NOAA Directed Projects 2012 - Submit Final Programmatic Report (Activities and Outcomes)
Grantee Organization: University of Guam
Project Title: Talakhaya Watershed Soil Loss Assessment (CNMI)

Project Period	10/01/2012 - 12/31/2014
Award Amount	$123,600.00
Matching Contributions	$23,000.00
Project Location Description (from Proposal)	Badlands in Rota, CNMI watershed
Project Summary (from Proposal)	Design and carry out a study to assess and quantify the change in soil loss from Talakhaya watershed badlands as a result of the revegetation efforts being conducted by Rota DLNR-Forestry staff.
Summary of Accomplishments	Following the installation and the use of the equipment such as water meters, barometric level loggers, turbidity meters, the water flows as well as the turbidity level of each stream leading to the ocean from the Talakhaya watershed were monitored on monthly basis. The monitoring of streams were compared with the areas with the Vetiver grass plantation in order to assess the effect of vegetation type on reducing the sedimentation load into the ocean and the coral reef near the shorelines. The analysis of the soil and water sampling from the areas of watershed re-vegetated with new planting techniques using Vetiver grass was also compared with areas of watershed without any Vetiver plantation in order to evaluate the effectiveness of the environmental impact of the Vetiver plantation on the watershed as well as the coral reef area fed by the stream water from the Talakhaya watershed area.
Lessons Learned	The primary water quality measure observed in this study was turbidity. it became evident that given a few years for the plants to establish themselves and provide their extensive barrier capacities it is expected that the turbidity levels of the re-vegetated sites will then decline. The re-vegetation is still in progress and therefore more time is required for the vegetation specially the Vetiver grass to show its effect on the sediment loading reduction from the affected watershed. Moreover, from the up-to-date data, it appears that re-vegetation could possibly have a positive impact on reducing sedimentation over a longer period.

Conservation Activities	the main activity was to design a monitoring protol to monitor the impact of revegetaion of Talakhaya watershed on sedimentation and sediment loading
Progress Measures	Acres of exposed soil revegetated
Value at Grant Completion	impact of the work

Conservation Outcome(s)	The stage discharge curve was developed which is essential to future management of the watershed
Conservation Indicator Metric(s)	Sedimentation rate in streams/rivers (mg/cm2/day)
Baseline Metric Value	123,000
Metric Value at Grant Completion	123,000
Long-term Goal Metric Value	environmnental
Year in which Long Term Metric Value is Anticipated	10

Talakhaya Watershed Soil Loss Assessment Project
Status as of November 2014

Prepared by:
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Background Information:
The Talakhaya watershed in Rota (Fig. 1) is identified as a Coral Reef Management Priority site for the Commonwealth of the Northern Marianas Islands (CNMI). Since 2006, CNMI resource management agencies including Division of Forestry, Division of Environmental Quality, Department of Lands and Natural Resources, and the Luta (Rota) Soil and Water Conservation District have collaborated on restoring the Talakhaya watershed badlands in Rota. These agencies have worked with USDA Natural Resources Conservation Service in identifying Best Management Practices (BMPs) and restoration projects. Beginning in 2007, NOAA Coral Reef Initiative (CRI) funds were awarded to CNMI to begin re-vegetation efforts of the badlands areas in Talakhaya in Rota. These efforts endured mixed success, with successful re-vegetation followed by human-induced burning of the area. In 2010, federal and jurisdictional partners came together to develop a Conservation Action Plan (CAP) for the Talakhaya watershed. The CAP highlights the need for continued re-vegetation (include the Vetiver grass) for the eroding areas, assessing rate of soil loss in the watershed, addressing intentional burnings with education and fire prevention campaigns, surveys of community attitudes, and the hiring of seasonal field agents for increased surveillance, among other objectives (Bickel, 2012).

Project Goals:
The Talakhaya Watershed Soil Loss Assessment project assisted in meeting Objective A3 ‘Reduce Soil Loss’ of the Talakhaya CAP. The existing re-vegetation efforts in the Talakhaya watershed however, did not have a component for quantifying the effects they might have in terms of reduced sedimentation. This project therefore, aimed to quantify the reduction in sediment (if any) as a result of re-vegetation efforts currently occurring in Talakhaya watershed.

Description of the project site:
The island in Rota is the southernmost island in the Commonwealth of the Northern Marianas Islands (CNMI) and the second southernmost island of the Marianas Island Archipelago. The island is located roughly 60 km north of the island of Guam

The island of Rota consists of well-developed limestone terraces with six different levels and Sabana being the uppermost terrace (Sugawara, 1934).

The Talakhaya Watershed has been described as “a large, relatively steep exposure of weathered volcaniclastic material” and contains the island’s only surface streams (Keel et al, 2005). The only areas on the island that contain exposed volcanic rock are on Sabana and the Talakhaya Watershed (USDA SCS, 1994). The streams of the Talakhaya Watershed are fed by the Water Caves in Sabana, several of which also act as the source of the island’s potable water. Studies of the Matan Hanom Spring discharge have shown large variation in the amount of discharge during wet seaon at “5.4 million gallons per day (mgd), dry season discharge at 0.5 mgd, and an average daily flow of 1.8 mgd (USDA SCS, 1994).”

Although there has been some limited unpublished data collected for rainfall on Rota and the Talakhaya Watershed area by USGS, attempts to obtain this data and its sources proved unfruitful as it is unavailable online or by both the Hawaii and Guam offices. Other rainfall information for the island has been collected by WERI (the Water and Environmental Research Institute) and by the National Weather Service from the Rota International Airport, although both data sources are collected outside of the project area (USDA NRCS, 2008).

GIS data is largely limited as well in the area. Rainfall, soils, land cover, and elevation data is also constrained by limited information. Furthermore, access to majority of the watershed is limited by lack of proper road infrastructure and land accessibility as several areas are privately owned. On the other hand, several studies in the Talakhaya Watershed area have focussed on the water caves, which supply the island’s drinking water (Matan Hanom and As Onan Caves) and also serve as the source for the area’s streams (Keel et al, 2007 and USDA SCS, 1994). The baseline soil descriptions for this study were obtained from the soils of Rota and the Northern Marianas Islands by Young (1986) and were utilized in this study as a reference for the expected soil types in the Talakhaya Watershed.

Methodology:

Site visits to the Talakhaya Watershed area along with representatives from Rota Department of Lands and Natural Resources (DLNR) Forestry section representatives provided insight into the planning of the approach and equipment to determine soil loss from the watershed that would be most feasible in terms of cost, safety, manpower, environmental impact, and ensuring accuracy of data to meet project goals.

Upon determining the measurement parameters and types of devices to be used to best collect data, the supplies and devices needed were ordered beginning December 2012. Devices ordered for the use of the project included: 16 OnSet Hoboware level loggers, 4 Hoboware rain gauges, 1 Hach portable flow meter, and 1 Horiba multi-parameter meter (temperature, pH, dissolved oxygen, turbidity, electrical conductivity, and total dissolved solids measurements). Data collected from such instruments were used to determine the hydrology of the watershed and the level of sediment that is travelling through the streams (Fig. 1) to be deposited in the nearby Bays. Installation of the level loggers began in February 2013 and was completed on April 2013. Installation of rain gauges began on May 2013 through June 2013.

With the installation of equipment initiated, the data collection phase of the project also begun with the collection of level logger and rain gauge data from the fixed device installations.

In addition to the fixed device data collection, the collection of data from the flow meter and multi-parameter meter also begun in the fixed stream sites as shown in Figure 1, where level loggers have been installed (Fig. 1). The collection of data from these devices was conducted during monthly site visits and installation trips to Rota.

GIS mapping (Fig. 1) of the level logger locations also was conducted with the assistance of Mr. Bill Pendergrass of the Rota BECQ office, one of the partner agencies working on the Talakhaya Project.

Following the installation and the use of the equipment such as water meters, barometric level loggers, turbidity meters, the water flows as well as the turbidity level of each stream leading to the ocean from the Talakhaya watershed were monitored on monthly basis. The monitoring of streams were compared with the areas with the Vetiver grass plantation in order to assess the effect of vegetation type on reducing the sedimentation load into the ocean and the coral reef near the shorelines. It should be pointed out that prior to the aforementioned investigation the Vetiver grass had been planted rather in sporadic bunches which was not effective in reducing sedimentation. Modification strategy for planting the Vetiver grass in the form of hedges was introduced and preformed then after.

The analysis of the soil and water sampling from the areas of watershed re-vegetated with new planting techniques using Vetiver grass is also being compared with areas of watershed without any Vetiver plantation in order to evaluate the effectiveness of the environmental impact of the Vetiver plantation on the watershed as well as the coral reef area fed by the stream water from the Talakhaya watershed area.

