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Technical Assessment of the Irrigation Systems of Marigot and Jacmel and Preliminary Observations on the Marigot Watershed

by

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Executive Summary

An irrigation system located near Marigot was damaged by flooding from Hurricane Georges. A water engineer and an agronomist were asked to determine what was needed to rehabilitate the system and to protect the system from damage from future storms. The site of a second irrigation system, planned for Jacmel, was also visited and recommendations made.

Irrigation Systems

The Marigot system has two components, one with intake at Rodaille, serving 360 ha on the east side of the Plantil River, and one with intake at Belle Roche serving the 165 ha on the west side. The canals at the field level were in good condition, although water management within individual fields appeared inefficient. The intake structures at Rodaille and Belle Roche were severely damaged. A syphon crossing under the river from the intake at Rodaille was destroyed. The east bank of the river was eroded several meters inland at this point and the course of the river was displaced eastward. Without protection, this bank will continue to erode eastward, with the loss of cropland and sections of the primary canal. A closed conduit crossing the dry riverbed appeared to be intact but was filled with rock and debris. A portion of the primary canal running along the west bank of the river from the Belle Roche intake was destroyed when the riverbank collapsed as a result of the flooding.

Because of the destruction to the upper portion of the Rodaille system, irrigators on the westside secondary canal constructed their own diversion, running water into the secondary canal and at one point passing water under the secondary canal. If this situation is allowed to persist, the system will be irreversibly damaged.

Recommendations:

- Relocate the intake for the Rodaille system upstream from the present site and on the east bank of the river, to avoid the need for a syphon.
- Build a new upper canal section to connect up to the existing primary canal.
- Install conservation structures to protect the primary canal from further erosion of the east bank of the river.
- Divert the stream channel westward within the riverbed.
- Clean the enclosed conduit and the canal between the syphon and the conduit
- Relocate the Belle Roche intake and the main canal.

The Jacmel system will require 17 km of main conveyance canal and will serve approximately 500 hectares, of which 300 ha will be in the lowland and 200 ha on hillsides. The most difficult part of the system will be the construction of the upper section of the canal along the steep river bank next to the proposed intake. The site proposed for the intake appears to be adequate. The

greatest hazard to the system will be the potential for increased soil erosion on the steep slopes due to the added water.

Recommendations:

- Provide training in soil and water conservation along with installation of the system at Jacmel
- Install conservation structures such as bench terraces on irrigated hillsides.
- Implement programs for irrigation system maintenance and water use management at Jacmel and at Marigot in order to ensure efficient water use and system longevity.
- Train system operators and users in system maintenance and water use management

Marigot Watershed

Evidence from the deposition of large rocks on farmland and widening of streambeds suggest that the flooding that occurred with Hurricane Georges was unprecedented. It appears unlikely that the extent of damage could be attributed to conditions in the foothills. These are fairly well vegetated to the northwest, although the foothills to the northeast, draining into the intermittent stream, have more extensive clearing and erosion.

The Marigot watershed drains a 12-15 km length along the south slope of the La Selle chain of mountains, which surpasses 2000 m in elevation. The Rivière Blanche and Plantil Rivers drain the western part of the watershed, while the eastern side is drained by intermittent streams originating in the high plateau that forms the buffer zone to Parc La Visite. Although the high peaks are forested, a vast area below this is almost devoid of trees. Some areas are intensively cropped with vegetables, but large areas have been used as pasture and the vegetation closely grazed. Soil and water conservation measures are virtually non-existent. Gullies and rill erosion are common.

Recommendations:

Soil and water conservation measures in the upper part of the watershed are required on a large scale in order to reduce the flooding hazard to the irrigation system at Marigot. These include:

- ravine stabilization measures
- establishment of woodlots and natural vegetation, contour plantings of trees and grasses
- introduction of soil and water conservation practices into improved crop production (rock walls, contour hedgerows, alley cropping and other agroforestry practices)
- improved soil fertility management
- greater emphasis on perennial crops
- improved livestock husbandry and pasture management.
- In the long term, a solution must be found to limit the free grazing of livestock that prevents the establishment of adequate ground cover.

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I. Introduction

The authors visited the Marigot area to inspect an irrigation systems damaged by Hurricane Georges and to determine what was needed to rehabilitate the system and to protect the system from damage from future storms. Three irrigation sites, two existing and one proposed were visited. Two sites are located near Marigot: Rodaille (360 ha commanding area) and Belle Roche (165 ha commanding area) were visited on March 1, 1999. One proposed new irrigation site was visited at the suggestion of our hosts on the return trip on March 2. It was located near Jacmel (around 500 ha commanding area).

II. Irrigation Systems

Both irrigation systems have severely damaged intake structures (photos 1 and 2) and conveyance structures on the intake side (photos 3 and 4). Based on observation of the Rodaille irrigation area, the irrigation field and most portion of the main canal and two secondary canals (photos 5 and 6) were not damaged as severely as the upper section of the main canal and the intake structure. However, most of the main canal section was badly sedimented at the time of visitation (photos 7 and 8). The sediment should have been carried and deposited by the flood from Hurricane George and/or sediment-carrying irrigation water during the normal operation. If the latter is the case, the irrigation system lacks scheduled maintenance of canal cleaning. Due to time constraints and logistics we did not visit the command area of the Belle Roche site. But we found that the intake structure and upper section of this irrigation system were severely damaged (photos 9 and 10). Each site will be described in terms of the damage and recommendations for renovation. The consultants were told that a local contractor has been selected for planning and designing of the water intake structure and the irrigation conveyance system renovation for both sites. Since the contractor is in the design stage of the system, our recommendations may be used to verify or confirm their plans.

A. Rodaille site

In general, the system at the field level seemed to be in a good condition at the time of our visit. Rock wall and metal gates along the irrigation main and secondary canals still looked new. The major problems are at the upper section of the main canal. With reliable maintenance and water management programs the system would provide the 360 ha with excellent benefit. One observation is that the irrigation could be used for more profitable crops than bananas as other crops would have 2-3 harvests with adequate water supplies. The field irrigation could be more efficient if the fields are better organized than the random running of water into banana fields. If crops are planted in rows, then water could be applied in furrow irrigation. Flooding irrigation may be practiced for other crops.

Observed problems:

1. **Severely damaged intake structure** - A new intake structure should be located on the east bank (photo 11) to avoid a stream crossing structure such as a siphon or flume. An upstream site from the current intake should be chosen to achieve this relocation. This observation agrees with the current plan by a local contractor which was mentioned to the consultants. However this will require a new upper section of main canal to connect to the existing main canal section that survived the hurricane.

2. **Washed off (?) siphon structure crossing the perennial river** - No evidence of the washed siphon pipes were found near the site. The siphon pipes may be still buried under the gravel. We could not understand any reason why the intake was located on the west bank of the river, across from the irrigation command area, thus requiring a siphon structure crossing the river. It is not common to have such expensive system by locating intake structure across stream. Had the diverted water been delivered to irrigate the west bank area, this intake site would have made sense, but we were told that the canal does not irrigate the west bank. The only advantage we could see was the natural rock which anchored the intake structure (photo 12). However, a structure for an anchor, if it were necessary, could have been built on the east bank to save the cost and trouble of a siphon structure.

