

9.0 LANDSLIDES

9.1 Introduction

Landslides were not pervasive in the near-fault region, but numerous failures did occur. Because of the large area affected by the earthquake, only a limited area of landsliding was investigated via field investigations. The field investigations predominantly consisted of observations during driving on major roads, and thus they only sampled a small fraction of the area affected by the earthquake. These field observations were supplemented by visual interpretation of aerial photographs using Google Earth.

9.2 Observations from Aerial Imagery

Figure 9.1 shows the landslides identified from aerial imagery by Dr. Ed Harp of the USGS. These landslides are concentrated in several regions: (1) along the deep, incised river valley that follows the fault trace, (2) along Route 204 about 15 km northwest of Jacmel, and (3) east of Route 204 about 10 km north of Jacmel. Smaller concentrations of landslides were observed near Provence in the west (Figures 9.2 and 9.3) and near Jacmel in the south. Failures observed in satellite imagery generally represent shallow slides (1 to 3 m thick) in which the overlying vegetation is stripped from the hillside. These types of failures have distinct features (i.e., bright, light colored areas surrounded by vegetation) that are easily identified in satellite imagery, but they must be large enough to be observed in the imagery.



Figure 9.1 Landslides (red) identified by aerial imagery by Ed Harp of the USGS. Green track is route traveled by GEER team on day of landslide investigation. (Imagery from Google Earth)

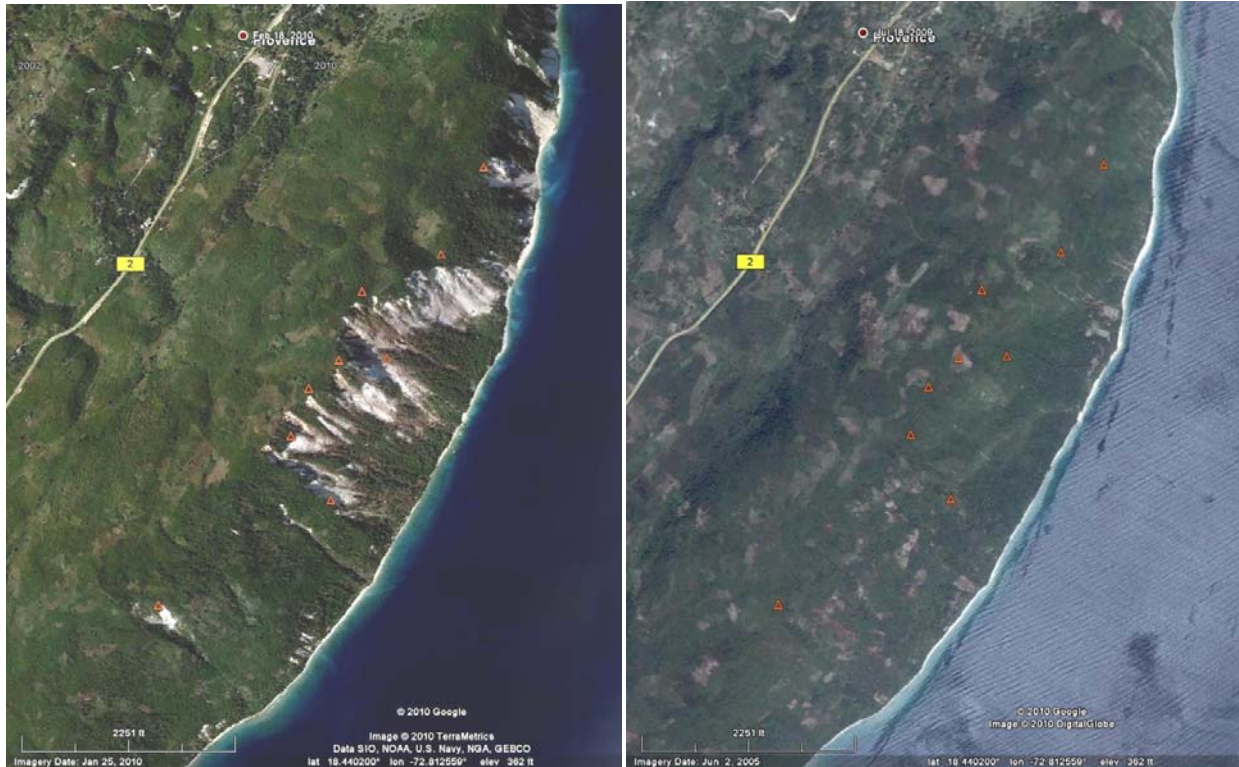


Figure 9.2 Post-earthquakes denuded slopes due to landslides near Provence (left) along with pre-earthquake image (right). These are relatively steep ocean bluffs. (Scarp locations mapped by Ed Harp. Photos provided by Google Earth)



Figure 9.3 Landslide scars near Provence in distance. (18.426166°N, 72.725825°E).

