D04 AQUATIC INSTRUMENT SYSTEM (AIS) SITE CHARACTERIZATION REPORT

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	04/09/2014	ECO-01702	Initial release
B	08/26/2014	ECO-02006	Revisions to sensor locations
C	1/05/2016	ECO-03461	Revisions to sensor locations and site design due to STREON descoping

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1 DESCRIPTION

1.1 Purpose

Information collected and described here is used to inform the site design activities for the NEON project Aquatic Instrument System (AIS). This report includes information gathered by the Aquatic (AQU) and Environmental, Health, & Safety (EHS) teams. The purpose of this report is for the science team to outline what is desired at each site within a domain in order to obtain the best scientific data possible to help answer NEON's Grand Challenge Questions; therefore, this is not a design document, but a report that is an input to the design process.

This report takes precedence over other documents and reports that may repeat the information contained herein.

The Appendices include summary tables for the convenience of the multiple audiences of this report; some of the information in the tables is repeated from the body of this report while other information is exclusive to the summary tables.

1.2 Scope

AQU site characterization information presented in this document is for the D04 aquatic locations: Río Cupeyes (core) and Río Guilarte (relocatable). Issues and concerns for each site that need further review are also addressed in this document according to our best knowledge. Unless otherwise noted, the information contained herein takes precedence over the same information repeated elsewhere; thereby, this document contains the official change-controlled information pertinent to these sites.

Disclaimer: All latitude and longitude coordinates are subject to the variation inherent in our GPS equipment and the conditions at the site. Some of the Aquatic sites are in narrow canyons with limited satellite coverage; resulting in coordinates that are not accurate to within 50 cm.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

AD[01]	
AD[02]	
AD[03]	
AD[04]	

2.2 Reference Documents

RD[01]	NEON.NPR.000008	NEON Acronym List
RD[02]	NEON.NPR.000243	NEON Glossary of Terms
RD[03]	[Reference to photos]	
RD[04]	[Reference to map(s)]	

3 D04 AIS SITE CHARACTERIZATION REPORT

3.1 Río Cupeyes

Río Cupeyes is a 2nd-order wadeable stream that drains a 6.13 km^2 catchment at the proposed NEON aquatic site. The watershed is comprised of old- and secondary-growth subtropical moist and subtropical wet forest. The flow regime in Río Cupeyes is typical of Puerto Rican streams draining rainforest catchments: characteristic discharge exhibits a strong seasonal pattern with low flows during the mid- to late- dry season (December through March) and high baseflow discharge during the annual wet period of May through November. Extreme high flow events may ensue as a consequence of tropical storms or hurricanes, which typically occur between June and December. The NEON reach of Río Cupeyes is located in a montane area with steep slopes where landslides may occasionally occur. No current signs of recent landslides are noticeable and the vegetation is thick. However, if a prolonged and intense storm occurs it may trigger some instability. Although the vegetation adjacent to the stream reach is dense and the stream exhibits a steep gradient, the channel is relatively free of vegetation and stabilized by large boulders.

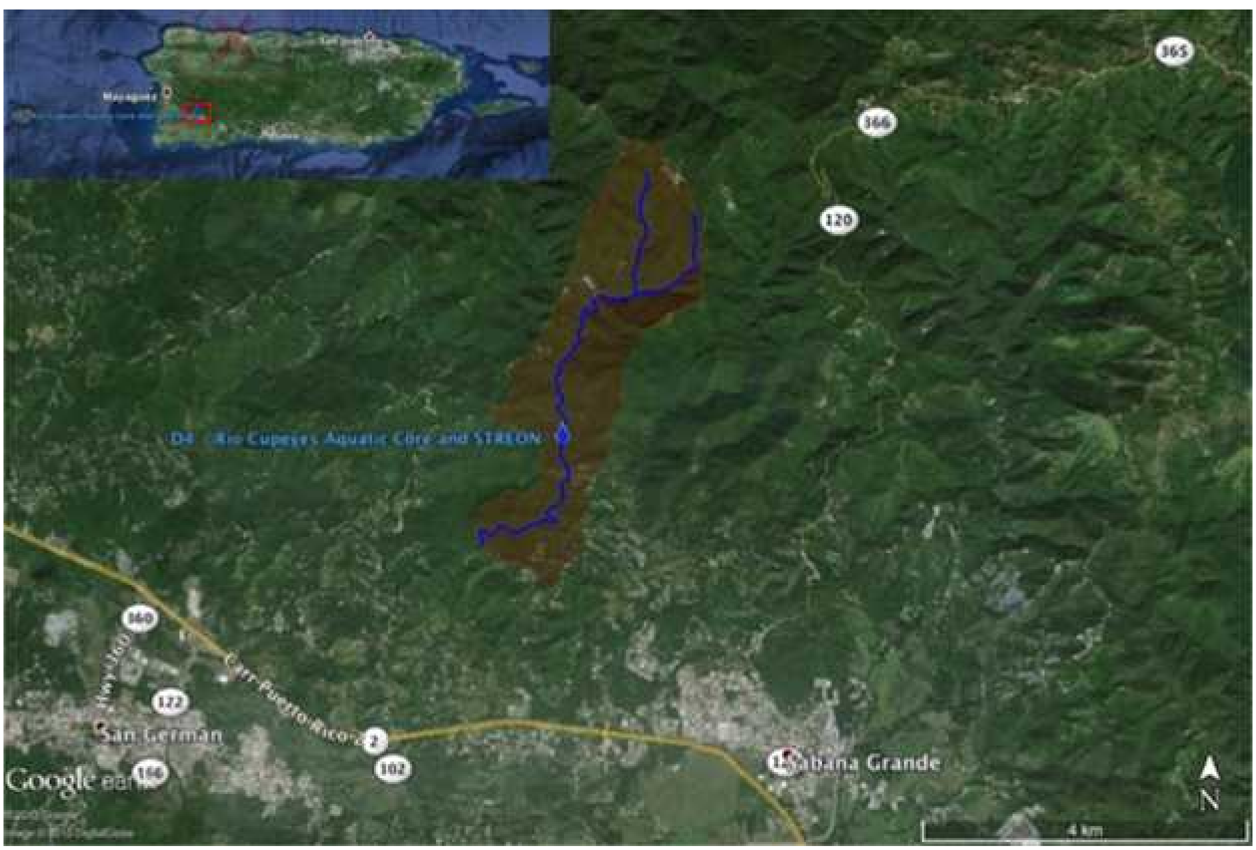

Figure 1. Map showing the location and extent of the Río Cupeyes catchment (shown in orange) where the NEON reach will be located (center point of reach shown in lower portion of catchment).

3.1.1 Historic Data

The following historic data was collected by government agencies as well as by NEON personnel who visited the site; recently collected data are considered provisional.

3.1.1.1 Hydrology

Hydrologic data is very limited for Río Cupeyes. The USGS has a station 50131800 that is located in the lower extent of the watershed near the confluence with Río Guanajibo in Sabana Grande. This USGS station is located 5.5 km downstream of the NEON reach. The watershed area of the Río Cupeyes monitored by this station drains 10.77 km^2. The data collected at this USGS station is limited to 7 sampling bouts: 5 taken from 1960 – 1966 and 2 taken from 2009 – 2010. NEON has performed 16 discharge measurements in the NEON reach during 2014 – 2015. The discharge data collected by the USGS was multiplied by a factor of 0.569 to account for the difference in catchment size between the USGS station and where the 2014/2015 measurements were made. The average monthly data that is available is shown in Figure 3 below. These monthly values have a high level of uncertainty due to the very limited dataset and scaling factor. The data suggest the baseflow during the wet season is 2 – 3 times higher than that of the dry season. The EPA model estimate (NHDPlus v2.1) for annual mean flow is 195 LPS in the upper catchment and NEON reach. This is 3-4 times higher that our available dataset suggest; however, the available data does not characterize the wet season well.

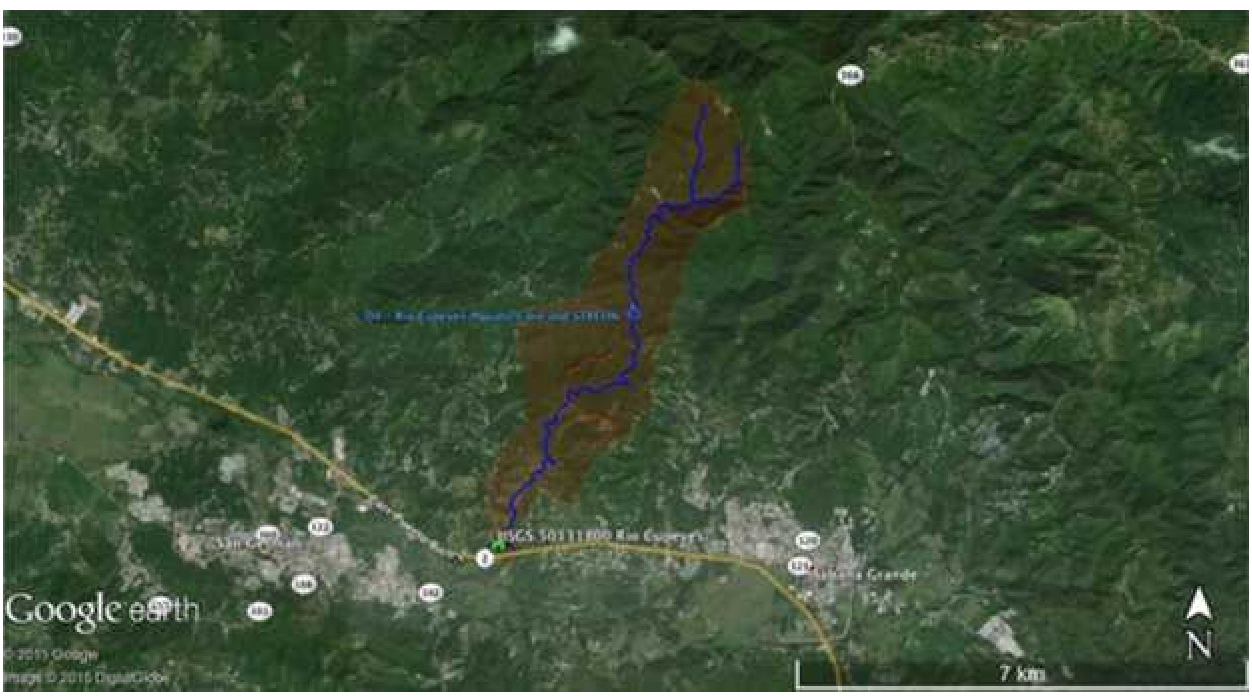

Figure 2. Map showing USGS station 50131800 on Río Cupeyes in relation to NEON site and catchment (orange).

