Manual for GEER Reconnaissance Teams [V.4]

[1] INTRODUCTION

The Geotechnical Extreme Events Reconnaissance (GEER) Association, which is supported by the U.S. National Science Foundation, organizes the response of the geo-professional community to extreme events with geotechnical consequences. Extreme events that provide the opportunity to learn important lessons and to advance understanding are identified by the GEER Steering Committee, and a GEER reconnaissance team is organized.

The purpose of this manual is to standardize reconnaissance practices among researchers so as maintain safety in the field, improve the overall quality of the data collection effort, and to best organize the findings for digital report and map delivery. This fourth edition of the manual includes expanded discussions of the purpose and criteria for organizing a reconnaissance activity, the role of social media in organizing field teams, smartphones, and GPS cameras. The improvement of this manual is a GEER membership-wide responsibility. Your suggestions and input are essential to improve the usefulness of this manual for the next GEER field effort.

The primary goals of the GEER team are to survey the damaging geotechnical aspects of the event, to document key sites to develop well-documented case histories, and to identify opportunities for further research. Previous reconnaissance missions of important events have served an important role in defining geotechnical engineering research and has led to significant advancements in our understanding of geotechnical phenomena, such as the effects of co-seismic surface fault rupture, ground motions, and liquefaction on the performance of engineered systems, the effects of rain-induced earth movements (e.g., landslides) on infrastructure, and the effects of flooding and storm-surge-overtopping on banks, levees and roadways.

Historically, reconnaissance teams collected data and documented observations using conventional (modern, at the time) data recording and measurement tools, such as photography, note taking, and surveying. Development of advanced technologies, such as Internet-based mapping techniques, remote sensing, and digital imaging, now offer the opportunity to visualize and dramatically improve both the quality and quantity of data collected during post-event reconnaissance investigations, as well as the speed with which such observations are made available to the GEER community and geo-professionals worldwide. These technologies allow for detailed and near real-time spatial analysis of damage patterns that can be used to identify areas of high or anomalous response of the ground.

[2] PURPOSE of RECONNAISSANCE ACTIVITIES

Summary: Role of Reconnaissance
- Identify critical case histories
- Report findings rapidly by PDF, web, and Google Earth
- Teach new participants the key-elements of reconnaissance field work

The purpose of organizing investigations rapidly after an extreme event is to document engineering and scientific effects to advance research and practice. GEER teams' main goals are to quantify the spatial extent and characteristics of geo-failures and non-failures (e.g., ground failure cases, soil-foundation-structural failures, lifeline systems damage, as well as the excellent performance of earth dams, natural slopes, and structural systems). It is important to document both good and poor performance of geo-systems following extreme events. Due to the necessary recovery and reconstruction activities following extreme events, much of the critically important observable damage and delicate features are perishable. Toward that end, GEER develops a coordinated and rapid response for geo-researchers and geo-professionals so as to avoid self-assembled, less-effective, and ad-hoc post-event reconnaissance efforts. In addition, the findings of post-event investigations should be disseminated in a timely and unbiased manner, initially in the form of a quick web-based report, and then through a more comprehensive web-based report, archival publications, and data sets that are accessible to the worldwide engineering research and practice communities.

An aspect of a GEER study is to promote the standardization of measurement and reporting in reconnaissance efforts. Another important educational aspect of GEER activities is bringing together new faculty and graduate students in the field with experts who have the experience of participating in and leading numerous post-event investigations. This is done to advance the capabilities of individuals performing post-event reconnaissance and prepare the next generation of engineers and scientists to lead reconnaissance missions so that the geo-community may continue to learn from extreme events. As such, the training of technical skills to perform effective post-event investigations is critically important. Members of GEER studies are committed to improving the engineering and social communities through the collection, documentation, and dissemination of post-event engineering measurements and information.

Figure 1. GEER investigator measures buoyant civil-municipal utilities in liquefied soil, Kashiwazaki, Japan, 2007 (Site RK-14, 37.429630°, 138.607200°).