The concentration of landslides along Route 204 included many landslide dams that blocked two streams that flow east towards the road (Figure 9.4). These landslide dams were generated both by the debris of shallower soil slips, as well as deeper seated failures that appear to have been controlled by bedding. At least a few of these landslide dams breached in the weeks after the earthquake (Ed Harp, personal communication), but villages downstream were spared any inundation because the river valley was broad enough to accommodate the additional water.

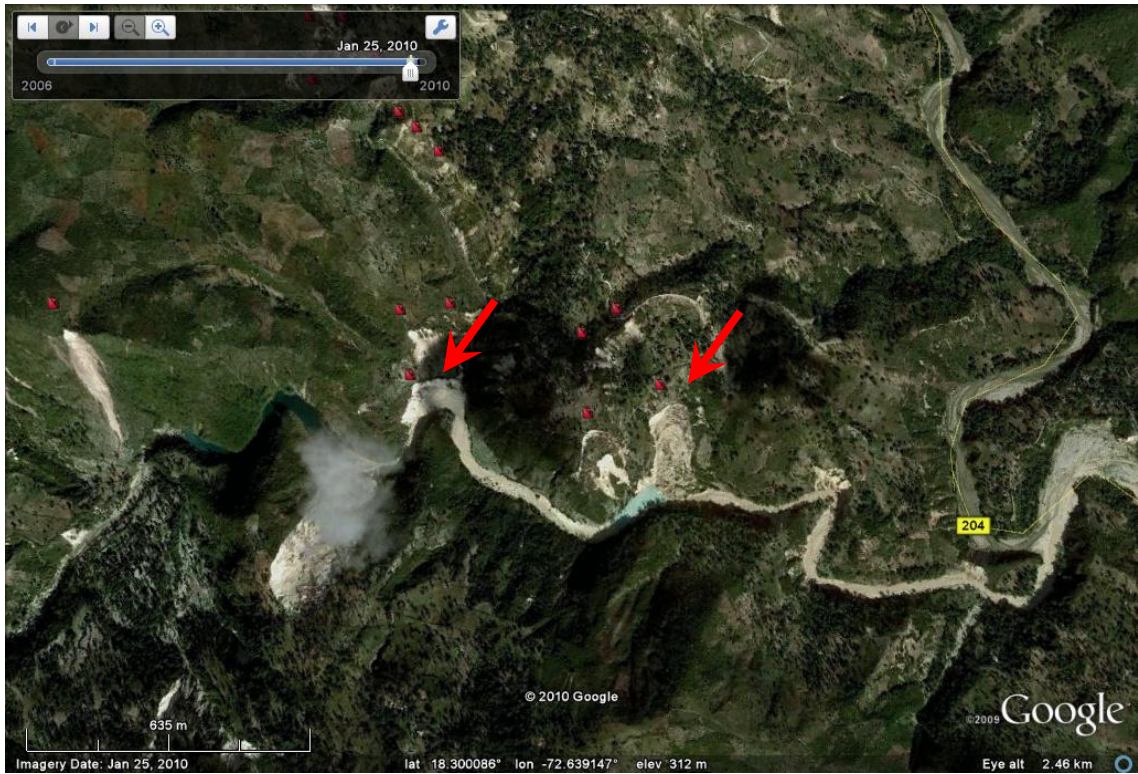
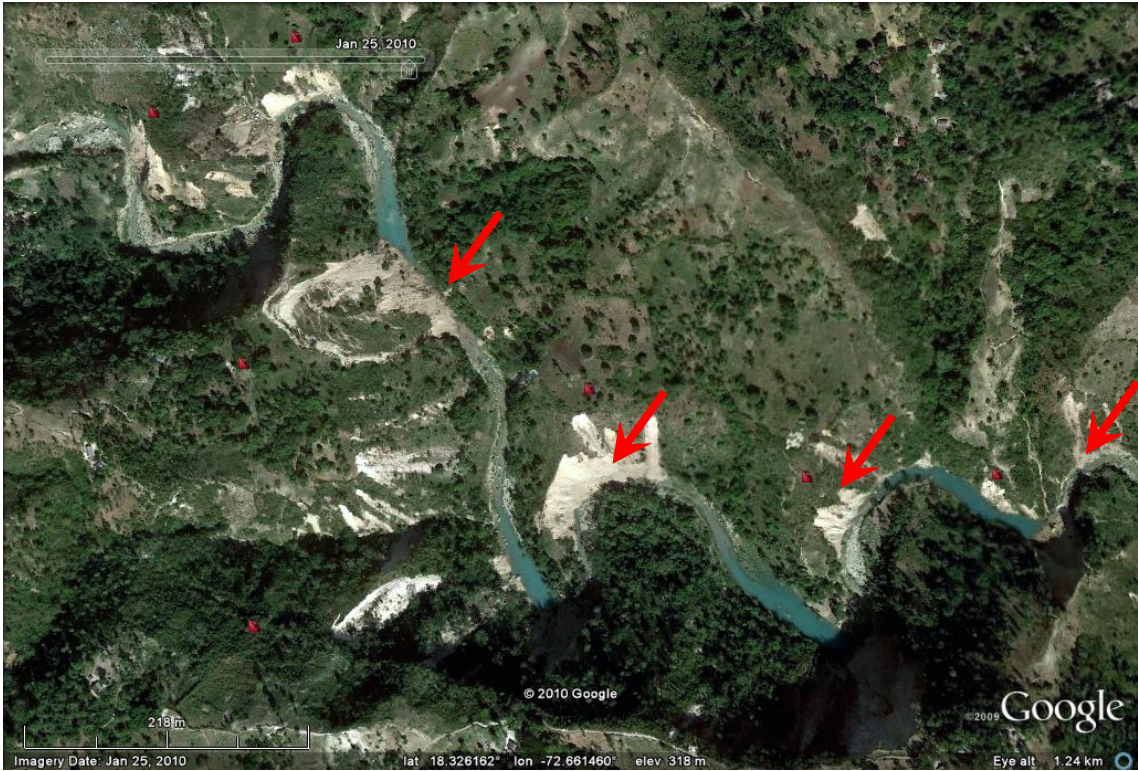