RESULTS:

Hydrology

Stream and Rainfall Data:

The four streams under monitoring have been categorized based on the upstream vegetation type to include one un-vegetated stream site within the project area that requires re-vegetation (coded TK1), two already re-vegetated areas within the project (coded TK2 and TK3), and a naturally well-vegetated site just outside of the project scope (coded TK4) to serve as our ideal model area.

The project design in this manner attempts to compensate for the lack of background data prior to the start of the re-vegetation efforts being undertaken. Although not ideal, the comparison of streams allows for a better understanding of the areas of the watershed under study than simply monitoring after the re-vegetation efforts with no other means of comparison to form a known baseline. As such, however there are various differences within each stream are aside from vegetation including but not limited to land use, watershed sub-basin size, stream length, and geology.

Our un-vegetated stream site (TK1) is perhaps the most hydrological dynamic of the sites (Fig. 3). Although oral history from local community members has indicated that this stream was normally perennial, the stream has become more intermittent. This has made data collection within the streams far more difficult especially during the dry season and through the early wet season. When reaching enough rainfall volume to fill the stream large quantities of sediment are also carried with the rainfall to be deposited within the stream and out into the ocean.

Due to an error with the Hobo Data Shuttle, there was a data gap between September 13, 2014 and October 27, 2014 for most of the level logger data.

Stream TK1 was also affected by Typhoon Vongfong on October 5, 2014 when a fallen tree blocked one of the in-stream level loggers and created a small dam, blocking additional debris, sediment, and water from flowing further downstream.

The re-vegetated stream sites (TK2 and TK3) act to illustrate the effects of the Talakhaya Revegetation Project on the lower reaches of the watershed. Although shown to be overall less dynamic than TK1, these streams still display high turbidity levels during high rainfall events (Fig. 4, 5). Given the need for the re-vegetated specially the Vetiver grass and other vegetation to become established before becoming fully able to protect sediment from reaching the streams and thereby the ocean, this lack of drastic difference in the unvegetated and revegetated areas is expected. Once given a few years for the plants to establish themselves and provide their extensive barrier capacities it is expected that the turbidity levels of the re-vegetated sites will then decline. Hence it is very important that the monitoring of the streams continues steadily without interruption and for longer period of time in order to accurately determine the effect of re-vegetation on sediment reduction via turbidity measurement.

It must be noted that although the stream sites chosen were indicated by local residents as having been historically perennial streams, the observations over the duration of the project have shown all streams (TK1, TK2, TK3, and TK4) to behave more intermittently. It may also be noted that "perennial streams are found only on the volcanic soils of Talakhaya," but "not all of the streams run perennially" (USDA SCS, 1994).

The natural vegetation stream (TK4) represents a stream without large badlands issues requiring the re-vegetation efforts that are required of the other stream basins in the study. As such, this stream represents an ideal vegetative cover that the re-vegetation sites should reflect or surpass in sedimentation and stream turbidity (Fig. 6).

According to Title 65 of the CNMI Administrative Code, "Turbidity at any point, as measured by nephelometric turbidity units (NTU), shall not exceed 0.5 NTU over ambient conditions except when due to natural conditions" for Class 1 waters which include all fresh waters in Rota such as the Talakhaya streams the CNMI code similarly follows the requirements of the Guam Administrative Rules and Regulations (GARR) set by the Government of Guam. Although the high variation level may be cause for concern, the turbidity data collected in the streams may not specifically violate the code because of a lack of determination of ambient levels has not been made for those streams, as well as the fact that the variations are largely due to natural erosion and runoff. The U.S. standard for turbidity does not aid in the determination of these streams in relation to a standard as it requires only that:

> 'Increased color (in combination with turbidity) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life (USEPA, 1986)'.

In relation to Hawaii Administrative Rules however, the streams measured exceeded the geometric mean of 5.0 NTU during wet season and 2.0 NTU during the dry season. The given values not to be exceeded more than 10 percent of the time at 15.0 NTU for wet season and 5.5 NTU during dry season as well as the values not to be exceeded more than two percent of the time of 25.0 NTU during wet season and 10.0 NTU during dry season, were all regularly exceeded by the streams measured in this study, including the naturally vegetated stream site, TK4 (Fig. 6).

A comparison of the daily stream turbidity measurement (Fig. 7) illustrates the high variability of stream turbidity levels. Figure 7 also illustrates the frequency for the peak turbidity measurement to be represented by the non-vegetated stream, TK1.

Rainfall vs. Turbidity:

The rainfall interval providing the most effect on stream turbidity appears at a 6 – hour interval in comparison against four selected intervals prior to turbidity measurement including 3, 6, 12, and 24- hours of rainfall data prior to stream turbidity readings (Fig 8, 9, 10, 11). This information however is limited by sampling frequency and the random determination of turbidity data collection relative to storm events.

Because of a lack of fixed loggers or regular intervals to measure in-stream turbidity, the information provided by the graphs (Fig 8, 9, 10, 11) includes data collected during site visits with a water quality meter to measure turbidity and other water quality data. As such, this comparison between turbidity and rainfall prior to such measurements is not representative of peak turbidity levels, which would be more indicative of the effect of rainfall on turbidity including reaction time and overall change in turbidity during storm events. Given the available information however, the peak reaction of turbidity is within 6 hours of rainfall events for TK1 (R^2=0.58584), TK2 (R^2=0.09473), and TK4 (R^2=0.16298) (Fig. 9). The peak reaction for TK3 (R^2=0.32768) was shown to have occurred within 12 hours of a rainfall event (Fig. 10).

Rainfall v Discharge:

Similarly, peak stream discharge and their rainfall reaction times cannot be fully determined because of lack of in stream loggers, sampling frequency, and also the safety of individuals. Some of the streams, especially the non-vegetated TK1, are known to have dynamic reactions to changes in rainfall and therefore in-stream discharge measurements during such events would pose significant safety hazards. Based upon the same 3, 6, 12, and 24-hour interval comparisons between streams discharge measurement (Fig 12, 13, 14, 15) and prior rainfall intervals the 12-hour rainfall interval (Fig. 14) appeared to have the largest influence upon stream discharge with the effect peaking off at the 24 hour interval (Fig. 15) comparison. The stream discharge however was also seen represented in earlier intervals including both the 3 hour (Fig. 12) and 6 hour (Fig. 13) rainfall events indicating a varying influence of rainfall on stream discharge over the 24 hour period of rainfall measured. For TK1 (R^2=0.59635) and TK3 (R^2=0.21014), the peak reaction occurred within 3 hours of a rainfall event. For streams TK2 (R^2=0.55069) and TK4 (R^2=0.34024), the peak reaction correlation occurred within 24 hours of a rainfall event. These R^2 values might be improved with additional data collection as the effect of re-vegetation might become more distinct over a longer period of time. As indicated earlier the re-vegetation is currently in progress and therefore more time is required for the vegetation specially the Vetiver grass to show its effect on the sediment loading reduction from the affected watershed.

The time-reaction for stream discharge to rainfall events further illustrates the difficulty in comparing the measured streams against one another given the large variability in stream behaviors. Of the streams measured, TK2 (one of the re-vegetated stream sites) was the most dynamic in reaction to rainfall events with much larger increases in stream flow in reaction to varying amounts of rainfall than any of the other streams (i.e. TK1, TK3, and TK4), which all had similar discharge reactions to varying rainfall events. This difference may be attributed to the varying sizes of the stream basins and such comparisons of size must thereby also be made.

Stage Discharge Curve:

A preliminary stage discharge curve (Fig. 16) was developed for the four streams measured in the study. The stage discharge curve was developed from the stream flow measurements conducted and the stream level measured by the installed level loggers.

An accurate stage discharge curve should utilize several years' worth (e.g. 25 or 50 years of stream level and discharge data) of water level and stream flow data. The development of an accurate stage discharge curve for the primary rivers of the watershed is essential to future management of the watershed because the stage discharge curve removes the need for the weekly flow measurements of the watershed by providing a measurement of flow level in the rivers.

The stage discharge curves developed for this study utilized only one-year of data collected (Fig. 16). Therefore, this does not provide a fully accurate estimate of the flow and water level relationship of the streams. However, the stage discharge curve developed can serve as the basis for future hydrologic studies within the Talakhaya Watershed. It is recommended that flow and level recordings of the streams continue to be measured (at least for one full El Nino and/or LaNino cycle) in order to obtain a more accurate estimate of the watershed behavior for future studies.