Anyone who serves on a GEER post-event reconnaissance effort that is funded in part by the National Science Foundation agrees to make the collected data available conveniently and rapidly to the engineering and scientific research and practicing professional communities.

Criteria for GEER Response

GEER Objectives

The GEER Association organizes and supports reconnaissance efforts by geo-researchers after severe natural and human-caused disasters (i.e., "extreme events") and develops techniques to capture perishable data efficiently to learn from these events. It distributes findings from these reconnaissance efforts through timely GEER web reports, peer-reviewed papers, and technical seminars. The primary objectives of GEER are:

1. Document geotechnical engineering, engineering geological, and related effects of important extreme events to advance research and practice.
2. Employ innovative technologies for post-event reconnaissance.
3. Advance the capabilities of individuals performing reconnaissance of extreme events.
4. Train individuals to perform effective reconnaissance and facilitate access to equipment required for sensing and data collection.
5. Develop a coordinated response for geo-researchers and geoprofessionals to form effective reconnaissance teams, and work effectively with organizations that focus on other disciplines.
6. Promote the standardization of measurement and reporting in reconnaissance efforts.
7. Disseminate timely and accurate post-event web-based reports and data.

GEER Response Considerations

After collecting as much information as possible about a promising candidate event based on news reports, online information, social media images and comments, correspondence with other agencies, and local contacts, and discussing the potential desirability for and benefits from a response, the GEER Steering Committee (SC) votes to decide whether a response is warranted. GEER does not send reconnaissance teams to every significant extreme event that occurs. After each major event, an assessment is made by the GEER SC, in consultation with NEHRP agencies, ASCE, EERI LFE, and other organizations to determine if important data can be garnered that potentially will make significant advancements in the research and practice of geotechnical engineering. Research resources are limited, so the GEER SC should recommend funding only of internal GEER-supported post-event reconnaissance efforts or submission of new proposals for Rapid Response Research (RAPID) if critical information and well-documented case histories are likely to be obtained. This focus on early identification of strategic priorities for study and the potential for lessons to be learned from extreme events should guide not only whether a response is appropriate but also the scale of the response. The ultimate decision whether to respond or not is embedded within a series of technically centered considerations:

- the opportunity to learn about new hypotheses or models (e.g., recently developed analytical procedures to evaluate erosion potential for overtopped levees);
- the availability of additional relevant field data to supplement data gathered in the GEER reconnaissance (e.g., strong ground motion instrumentation or pre-event survey data); and
- the potential for a comparable event to occur in the future in the US (e.g., a large subduction zone earthquake elsewhere in the world may be critically valuable to the Pacific Northwest US where the potential for such an event is high but which has not been subjected to one in recent history).

GEER Team Organization

If the vote of the GEER SC is positive, the SC identifies a team leader and provides a scope of the reconnaissance (e.g., budget). After the team leader agrees, responsibility for the reconnaissance effort is transferred to the team leader, and she or he selects the team members with input from the SC. Teams should be diverse in terms of reconnaissance experience (e.g., assistant professors without reconnaissance experience should be included), age, gender, geographic location, etc. It is important to provide reconnaissance experiences to a wide range of researchers, such that the pool of researchers experienced in reconnaissance grows. The GEER team performs the reconnaissance in accordance with the GEER Reconnaissance Guidelines and publishes its quick web-based report within two weeks after the event and publishes the first version of its final comprehensive observations report within four to six weeks after the event.

[3] Focal Points of GEER Investigations

Summary: Focal Points of GEER Investigations

• Identify the unique characteristics of the extreme event
• Identify the spatial and societal context of the event; the loading/demand aspects; the capacity/strength/resilience aspects; the geotechnical and geotechnical/structural/societal effects
• Assess what advanced tools could be used to improve the reconnaissance effort

In the first days of the reconnaissance effort, it is important to gain a broad overview and understanding of the event. As such, the team focuses on region-wide searches. Each team member is explicitly tasked to focus on specific topics but should make observations of all key features of the event. Early morning and evening meetings should be designed to maximize efficiency, best utilize individual expertise, and focus the topic-leaders who will synthesize observations of a specific topic from the observations of all team members. In the later days of the reconnaissance effort with the team's overarching view of the effects of the event, the team can focus on more narrowed searches to better detail specific aspects of the event that are most important.