3. **A sediment-filled box-type closed conduit crossing the dry bed river** - It appeared that the long closed conduit has no other damage than sedimentation in it (photos 13 and 14). This was observed from its inlet and outlet and manholes along the conduit. Some manholes have a raised access but at least one of them has an access lower than the ground level where foreign materials could easily enter. The main canal section between the outlet of siphon and the closed conduit was completely sedimented from the flood water (photo 15). Except for the sediments deposited in the upper section of the main canal, the rest of the conveyance system does not show any serious damages. **It is suggested to save the upper section of the main canal below the siphon outlet and whole length of the closed conduit. This would be done by re-routing the main canal from the new intake structure at or below the outlet of the existing siphon if feasible (photo 16). However, it will require certain conservation practices along the eroded east bank (photo 17) in order to stabilize the main canal below the siphon outlet and**

other infrastructure from flooding. Otherwise it is recommended to re-route this section of the main canal further inland near the foothill and connect to a more stable section of the main canal and to the closed conduit. Such structures as siphon, closed conduit and flume are the most expensive structures per length to build for an irrigation conveyance system.

4. **The irrigators in the westside secondary canal have started to damage/abuse the conveyance systems to get water into the canal** - This damage to the irrigation system is an indirect effect of the hurricane. The west-side secondary canal (photo 18a) had water flow at the time of observation. The water was carried from the river using a rock diversion dam (photo 18b) and an earthen canal which the irrigators installed. The water was conveyed to the secondary canal by the earthen canal (photo 19). Also a portion of the water was conveyed to a nearby field by passing the water through a dug-out hole under the secondary canal. We did not observe any other cases, but if the situation (no water supply in the main canal) continues, there will be more of this and similar types of damage/abuse and eventually irreversible damage will be done to the irrigation system. One observation showed that canal maintenance was not adequately done, due to lack of flow or lack of a maintenance program. This was shown by the accumulated trash and sediments in most of the canal sections.

5. **Diversion of the perennial river** - The newly eroded east bank near the intake structure (photo 20) not only caused problems to the irrigation system but caused loss of community infrastructure. Without action to protect the bank, it will continue erode into further inland. One potential solution in addition to protecting the river bank with conservation structures is to divert the current course of the flow. **The area between the damaged intake and the present river course (photo 20b) needs to be excavated to open a new course away from the eroded bank. The excavated material may be used to block the current flow to guide the river into the new course. The eroded river bank should be re-graded with an acceptable slope and protect with rock-concrete structure or gabions.**

B. Belle Roche site

The intake structure of this site was washed off and broken in half and upper section of the main canal was destroyed (photo 21) as the river bank collapsed due to the flooding. One problem was that the main canal was installed along the fragile river bank. It would be necessary to re-route the main canal and relocate the intake structure. The local engineer has proposed to use an old structure located further inland from the broken section of the canal. As the elevation drop is adequate to convey water by gravity, it would be an acceptable proposal. Otherwise the intake structure should be located further upstream and the canal be rerouted in further inland. This may provide more land under irrigation while having the canal in a safer condition.

C. A proposed new irrigation system on the west bank of Jacmel

We were told that the system will require up to 17 km of main conveyance canal, primarily along the hills, to irrigate a low land across the river from Jacmel and the hillsides (photos 22

and 23) along the canal. The proposed total irrigation area is around 500 ha, around 300 ha of the low land and remainder on the hillsides along the canal. The most difficult part of building this system is to build an upper section of the canal immediately after the proposed intake site which will run along the steep river bank (photos 24). The site proposed to install an intake structure seems to be adequate as a natural rock on each side of the river may be used to anchor the structure (photo 25). **Since the system will be used to irrigate steep hillsides along the canal, it is extremely important to train the irrigators for soil and water conservation such as bench terraces. Without proper control of the irrigation water at the field level, more severe soil erosion problems will develop than without additional water to the field.**

D. Importance to Irrigation System Programs of Maintenance and Water Management

It should be noted that irrigation systems need reliable system maintenance and water management programs for efficient water used and system longevity. Efficient water use prevents any future conflicts of water uses among the users, especially during low flow seasons. Disputes over water use among irrigators have often resulted in abused irrigation systems. These have included personal modification of the system to deliver more water to one's own field. It is strongly recommended to develop system maintenance and water management programs for each irrigation system. The programs should include training of the operators as well as irrigators about importance of water use efficiency and system maintenance.

Photo 1. Inlet structure at Rodaille site. Note the broken and washed out left wing and rock-anchored right wing. Main canal is located behind the sluice gate.

Photo 2. Intake structure at Belle Roche site. Note the broken left wing. The intake sluice gate locates behind the wall covered with grass.

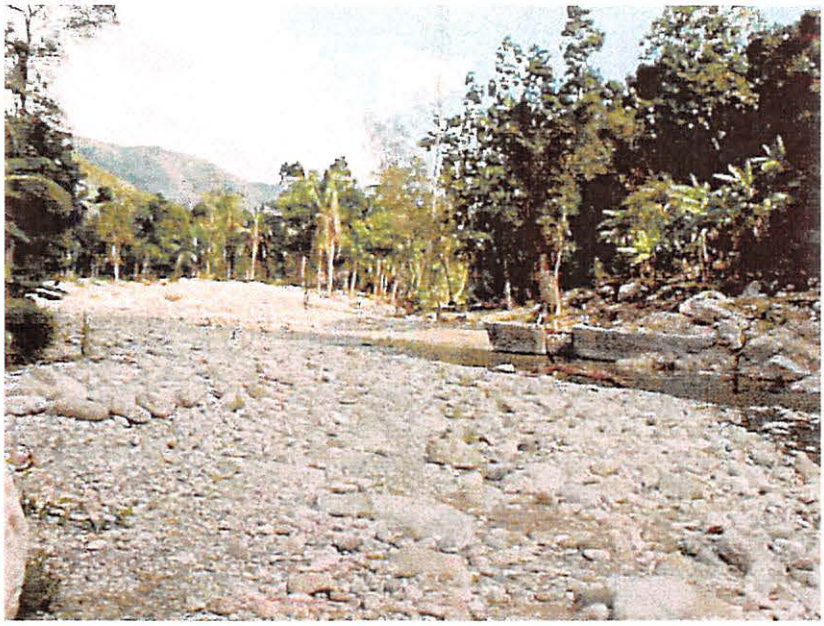
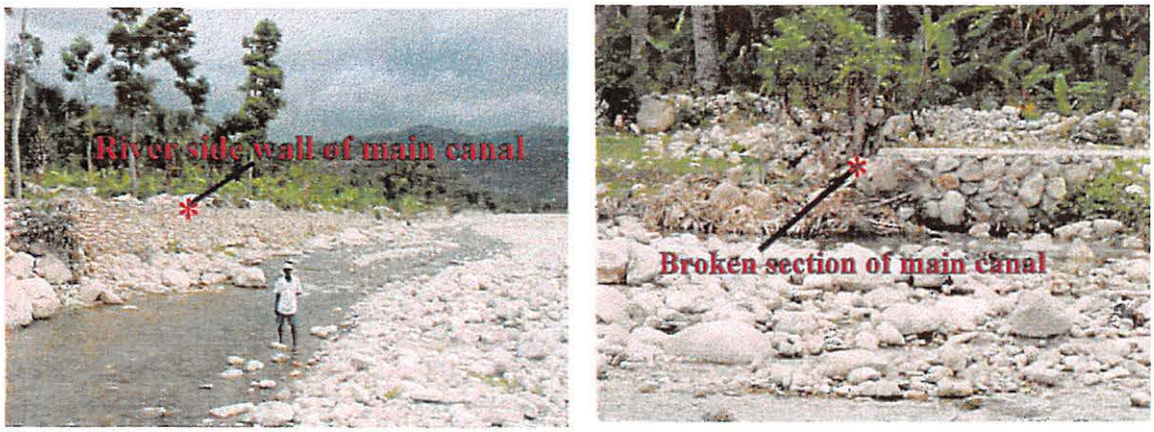


Photo 3. Damaged upper section of main canal at Rodaille site. The embankment on the left of the intake structure was broken and washed out and the river bottom was exposed to the main canal.