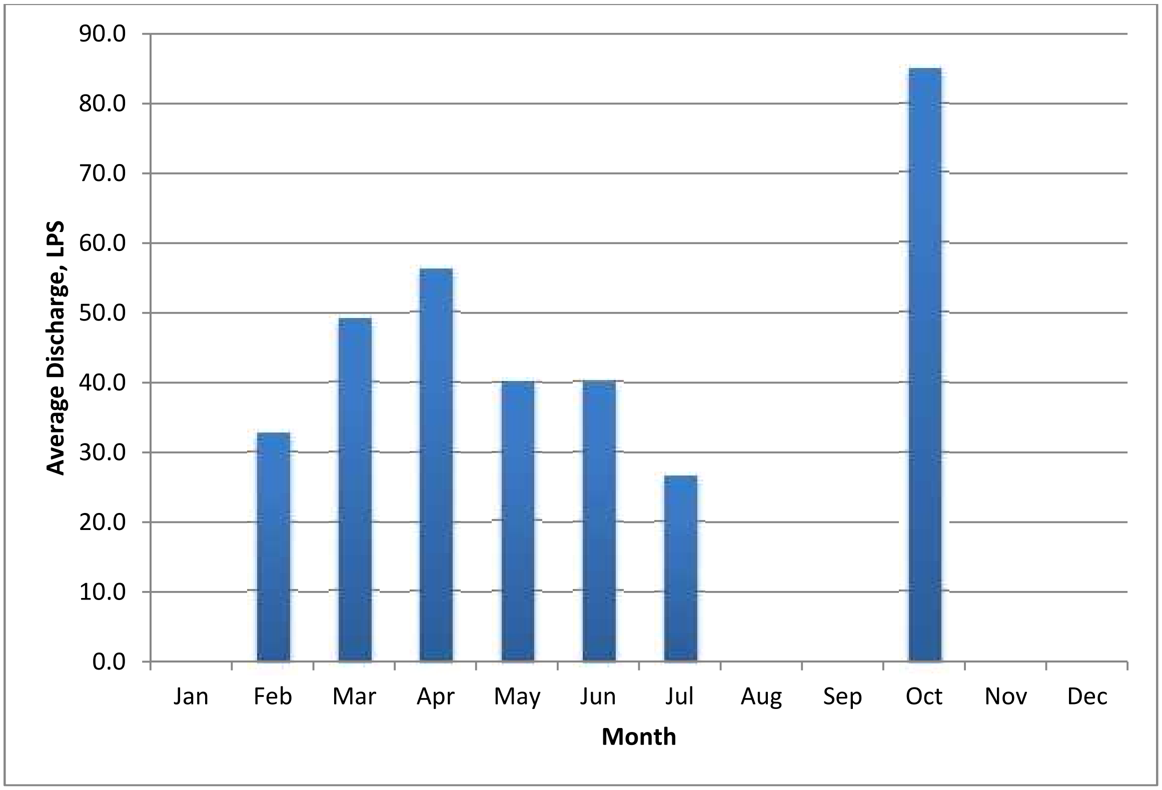

Figure 3. Average monthly discharge, in LPS, for the NEON reach wihtin Río Cupeyes.

3.1.1.2 Meteorology

The closest NOAA weather station is located in Maricao, approximately 6.5 km north of the Rio Cupeyes site. It is located on other side of the summit of the mountains that make of the catchment for Rio Cupeyes. Given the proximity and consistent environment, this station should serve a suitable proxy for local weather at the NEON site.

Figure 5 below shows the monthly averaged data for temperature and precipitation collected from 1981 – 2010. The average precipitation is 2 – 4 inches during the dry season and exhibits a bi-modal pattern during the wet season with increasing precipitation during April and May, with a typical decrease in June, before increasing through October.

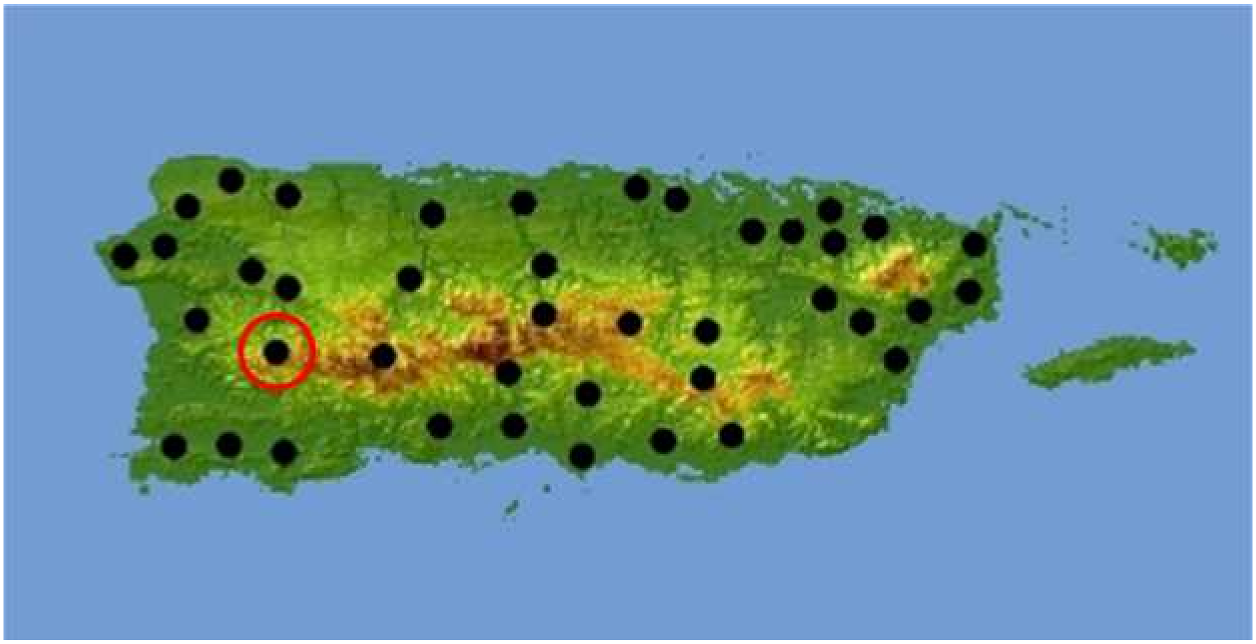

Figure 4. Map showing the location of the NOAA weather station used for historic meteorological data at Río Cupeyes.

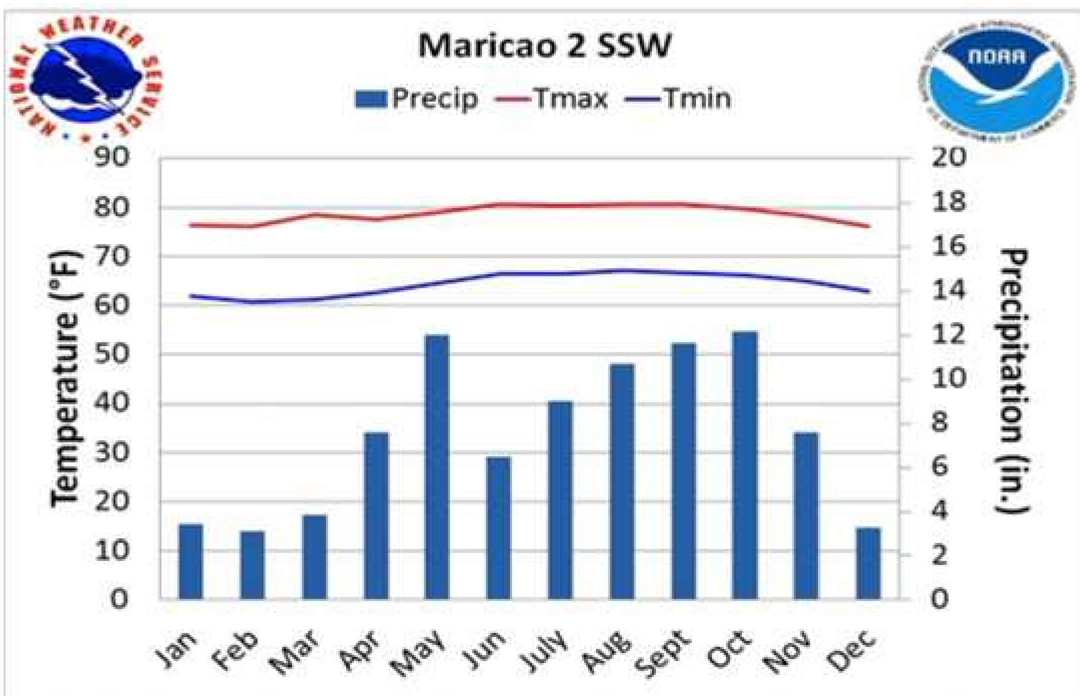

Figure 5. Monthly averaged data for 1981 -2010 collected in Maricao, PR.

3.1.2 Site Power

Electricity is delivered to the residential area north of Saban Grande along PR 363. The Puerto Rico Electric Power Authority (PREPA) manages these lines. It is planned to extend power from the road above the pasture at the site to the portal using poles and private lines. The planned route will run west from the existing power and then turn north before continuing west along the tree line that separates the old access road and the new access road within the pasture (Figure 6).

3.1.2.1 Aquatic Auxiliary and Aquatic Portal Locations for Construction

The initial estimated location for the Aquatic Portal and Auxiliary Portal is near the stream access gate just west of the old (not currently used) access road. It is planned to run the pole power down to the Portal location. Rather than run conduit back up the hill to the met station location, it is planned to run power and communication lines back up the poles to extend them back to the met station and precipitation field device posts. This will provide lower risk to infrastructure for the core site. The pole near the met station needs to be carefully placed with respect to the sensor locations to ensure that it does not impact measurements and meets the NEON science requirements. In particular the distance between the pole and the precipitation sensors (rain gauge and wet deposition collector) must be two times the difference in the height of the pole and the inlet of the sensors (60” above ground). This must also take ground slope into account. The location of the power pole and its distance and orientation relative to the met station and precipitation sensors are described in the following section (3.1.3).