Soils:

A total of seven composite samples were collected (Table 2) for testing at various areas within the Talakhaya Watershed including badland (Samples 1 and 3), savanna (Samples 2, 4, 6, and 7), and shoreline (Beach) (Sample 5). The mapped sample areas include Akina Badland Complex, 30 to 60 percent slopes and Chinen Clay loam, 15 to 30 percent slopes, while the beach area is identified as Takpachao Variant-Shioya Complex, 1 to 10 percent slopes (Young, 1986).

All samples tested (Table 2) with the exception of the sample 5 (the beach sample) contained low pH levels and were thereby more acidic. Organic matter was low in all areas except for sample 6 and 7, which were sites located near several *Acacia* trees which were planted as a part of the revegetation project. The leaf litter produced by these trees can explain the high organic content seen in these areas (soil samples).

Table 2: Soil Sample Analysis for Talakhaya Watershed

Soil Sample Analysis											
#	pH	% O.M.	E.C. µS/cm	% Sand	% Silt	% Clay	Soil Texture	K (ppm)	Ca (ppm)	Mg (ppm)	P (ppm)
1	5.59	0.16	78.7	60.92	20.52	18.56	Sandy Loam	No Cal.	11949	941	1.62
2	4.98	0.16	134.8	34.92	29.80	35.28	Sandy Clay Loam to Clay Loam	No Cal.	12013	972	1.23
3	5.45	0.16	60.6	50.92	23.80	25.28	Sandy Clay Loam	No Cal.	17133	824	1.36
4	4.50	1.48	55.3	30.92	33.80	35.28	Clay to Clay Loam	No Cal.	12765	890	0.12
5	8.92	0.16	632.0	78.92	7.44	13.64	Sandy Loam to Loamy Sand	No Cal.	8153	963	0.09
6	4.47	3.45	101.8	10.92	23.80	65.28	Clay	No Cal.	5016	860	1.49
7	4.49	5.42	129.0	19.28	19.44	61.28	Clay	No Cal.	3725	736	1.89

Soil texture measurements (table 2) showed high sand content in samples 1, 3, and 5, which are expected as samples 1 and 3 were taken from badland areas where most of the clay content would have already eroded away and sample 5 was located along the beach. In contrast, the clay content was high in samples 6 and 7, which were taken in similar savanna environments in close proximity to one another.

Nutrient content measured (Table 2) included calcium (Ca), Magnesium (Mg), and Phosphorus (P). Potassium (K) data was unavailable (and continues to be to this date) due to machine calibration issues. Calcium and Magnesium levels in all samples taken were shown to be very high, where 2000 ppm Ca and 200 ppm Mg are at the higher limits of the spectrum. These values may therefore pose toxicity risks to plants and limit non-tolerant vegetation from growing. Phosphorus levels in contrast were very low in all areas measured, where 10 ppm P is the lower limit of the spectrum. These soils are therefore lacking in available nutrients for large vegetation to become established.

Recommendations:

From the up-to-date data, it appears that re-vegetation could possibly have a positive impact on reducing sedimentation, however:

- New growth especially the Vetiver grass must have time to establish itself especially following the modified planting techniques

- More data is required as re-vegetation is still on-going and becoming established and may have more distinct effect on reduced sedimentation.

- Continued monitoring is necessary in order to obtain more data for producing more defined lines in the graphs obtained from the data.

- Need for increased community awareness in order for them to appreciate the effects of conservation and the preservation of natural resources in this island. Furthermore, the efforts of this project should develop a sense of stewardship for protecting the watershed from further degradation in order to protect the coral reef in the ocean.

- Other monitoring procedures such as stream water sampling from the upper sections of the rivers (where there is continues water flow) as well as frequent and established pattern of shoreline samplings are needed to compliment the obtained data from data loggers and turbidity probe.

- More frequent water sampling especially within the proximity of each storm event could possibly provide better results regarding the turbidity differences between the rivers as they might be affected by the re-vegetation efforts within the individual watershed under the study.

References:

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Talakhaya Watershed Soil Loss Assessment Project
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Prepared by:
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Figure 1: Talakhaya watershed working Map (courtesy of Bill Pendergrass of the Rota BECQ office) shows the ‘major’ streams and the location of the level loggers that are used for monitoring the effect of re-vegetation of the watershed.

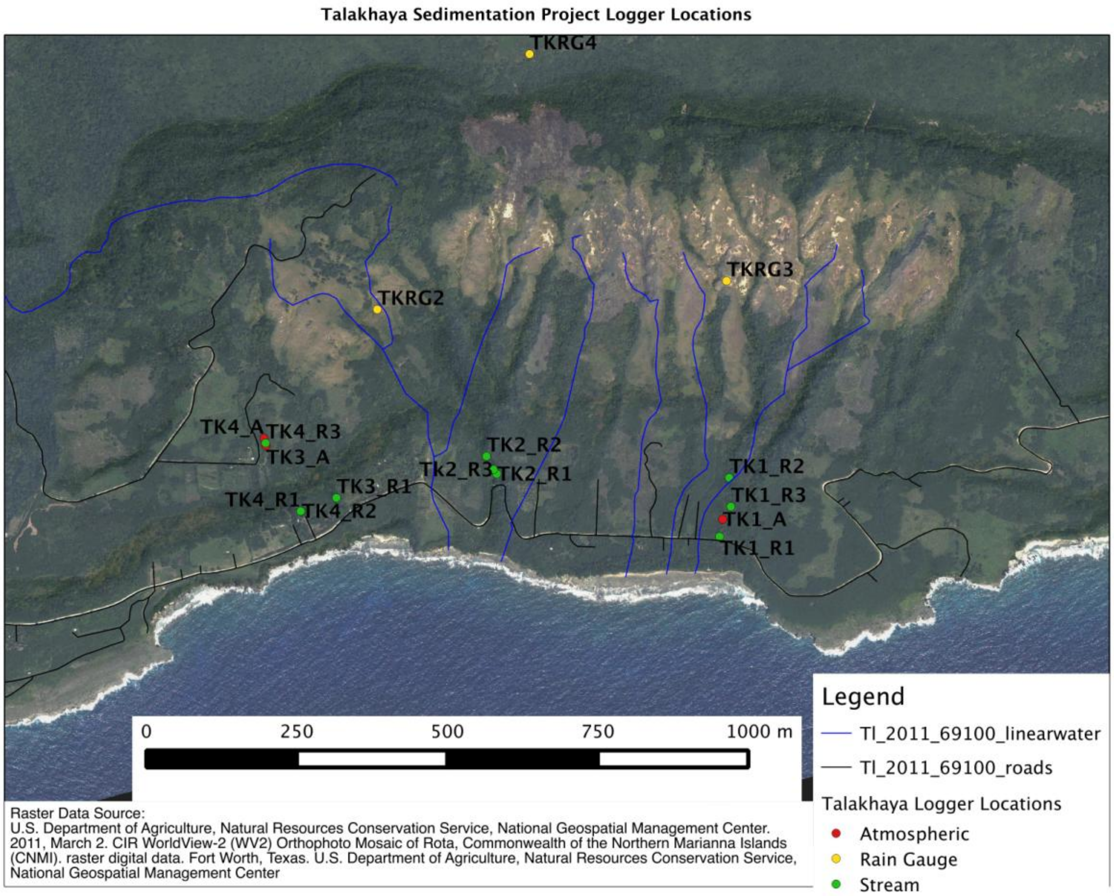


Figure 2: Talakhaya Sedimentation Project Logger Locations (USDA NRCS, National Geospatial Management Center, 2011).