Especially in heavily populated areas, social media sites such as YouTube, Twitter, Instagram, and probably an increasing number of others, are an excellent searchable source of descriptions and images (still and moving) of the event itself or of conditions before the GEER team is onsite. Many of these will be geo-referenced, though typically at the site where the post (for example, a Tweet) is made, and this may not be the site of the observation, so other information in the description, photo or video is useful to locate the observation. When searching these sites, it is important to use lay terms and local place names to the extent possible; for example, terms like fault rupture and headscarp will likely generate few returns. This type of early reconnaissance can help direct and prioritize the efforts of the GEER team once onsite.

Figure 2. Morning field team meeting to plan the day's reconnaissance, L'Aquila, Italy, 2009 (42.364604°, 13.365778°
).

Every extreme event is unique and has its own signature and characteristics. It is useful to organize the GEER reconnaissance effort and the resulting GEER report in terms of the event's context, its demand, its effects, and the tools best employed to document the event. The observational focal-points for the reconnaissance effort should be organized as follows:

A. CONTEXT

1. Areal extent
2. Societal setting
3. Antecedent conditions
4. Geological setting
5. Seismological aspects
6. Meteorological aspects
7. Multi-event considerations
8. Scale effects

B. DEMAND

1. Wind and wind-driven surge
2. Rainfall/Snowfall/Snowmelt/hail intensity and flooding
3. Drought and temperature extremes
4. Surface fault rupture/tectonic deformation and ground displacement/strain
5. Tsunami/seiches or drawdown/run-up effects
6. Earthquake ground shaking characteristics
7. Volcanic eruptions (lava flows and ash fall) and solidification/accumulation effects
8. Landslides, rock fall, debris flows, and lahars
9. Geology-related ground movements, e.g., karst subsidence, collapse, expansive soils/piping
10. Human-induced ground movements, e.g., mining subsidence, excavations

C. EFFECTS

1. Disruption or sedimentation of waterways
2. Scour and erosion effects
3. Impacts to infrastructure from landslides, rock fall, and debris flows, including burial
4. Impacts to infrastructure from other ground movements
5. Local amplification effects of ground shaking (e.g., site and topographic effects)
6. Liquefaction and its effects, including lateral spreading, settlement, and ejecta
7. Earth and waste structures, e.g., dams, tailing dams, levees, landfills, and retaining systems
8. Ports, harbors, and waterfront structures
9. Transportation systems, e.g., bridges, tunnels, highways, and railroads

10. Lifeline systems, e.g., water, wastewater, power, natural gas, and communications
11. Industrial facilities and storage tanks
12. Infrastructure damage, especially anomalous or localized damage and collateral damage
13. Acceptable to excellent performance of infrastructure despite intense demands
14. Impacts on emergency management and emergency response and recovery

D. TOOLS

1. Remote sensing, e.g., satellites, drones
2. Wireless sensors
3. Lidar, photogrammetry, and other survey tools
4. Geophysical methods, e.g., MASW, SASW
5. Penetration tests, e.g., Swedish Weight Sounding, Dynamic Cone Penetration

The team members should be cognizant of all the possible important observational aspects of the extreme event and should be actively searching for evidence related to each of these. It is useful to review previous web-based GEER reports to ensure that all key aspects of an event are considered in developing the scope of the reconnaissance.

[4] FIELD MEETINGS

Summary: Meetings

• Morning meeting to assign tasks, plan work, and conduct safety briefing
• Evening meeting to review observations
• Meetings emphasize safety!
• Important to disseminate working data, field Google Earth maps, etc.