(a) (b)

Photo 4. Upper section of main canal at Belle Roche below the intake structure has survived due to the rock wall structure, but the lower part of this section has been broken as shown in the right photo.

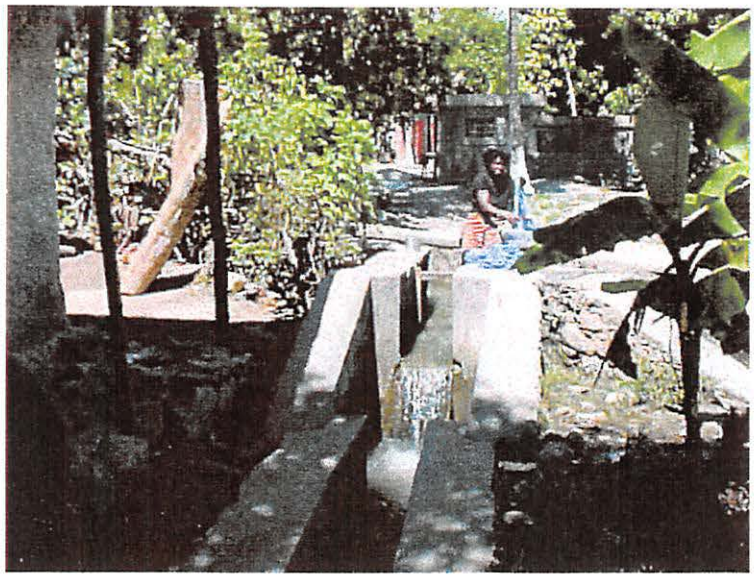


Photo 5. Fully functioning west-side secondary canal even when main canal is dry.

Photo 6. Undamaged section of main canal. Except for the upstream section the main canal below the siphon structure survived the hurricane George. Sedimentation and trash accumulation were excessive which would cause serious problems if not adequately cleaned up.

Photo 7. Sediments and trash accumulated in a section of main canal. This is outlet side of the siphon. The canal structure is near perfect at this and most sections of the main canal. Most damage was done to the intake and siphon sections.

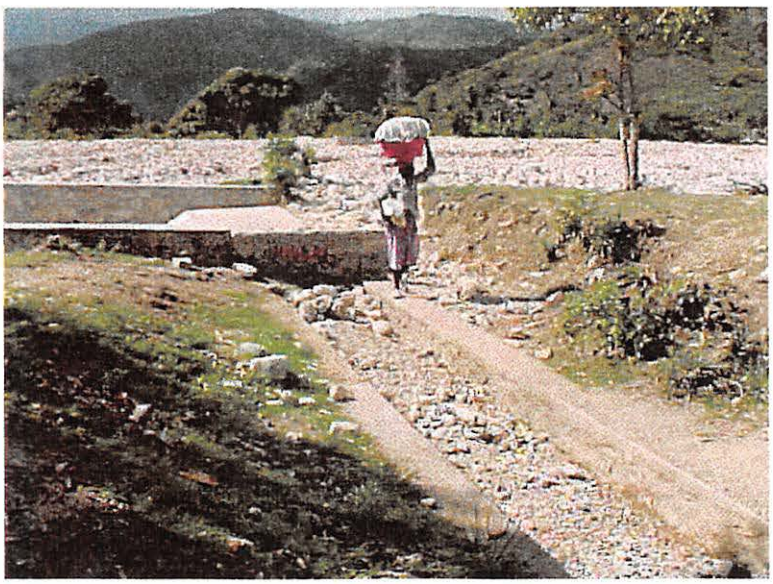


Photo 8. Sediments completely filled up the main canal at the outlet site of the closed conduit. This was caused mainly by the flooding.

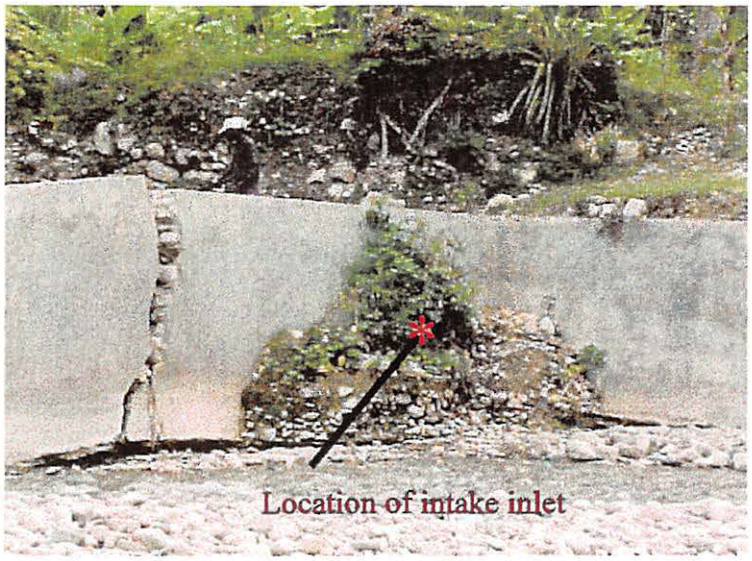


Photo 9. Damaged intake structure at the Belle Roche site. Damaged left wing and washed foundation of the structure.

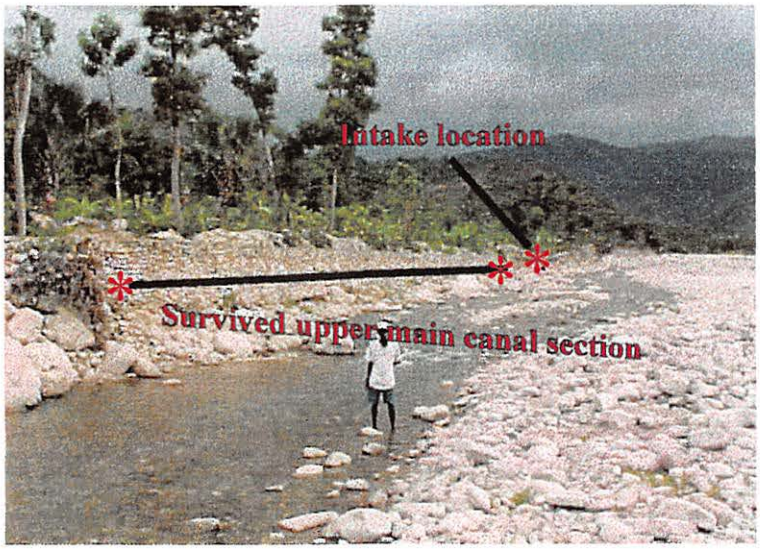


Photo 10. Damaged upper section of main canal at the Belle Roche site. The rock walled section of the main canal survived the flooding but the left end of the section was completely cut off.