Figure 6 A Google-Earth-Derived Image of Aquatic Auxiliary Portal for D04 Río Cupeyes

Table 1 Aquatic Portal Location

Aquatic Portal	Latitude	Longitude
Location	18.109118°	-66.985885°

Table 2 Aquatic Auxiliary Portal Location

Aquatic Auxiliary Portal	Latitude	Longitude
Location	18.109118°	-66.985885°

3.1.3 Sensor and Infrastructure Locations for Construction

The GPS coordinates for S1 and S2 presented in Table 3 were obtained by AQU with support from EHS. The GPS coordinates for the met station, secondary precipitation gauge (tipping bucket) and wet deposition collector (NADP) are given in Table 4.

The Met Station and Precipitation Sensors are placed in open pastoral land, which has better satellite coverage; however, many aquatic sites are in narrow canyons or covered by dense canopy, which reduces satellite availability. In these situations, AQU will provide a description of the location and an approximate GPS location (e.g. not accurate to within <1m). This description will suffice for the planning stages, but sites will likely need to be physically marked prior to construction.

Note that coordinates were estimated by measuring distances from known geographic features (such as tributaries) due to poor satellite coverage at the site. Therefore, coordinates should be cross-checked with distances from geographic features that are also provided below. The following coordinates are to be used for the input to the AIS design:

Table 3 S1 and S2 sensor locations.

Sensor	Latitude	Longitude
S1	18.112450°	-66.986729°
S2	18.110180°	-66.986340°

Table 4 Met station and precipitation sensor locations.

Sensor	Latitude	Longitude
Met Station	18.108715°	-66.984914°
Met FDP	18.108769°	-66.985060°
Secondary Precipitation Gauge	18.108722°	-66.985066°
Wet Deposition Collector (NADP)	18.108701°	-66.985027°
Precip. FDP	18.108769°	-66.985067°
Power Pole	18.108836°	-66.984938°

A small tributary enters Río Cupeyes on the left bank approximately 80 m upstream from the current access point (hole in a barbed wire fence). Immediately upstream from this point is the 0 m mark for the lower extent of the AQU reach. The full AQU sampling reach extends 1000 m upstream as shown in Figure 7. There is another small tributary entering Río Cupeyes on the right bank approximately 500 m upstream from the 0 m marker. The sensor reach cannot span this tributary for proper metabolism measurements and therefore it constrains the sensor reach to either above or below this point. There are multiple pools suitable for in-stream infrastructure and sensor deployments within the lower 500 m portion of the reach in which we have focused our current investigation.

S1 is located approximately 359 m upstream, while S2 is located approximately 64 m upstream from the lower tributary. The reach length between S1 and S2 is approximately 300 m.

The met station and precipitation sensors (tipping bucket and wet deposition collector) as well as their associated power and communication boxes (Field Device Posts) can be located in the pastoral land on the western slope below the AQU reach. There are several flatter plateaus that have been cleared of trees for grazing cattle. These plateaus provide ideal locations for capturing the local meteorology of the watershed. We initially chose three potential locations that were presented to the landowner and manager. The hosts have chosen the location that is presented here. Cattle fencing will be needed to protect both livestock and NEON property given that this land is actively grazed.

Figure 7 Kmz File of D04 Río Cupeyes denoting locations of S1, S2, Met Station and precipitation sensors.

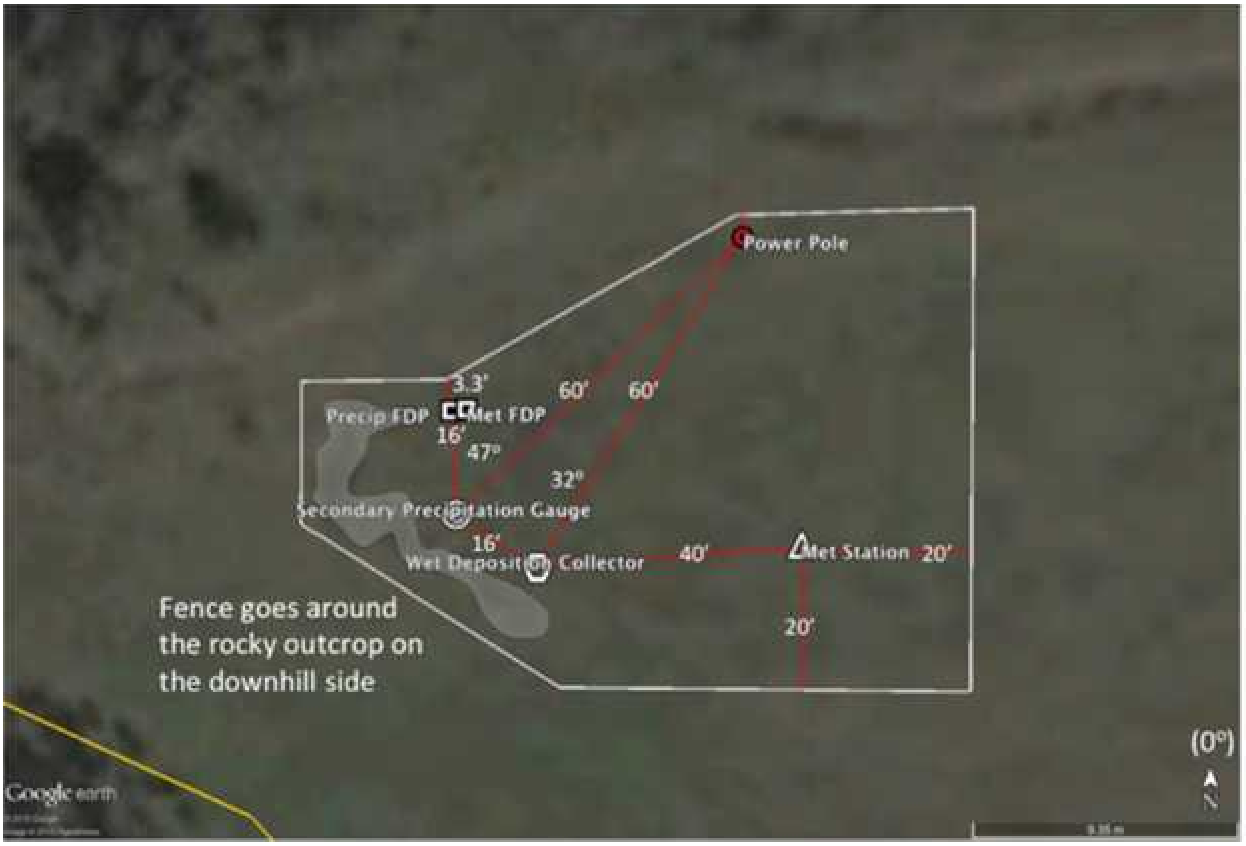

Figure 8 Layout for installation of the met station, precipitation gauge and wet deposition collector, associated field device posts, and power pole within cattle fencing (white lines). Access road is shown in yellow. Rocky outcrop is shown in grey.

The met station has a 12 m exclusion zone for objects that will impact the radiation measurements (see Figure 9 below). NEON infrastructure is thus placed at the edge of this boundary to meet the scientific requirements. In addition, the wet deposition collector and precipitation gauge (tipping bucket in this case) shall be place between 5 – 30 m apart and installed at the same height. One field device post will be needed to power the met station and an additional one is needed to power both the secondary precipitation gauge and the wet deposition collector. These can be co-located in an area that does not impact any meteorological measurements. Figure 9 below shows the chosen layout for the given location that will allow all scientific measurement requirements to be met.

The cattle fence will be placed in a perimeter that minimizes the area needed while meeting NEON requirements. The cattle fence shall be placed 6 m away from the mast of the met station. There are no other spatial requirements. The fence here is placed around the rocky outcrop that forms the plateau on the hillside for ease of construction and maintenance. It then provides a 1 m buffer around remaining infrastructure for safe access.