At GEER team meetings, it is worthwhile to note that time is limited, and the team members should maximize the efficiency of their data gathering. One example that has proven useful for improving efficiency is to make simple measurements of damage during the first visit to a given site (e.g., measuring bridge offsets, lateral displacements). Sites of high interest can be revisited for additional measurements, or laser scanning if warranted. The team should be reminded to look for common features that indicate severity of shaking or damage (e.g., percent and direction of toppled tombstones). It is important to collect information objectively without falling into the trap of collecting only that information that supports one possible mechanism.

Morning meetings should be focused to specify the topics and locations a group will be covering according to the research specialty of the group, site access, and the overall needs of the reconnaissance team. A mandatory daily safety briefing reminds team members of potential dangers involved in post-event reconnaissance. The morning meeting is also a good time to disseminate the daily Google Earth-style reconnaissance map KML file.

Evening meetings focus on observations, implications, and geographic extent of the daily observations. The evening is a good time to assess the broad implications of the observations up to that point in the reconnaissance, and to adjust the direction of focus of the reconnaissance team.

One team member should be tasked as the data manager who will be the central gatherer and organizer of daily GPS waypoints, track-logs, text observations in EXCEL files, and photographs. These data can be used by the data manager to generate Google Earth reconnaissance maps rapidly for the team and disseminate these maps onto everyone's laptop. With an internet connection, the GEER Association FTP site is an important asset for gathering and disseminating information. If the Internet is available to the reconnaissance team members, the FTP site should be the focal point for data exchange.

At the end of the reconnaissance effort, each team member should be charged with the responsibility of synthesizing the observations for which they are the topic leader. The team members should be given a specific date to complete a draft of their section. All team members should organize their photographs into Waypoint-name-specific folders and complete the GPS waypoint/ photograph description Excel file.

[5] FIELD SAFETY

Summary: Safety

- GEER demands a culture of safety
- First aid kits in every vehicle
- First aid training for every participant
- Location of nearest medical facility in the reconnaissance-focus area

Extreme event reconnaissance, by its nature, exposes the team to a number of potential hazards. Above all else, the safety of team members should be the highest importance for the reconnaissance team leaders and for all members. It is important to promote a *culture of safety* among the reconnaissance team members that minimizes risk-taking and exposure to hazards. The principal threat to team members is due to compromised transportation systems.

Invariably for reconnaissance of earthquake effects, the team will experience unusual driving hazards. Team members should use caution to identify the "end of the road" beyond which walking will be necessary. It is common for cut and fill roadways to be in a state of partial or complete failure, and caution should be used whenever crossing roadways subject to landslides. Other hazards can be in the form of collapse of compromised structures, earth instabilities, wind and rain storms, aftershocks, unclean food and water, crime threats, and so on. For reconnaissance of some landslide effects, unstable slopes, loose saturated areas, and potential block falls will comprise the principal hazard. Reconnaissance team members must strive to remain alert and aware of their surroundings at all times, recognize that they are in an unusual environment, and use and appropriate level of caution.

It is recommended that all participants have first aid training, and that first aid training is an important element in being selected for the reconnaissance team. Each team should have Red Cross basic first aid manuals first aid manuals for each reconnaissance vehicle; a first aid kits for cars (see appendix 1); hand cleaner and hand sanitizer; 1-2 days backup water food and sunscreen and sun hats. In bear country, teams should possess bear pepper-spray or large caliber firearms if the team member is trained through an official and recognized firearm safety-training program (e.g., USGS Bear Safety Training Program).

Figure 3. Mapping soft-ground deformation, Niigata, Japan, 2007 (Site RK13, 37.40555, 138.60197.