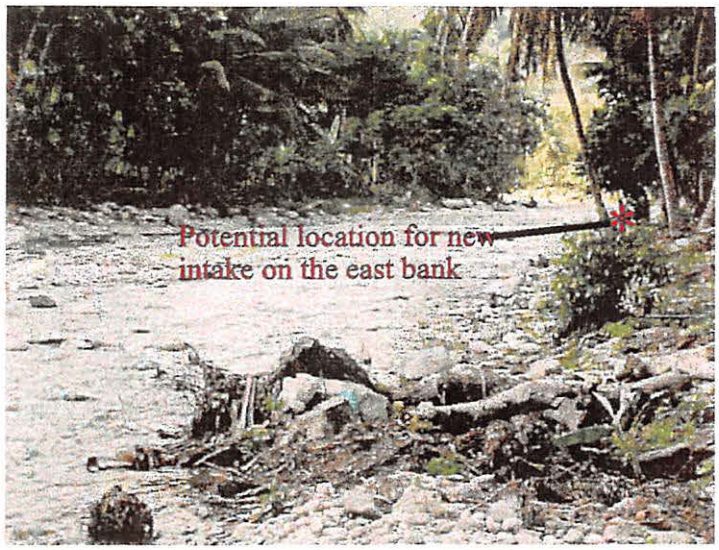


Photo 11. Potential location of a new intake site on the east bank of the river to avoid a river crossing structure. Location is determined by the elevation change in the river which should be high enough for gravity supply to the undamaged section of the main canal. The new connecting section may be routed near the foothill to avoid future damage by flooding or bank erosion.

Photo 12. Intake structure at the Rodaille site. Note that the natural rock on the right wing which was used to anchor the structure. The right wing survived the flooding due to the anchor. It is a good idea to anchor an intake structure to a strong object such as natural rock. In case no such object is found, an artificial structure similar to natural rock may be located at more convenient and proper location for intake structure. Existence of such anchoring object should not govern the location of intake.

Photo 13. Practically undamaged closed conduit structure crossing dry-bed river. The conduit may have been filled with sediment from the flooding.

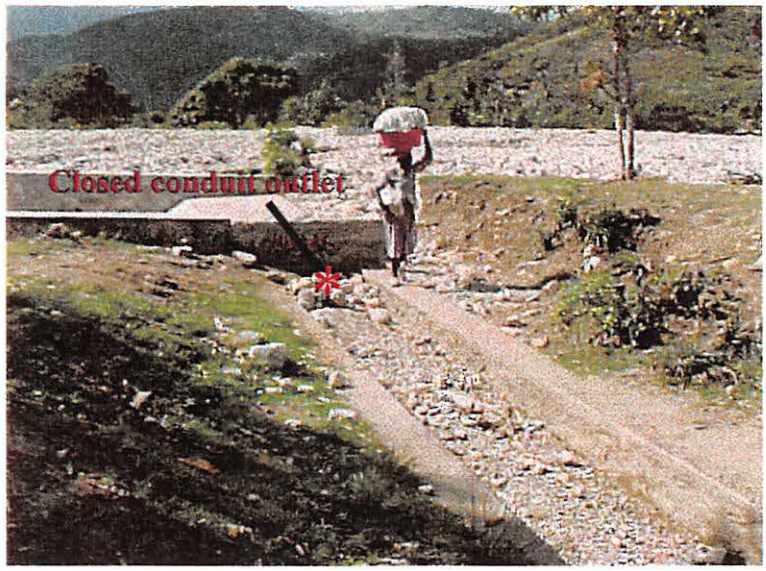


Photo 14. Sediments and gravel filled main canal at the closed conduit outlet.

Photo 15. Main canal section between siphon outlet and closed conduit inlet.

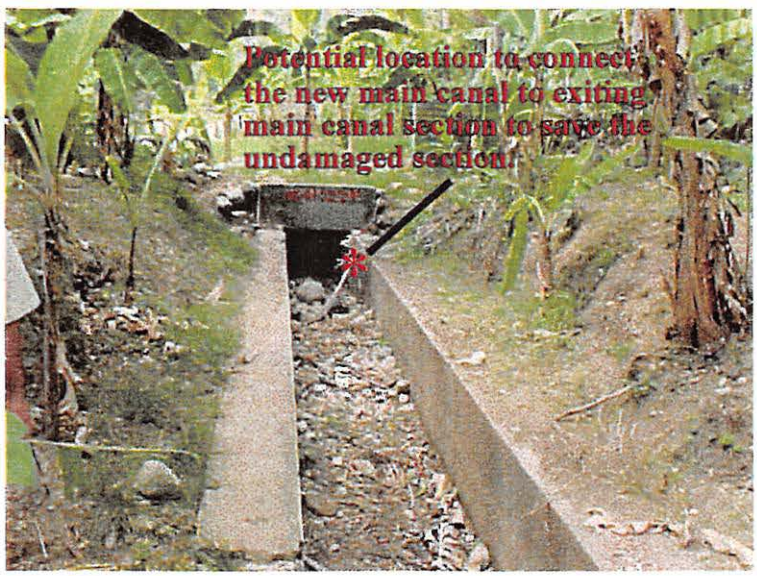
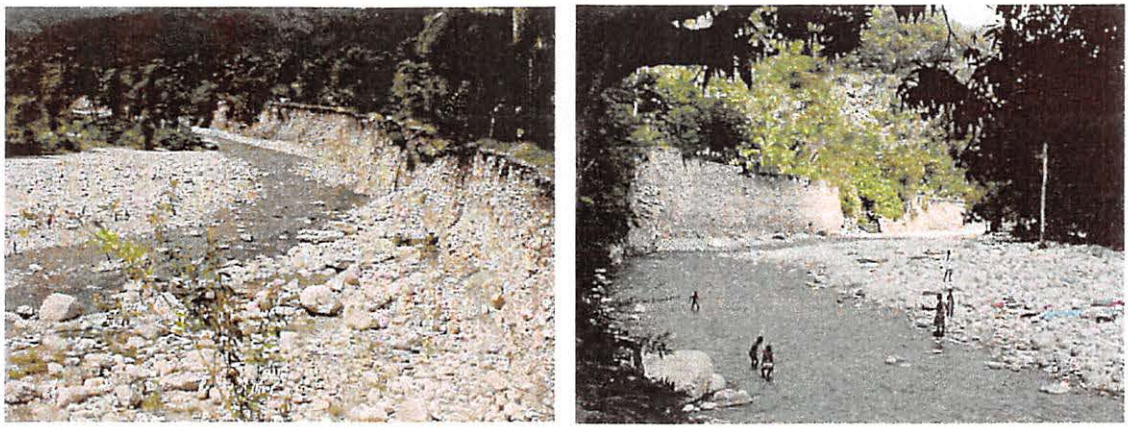
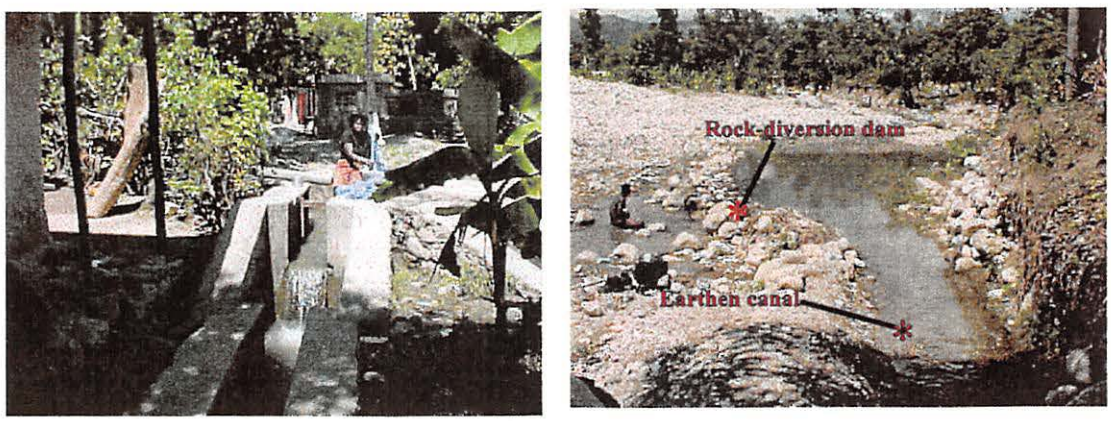