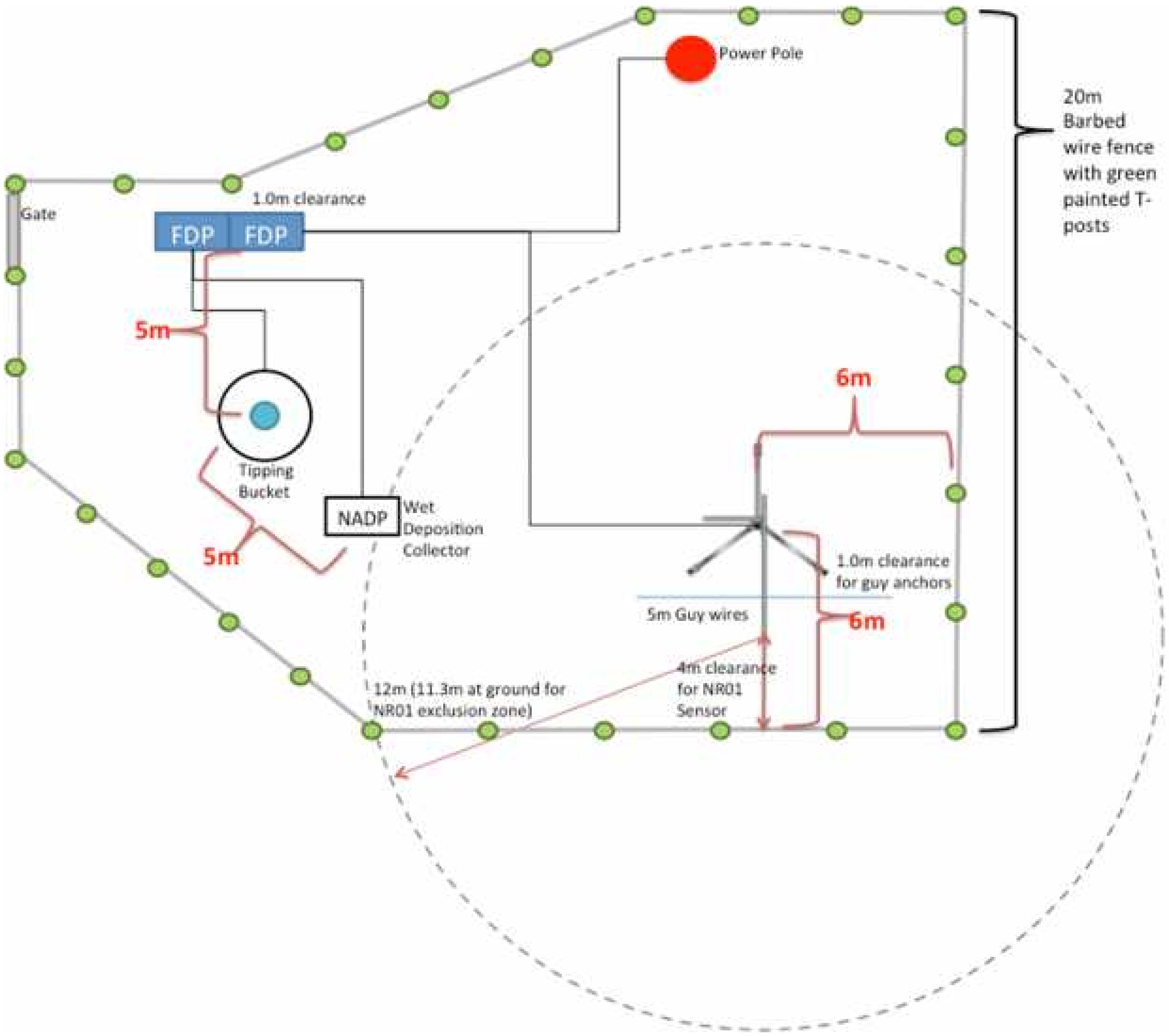

Figure 9. Schematic representation of met station, precipitation sensors, power pole and cattle fencing layout.

Figure 10 shows an upstream perspective of the pool where S1 will be installed. This pool currently spans approximately 2 m in the longitudinal distance and is approximately 3 m wide with an average depth of 52 cm. The canopy cover in this area is 78%. This pool provides the dimensions necessary to support upstream infrastructure. However, there is some braiding around the large boulders that form the upper bounds of the pool. Braiding is not ideal for monitoring because sensor locations should be chosen to represent the bulk of the water in the stream channel and some geomorphological features may contribute to environmental differences and changes in flow that make that difficult. This braiding is minimal and the bulk of the water flow (approximately 85%) still passes over the sensor location. Furthermore this braiding may only be evident during low flow conditions (as shown below during a recent October 6, 2015 visit). One important feature to note is the area of significantly reduced flow on the right bank side of the pool. Areas of increased residence time of the water allow for more biological and chemical activity in the water, which create microenvironments that may be different than the bulk of the flowing water. When attempting to monitor the aquatic ecology at the reach scale it is important that the sensors be placed in areas that capture the "average" of these microenvironments along with other habitats present in the system rather than being placed in an area that may bias the measurements. To mitigate the risk of the hydrodynamics of the pool biasing the sensor measurements in S1, the gravel bar at the tail of the pool will be excavated and this material will be used to partially fill the right bank downstream boundary of the pool in order to 1) allow for secure placement of the aquatic infrastructure in the appropriate location and depth within the pool; and 2) maximize flow past the sensor set. Figure 11 shows the downstream perspective of the S1 location and illustrates the areas of excavation and placement of the bed materials to accomplish the stated objective.

Figure 10. Upstream perspective of S1 location at D04 Río Cupeyes.

Figure 11. Downstream perspective of S1 location at D04 Río Cupeyes showing the sensor location within the pool (red box), the primary flow (blue arrow), area of excavation (red) within the existing gravel bar and where excavated material is to be delivered (green).

Figure 12. Raw and processed image of canopy taken at the 350 m marker near the 359 m S1 pool.

Figure 13 shows the upstream perspective of the pool where S2 will be located. This pool currently spans 11 m in the longitudinal distance and is approximately 4 m wide with an average depth of 100 cm. The canopy cover near this location is 80.5%. This pool is more of a run-type pool that is formed from a single boulder and a bend in the left bank. The sensors will be located in the tail of the pool near the near the end of the exposed roots on the left bank. This is a well mixed pool within a stretch where the channel is constrained. Figure 14 shows the downstream perspective of the pool and the location of the proposed sensor infrastructure.

Figure 13. Upstream perspective of S2 location at D04 Río Cupeyes.

Figure 14. Downstream perspective at S2 location at D04 Río Cupeyes.

Figure 15. Raw and processed image of canopy taken at the 50 m marker near the 64 m S2 pool.

Figure 16 shows the location of the met station. As noted above, this plateau is formed by a rocky outcrop which is shown in the picture. There is some dead vegetation that should be removed during construction. The locations of the precipitation sensors and met station are shown with red arrows in Figure 16. The trees to the north (left side of picture) are at an angle of 30°, indicating they are over twice as far away as they are tall from the location of the precipitation sensors and meet the spatial requirements for these measurements.

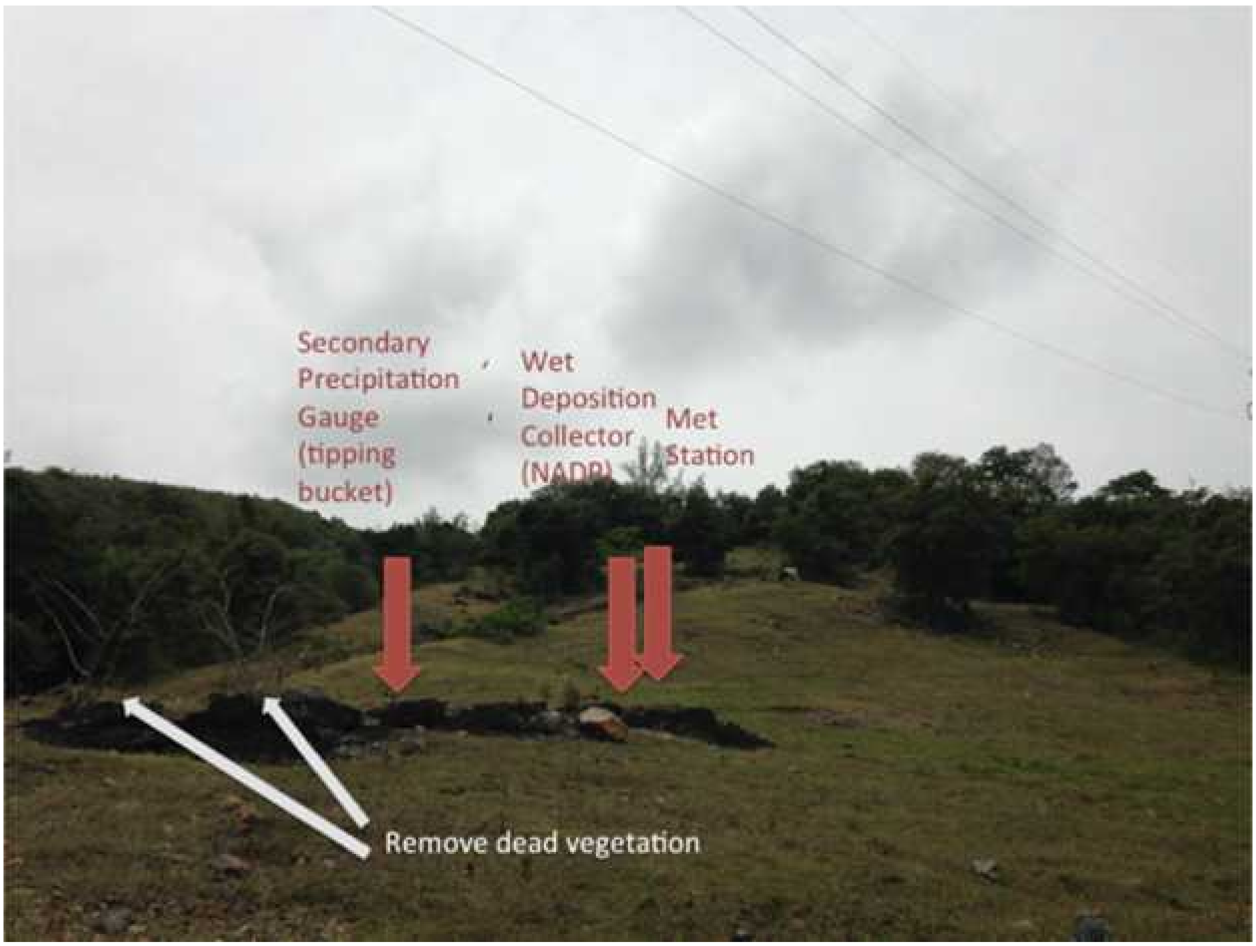

Figure 16. Uphill perspective of locations of precipitation sensors and met station at D04 Río Cupeyes. Station will be located on a flatter plateau created by a rocky outcrop within the hillside. Vegetation within the fenced area will need to be removed prior to installation.

3.1.3.1 Stream Reach Characterization

Stream sensor locations are determined by finding pools that accommodate the infrastructure and sensors while being spaced such that the travel time of the water at baseflow is approximately 30-45 minutes. This ensures that we will be able to maximize our accuracy and data coverage for calculations of whole stream metabolism. To assess the travel time, a single pulse of NaCl (table salt) is injected as a tracer which is then monitored with conductivity probes. Three salt injections were performed during October 2015 site visits. We did a single pulse from near the top of the reach at 860 m and then monitored the response at 4 pools at 835 m, 792 m, 481 m and 64 m. On subsequent days, injections were also performed between 359 m and 64 m and 490 m and 290 m. All of these flow times were consistent across the reach which suggests that the reach is relatively homogenous at the reach scale within our permitted site boundary. That is to say, the gradient, number of various habitats (pools, runs, riffles – see Appendix), meanders and subsurface flow and hyporheic exchange is consistent across the 1000 m reach. This is illustrated by the regression shown in Figure 17.