[6] SMARTPHONES and SOCIAL MEDIA

Summary: Communications

- Every participant has a 'SMARTPHONE.'
- SMARTPHONES with integrated GPS/Camera, SMS text, email, cloud storage, and specialized apps can serve an excellent all-in-one reconnaissance tool.
- External batteries, spare batteries and/or car charging tools are needed for using SMARTPHONES all day in the field
- SMARTPHONES allow [1] Social media, SMS text, photo, data, and video communication with other team members and cloud storage, [2] efficient gathering of field notes, [3] serves as a usable GPS device for waypoints and track logs, and [4] exports Google Earth KML files for the reconnaissance report.

SMARTPHONES, essentially integrated handheld computers-cameras-GPS units, are essential for the modern reconnaissance. These devices integrate all the basic functions required of reconnaissance devices, i.e., communication, GPS, recorder of field notes, and camera.

Communication in the field is critical to the safety, efficiency, and ultimate success of reconnaissance team effort. Every independent reconnaissance party should have at least one phone. In most parts of the world, the 3G, 4G, and GSM standards will allow your cell phone to operate overseas. [Note many Verizon CDMA phones are not compatible with most international systems.]

If the reconnaissance is overseas, before leaving for reconnaissance effort, call or visit your mobile phone retailer and turn on an international voice and data package. Typically this service can be turned off after returning to the United States. You will be able to send and receive e-mail, text message, and access the Internet from your phone.

Text messaging has proven to be an excellent means of transmitting addresses and information during recent reconnaissance efforts. Rental cell phones can be leased at airports; ‘Pay as you go phones’ are generally available in cities. The reconnaissance team leader should collect and disseminate by email and paper copy the telephone numbers of all the reconnaissance team members.

A platform that allows each member to instant message their observations and locations to the entire reconnaissance team can be made using social media. Each member should create either a Google+ Circle or a Twitter account and add other team members to the Circle or follow the other team members on Twitter. Throughout the day, each member can inform the group in a standardized way (e.g., Site ID, Latitude, Longitude, Observation) of its location with text and photos.

One member of the group can use the Twitter feed to populate observations in the Google Earth map for the reconnaissance. Another powerful aspect of using social media is that it levels the communication access of all members on the team and negates the need for a physical centralized command. This allows the GEER reconnaissance leader to know where participants are at any time and allows the team to redistribute immediately resources as needed based on field observations.

Figure 4. Typical Twitter feed that identifies the sender, site name, WGS84 coordinates, observation, and initials of the GEER member present at the site.

Phones require external power to operate all day in a reconnaissance. This is especially the case of the team is working on foot away from a vehicle. Team member should purchase a car adapter and an external power battery before the reconnaissance. The power supplies made by Verbatim, PowerPack, Morphie ‘Juice Pack’ and uNu are examples of external USB batteries useful for keeping smartphones charged.

Aside from cell phones, Motorola walkie-talkies are extremely useful during reconnaissance efforts, and communication on them is free. Cell phone costs are a major expenditure for GEER, and Walkie-Talkies help defray these costs. They work in remote locations when cell phone coverage is not available, and keep groups that temporarily separate in contact. Walkie-Talkies are also an excellent and free way for multiple vehicles that caravan to a site with a radio-‘speakerphone’. Motorola radio receiver/transmitters are the standard units to purchase. One person should be tasked with the responsibility of setting multi-channel Motorola Walkie-Talkies set to same Channel (frequency) and sub-channel number.

[7] FIELD NOTES, POSITIONING and the GLOBAL POSITIONING SYSTEM (GPS)

Summary: GPS

- Every investigator has a GPS unit
- GPS units are set to WGS84, *record* and *report* in decimal degrees and meters
- Understand waypoints *before* the reconnaissance
- Understand 'Track logs'
- Understand WAAS
- Investigators knows how to download and display data in Google Earth

In GEER extreme-event reconnaissance, all recorded information, photographs, and data observations must be located with latitude and longitude coordinates. It is critically important that all reconnaissance team members have GPS units and know how to use them. Properly positioning data is critical for building the Google Earth reconnaissance map, locating photographs, and writing a comprehensive reconnaissance report. GPS track logs also passively monitor the travel of each reconnaissance team vehicle during the field day. As such, gathering all the GPS track logs into the daily Google Earth reconnaissance map can immediately identify areas where the reconnaissance team has not yet visited, as well as where adequate or too much emphasis has been expended.