Figure 9.4 Landslide dams (red arrows) and retained lakes west of Route 204 and approximately 15 km northwest of Jacmel (top: N18.326162, W72.66146, bottom: N18.300086, W72.639147).

9.3 Observations from Field Reconnaissance

In general, the slides observed during field reconnaissance occurred in over-steepened road cuts, over-steepened quarry walls, and over-steepened eroded stream banks. Most of the natural slopes that were observed performed well, as long as no over-steepening had occurred. Where over-steepening had occurred as a result of grading (e.g., road cuts), erosion, or quarrying, rockslides were common. The discussion of landslides in this section will focus on the hills of Petion-ville, south of Port-au-Prince, and on a 10 km segment of Route 204 south of Dufort. The segment of Route 204 investigated is shown in Figure 9.1.

Numerous topples or falls were observed in over-steepened road cuts in weathered and sheared bedrock within the hills of Pétiion-Ville (Figure 9.5), an upland suburb to the southeast of Port-au-Prince. These over-steepened cut slopes had estimated inclinations of $\frac{1}{4}H:1V$ or steeper; many were nearly vertical and some remaining un-failed cuts were actually locally overhanging. These slopes had estimated heights on the order of 1.5 to over 6 m. The falls generally included relatively slender slivers, typically involving 0.3 to 1.0 m thick of material. The material fell to the base of the slopes, forming a wedge on the roadside or sidewalk, and frequently encroaching onto the roadway.

There were also many of these very steep road cuts that remained unfailed following the earthquake, as evidenced by the presence of vegetation, dust, and debris on the faces of the slopes (Figure 9.6). However, most of the unfailed slopes exhibited a wedge of raveled material at the base of the slope with established vegetation, suggesting the raveling had been occurring for some time and was not related to the recent earthquake, or with only minor toppling in the recent earthquake (e.g., Figure 9.5).

One area of more significant landslides was observed downhill from Petion-Ville along Rue Fernand. This landslide contained the rubble of several adjacent structures that had collapsed (Figure 9.7). There were scarp-like, near vertical surfaces near the top of slope, which could suggest that a rotational failure occurred beneath the now-collapsed structures. However, scarps of the observed height generated through a rotational failure would require a large volume of soil to be pushed out near the toe of slope. This volume of material did not appear to be present or to have been removed from the site. Furthermore, the soils are conglomeratic and likely have high friction angles, which would make the site an unlikely candidate for a rotational failure mechanism. It is more likely that the failure was initiated by basement/retaining walls for the overlying structures.



Figure 9.5 Vertical cut remaining relatively stable with minor rock fall/topples.



Figure 9.6 Stable near-vertical road cut and masonry wall. (N18.531873, W72.313045).