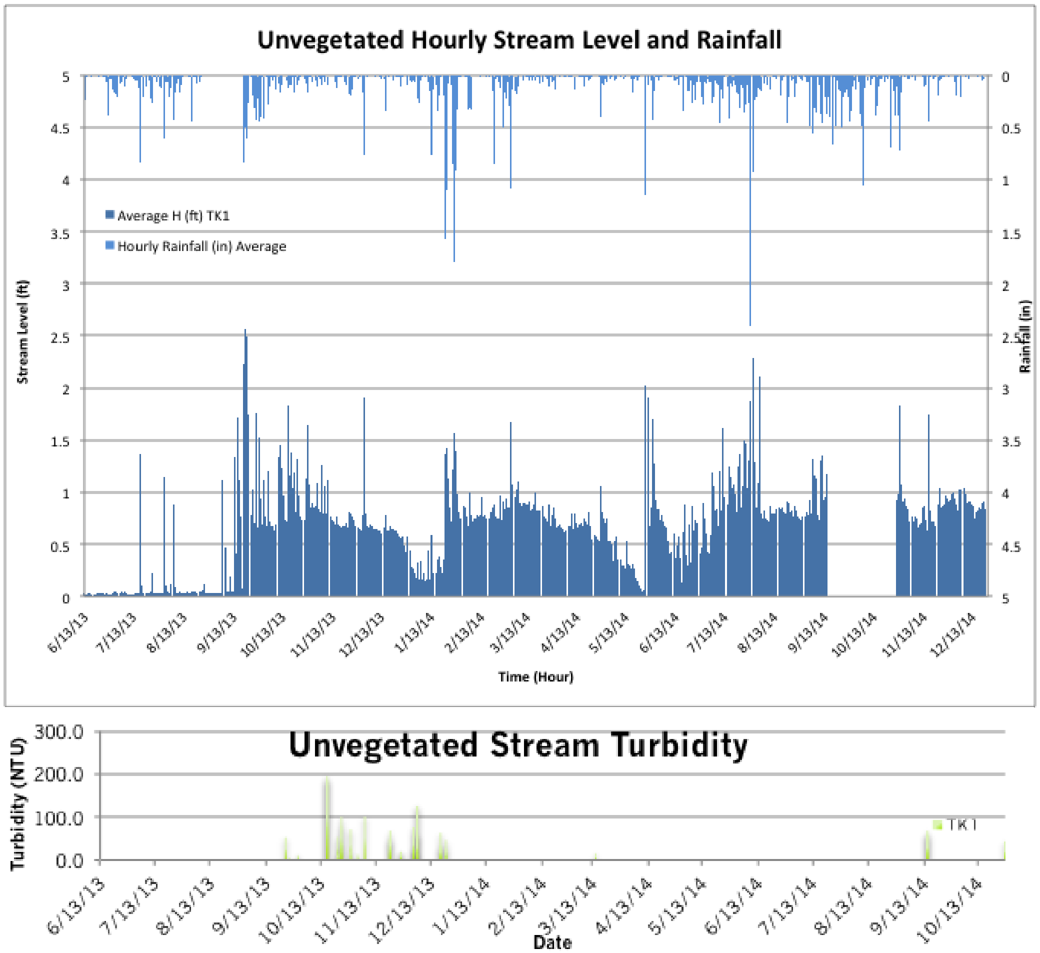


Figure 3: Unvegetated Hourly Rainfall, Stream Level, and Turbidity for TK1

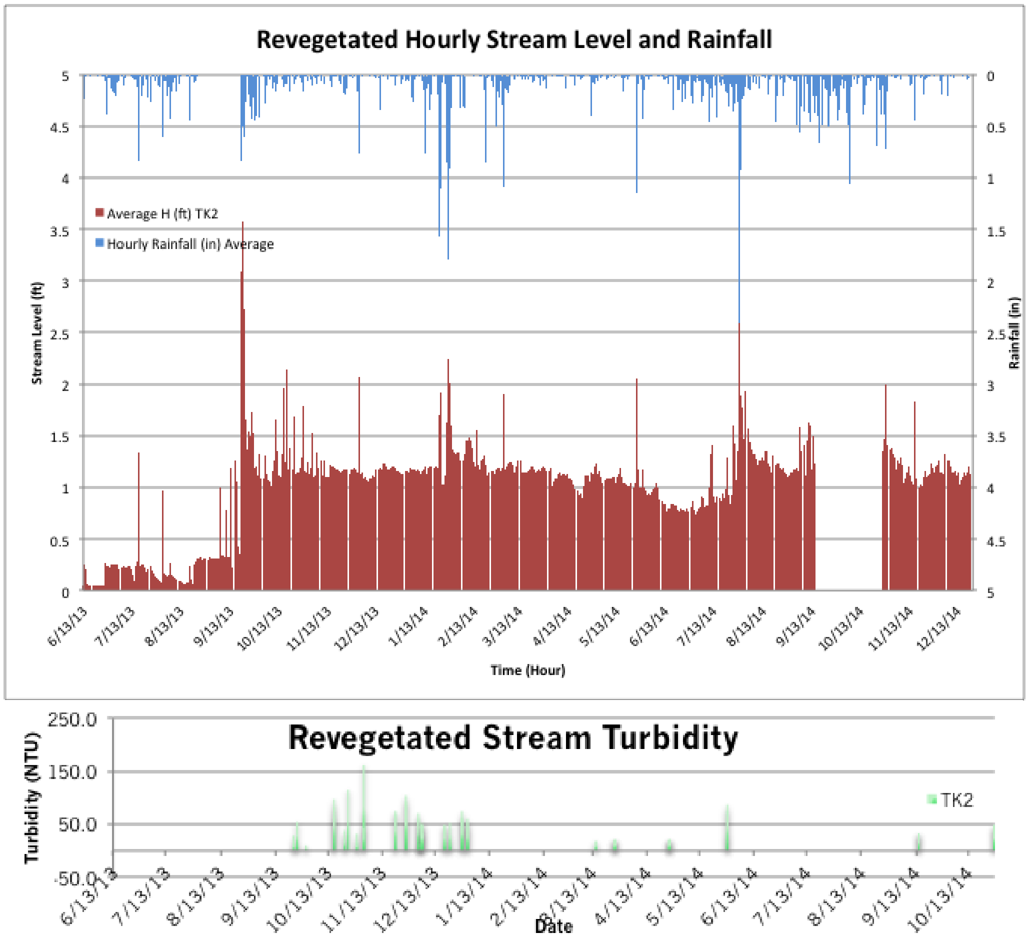


Figure 4: Revegetated Hourly Rainfall, Stream Level, and Turbidity for TK2

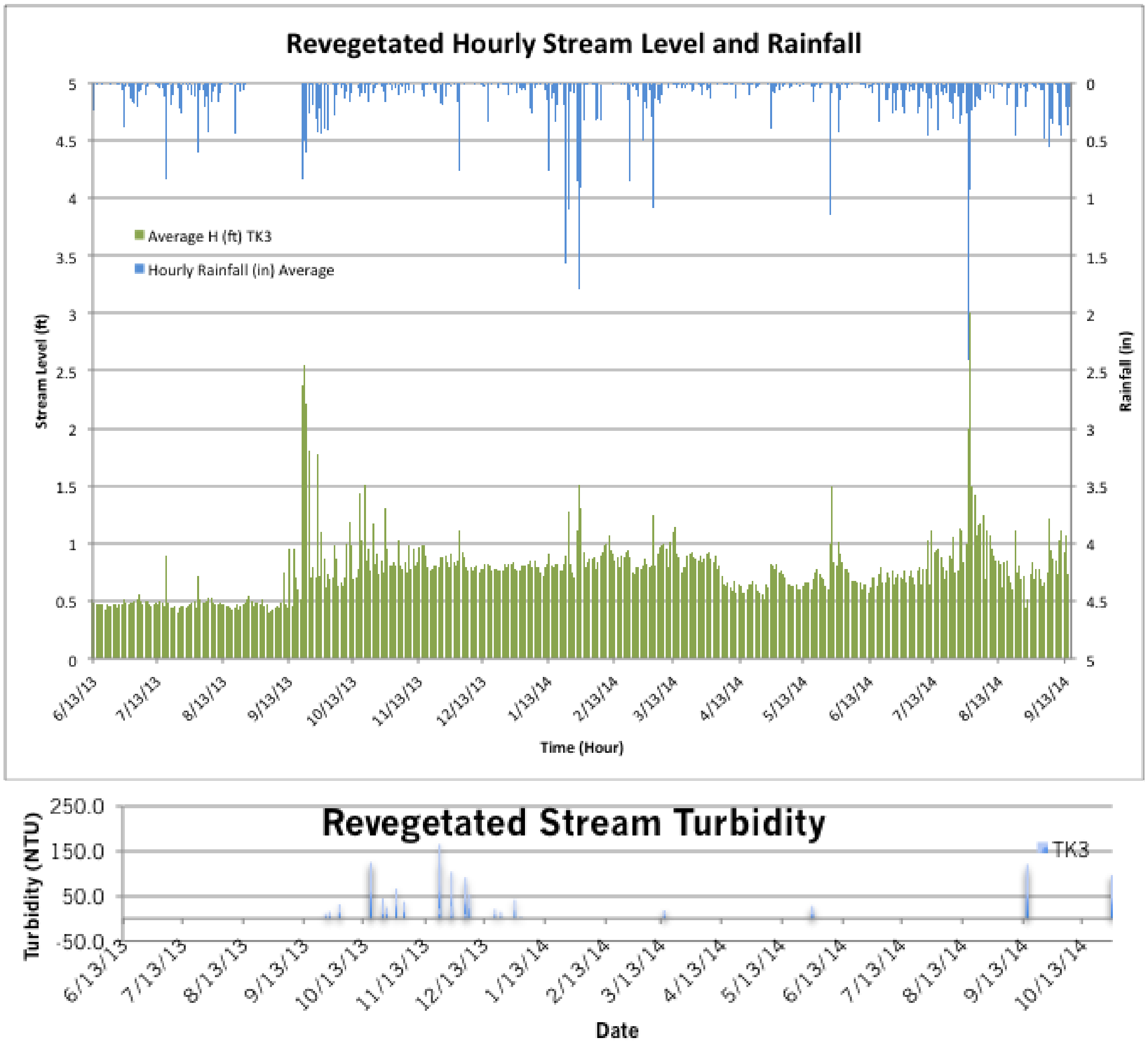
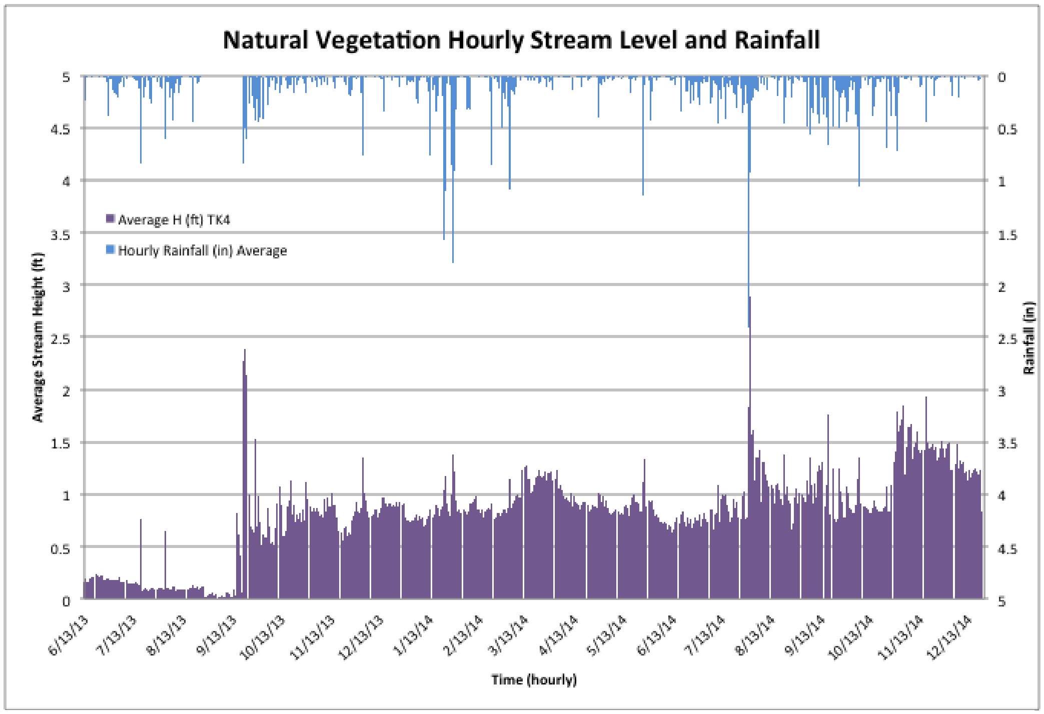


