														
		Forcypominae	1																			
	Chironomidae	Chironominae	3	13	1	1	6	5	6	7	2		1				2	3		4		
		gen. indet.															1					

Order / group	Family / group	Genus / group	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
			Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
		Orthocladiinae		1			5	3			1					3						
		Tanypodinae	2	1	2	2	1	5	1	1									1	1		
		Tanytarsini					1				1											
	Culicidae	Anopheles	2																			
		Culex				1											1					
		gen. indet.						1														
	Simuliidae	Simulium					15	1			41	1	1	63	4	33		3		1		
	Tipulidae	Hexatoma												1								
Ephemeroptera	Baetidae	Americabaetis		1			13	10			1	4	1	4		2		1		1		
Ephemeroptera	Baetidae	Baetodes												1								
		Callibaetis*					7	7														
		Camelobaetidius												1								
		Fallceon											1									
		gen. indet.										1										
		Moribaetis*												1								
	Caenidae	Caenis*				1	5	5				1						1			1	
	Leptohyphidae	Cabecar*	1	3		4	17	4		1		2		1								
		Epiphrades				1																
		Leptohyphes												1								
		Tricorythodes										2								1		
	Leptophlebiidae	Farrodes				1	20	2			1	12		3								
		gen. indet.															1					
		Terpides*		2										2			2					1

Order / group	Family / group	Genus / group	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
			Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
		Thraulodes					5															
		Ulmeritoides*	2		2	3						2							1	1		
Hemiptera	Belostomatidae	Belostoma						1														
	Gerridae	gen. indet.		3		2			1			1						2				2
		Potamobates unidentatus					1											1				
	Mesoveliidae	Mesovelia	1																			
		Mesoveloidea			1																	
	Naucoridae	Ambrysinae									1	1										
	Nepidae	Ranatra*			1	1																
	Notonectidae	Martarega*																12			2	1
		Notonecta*				1																
	Veliidae	gen. indet.						1														
		Microvelia	3						1								3	5				1
		Rhagovelia				8	6	17			3	11	2	9	6	5		2		3		
Megaloptera	Corydalidae	Corydalus												1								
Odonata	Calopterygidae	Hetaerina											2	2	3	1	1	3		2		
	Coenagrionidae	Argia			1	1	5	5						1								
		Enallagma*				4		11														
		gen. indet.						1														
		gen. indet.															1	1		1		
	Gomphidae	Agriogomphus*						1														

Order / group	Family / group	Genus / group	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
			Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
		Epigomphus									1											
		gen. indet.									1											
	Libellulidae	Brachymesia*				1																
		Brechmorhoga									1											
		Elga*				1																
		gen. indet.	2		1						2	2						2				
		Macrothemis*											1	1						2		
		Micrathyria*																1				
		Neocordulia*												1								
	Megapodagrionidae	Heteragrion*									1	1										
		Thaumatoneura *										2										
	Perilestidae	Perissolestes*		1								2			1							
Plecoptera	Perlidae	Anacroneuria										11	3	11				1				
Trichoptera	Helicopsychidae	Helicopsyche										1										
	Hydropsychidae	Centromacronema *										1										
		Leptonema											3	9								
		Smicridea					4				4	1			1					5		
	Philopotamidae	Chimarra												1								
Tricladida	Planariidae	gen. indet.		1																		
Trombidiformes	fam. indet.	gen. indet.					2	1														1
Basommatophora	Physidae	gen. indet.		1				1	1													

Order / group	Family / group	Genus / group	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
			Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Basommatophora	Planorbiidae	gen. indet.															1					
Rhynchobdellida	Glossiphoniidae	Helobdella cf. triserialis*							1	1												
		Helobdella elongata*	1																			
		Placobdella ringueleti*	1						1													
Neotaenioglossa	Thiaridae	gen. indet.			6	1			5	2												
Oligochaeta	fam. indet.	gen. indet.															1			1		
Decapoda	Palaemonidae	Macrobrachium																			1	
	Pseodothelphusidae	gen. indet.										2										
		Total of individuals	20	29	16	35	113	86	17	12	67	62	15	118	17	47	19	41	2	23	4	8
		Total of taxa	12	12	9	18	15	22	8	5	17	20	9	20	7	8	11	14	2	12	3	7

(*) Least common taxa or with limited distribution in the country, taken as reference material deposited in the Zoology Museum, UCR.

Anexx 9-2: Table with BWMP-CR indexes, Shannon´s diversity, Dominance and Jacquard´s Equity for sampling sites in Route 1856. 2013-2014.