Figure 9.7 Several buildings have collapsed in this location. Although there are scarp-like near vertical surfaces near the top of slope that may suggest the possibility of a deeper rotation failure, in our opinion the observed conditions are likely due movement of soils adjacent to failed walls, as discussed in the text. (N18.528406, W72.309920).

There were numerous rock falls, rock topples, and shallow rockslides in over-steepened road cuts along Highway 204 (e.g., Figures 9.8 through 9.12), although few of these were obvious in the aerial imagery. Many of these failures, as well as similar failures elsewhere, inhibited relief supplies from reaching many upland communities. The cut inclinations where the majority of the failures occurred are estimated to be on the order of about $\frac{1}{4}H:1V$ to $\frac{3}{4}H:1V$, and ranged from a few meters high to over 10 m high. The failures were frequently in fractured, friable, blocky sedimentary materials. These blocks were stacked in a statically stable configuration that did not resist the seismic accelerations, and the blocky material simply deaggregated and cascaded to the bottoms of the slopes. In some locations rockslides occurred along bedding planes, but more often the exposed scarp revealed that the bedding was relatively level or dipping into the slope and the failed material pulled away from random discontinuous surfaces.

Some chalky limestone quarries (recent activity of the quarries was not checked) had moderately high steep slopes that also failed in rock topples or rock falls. Occasionally these resulted in large boulders rolling onto roadways (Figure 9.8). Similar failures occurred in over-steepened road cuts through chalky limestone.



Figure 9.8 Topple or fall included several large boulders in this old quarry.
(N18.439010, W72.646168).

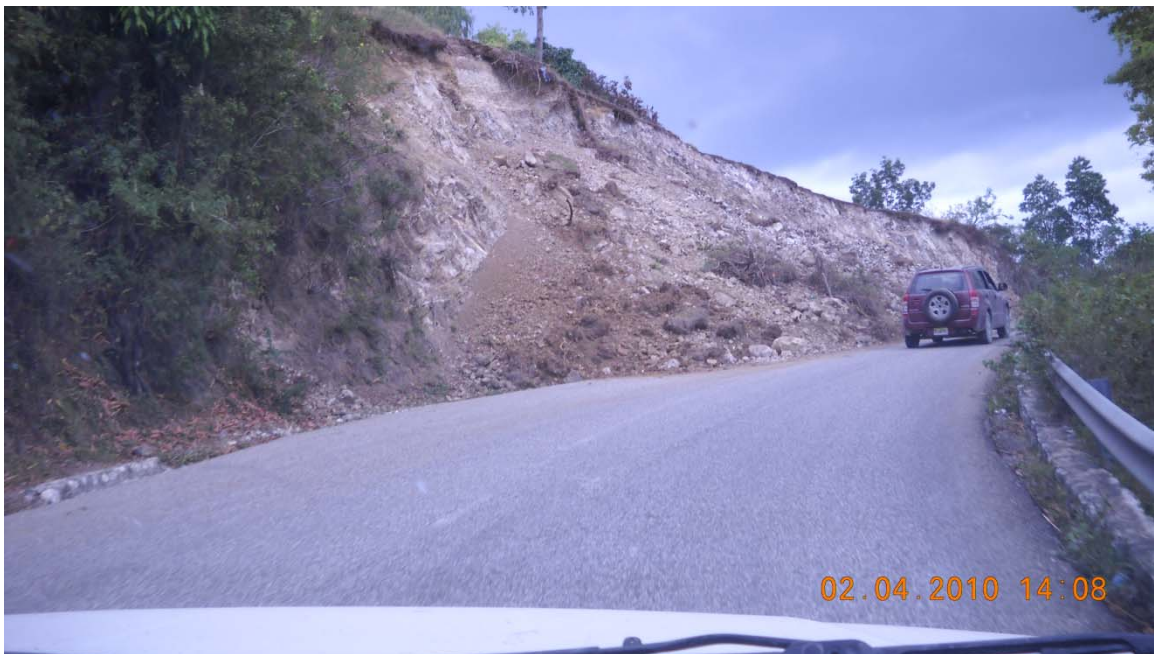


Figure 9.9 Rock topple or rock fall from over-steepened road cut.
(N18.412741, W72.638576).



Figure 9.10 Shallow rock topple or rock fall from over-steepened road cut. Debris slid over the top of stable gabions at the toe of the slope. (N18.409159, W72.638815).



Figure 9.11 Relatively shallow slip-out of regolith. Disaggregated material flowed over stable gabions and blocked over half the road. (N 18.409159, W72.638815).



Figure 9.12 Shallow slip-out of soil in upper road cut. Soil slid over the top of the surviving masonry wall and slope protection. (N18.440270, W72.636207).