Figure 5: Revegetated Hourly Rainfall, Stream Level, and Turbidity for TK3



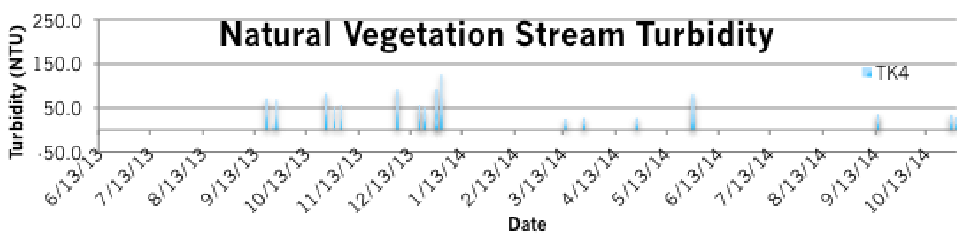


Figure 6: Non-vegetated Control Hourly Rainfall, Stream Level, and Turbidity for TK4

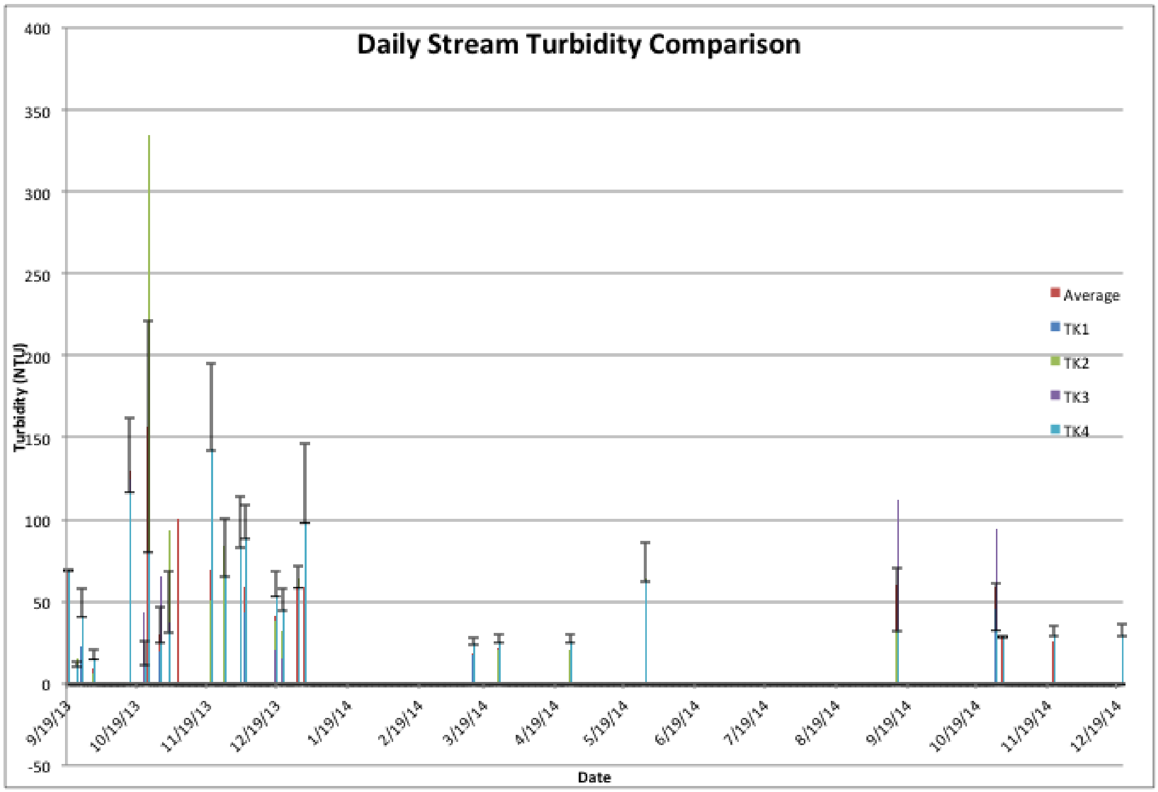


Figure 7: Daily Stream Turbidity Comparison