		Site 1		Site 2		Site 3		Site 4		Site 5	
	Index	**Dwn**	**Ups**	**Dwn**	**Ups**	**Dwn**	**Ups**	**Dwn**	**Ups**	**Dwn**	**Ups**
2014	**BMWP-CR**	34	44	28	43	41	66	8	10	62	75
	Quality	Poor	Poor	Poor	Poor	Poor	Regular	Very poor	Very poor	Regular	Regular
	Diversity	2,39	1,94	1,93	2,59	2,46	2,65	1,73	1,23	1,69	2,55
	Dominance	0,10	0,24	0,20	0,10	0,10	0,09	0,23	0,39	0,40	0,11
	Equity	0,96	0,78	0,88	0,90	0,89	0,86	0,83	0,77	0,58	0,84
2013	**BMWP-CR**	48	76	62	44	55	72	50	27	63	84
	Quality	Poor	Regular	Regular	Poor	Poor	Regular	Poor	Poor*	Regular	Regular
	Diversity	2,21	2,69	2,79	2,40	2,14	2,95	2,49	1,80	1,95	2,53
	Dominance	0,14	0,08	0,08	0,10	0,21	0,07	0,11	0,19	0,25	0,14
	Equity	0,89	0,90	0,92	0,96	0,70	0,88	0,86	0,92	0,69	0,78

		Site 6		Site 7		Site 8		Site 9		Site 10	
	Index	**Dwn**	**Ups**	**Dwn**	**Ups**	**Dwn**	**Ups**	**Dwn**	**Ups**	**Dwn**	**Ups**
2014	**BMWP-CR**	35	80	26	24	33	46	10	44	13	24
	Quality	Poor	Regular	Poor	Poor	Poor	Poor	Very Poor	Poor	Very Poor	Poor
	Diversity	2,08	1,86	1,68	1,12	2,40	2,41	0,69	2,28	1,04	1,906
	Dominance	0,14	0,31	0,22	0,51	0,10	0,13	0,50	0,12	0,375	0,1563
	Equity	0,95	0,61	0,86	0,54	0,96	0,87	1,00	0,92	0,9464	0,9796
2013	**BMWP-CR**	34	45	75	66	55	48	20	37	44	33
	Quality	Poor*	Poor	Regular	Regular	Poor	Poor	Poor*	Poor	Poor	Poor*
	Diversity	1,93	2,36	2,62	2,49	2,49	2,42	2,02	2,01	1,58	1,77
	Dominance	0,17	0,11	0,08	0,11	0,10	0,11	0,17	0,20	0,36	0,23
	Equity	0,93	0,95	0,97	0,90	0,94	0,94	0,84	0,84	0,64	0,85

*Categories that were undervalued in the 2013 report as red (very poor), being the correct category orange (poor) according to the score obtained (Annex 3).

Anexx 9-3: Table showing water quality according to the sum obtained in the BMWP-CR index, in accordance with Regulation No. 33903 MINAE-S (La Gaceta, Sept. 2007).

Quality Level	BMWP'	**COLOR**
Excellent quality waters	*>120*	**Blue**
Good quality waters, not polluted or not impacted in a sensitive level	*101-120*	**Blue**
Regular quality waters, eutrophy, moderate pollution	*61-100*	**Green**
Poor quality waters, polluted	*36-60*	**Yellow**
Poor quality waters, very polluted	*16-35*	**Orange**
Very poor quality waters, extremely polluted	*<15*	**Red**

Anexx 9-4:Taxa richness and individual abundance of aquatic macro-invertebrates collected in study sites along Route 1856, Juan Rafael Mora Porras Road, July - August, 2013. Downstream (Dwn) y Upstream (Ups) from the Route 1856.

Taxon	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Coleoptera																				
Dytiscidae																				
Derovatellus															1					
Vatellus																1				
Gen. Indet.		1													1	1				
Elmidae																				
Cylloepus									1											
Heterelmis									2											
Hexacylloepus									1											
Macrelmis									1					1						
Microcylloepus						1														
Hydrophilidae																				
Gen. Indet.	2						2						1							
Limnichidae																				
*Limnichites**	8		1												3		8	1		1
Psephenidae																				
Dicranoselaphus *																			1	
Ptilodactylidae																				
Anchytarsus									1				1							
Scirtidae																				
Gen. Indet.		1					2													
Staphylinidae																				
Gen. Indet.																				1
Lampyridae *																				
Gen. Indet.																1				
Dryopidae																				