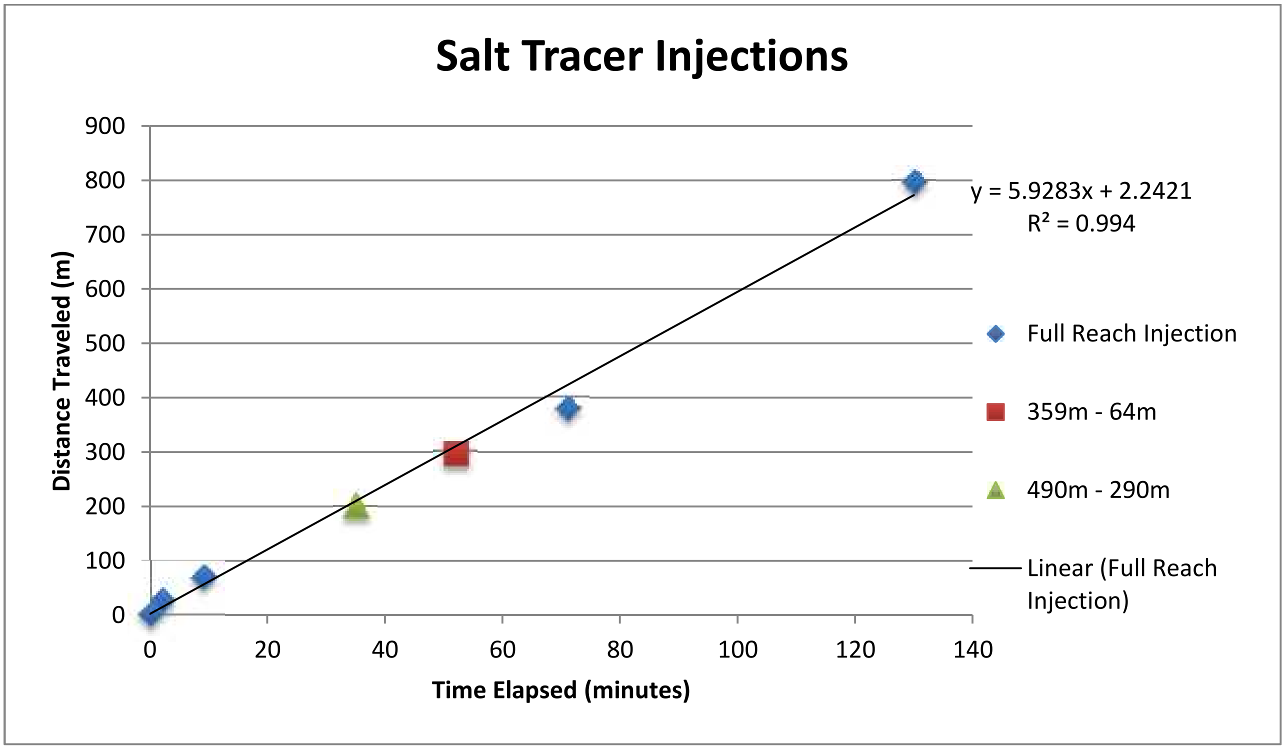

Figure 17. Graph showing the linear correlation of travel time along the stream reach.

The 359 m and 64 m pools were chosen based on the travel time despite it being on the long side of acceptable with the understanding that the flow was exceptionally low when these were performed (25-38 LPS). The average discharge is estimated to be somewhere between 50-100 LPS and is likely only this low during dry periods.

The dataset availability is very limited and this ~300 m reach was chosen based on that data. However, it should be noted that there is the remote possibility that we may need to extend the sensor reach to maintain metabolism measurements under consistently higher flows than seen during the October 2015 visit. Alternatively, if lower flows become more frequent, the reach may need to be shortened. There are alternative pools that we have identified that will allow us to move the infrastructure to maintain data quality and coverage for this site over the 30-year project.

Figure 18 shows the locations of the alternative pools located at 290 m, 481 m, and 490 m. We request the field device post (FDP) associated with S1 be located 40 m upstream (north) of the sensor set to allow for the more likely scenario of extending the sensor reach to the 481 m pool, while only needing to use a longer Ethernet cable without moving the FDP or extend conduit.

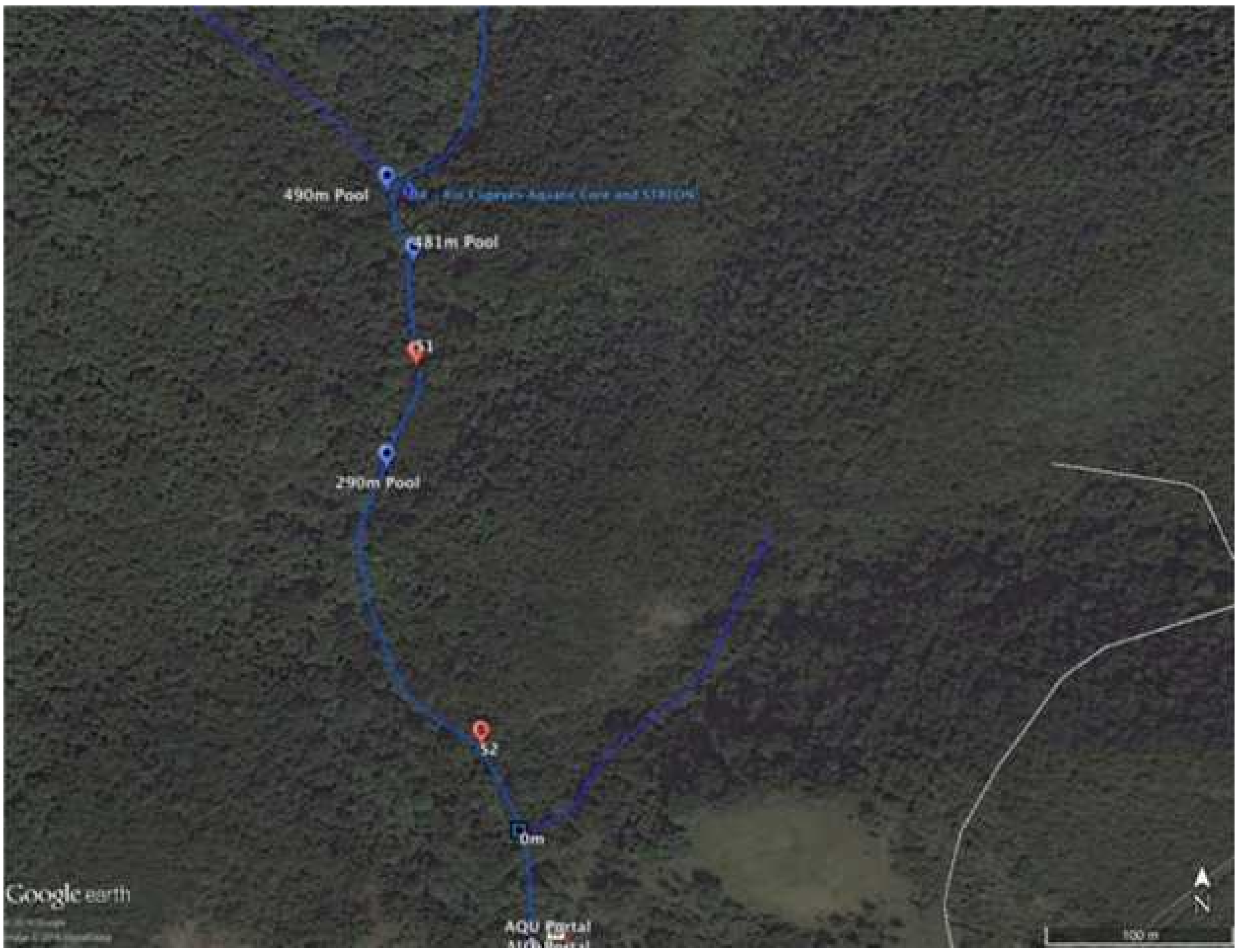

Figure 18. KMZ showing the locations of additional pools that may be considered as options should we need to move S1 to adjust the reach length in light of future flow data.

3.1.4 Groundwater Wells

The groundwater observation wells network at the site will consist of 8 wells installed using a powered hand-auger system. Topography at the site is dominated by steep mountains rising from the stream, in some cases exposing tall bedrock walls at the streams edge, which form portions of the stream banks

(Figure 19). Scattered along the stream banks are relatively flat terraced areas constructed of shallow soils overlaying the bedrock. The wells will be installed in these flat terraced areas along the stream reach. The required drilling depth will vary between 5-10 feet below ground surface. Access to the site for drilling activities will be via one of the proposed pathways directly east or west of the stream. Access to the well locations is anticipated to be relatively challenging due to the topography of the region and dense vegetation on the stream banks. Prior to initiation of the drilling activity, the access pathway will be established to provide easier access to the drilling locations.

The exact location of wells may vary during the drilling process due to the dense presence of boulders and shallow bedrock in the subsurface which were observed during the visit. Probing of the subsurface will be performed prior to drilling the wells to establish depth to bedrock and to locate obstructions. Thus, actual locations of wells will vary slightly from the plan if subsurface obstructions are encountered.

AQU prefers the surface completion of the wells to include an above-grade stick-up protective cover and be minimally invasive. Puerto Rico has several requirements for construction of groundwater monitoring wells that NEON will either need to meet or apply for a waiver. Chief among the requirements are 1) an acceptable grout to fill the annular space such as neat cement, bentonite chips, or a bentonite / cement mixture; 2) surface seal of the well requires a poured concrete or cement slab poured around a steel outer casing with a locking cap; and 3) a licensed well driller is required to be onsite.

Figure 19. Topographic map of D04 Río Cupeyes.

3.1.5 Geology, Flora and Fauna

3.1.5.1 Geology

The Río Cupeyes watershed is within the Maricao State Forest, which has a rich biodiversity of fauna with over 500 species of vascular plants. The watershed area is what is considered a wet subtropical forest with shallow, excessively drained serpentine soils. Serpentine soils are derived from ultramafic bedrock, which exhibit low calcium/magnesium ratios, low nitrogen, potassium and phosphorous, and high concentrations of nickel and chromium.