All smartphones and many cameras now have integrated GPS units that geo-tag photographs and videos, and collect track logs. GPS units can be used where access to open sky is unobstructed. Vehicle-ready GPS units with routing software and real-time traffic subscriptions can also provide extremely helpful map displays to navigate to specific addresses or avoid traffic bottlenecks. An example of a useful iPad/iPhone application for recording GPS positions, photos, and field observations that has been used successfully by GEER members is 'Field Notes PRO.'

With GPS track logs turned on throughout the day, a typical handheld GPS unit will consume a set of batteries each day. The team should be prepared with an adequate supply of extra batteries to last the duration of the reconnaissance. Units with color displays tend to have a decreased battery life compared to grayscale displays, requiring more frequent battery changes. Power saving settings should be turned on to turn off backlighting and put the screen to sleep when not actively in use.

For most of the needs of a reconnaissance effort, a simple WAAS augmentation (discussed below) GPS unit is adequate in the United States. WAAS generally does not yet work off the North American continent, though similar systems are being put in place in Europe and Asia that should be accessible to your GPS receiver soon. Specific needs may require Differential GPS (DGPS), or real-time Kinematic (RTK-DGPS) positioning, for example in the case of lidar data collection. This positioning need must be supported by the researcher employing these data collection systems and is not the general responsibility of the GEER reconnaissance team.

Detail on Satellite Position and Time Aspects of GPS

The United States Government Department of Defense operates NAVSTAR (Navigation Satellite Timing and Ranging), the first Global Positioning System (GPS). NAVSTAR employs a suite of 24 operational satellites and orbiting backup units that transmit to earth the estimated satellite position and time based on onboard atomic clocks. The satellites are in groups of four (90° path offset), in six evenly spaced orbits (60° lateral-offset), and have right ascension angles of 55 degrees to the horizon. The nearly perfect circular orbits at 20,200 kilometers above the Earth's surface allow the satellites to make two orbits per each sidereal day (23 hours, 56 minutes).

This permits the satellites constellation to be in the same grouping and position overhead, every day at the same sidereal time. Recently, the Russian Federation has deployed a constellation called GLONASS, and additional constellations are planned by China and the European Union. Receivers that can pick up multiple GPS constellations will have improved positioning accuracy.

The GPS receiver computes the location of the operator by knowing where a minimum of 4 satellites is overhead and the satellite ranges to the observer (distances). Because the satellites are overhead in approximately the same position every day, the GPS receiver can estimate the approximate location based on the NAVSTAR almanac data for the satellite. These data are continuously transmitted and stored in the memory of the GPS receiver. The almanac data are routinely updated every four hours with new ephemeris data information as the satellites orbits change. Sometimes, the GPS device will take a long time (10^{+} minutes) to identify a new location, because it needs to receive new almanac and ephemeris data for your position.

The distance from a given satellite to the receiver equals the velocity of the transmitted signal times the travel-time delay. The satellite generates a pseudo-random code, as does the GPS receiver. The time delay, and subsequently the range, to each satellite are estimated by determining the time delay (shift) in a phase locked loop. Three satellites are needed for a crude triangulation, and a fourth satellite is needed to precisely set the receivers clock time, improving the overall average position accuracy to approximately 15 meters per point measurement.

