

waves; these blasts involve approximately 100 holes in the bedrock and about 36 000 kg of ammonium nitrate and fuel oil. However, the strength of seismic signals or ground vibration due to these large quarry blasts are much reduced due to the practice of sequential firing of blasting caps with 25 ms delays. The peak amplitudes of the seismic signals from quarry blasts are approximately proportional to the maximum charge size per delay, not the total charges detonated within a quarry blast. Note that each delay consists of shot holes fired within ± 8 ms, hence a quarry may have several delays. (Kim et al. 1994). An example of waveform data from a quarry blast (ID #8 in Table B-3) is shown in Figure B-7. (Note that the teleseismic *P* wave also shown in Figure B-7 as event ID #6 is associated with the distant earthquake that occurred earlier.) Ten of the events in Table B-3 (ID #7 through ID #16) were associated with quarry blasts, with magnitudes varying between 0.2 to 1.4. The locations of these events are plotted on the map in Figure B-8.

B.6.3 Unidentified Weak Signals

In addition to the seismic signals already discussed, about a dozen other weak signals were recorded by one or more of the seismic stations in the area. These were screened to identify those that had characteristics of the previously identified signals emanating from the WTC site; namely, signals with the strongest amplitudes in the east-west component at PAL. All but five of the weak signals at PAL were eliminated based on this criterion. Because the signals were very weak and (except for ID # 21) not detectable at stations other than PAL, it could not be positively confirmed that they originated, in fact, from the WTC site. An examination of the video and photographic records by NIST at times corresponding to these weak signals did not reveal any particular events that could have acted as sources for this seismic activity.

B.7 SUMMARY OF SEISMIC DATA

Table B-4 lists, according to the time of occurrence, all 22 seismic signals identified between 8:46 EDT and 17:21 EDT on Sept. 11, 2001, recorded at six stations around the metropolitan New York City area. Figure B-9 is a seismogram of the period starting at 10:00 EDT taken at the PAL station, with event ID numbers included. Events #4 and #5 (in blue) are the collapses of WTC 1 and WTC 7, respectively; events #6 through #17 (in black) have been attributed to distant earthquakes and local quarry blasts; and events #18 through #22 (in red) are undetermined.

The five largest seismic events were due to collisions of the two aircraft into the WTC towers, their subsequent collapses, and the collapse of WTC 7. Consistent event times for the impact of the towers by the aircraft were obtained between the current seismic analysis and the analysis of the photographic evidence in NCSTAR 1-5A.

The times attributed to the collapses of WTC 1 and WTC 2 in Table 5-1 (NIST NCSTAR 1-9), column 3, and Table 3-1, column 3 (NIST NCSTAR 1-5A) differ from the seismic signal times because the column 3 times refer to the time when the upper portion of each tower above the airplane impact damage was observed to suddenly tilt, while a seismic signal was not generated until a substantial portion of the building debris hit the ground. If this time interval is accounted for, the NCSTAR 1-5A times compare well with the seismic origin times.