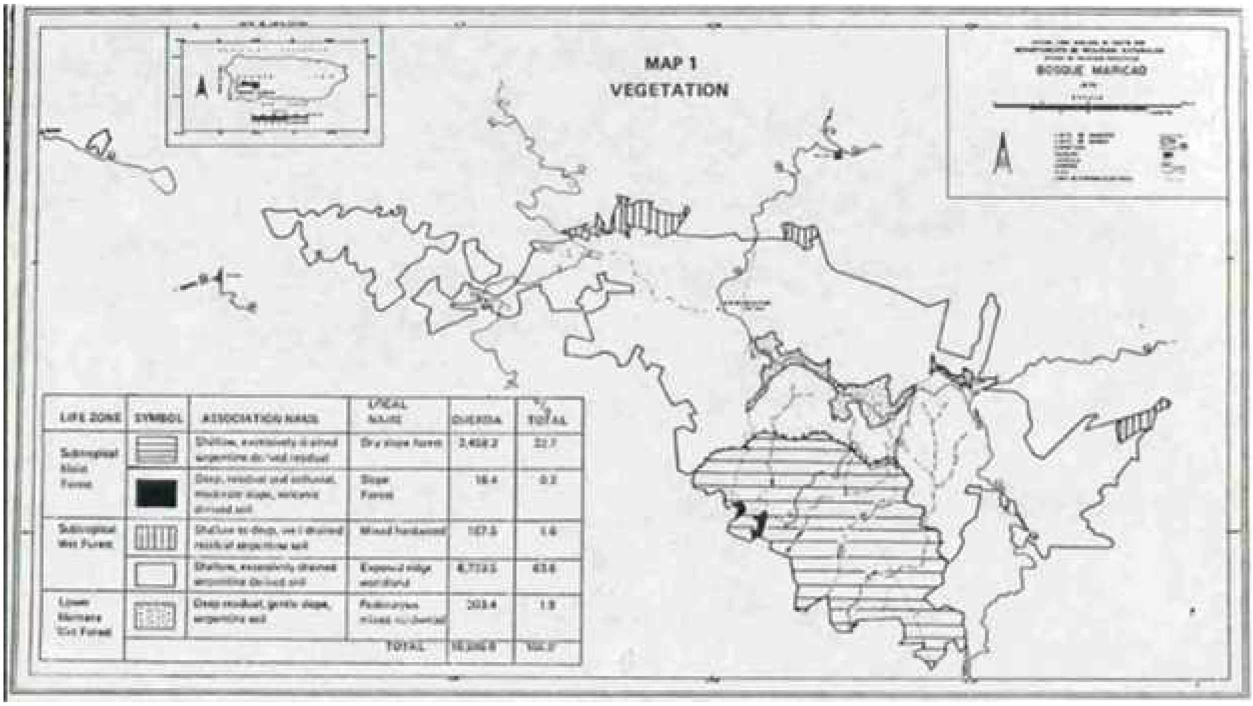

Figure 20. Map showing the boundary and land cover for the Maricao Forest.

3.1.5.2 Flora

During 2010-2011 site visits, the following plant density and type were observed by the AQU team:

Forest cover along the NEON reach of Río Cupeyes consists of mature, mostly second-growth wet subtropical forest. Dominant tree species in the riparian zone include caimitilllo (*Micropholis chrysophylloides*), white cogwood (*Homalium racemosum*), roble colorado (*tabebuia schumanniana*), mango (*Mangifera* spp.) and Stahl's stopper (*Eugenia stahlii*). Undercover growth consists of dense stands of shrubs, small trees and vines. Thick masses of vines that descend from the canopy directly into the stream channel are very common.

During an October 2015 site visit canopy pictures were captured at 50 m increments (measured and flagged markers) up the stream reach. These images were processed using ImageJ in which the images were converted to RBG stacks; the grayscale layer theresholds were adjusted to convert each image to black and white (low = 0, high = 100) and then the percent area was calculated. The percent canopy coverage ranted from 22.8 – 83.2% with the average across the 1000 m reach being 68.6%.

Figure 21. Typical riparian canopy vegetation at D04 Río Cupeyes.

Figure 22. One of the large cupey trees that the stream is named for.

Figure 23 The carrasco (*Comocladia glabra*) is related to poison ivy and induces a similar reaction when skin comes in contact with the sap and foliage. This small tree is common along much of the watershed.

Figure 24. Riparian and upland vegetation along Río Cupeyes channel can be extremely thick, such as the bamboo stand shown here.

3.1.5.3 Fauna

There is a variety of aquatic fauna within Río Cupeyes which include fish and freshwater crustaceans. The Maricao Forest and Río Cupeyes watershed are home to many species of amphibians and reptiles. The following pictures illustrate some of the fauna seen by NEON AQU staff during site visits.

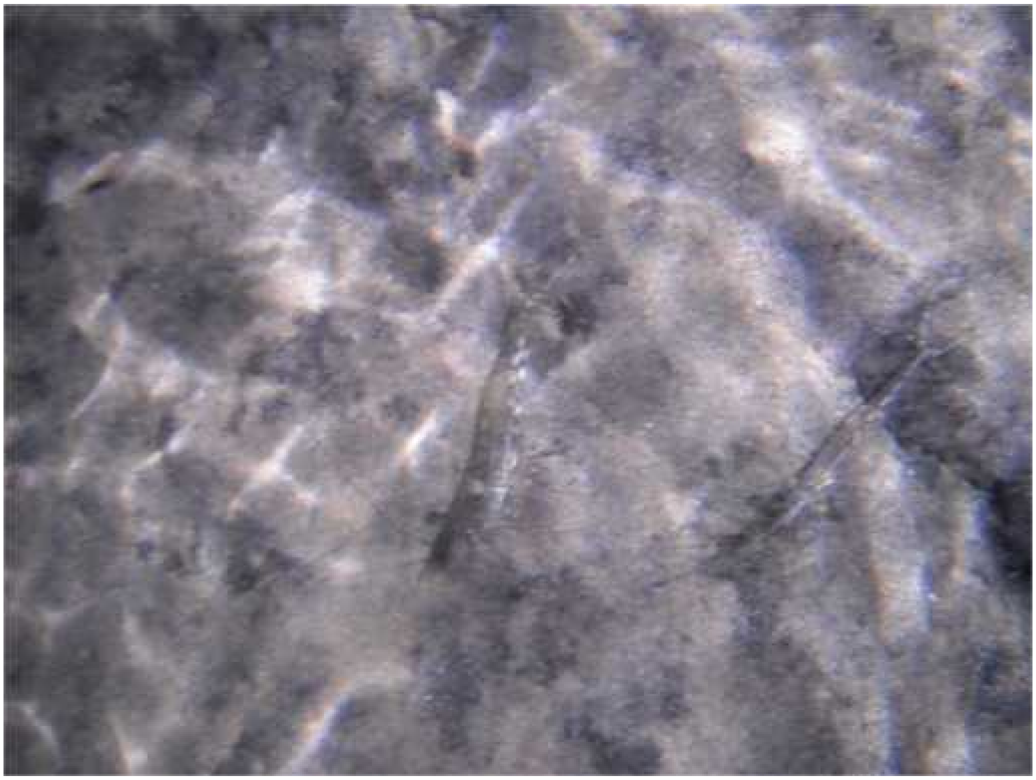

Figure 25. *Xiphocaris elongata*, freshwater shrimp are common in Rio Cupeyes.

Figure 26. *Epicrates inornatus*, Puerto Rican boa are common in the mountainous and rocky watershed. They can reach up to 2m long but are not venomous, nor aggressive.

Figure 27. Anolis species of lizard ubiquitous to the Maricao Forest.

Figure 28. Epilobocera sinuatifrons, the only freshwater crab on the island. It reaches about 13 cm.

Figure 29. Shell of a tree snail, *Caracolus caracolla*.

Figure 30. Large termite nest in a tree.

Figure 31 Stinging wasps nests are commonly found in the riparian vegetation that hangs into the channel. They are not aggressive, but will sting if their nest is disturbed.

3.1.6 Bank Morphology

The bank angle is estimated from the top of the bank, where one might stand to observe the stream, to the top of the water. The estimated angle is from the water to the bank, as illustrated in the figure below.

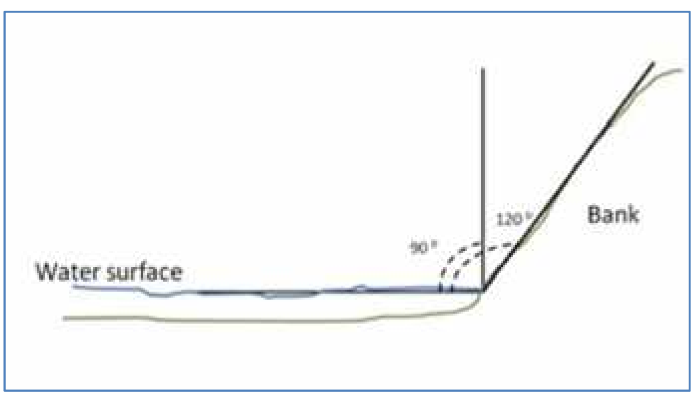

Figure 32 How Bank Angle is Measured

During 2015 site visits, AQU observed the following bank attributes at S1 and S2:

Table 5 Bank attributes at D04 Río Cupeyes:

Morphology Type	S1	S2
RB* angle	157˚	170°
LB* angle	119˚	90°
Maximum water height	3.0 m	3.0 m
Bankfull width	10 m	11.9 m
Substrate composition	30% boulder, 50% cobble, 15% pebble, 5% sand	10% sand, 50% pebble, 40% cobble

* RB (right bank) and LB (left bank) are determined by facing downstream.

Figure 33. At least one bank is typically gently-sloping along most locations of Río Cupeyes.

Figure 34. Typical bank along the AQU reach of Río Cupeyes. While banks are occasionally very steeply sloped, gradual slopes are more common.

Figure 35. Channel substrate in D04 Río Cupeyes consists of a heterogeneous mix of sand, cobble, pebble, large boulder and large areas of exposed bedrock.

Figure 36 Although much of the channel substrate consists of small particles that will likely be displaced during high discharge events, large, relatively immobile boulders are also ubiquitous along the channel margins.

3.1.7 Site Access Needs

It is proposed that NEON will install controlled access gates at the road and the stream. The locations of the proposed gates are given in Table 6. There is an unpaved road cut into the mountain side that is maintained by the landowner (see Figure 18). The road becomes more difficult to navigate safely beyond the switchback where deep ruts and exposed roots make traction very difficult when wet. The final descent to the stream bank on the road is steep and composed of lose cobble, boulders, and exposed bedrock. It is proposed that NEON may enter into an agreement to share use and maintenance of this road. This will provide driving access for hauling sampling and maintenance equipment by field technicians. There is a parking area next to the stream bank at the bottom of the road, which is shown as the yellow shaded area in Figure 18, which may accommodate up to 4 vehicles.