Taxon	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Elmoparnus												1	1							
Diptera																				
Ceratopogonidae																				
Bezzia			1							1										
Probezzia			1															1		
Chironomidae																				
Chironomini	9	4	2			2	1										1			
Orthocladiinae			1		2	1										1				
Tanypodinae			2	2	1	10				1					2			2		
Tanytarsini			2		1	4								1				1		
Gen. Indet.			1		1	5											1			
Tipulidae																				
Hexatoma													1							
Gen. Indet.														1						
Culicidae																				
Aedes																			1	
Anopheles		1																		
Culex			1																	
Gen. Indet.															1					
Simuliidae																				
Simulium					13	1			32		1	1		1						
Ephemeroptera																				
Baetidae																				
Americabaetis		2			49	10	13		2	2					1			3		
Apobaetis	1	1	1	1		3									1		2	1	2	2
Callibaetis			1			1														
Cloeodes		1			1	1	1			2										
Fallceon					1												1			

Taxon	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Caenidae																				
Caenis	2	4	6	2	2	13														
Leptophlebiidae																				
Farrodes		5		1	11	6			15	17		2	3	1				1		
Terpides *		7				1				22					2				1	
Tikuna *																2				
*Ulmeritoides**	6	1	1	1				3		1						4		1		
Heptageniidae																				
*Maccaffertium**										3										
Leptohyphidae																				
Cabecar *										4										
Epiphrades		1			3	7	9								1	1				
Leptohyphes					3				1	1										
Tricorythodes	3	7	2	1	1	5	1		2	9					4	1				
Vacupernius *		1																		
Hemiptera																				
Belostomatidae																				
Belostoma							1													
Gen. Indet.							2													
Gerridae																				
Brachymetra albinervis								1		1										
Potamobates													1							
Potamobates unidentatus											2	3		1						
*Rheumatobates bergrothi**																1	1			
Tachygerris												2								
Telmatometra					1			1											1	
*Telmatometra withei**							1													

Taxon	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Gen. Indet.	1	1	1				3	3	1						1		7		7	6
Corixidae																				
Tenagobia							1									1	1			
Hydrometridae																				
Hydrometra				1																
Nepidae																				
*Ranatra**	1																			
Notonectidae																				
*Martarega**	3		1				2										6		25	
Gen. Indet.	2	3	7	6											2		34		27	16
Veliidae																				
Microvelia																1	1			1
Rhagovelia				1	14		5		3	1	4	2	2	4			2	9	1	
*Stridulivelia**												3								
Odonata																				
Calopterygidae																				
Hetaerina							5		2	1										
Coenagrionidae																				
Acanthagrion						3	1			1										
Argia						19	1	1		2										
Megapodagrionidae																				
Heteragrion		1								1										
Protoneuridae																				
Neoneura *	2	4	2			3	2	1							1			2		
Gen. Indet.																			1	
Platystictidae																				
Palaemnema *											1			4						
Polythoridae *																				

Taxon	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Gen. Indet.													1							
Gomphidae																				
Agriogomphus *										1										
Epigomphus		1								1			1							
Erpetogomphus																1				
Perigomphus *														2						
Gen. Indet.													1							
Libellulidae																				
Zenithoptera *						1														
Gen. Indet.		1		2		2			1							3		1	2	
Corduliidae																				
Neocordulia *												1								
Fam. Indet.																				
Gen. Indet.					2	1				1										
Trichoptera																				
Glossosomatidae																				
Protoptila										1										
Helicopsychidae																				
Helicopsyche										2										
Hydropsychidae																				
Leptonema											1	5	2	8						
*Macronema**										1										
Smicridea					7				1	1		1		2						
Leptoceridae																				
Nectopsyche		4								3	1		1		1					
Oecetis			1		2															
Polycentropodidae																				

Taxon	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Cernotina *						5														
Calamoceratidae																				
Phylloicus																2				
Plecoptera																				
Perlidae																				
Anacroneuria									6		1	2	2	3						
Megaloptera																				
Corydalidae																				
Corydalus												2		1						
Lepidoptera																				
Pyralidae																				
Gen. Indet.																			1	1
Dictyoptera																				
Blaberidae																				
Gen. Indet.								1												
Trombidiformes																				
Fam. Indet.																				
Gen. Indet.			6	3	2	2	5								1					
Haplotaxida																				
Haplotaxidae																				
Gen. Indet.	2		1								2			1	1					
Naididae																				
Gen. Indet.						1														
Rhynchobdellida																				
Glossiphoniidae																				
Haementeria				1																

Taxon	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Fam. Indet.														1						
Tricladida																				
Planariidae																				
Gen. Indet.					1				1											1
Architaenioglossa																				
Ampullariidae																				
Gen. Indet.																			1	
Basommatophora																				
Lymnaeidae																				
Gen. Indet.			1			12				1										
Physidae																				
Gen. Indet.				1																
Planorbidae																				
Gen. Indet.						2														
Neotaenioglossa																				
Hydrobiidae																				
Gen. Indet.		1																		
Sorbeoconcha																				
Thiaridae																				
Gen. Indet.						3														
Decapoda																				
Palaemonidae																				
Macrobrachium					1								2	2						
Pseudothelphusidae																				
Gen. Indet.													1							
Isopoda																				