Photo 16. Potential site to connect the new main canal to exiting main canal to save the existing main canal and the closed conduit.



(a) (b)

Photo 17. Severe bank erosion which destroyed the road and canal. Left: from downstream side. Right: from upstream side. A drastic river course change is required to prevent further bank erosion.



(a) (b)

Photo 18. West side secondary irrigation canal which carries water where the main canal is dry. The water was diverted by a rock-diversion dam and an earthen canal built by the irrigators of the west side secondary canal.

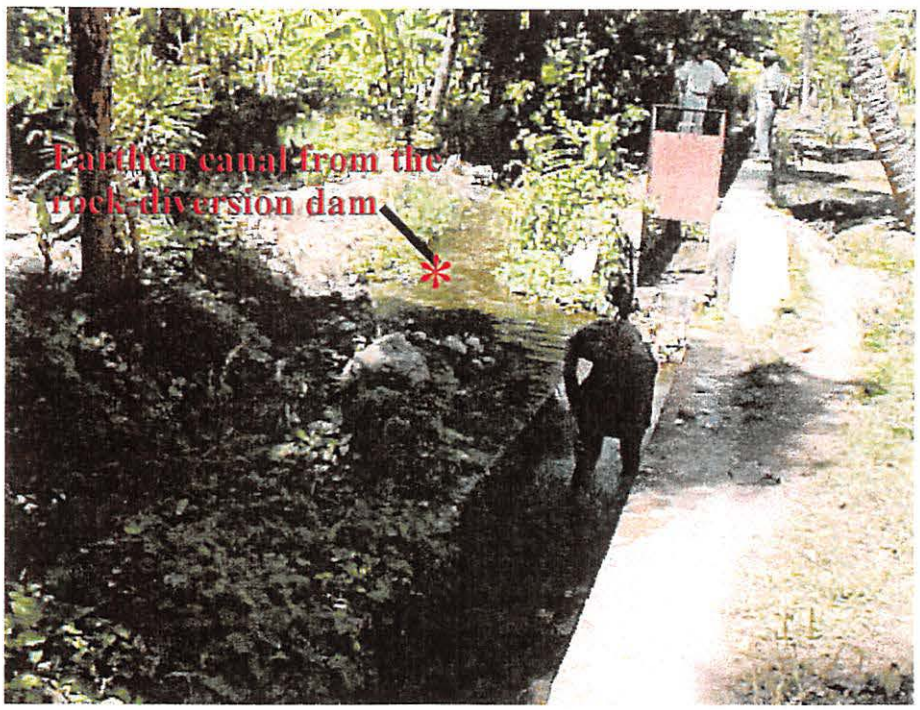
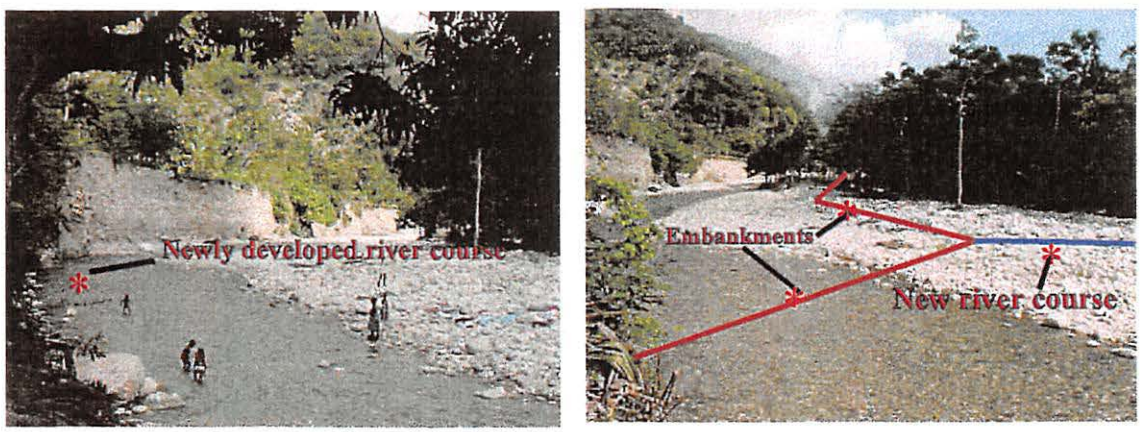


Photo 19. As no water is supplied from the system, irrigators have started to solve the problem by modifying the system's function. Such activities will eventually cause serious damage to the system.

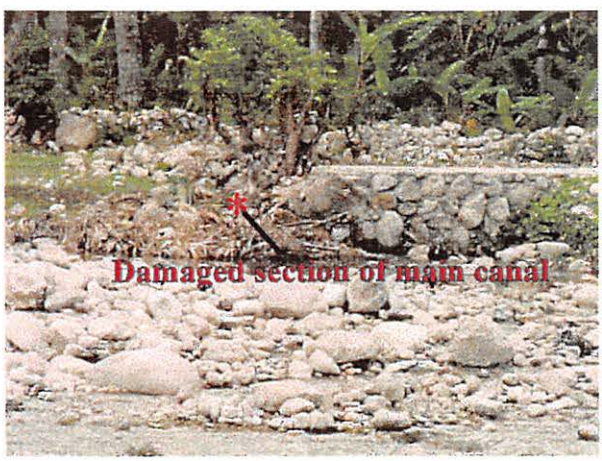


(a) (b)

Photo 20. The flooding caused bank erosion and changes the river course further inland while depositing more sediments on the right side of the flow. Stabilization of the bank and change of the river course is necessary to protect the hillside. (b) shows approximate location of embankments and new river course open.

(a)

(b)



(c)

Photo 21. Damaged intake structure, upper section of the main canal and a broken section of the main canal due to bank erosion at the Belle Roche site.

Photo 22. The 300 ha major irrigation command area, the lowland on the west bank of the Jacmel River.