Table 6. Locations of access gates at the road and the stream.

Access Gates	Latitude	Longitude
Road Gate	18.107407°	-66.983976°
Stream Gate	18.109015°	-66.986017°

Figure 37. Access gates are indicated by the white diamonds at the road and the stream. The access road through the site is shown in yellow and the stream shown in blue.

3.1.7.1 Science Perspective on Access Needs (Pathways, Stairs, Etc.) to Reduce Site Erosion/Impact

There is an existing road on the western property that runs along the reach to nearly 700 m upstream from the access point. The landowners of this property have decided not to accept the initial land use agreement. However, NEON may propose to lease the land based on an agricultural land use type agreement. This would allow FOPS to access the upper extent of the stream reach for sampling more easily with equipment. Figure 36 shows the current GPS track for this road.

Figure 38. KMZ showing the GPS coordinates of the existing road that on the western property that may be used for access.

If the western landowners decline to offer us a lease option, a trail along the eastern bank will need to be constructed to provide access and run the conduit for power and communications up to S1. It is requested that this trail be extended to the upper right bank tributary.

Figure 39. Proposed trail to be constructed on the eastern property to provide access and deliver power and communications to S1.

3.1.8 Power at the Site

Provided by PREPA.

3.1.9 Site Science Construction Constraints and Limitations

Site-specific issues to consider at D04 Río Cupeyes are:

- Severe high flow events are likely to occur that would place NEON personnel and installed facilities at risk. Such events are likely to ensue during the Atlantic hurricane season (June-December). Stream flow data and weather updates shall be monitored closely by NEON personnel to ensure safe conditions are present.

Driving and access constraints for D04 Río Cupeyes are:

- A new, ~1100 m long footpath will need to be developed along one bank of Río Cupeyes to provide access to sensor and sampling locations. Such a footpath will require clearance of thick vegetation and necessarily traverse steep slopes.
- The access path should begin from the parking area at the bottom of the access road through the pasture
- Driving through the pasture will require a 4-wheel drive vehicle
- The parking area will accommodate 3-4 vehicles

3.1.10 Other Issues

No other science issues are identified at this time.

3.2 Río Guilarte

Río Guilarte site is a 2nd-order, wadable stream that drains an 11.0 km^2 watershed comprised of agricultural lands and subtropical moist/wet forest. The flow regime in Río Guilarte is typical of Puerto Rican streams draining rainforest catchments: characteristic discharge exhibits a strong seasonal pattern with low flows during the mid- to late- dry season (December through March) and high baseflow discharge during the annual wet period of May through November. Extreme high flow events may ensue as a consequence of tropical storms or hurricanes, which typically occur between June and December. The NEON reach of Río Guilarte is located in a montane area with steep slopes, though the channel is stabilized by large boulders. Sensor and sampling locations in the NEON reach of Río Guilarte may, however, be accessed easily, as the surrounding land is an agricultural research station owned and operated by the University of Puerto Rico.

3.2.1 Aquatic Auxiliary and Aquatic Portal Locations for Construction

Please Note: If power/comms is coming from a co-located TIS site, then the Aquatic Auxiliary Portal is the TIS Auxiliary Portal, and the Aquatic Portal is the TIS Instrument Hut.

The initial estimated location for the Aquatic Auxiliary Portal is:

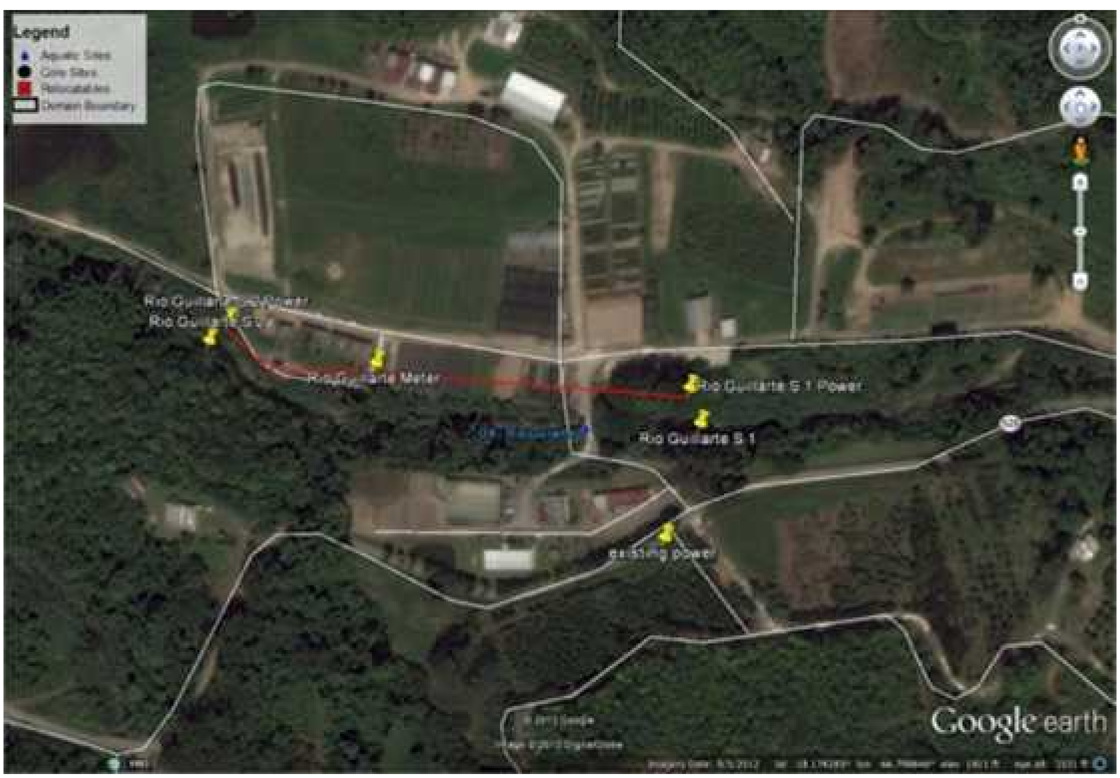

Figure 19 A Google-Earth-Derived Image of Aquatic Auxiliary Portal for D04 Río Guilarte

Table 7 Aquatic Auxiliary Portal Location

Aquatic Auxiliary Portal	Latitude	Longitude
Location	18.174370°	-66.799610°

The initial estimated location for the Aquatic Portal is:

Table 8 Aquatic Portal Location

Aquatic Portal	Latitude	Longitude
Location	18.174370°	-66.799610°

3.2.2 Sensor Locations for Construction

The GPS coordinates for S1, S2, met station, NADP and precipitation presented in Table 9 were obtained by AQU with support from EHS. Many aquatic sites are in narrow canyons or covered by dense canopy, which reduces satellite availability. In these situations, AQU will provide a description of the location and an approximate GPS location (e.g. not accurate to within <1m). This description will suffice for the planning stages, but sites will likely need to be physically marked prior to construction.

In contrast to Río Cupeyes, satellite availability at Río Guilarte was adequate to determine high-quality GPS points for sensor locations. The following coordinates are to be used for the input to the AIS design:

Table 9 Sensors S1 and S2 locations.

Sensor	Latitude	Longitude
S1	18.174080	-66.797932
S2	18.174514	-66.800451

The distance between S1 and S2 is approximately 310 m.

Table 10 Meteorology sensor locations.

Sensor	Latitude	Longitude
Met Station	18.174680	-66.797516
Precipitation	18.174735	-66.797608
Wet Deposition Collector	18.174724	-66.797630

Figure 40 Kmz File of D04 Río Guilarte Denoting Locations of S1, S2, NADP and Met Station and Precipitation Sensors

Figure 41 S1 location at D04 Río Guilarte, facing downstream and right bank.

Figure 42 S2 location at D04 Río Guilarte, facing the right bank.

Figure 23 met station and precipitation sensors location at D04 Río Guilarte next to an existing NOAA weather station.

Figure 43 The left bank of Río Guilarte is typically steeply-sloped and tall (~12 m). Thus NEON infrastructure would best be positioned from the right (north) bank. Shown here is the S1 location left bank.

The phenology camera will need to be placed on the right bank above the high flow level- approximately level with the bridge. This will require the phenocam be mounted onto a 12’ channel strut anchor in place of the normal 8’. Because of the fluctuations seen in stream discharge we will need to install 2-3 staff gauges to capture the variability. Table 11 gives the location of the camera and the base flow staff gauge. Figure 24 illustrates the locations of the staff gauge and phenocam near S1. Figure 25 shows where the staff gauge will be located in the stream from the viewpoint of the camera.

Table 11 Staff Gauge and Camera locations.

Sensor	Latitude	Longitude
Staff Gauge	18.174109	-66.798106
Phenology Camera	18.174174	-66.798108

Figure 44 Phenology camera and staff gauge locations near S1.

Figure 45 Location of staff gauge in the stream from the view of the phenocam location.

3.2.3 Groundwater Wells

Figure 25 Initial Groundwater Well Locations Based on EMS kmz File at D04 Río Guilarte

Table 12 Groundwater well locations.

Well ID	Latitude	Longitude
D04-GUIL-OW-01	18.174549°	-66.800405°
D04-GUIL-OW-02	18.174475°	-66.800318°
D04-GUIL-OW-03	18.174597°	-66.800249°
D04-GUIL-OW-04	18.174174°	-66.799749°
D04-GUIL-OW-05	18.174614°	-66.799423°
D04-GUIL-OW-06	18.174177°	-66.799235°

3.2.4 Riparian Vegetation Cover

During 2010-2011 site visits, the following plant density and type were observed by the AQU team:

Riparian vegetation along Río Guilarte consists of tall grasses, shrubs, citrus trees and in some places a very narrow (~50 m) band of trees. The canopy at Río Guilarte is relatively open and sensor locations may be accessed from the facility roads easily.

Figure 46 Typical riparian vegetation at D04 Río Guilarte.