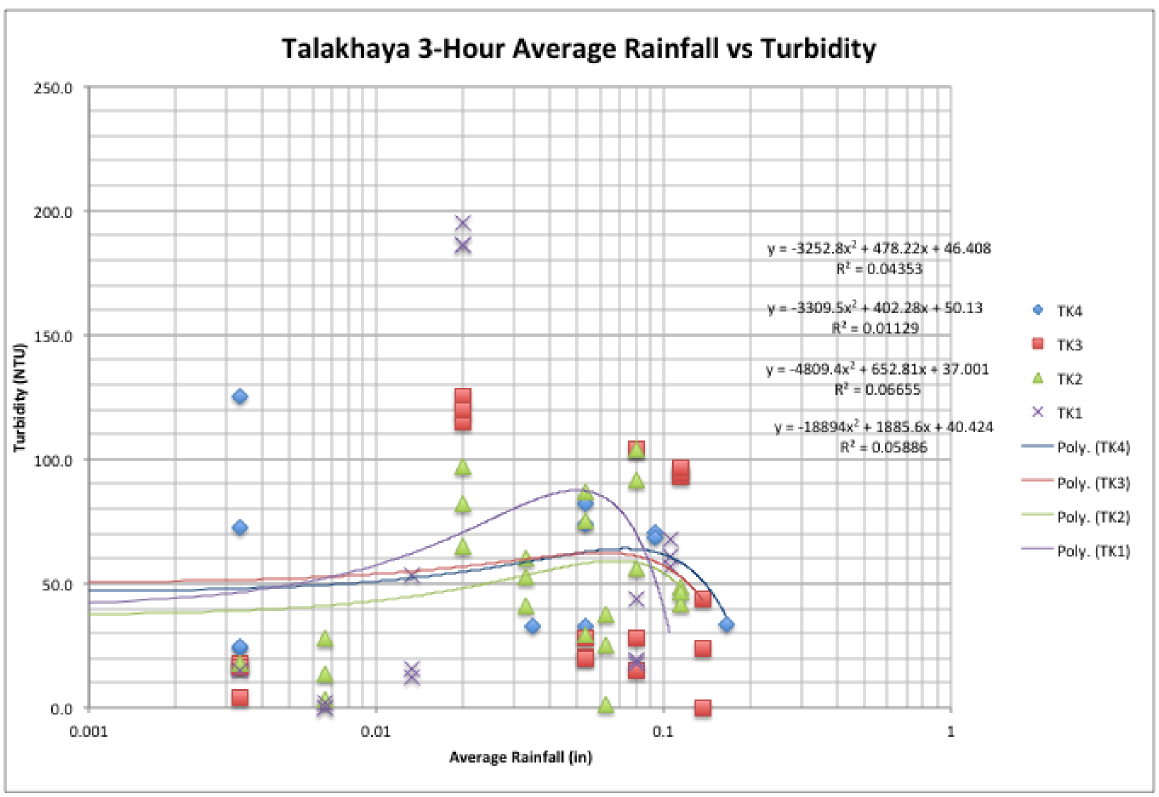


Figure 8: Talakhaya 3-Hour Average Rainfall vs Turbidity

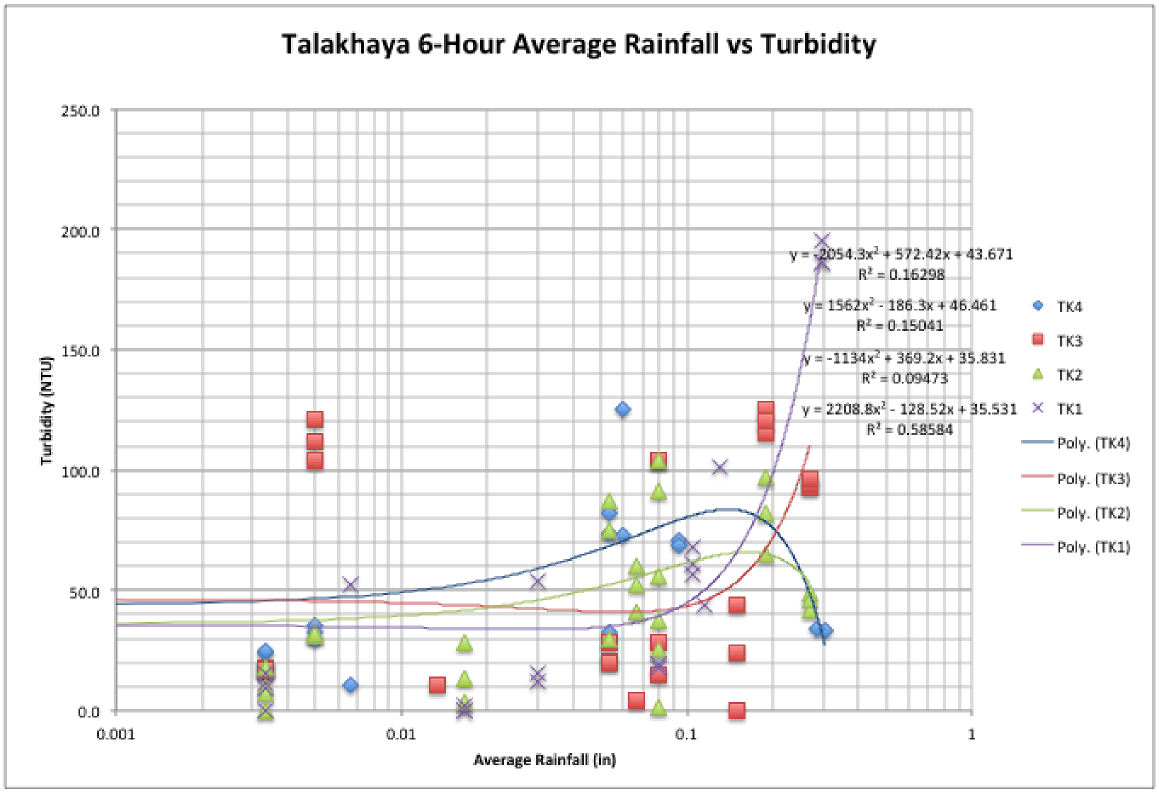


Figure 9: Talakhaya 6-Hour Average Rainfall vs Turbidity

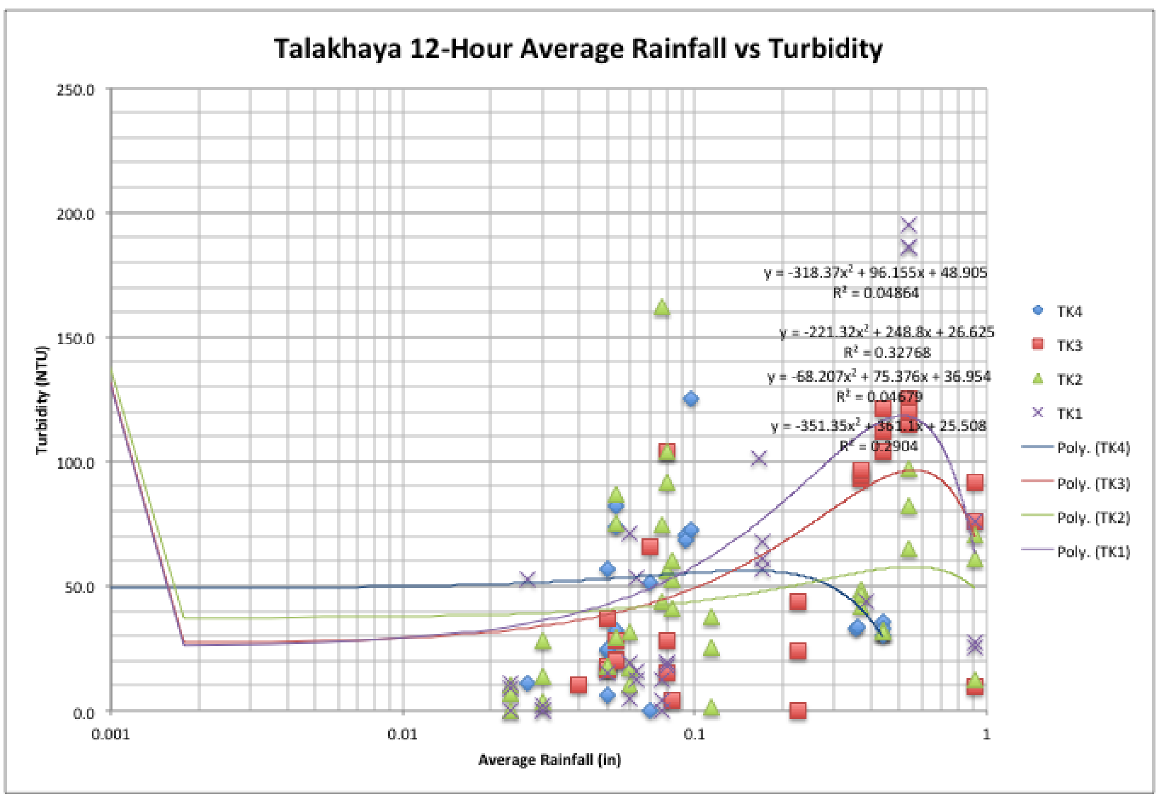


Figure 10: Talakhaya 12-Hour Average Rainfall vs Turbidity

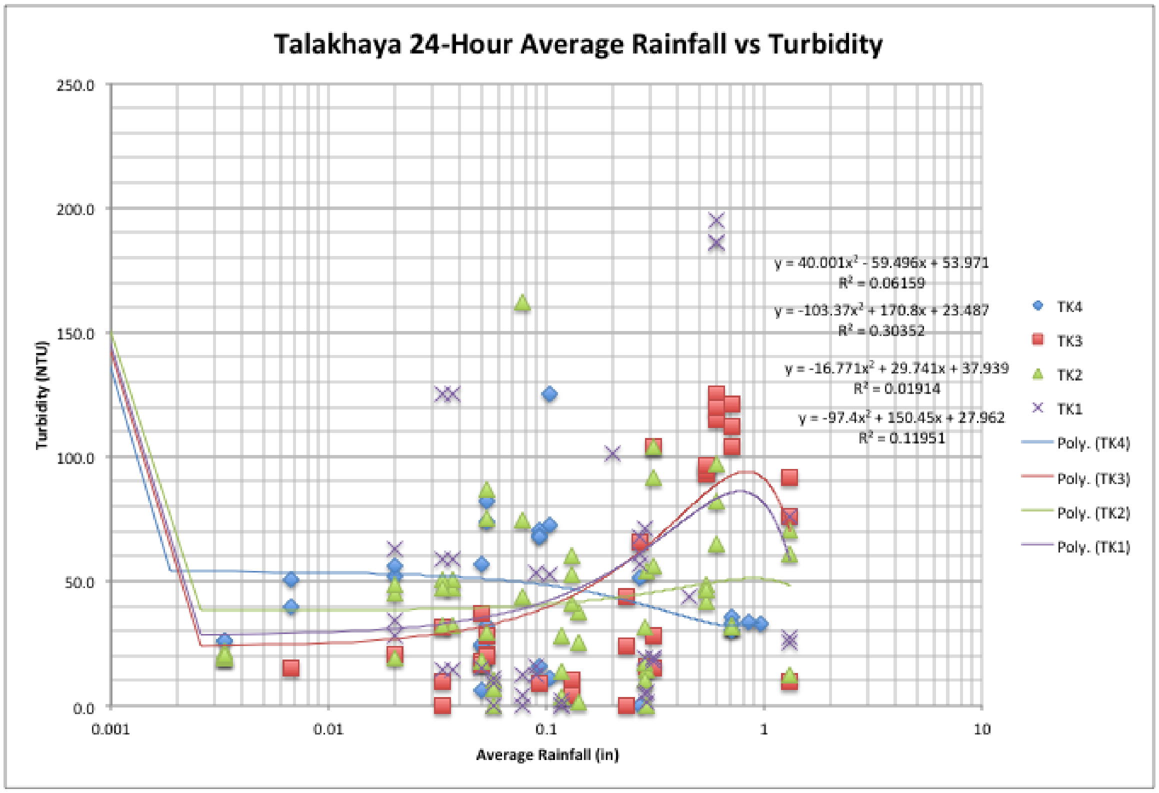