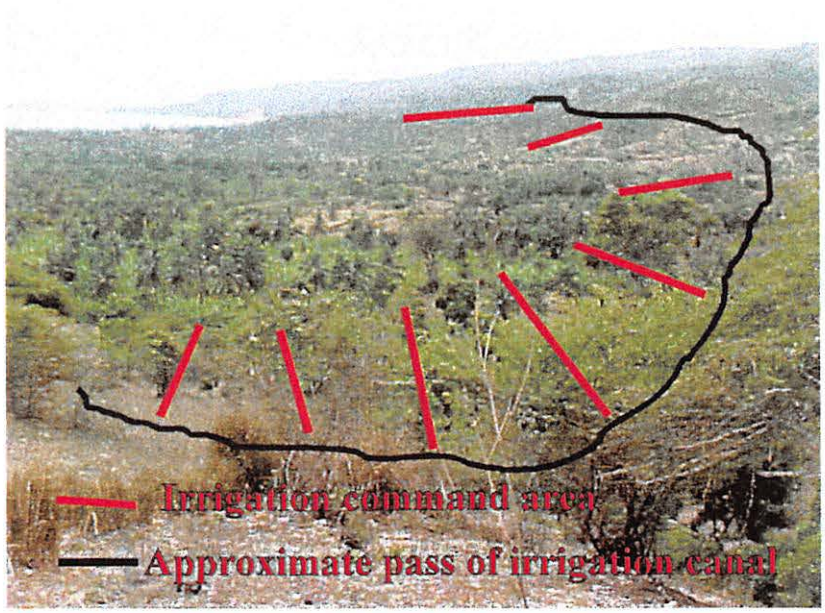


Photo 23. Approximate pass of the proposed irrigation canal along the hillside.

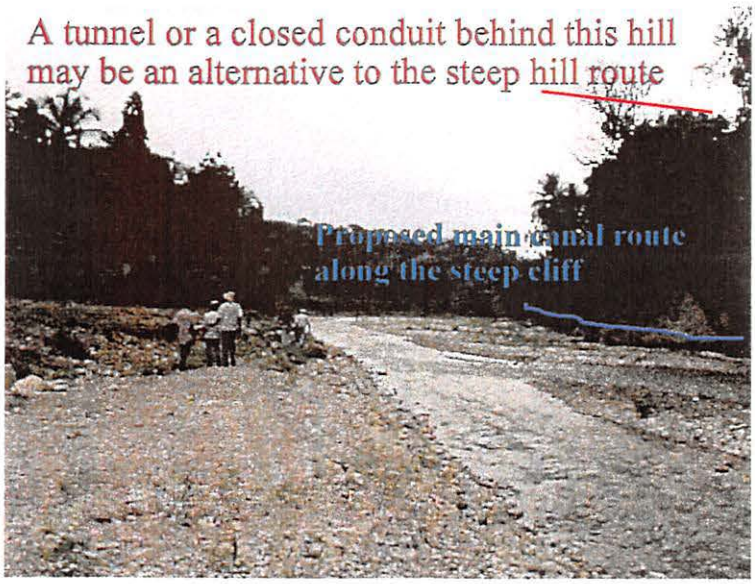


Photo 24. A steep cliff on the west bank will be a difficult task to route the main canal as proposed. An alternative would be to install a closed conduit or a tunnel behind the hill. This section of the proposed main canal is relatively short.

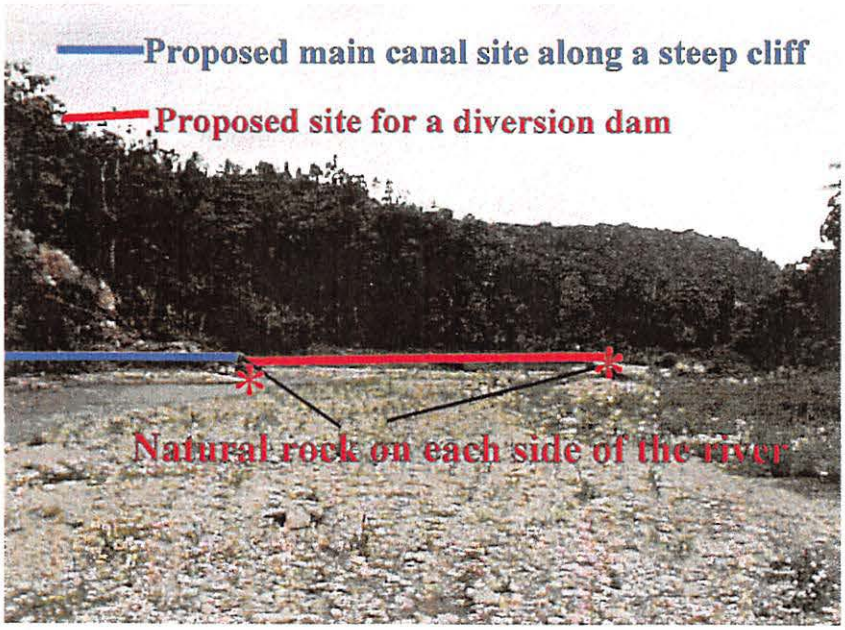


Photo 25 Proposed intake and upper section of the main canal route.

III. Observations on the Marigot Watershed

Due to time limitations, we did not venture into the upper reaches of the watershed, which would have required at least an extra two days of travel to adequately observe, given the scale of the watershed. However, the second author has visited part of this watershed previously, and inferences are drawn from that visit.

E. Extent of Watershed

The lowest portion of this watershed consists of an alluvial fan at the mouth of the Rivière des Plantils. According to the hydro-geology map of Haiti (United Nations Map 3604 (f), 1990, 1/250,000), the Plantils river flows in a southeasterly direction from a point approximately 12 km inland from the mouth. Approximately 3.5 km from the source, a second river, the Rivière Blanche, joins the Plantils river. This river is approximately 12 km long, flowing from a point near the top of the southern slope of the Chaine de La Selle in a southwesterly direction until it meets the Plantils river at right angles and flows to the southeast.

Between the irrigated plain of Peredo and the intake at Rodaille, the primary irrigation canal crosses a major dry streambed (Photo 26) which drains into the Plantils. This is an intermittent stream is shown on the map to originate 7.5 km to the northeast, west of the village of Berry. Another fork of this intermittent stream originates approximately 5 km due north of its junction with the Plantils. It is probably safe to estimate that the above-mentioned streams drain approximately 12 - 15 km length of the mountain range which runs east to west.

F. Scope of flooding caused by Hurricane George

During periods of normal flow, the Plantil is an unimpressive, shallow stream, perhaps 5-6 m across at its widest point. During Hurricane Georges, it was able to fill a very sizeable streambed (photo 27), cut several meters into a high bank (photo 17) and overflowing its banks at the narrowest point (photo 11). The tomb shown in photo 28 has watermarks that indicate a water level perhaps 2-3 m above the stream banks and 4-5 m above stream level at the time of our visit. Equally impressive were the large rocks and boulders deposited by the overflow from the intermittent stream approximately 50 m from the banks of this dry streambed (photos 29). This indicates tremendous volume and force to move such large rocks such distances outside of the river bed. The fact that this deposition was on farmland that did not appear unusually stony suggests that the flow was unprecedented in recent times.