3.2.5 Bank Morphology

The bank angle is estimated from the top of the bank, where one might stand to observe the stream, to the top of the water. The estimated angle is from the water to the bank, as illustrated in the figure below.

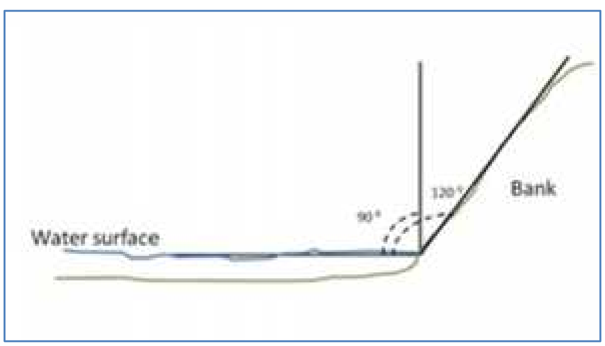

Figure 47 How bank angle is measured.

During 2011 site visits, AQU observed the following bank attributes at S1 and S2:

Table 13 Bank attributes of sensor locations at D04 Río Guilarte.

Morphology Type	S1	S2
RB* angle	160°	160°
LB* angle	95°	160°
Maximum water	2.5 m	3.3 m

height		
Bankfull width	10.9	19.7 m
Substrate composition	20% boulder, 50% cobble/ pebble, 30% sand	20% boulder, 30% cobble/pebble, 50% sand

* RB (right bank) and LB (left bank) are determined by facing downstream.

3.2.6 Site Photos

The following photos are representative of the site.

Figure 48 Large boulders are a dominant feature of the Río Guilarte substrate regime.

Figure 49 Aside from large boulders, Río Guilarte substrate consists of a heterogeneous mixture of cobble, pebble and sand.

Figure 50 Although the NEON Río Guilarte reach is close to the agricultural station roads, some vegetation will need to be cleared to facilitate access to sensors.

Figure 51 A single-lane bridge crosses Río Guilarte approximately midway through the NEON reach.

Figure 52 Río Guilarte features several large, slow-moving pools.

Figure 53 Well-maintained access roads traverse the property surrounding the NEON reach of Río Guilarte.

Figure 54 Activities and security at the research station should help ensure that NEON equipment at Río Guilarte remains safe from theft and vandalism.

3.2.7 Site Access Needs

The access roads for the University of Puerto Rico's agricultural research station will substantially facilitate access. Two short paths a maximum of 20 m long may need to be cleared through herbaceous vegetation from the road(s) to the sensor locations on the right bank on the stream. No further access constraints exist.

3.2.7.1 Science Perspective on Access Needs (Pathways, Stairs, Etc.) to Reduce Site Erosion/Impact

Access from the research station roads to the stream channel will require the clearing of two short footpaths through riparian vegetation. The map below illustrates the approximate locations of these paths. There is currently an existing footpath from the parking area to the stream from the north bank as shown in Figure 35. This path should be maintained and/or reinforced with stairs for access to S1, phenocam and staff gauge.

Figure 55 Routes of required paths to provide access at D04 Río Guilarte.

3.2.8 Communications at the Site

The local communications company is located in Appendix C for additional IT info

3.2.9 Power at the Site

The local power utility company is PREPA Victor Cruz Mendez 787-521-6226.

3.2.10 Site Science Construction Constraints and Limitations

Site-specific issues to consider at D04 Río Guilarte are:

- Severe high flow events are likely to occur that would place NEON personnel and installed facilities at risk. Such events are likely to ensue during the Atlantic hurricane season (June-December).

Driving and access constraints for D04 Río Guilarte are:

- Two short footpaths will require clearing to access the sensor locations. These footpaths will likely be no more than 40 m long.

3.2.11 Other Issues

No other science issues are identified at this time.

4 APPENDIX A. FCC SUMMARY TABLES FOR AIS SITE COMPONENTS AT D04

4.1 Río Cupeyes FCC Summary Table

Site Component	Latitude	Longitude	Units
Stream, Lake, or River	Stream		Description
Aquatic Auxiliary Power Portal location	18.109118°	-66.985885°	Lat, Long in degrees
Aquatic Portal location	18.109119°	-66.985867°	Lat, Long in degrees
Access Gates needed? Where	Yes – at road and at stream		
Access Gate 1 (road)	18.107407°	-66.983976°	Lat, Long in degrees
Access Gate 2 (stream)	18.109015°	-66.986017°	Lat, Long in degrees
Pathway needed? What is length?	Yes –maintained native extended from parking area to S1		Yes/no, description w/ length
Pathway start location	18.109015°	-66.986017°	Lat, Long in degrees
Pathway end location	18.113480°	-66.986850°	Lat, Long in degrees
Stairs or ladder needed?	No		Yes/no, description
Stairs top location			Lat, Long in degrees
Stairs length			Meters
Ladder top location	Site1-LadderTopLat	Site1-LadderTopLong	Lat, Long in degrees
Ladder length	Site1-LadderLength		Meters
Boardwalk needed? What is length?	no		Yes/no, description w/ length
Boardwalk start location	Site1-BrdwlkStartLat	Site1-BrdwlkStartLong	Lat, Long in degrees
Boardwalk end location	Site1-BrdwlkEndLat	Site1-BrdwlkEndLong	Lat, Long in degrees
Shall stairs, boardwalk be installed during construction?	No		Yes/no, description
Fencing needs	Cattle Fencing placed around met station, precipitation sensor and wet deposition collector		Description
Site management	Shared maintenance of road		Description
Any additional site specific information			Description

4.2 Río Guilarte FCC Summary Table

Site Component	**Latitude**	**Longitude**	**Units**
Stream, Lake, or Stream+STREON	Stream		Description
Aquatic Auxiliary Power Portal location	18.174370°	-66.799610°	Lat, Long in degrees
Aquatic Portal location			m away from bank, direction
Pathway needed? What is length?	Yes two pathways are needed; one new (West) and one is existing (East) The East pathway needs stairs in steep sections		Yes/no, description w/ length
West Pathway start location	18.175091	-66.801315	Lat, Long in degrees
West Pathway end location	18.174843	-66.801386	Lat, Long in degrees
East Pathway start location	18.174387	-66.798147	Lat, Long in degrees
East Pathway end location	18.174137	-66.798102	Lat, Long in degrees
Stairs or ladder needed?	Yes 2 sections to be added to the East pathway for the steep banks		Yes/no, description
Stairs 1 top location	18.174387	-66.798147	Lat, Long in degrees
Stairs length	4		Meters
Stairs 2 top location	18.174174	-66.798108	Lat, Long in degrees
Stairs length	3		Meters
Boardwalk needed? What is length?	No		Yes/no, description w/ length
Boardwalk start location	Site2-BrdwlkStartLat	Site2-BrdwlkStartLong	Lat, Long in degrees
Boardwalk end location	Site2-BrdwlkEndLat	Site2-BrdwlkEndLong	Lat, Long in degrees
Shall stairs, boardwalk be installed during construction?			Yes/no, description
Fencing needs	No		Description
Site management			Description
Any additional site specific information			Description

5 APPENDIX B. EHS SUMMARY TABLES FOR AIS SITE COMPONENTS AT D04

5.1 Río Cupeyes EHS Summary Table

Site Component	Latitude	Longitude	Units
Sensor 1 (S1) location	18.112450°	-66.986729°	Lat, Long in degrees
S1 Field Device Post	40m to North (to allow for potential movement of sensor location)		Meters from S2
Sensor 2 (S2) location	18.110180°	-66.986340°	Lat, Long in degrees
S2 Field Device Post	20m radius		Meters from S2
Met Station location	18.108715°	-66.984914°	Lat, Long in degrees
Met Field Device Post	18.108769°	-66.985060°	Lat, Long in degrees
Precipitation Gauge (tipping bucket)	18.108722°	-66.985066°	Lat, Long in degrees
Wet Deposition Collector	18.108701°	-66.985027°	Lat, Long in degrees
Precipitation Field Device Post	18.108769°	-66.985067°	Lat, Long in degrees
Aquatic Auxiliary Power Portal location	18.109118°	-66.985885°	Lat, Long in degrees
Aquatic Portal location	18.109119°	-66.985867°	Lat, Long in degrees
Met area power pole location	18.108836°	-66.984938°	Lat, Long in degrees

5.2 Río Guilarte EHS Summary Table

Site Component	Latitude	Longitude	Units
Sensor 1 (S1) location	18.174080	-66.797932	Lat, Long in degrees
Sensor 2 (S2) location	18.174514	-66.800451	Lat, Long in degrees
Discharge Sensor location (if needed)	Site2-DSLat	Site2-DSLong	Lat, Long in degrees
Met Station location	18.174680	-66.797516	Lat, Long in degrees
Precipitation Gauge (tipping bucket)	18.174735	-66.797608	Lat, Long in degrees
Wet Deposition Collector	18.174724	-66.797630	Lat, Long in degrees
Aquatic Auxiliary Power Portal location	18.174370°	-66.799610°	Lat, Long in degrees
Aquatic Portal location	18.174370°	-66.799610°	Lat, Long in degrees

6 APPENDIX C. IT SUMMARY TABLES FOR AIS SITE COMPONENTS AT D04

6.1 Río Cupeyes IT Summary Table

Site Component	Latitude	Longitude	Units
REQUIRED			
Aquatic Auxiliary Power Portal location	18.109118°	-66.985885°	Lat, Long in degrees
Aquatic Portal location	18.109119°	-66.985867°	Lat, Long in degrees
DESIRED			
Cell tower visible from site			Yes/no
Cell phone signal at site			Yes/no, which carrier?
Strength of cell phone signal			Description
Facility on property			Yes/no
Internet connectivity at facility			Yes/no, description
Phone number at facility location			Area code & first 3 needed

6.2 Río Guilarte IT Summary Table

Site Component	Latitude	Longitude	Units
REQUIRED			
Aquatic Auxiliary Power Portal location	18.174370°	-66.799610°	Lat, Long in degrees
Aquatic Portal location	18.174370°	-66.799610°	Lat, Long in degrees
DESIRED			
Cell tower visible from site			Yes/no
Cell phone signal at site			Yes/no, which carrier?
Strength of cell phone signal			Description
Facility on property			Yes/no
Internet connectivity at facility			Yes/no, description
Phone number at facility location			Area code & first 3 needed