Figure 11: Talakhaya 24-Hour Average Rainfall vs Turbidity

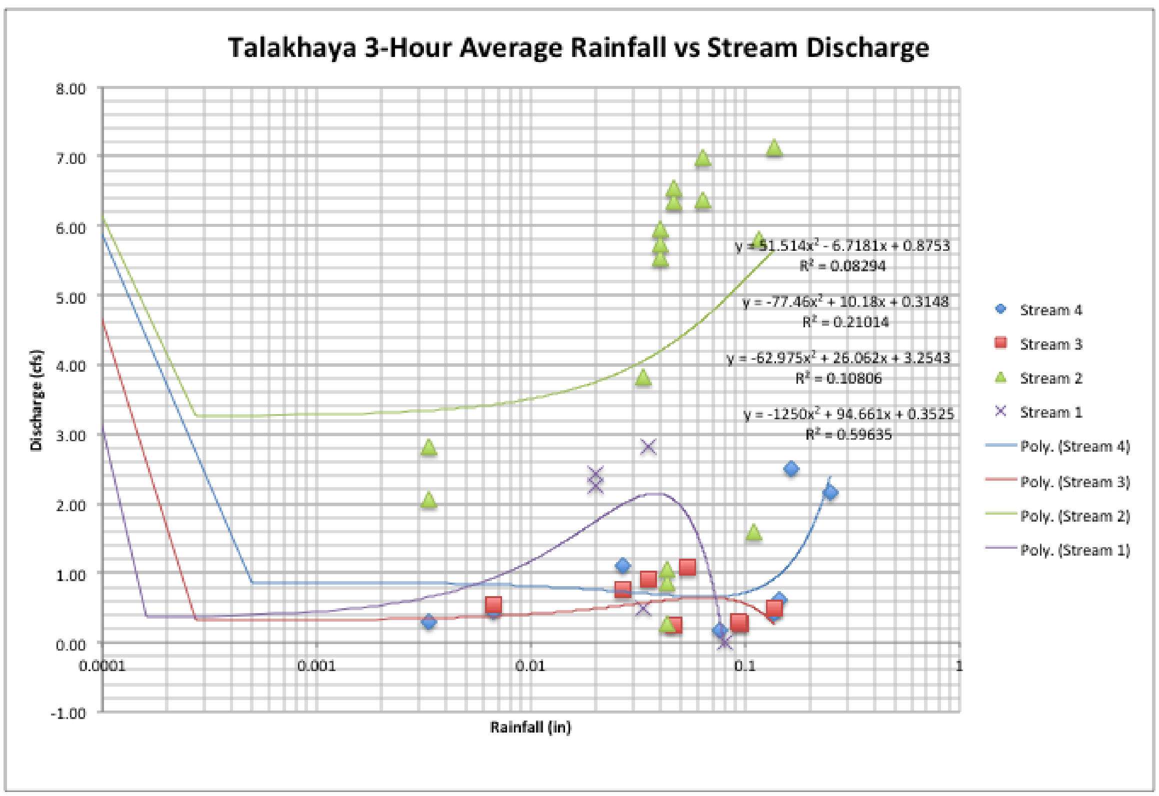


Figure 12: Talakhaya 3-Hour Average Rainfall vs. Stream Discharge

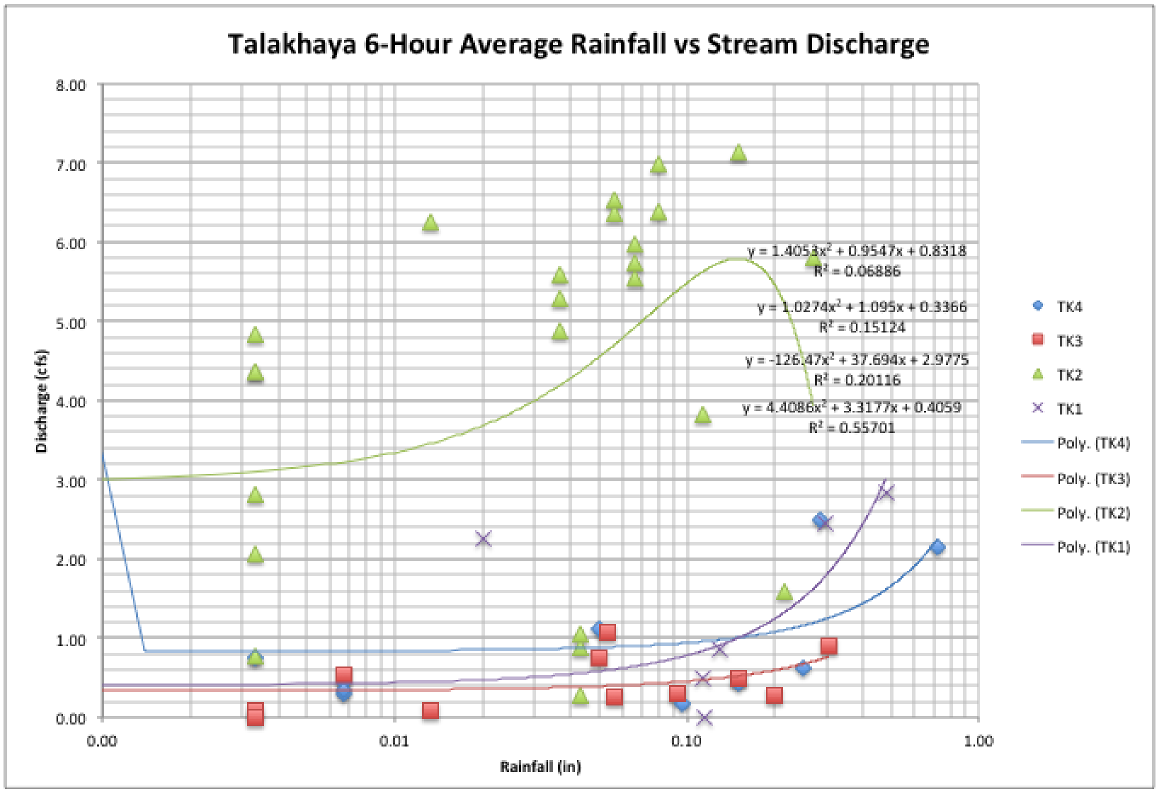


Figure 13: Talakhaya 6-Hour Average Rainfall vs. Stream Discharge