The foothills surrounding the Plantil river appeared fairly well vegetated (photos 27). The foothills surrounding the intermittent stream were less well vegetated (photo 26a) and some gully formation was evident nearby (photo 26b). Nevertheless, the extent of flooding damage that occurred in the neighborhood of the irrigation system cannot be explained by the runoff from these foothills. Clearly, much of the water flow in the two streams comes from higher up

in the watershed.

The Rivière Blanche appears to have its origins within La Visite Park, while the main branch of the intermittent stream originates in the buffer zone of this park. This park has peaks at 2170 m, 2287 m and 2268 m elevation (CFET, 1996). The source of Rivière Blanche is located above 2100 m, approximately 15 km from the mouth of the Plantils. If one considers the route followed by the stream, one arrives at a 9 m drop in elevation for every 100 m traveled by the stream. The intermittent stream drops from 1400 m to about 200 m elevation in about 7.5 km or 16 m per 100 m traveled. This slope explains the tremendous force that a large volume of water will have traveling down these streambeds. The southern slopes of these very high mountain ranges are on the windward side of the island, which means that they will capture a large amount of rain from weather systems coming from the southeast.

Although we did not visit the headwaters of the Plantis, the second author has traveled through the area where the intermittent stream originates, to Seguin, close to the source of Rivière Blanche. While the peaks of this mountain range are well forested, the condition of the surrounding areas within and around Parc La Visite are appallingly devoid of significant vegetative cover. Seguin is characterized by large areas of land where a grass and weed cover has been grazed to within centimeters of the surface (photo 30). According to local residents, horses and cattle are sent to this area for grazing during the winter dry season (November to February) from as far away as Marigot and Jacmel (CRDA, 1998). Platon L'Etang is characterized by large expanses under cultivation (photo 31) without any soil conservation practices, despite steep slopes. Vegetables, such as onions and cabbages are the primary crops, grown on raised beds. These crops do not provide adequate cover for the soil (photo 32). Gully formation is in evidence at several locations, such as these rapidly extending gullies on moderate slope at Cassédent (photos 33). This barren landscape persists across the high plateau until one reaches the top of the foothills, where vegetative cover is more adequate.

Clearly, the most critical problem of this watershed is the denuded upper plateaux and slopes that are rapidly eroding and lack vegetative cover or other physical barriers to slow runoff and increase infiltration into the groundwater. The outcome is rapid flow of surface runoff and soil into gullies, ravines and streams resulting in flash floods at Pérédo and Rodaille. Although activities to protect the lower portions of the watershed are also needed, the focus should be on the upper part of the watershed.

G. Recommendations for Protection of the Watershed

Degradation in the upper portions of the landscape is so extensive that a major effort is required in order to have significant impact in the lower part of the watershed. Emergency engineering solutions are needed to halt the spread of gullies and enlargement of ravines. Key hotspots for erosion within the upper watershed should be pinpointed through use of aerial photography, in conjunction with hydrology and topography maps, supplemented by on-site visits. Recommendations on the proper construction of gully plugs are included in the report by Yoo (1994). Permanent vegetation barriers are needed in and around gullies and areas of

concentrated flow in order to hold the surface soil in place and to slow surface water movement into these depressions.

Sheet, rill and interrill erosion must be reduced through reestablishment of natural vegetation and woodlots, through implementation of improved crop management practices, including soil and water conservation, and through controlled livestock and pasture management. Among the conservation practices to be recommended under cropping conditions are use of tree hedgerows, grass rows and rock walls on the contour to hold soil to the hillsides and slow surface water movement. Alley cropping with leguminous trees that supply N to the crop as well as hold the soil is a promising option, but research is needed to determine the appropriate species and management practices for this high elevation. Prior research conducted at mid elevations by PLUS at Fort Jacques and by the Soil Management CRSP at Salagnac point to *Acacia angustissima* as the species with most potential. Improvement of soil fertility through agroforestry, increased use of legumes and through moderate use of commercial fertilizers might stabilize production on the better agricultural sites and encourage farmers to better protect their soil resource. The diversification of agricultural production with greater emphasis on perennial crops or annuals that provide a greater ground-cover would also contribute to reduced runoff and soil erosion. Realignment of vegetable beds to slow water movement along furrows would also help.

Livestock overgrazing is equally destructive to the upper watershed as is cropping and is more extensive. Open grazing means that fallow vegetation cannot develop, leaving the entire landscapes vulnerable to sheet and rill erosion. Provision of improved forage species and improved animal husbandry would help to alleviate the problem for individual farmers. Ultimately, limits should be placed upon free grazing of livestock.

While the technical solutions to these problems are readily apparent, these cannot be effective over the long term and over an extensive area without addressing the underlying social, economic and political realities affecting the inhabitants of the upper watershed. Some of these issues have been highlighted in the reports by CFET (1996) and CRDA (1998). It would be presumptuous to propose solutions here to these sometimes difficult and complex issues. However, dialogue with the inhabitants and community leaders within the upper watershed, as well as representatives of those coastal communities whose livestock play a major role in degradation of the watershed would appear to be essential prerequisites to finding solutions.

Institutional Considerations

It appears that much of the upper watershed affecting the irrigation system at Marigot falls within the "buffer zone" of Parc La Visite, and thus within the purview of the World Bank Forest and Parks Protection Project (ATPPF). Progress in implementing a research and extension program among inhabitants of this buffer zone has been slow, but is underway. USAID/Haiti could look for ways to enhance the effectiveness of the ATPPF buffer zone program, particularly in the area of soil and water conservation.

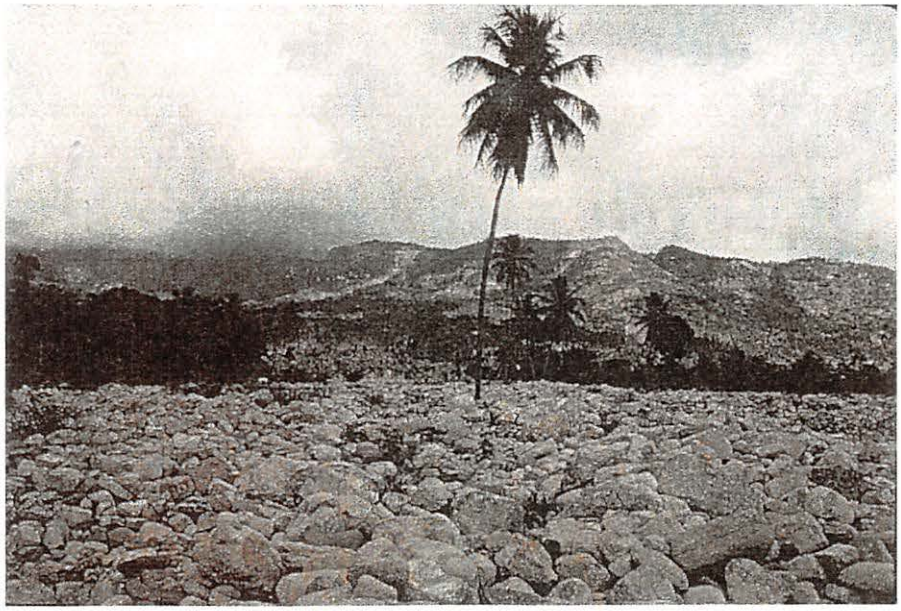
IV. Literature Cited

CFET. 1996. Zone 3: Parc La Visite: Diagnostic des communautés vivant au sein et dans le voisinage immédiat du Parc. Centre de Formation et d'Encadrement Technique, Projet d'Appui Technique à la Protection des Parcs et Forêts (ATPPF).