Taxon	Site1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7		Site 8		Site 9		Site 10	
	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups	Dwn	Ups
Fam. Indet.																				
Gen. Indet.																				1
Ostracoda																				
Fam. Indet.																				
Gen. Indet.						1														
Total of individuals	42	53	43	23	119	126	58	11	73	82	13	25	21	34	24	21	65	23	71	30
Taxa Richness	12	22	20	13	19	26	17	6	17	25	8	12	14	16	15	13	10	11	11	9

Anexx 9-5: Comparative table of scores in the Matrix of Importance of Environmental Impact from 2013 and 2014.

Matrix of Importance of the Environmental Impact (MIIA) for the Route 1856 project in COSTA RICA territory																
			Impact Characteristic												Assessment	
			+/-	IN	EX	MO	PE	RV	SI	AC	EF	PR	MC	I			
No.	Environmental Factor	Impact												2013	2014	2013	2014
1	Terrestrial Flora and Fauna	a. Cutting down forests in right-of-way and surrounding areas.	-	2 / **2**	1 / **1**	4 / **4**	4 / **4**	4 / **4**	1 / **1**	1 / **1**	4 / **4**	4 / **4**	4 / **4**	-34	**-34**	Moderate	**Moderate**
		b. Partial sedimentation of wetland borders along Route 1856.	-	1 / **1**	1 / **1**	4 / **4**	2 / **2**	2 / **2**	1 / **1**	4 / **1**	1 / **1**	2 / **2**	4 / **4**	-25	**-22**	Irrelevant	**Irrelevant**
		c. Elimination of trees and bushes located along riverbanks, due to flooding.	-	1 / **1**	1 / **1**	2 / **2**	2 / **2**	2 / **2**	1 / **1**	1 / **1**	1 / **1**	2 / **2**	2 / **2**	-18	**-18**	Irrelevant	**Irrelevant**
		d. Landslides and slope erosion that affect the forested edges of the Route.	-	1 / **1**	1 / **1**	2 / **2**	2 / **2**	2 / **2**	2 / **2**	4 / 4	1 / **1**	2 / **2**	4 / **4**	-24	**-24**	Irrelevant	**Irrelevant**
		e. Affectation of the wetland ecosystem (due to drainage, landfill and burning)	-	1 / **1**	1 / **1**	4 / **4**	2 / **2**	2 / **2**	1 / **1**	1 / **1**	4 / **4**	1 / **4**	4 / **4**	-24	**-28**	Irrelevant	**Moderate**
		f. Affectation of structural connectivity	-	1 / **1**	1 / **1**	1 / **1**	2 / **2**	2 / **2**	1 / **1**	1 / **1**	1 / **1**	1 / **1**	4 / **4**	-18	**-18**	Irrelevant	**Irrelevant**
2	Aquatic Flora and Fauna	g. Affectation of aquatic habitat	-	2 / **1**	1 / **1**	2 / **4**	2 / **4**	2 / **2**	1 / **2**	1 / **4**	4 / **4**	2 / **4**	2 / **2**	-24	**-31**	Irrelevant	**Moderate**
		h. Potential affectation of the micro-habitats and substrata of aquatic macro-invertebrates due to filling of interstitial spaces with sediment	-	4 / **1**	1 / **2**	2 / **3**	2 / **2**	2 / **2**	1 / **2**	4 / **4**	1 / **1**	1 / **1**	2 / **2**	-29	**-24**	Moderate	**Irrelevant**
		i. Potential decrease in taxonomic abundance and richness	-	1 / **2**	1 / **2**	2 / **3**	2 / **2**	2 / **2**	1 / **2**	4 / **4**	1 / **1**	1 / **4**	2 / **2**	-20	**-30**	Irrelevant	**Moderate**
		j. Potential affectation of the quality of water due to turbidity caused by sediments	-	4 / **4**	2 / **2**	2 / **4**	2 / **1**	2 / **1**	1 / **2**	4 / **1**	4 / **4**	1 / **2**	2 / **2**	-34	**-33**	Moderate	**Moderate**
3	Landscape	k. Landscape affectation due to construction works	-	1 / **1**	1 / **1**	4 / **4**	2 / **2**	2 / **2**	1 / **1**	4 / **4**	4 / **4**	1 / **1**	2 / **2**	-25	**-25**	Irrelevant	**Irrelevant**
	Total	**Environmental Impact Residual Value**												**-275**	**-287**		

Note: Data in bold refer to the evaluation of the same impacts assessment in this Follow-up and Monitoring Study.