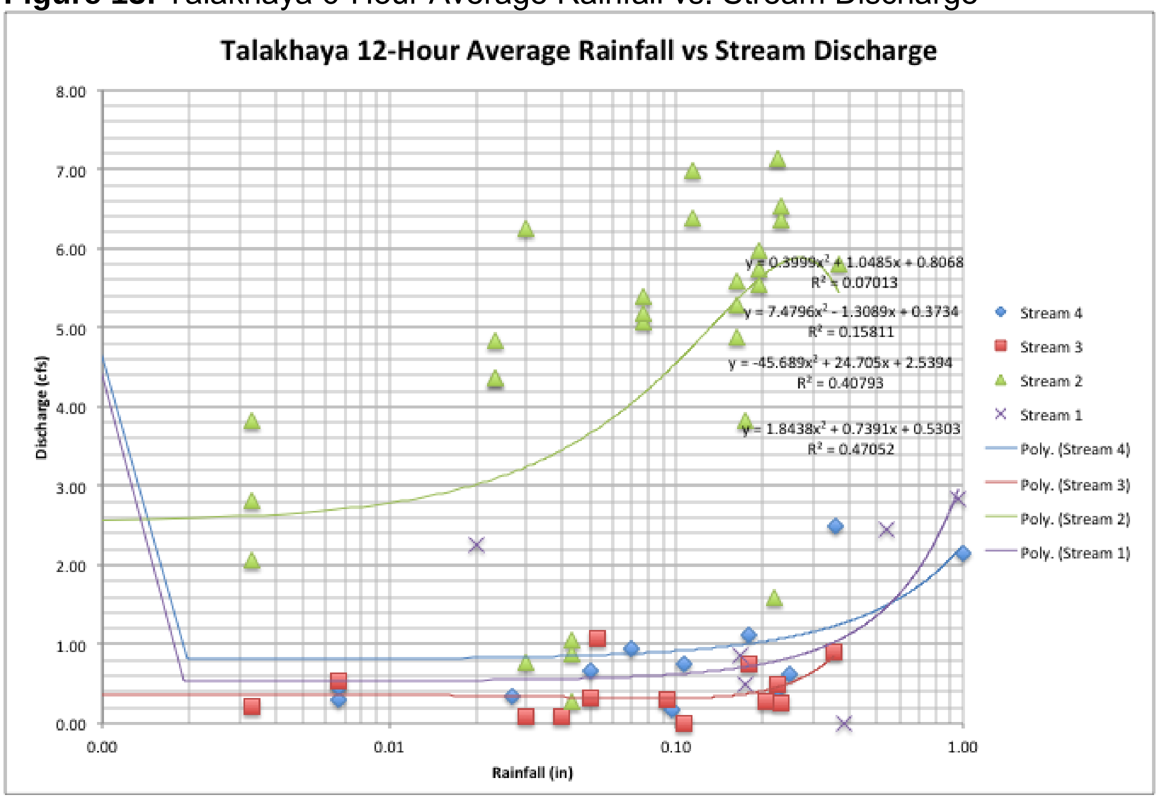


Figure 14: Talakhaya 12-Hour Average Rainfall vs Stream Discharge

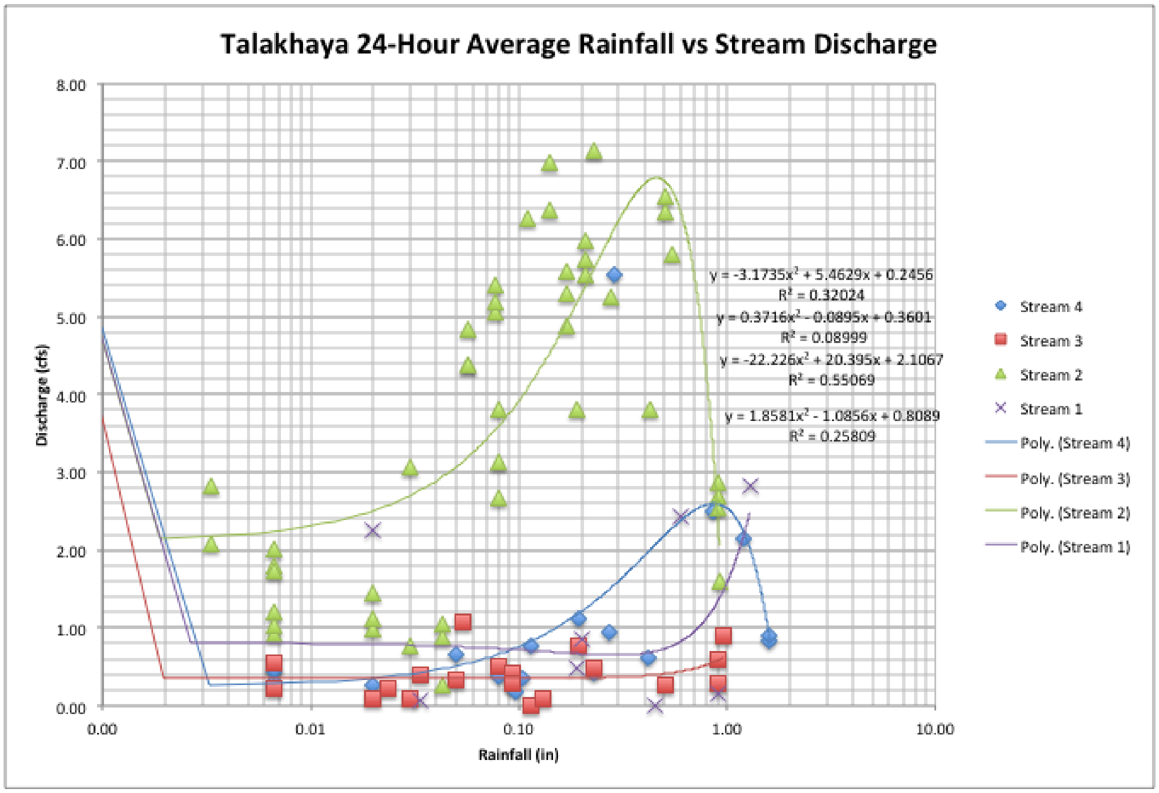


Figure 15: Talakhaya 24-Hour Average Rainfall vs Stream Discharge

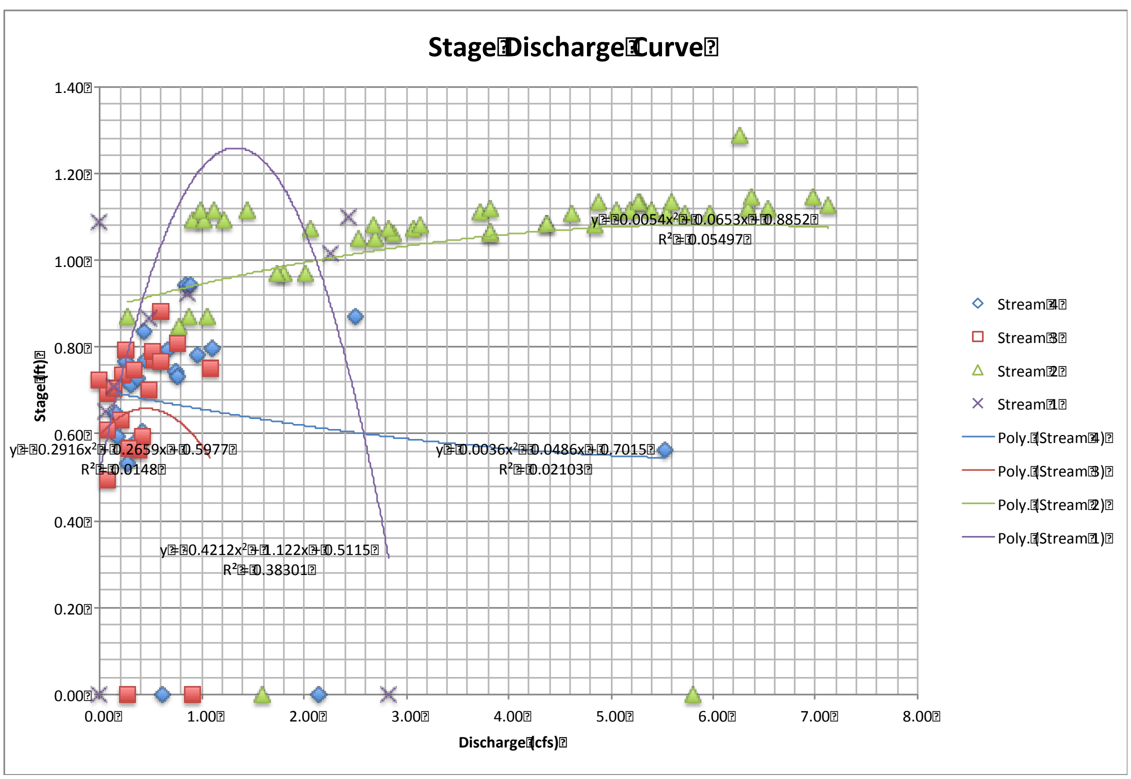


Figure 16: Stage Discharge Curve for Talakhaya Gauged Streams