CRDA, 1998. Aide Mémoire: Enquête Menée dans les Zones Tampons des Parcs et Forêts par l'Equipe CRDA - Assistance Technique SECID. Centre de Recherche et de Documentation Agricoles, Projet d'Appui Technique à la Protection des Parcs et Forêts (ATPPF).

United Nations, 1990. Carte Hydrogéologique République d'Haïti. Ministère de l'Agriculture, des Ressources Naturelles et du Développement Rural, Service National des Ressources en Eau, United Nations Map 3604 (f), 1990, 1/250,000

Yoo, K.H. 1994. Water Harvesting and Small-Scale Irrigation. SECID/Auburn PLUS Report No. 19, USAID/Haiti Economic Growth Office. 22 pp.



(a)

(b)

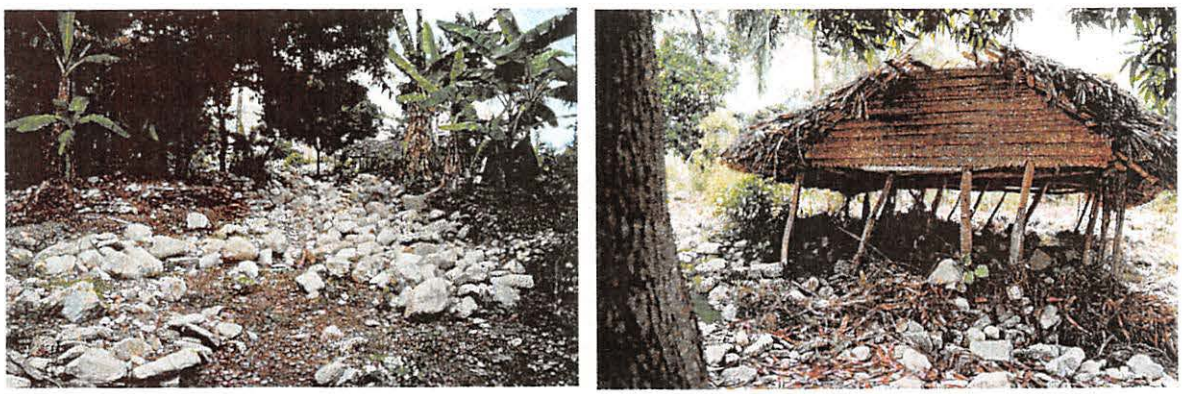
Photo 26. Large, dry riverbed of intermittent stream that joins Plantil river below intake at Rodaille. a.) Note partially vegetated foothills in background, with evidence of cultivation on slopes; b.) gully formed on nearby cleared hillside.

(a)

(b)

Photo 27. Views of Plantil riverbed showing vegetated foothills in background.

Photo 28. Dwelling and tomb across from damaged canal intake at Rodaille. Brown stains on the lower section of tomb show watermarks indicating level of floodwaters from Hurricane Georges a few meters above normal level of stream. Dr. Yoo and Marc-Eddy Martin shown at left of photo.



(a) (b)

Photo 29. Boulders deposited by Hurricane Georges by overflow from intermittent stream shown in a.) farmland; b.) destroyed farm structure.

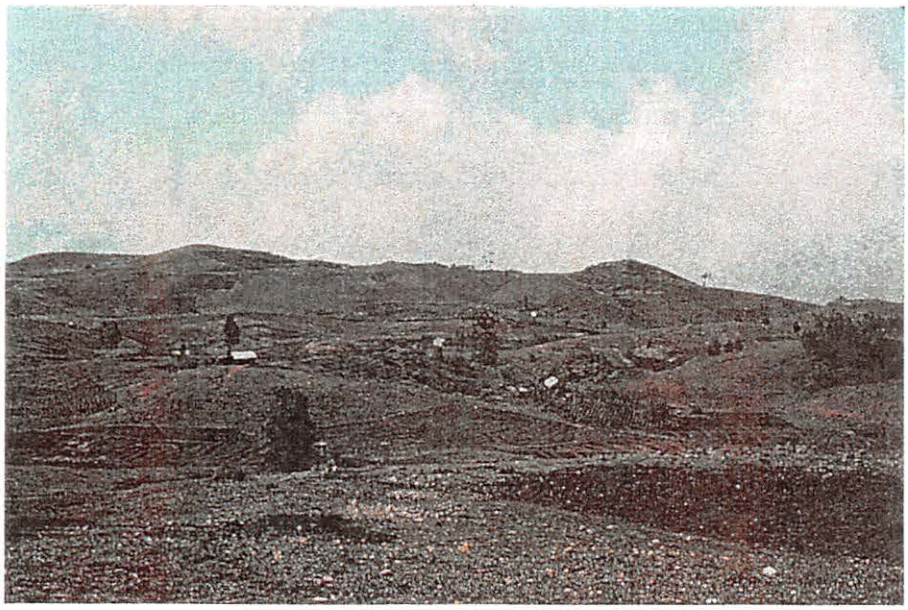
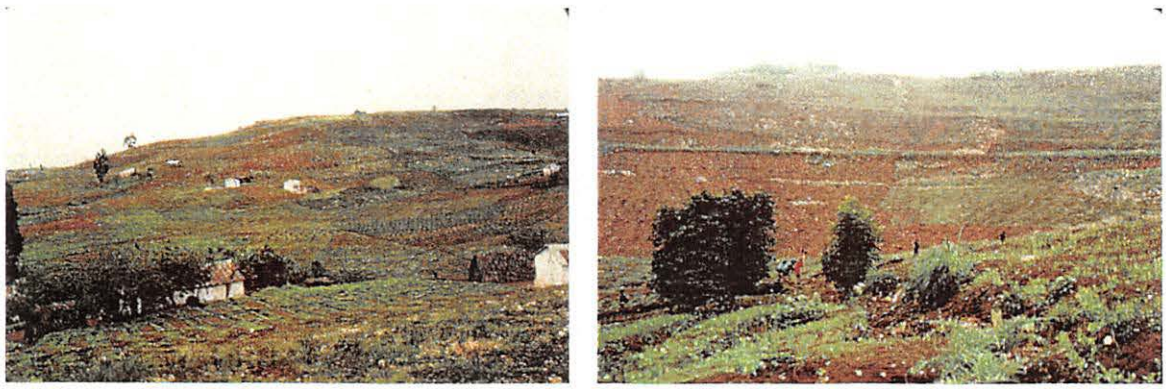


Photo 30. View of Seguin showing barren hillsides devoid of trees and with vegetation grazed to a few centimeters of the surface.



(a) (b)

Photo 31. Farming at Platon L'Etang, near Seguin, without use of soil conservation practices. Few trees and little natural vegetation remains. b.) Steep hillside in background shows eroded surfaces and poor land husbandry.

Photo 32. The vegetable production typical of this region does not provide adequate cover of the soil. Recently transplanted onions on raised beds shown here are typical of the agriculture in this area. Cabbage, carrot and Irish potato are other important crops.

Photo 33. Gullies on moderate slopes near Cassédent. Note sparse vegetation. Unless corrective measures are taken, gullies like these will spread at an alarming rate.