WAAS

To improve position accuracy, the Federal Aviation Administration, FAA, implemented the "Wide Area Augmentation System" (WAAS) to create a continent-wide crude differential GPS system. "Wide Area" refers to a network of continuously operating reference stations that cover all of the U.S., and portions of Canada and Mexico. These reference stations are positioned at precisely surveyed locations and compare GPS distance measurements to known values. Regional real time differential corrections are broadcast to two satellites in geo-synchronous orbits over the East and West Coast of the United States, and this information is beamed down to WAAS-enabled receivers. WAAS-capable receivers typically have accuracies of 1-2 meters horizontally and 6 meters vertically. WAAS-enabled receivers should have this feature turned on when measuring positions in North America. Similar systems are planned to improve the accuracy a GPS measurements in Europe, Asia, and Australia. For example, the European system currently under development is known as "EGNOS" or "European Geostationary Navigation Overlay System" and will be fully compatible with the transmission frequency of WAAS. Turn on WAAS for any reconnaissance activity.

WAYPOINTS

GPS units store locations as "waypoints." During the reconnaissance, specific locations where some aspect of the event has been noted are logged as "waypoints." It is critically important that during the reconnaissance of any site worthy of photography, observations, and documentation that its GPS coordinates be captured so the site can be relocated.

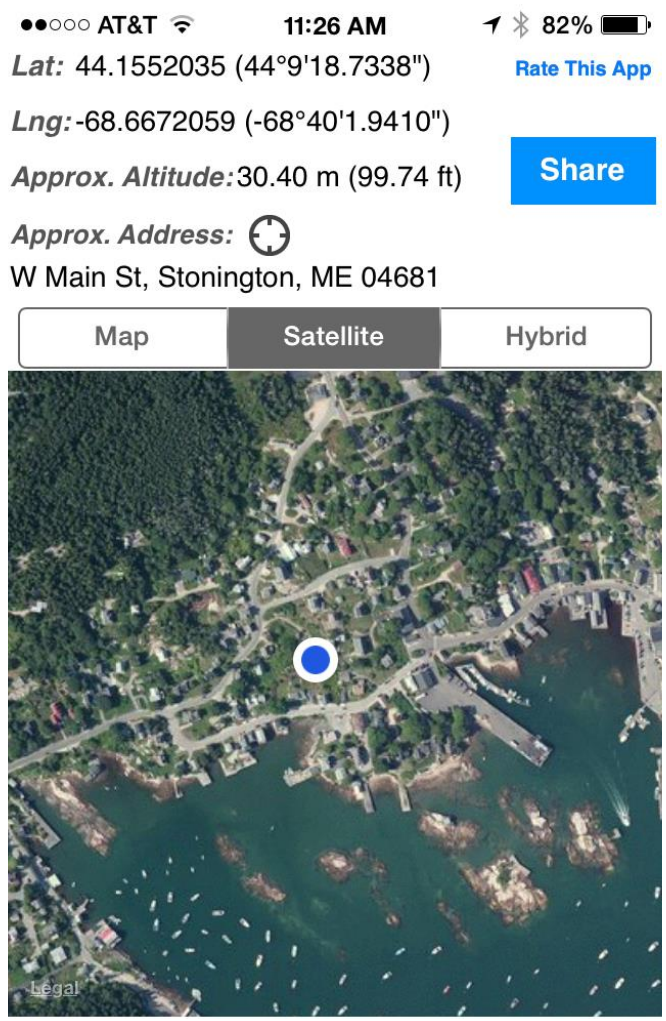

Figure 5. Example GPS application with decimal degrees, DMS, elevation and address on the iPhone.

Waypoints can also be created before going out to the field to navigate (or "GO TO") to that location. For example, if the plan to visit a specific site where the GPS coordinates are known, after selecting the waypoint from the waypoint list, the "GO TO" feature will draw a straight line to that point and guide you there with a pointer arrow, compass bearing, course line, or a "highway" representation.

When navigating to a waypoint, the GPS tracks the receiver location, speed, and direction of travel, how distant is the waypoint destination, and how long it will take to get there. The digital globe program Google Earth can directly import Garmin .GPX format files that include both waypoints and track logs.

TRACK LOGS

With track logs turned on, the GPS unit will automatically record movement throughout the day. Track logs are useful for identifying the path all the reconnaissance team members have visited, and for geo-referencing photographs when no waypoints are taken. Track logs are especially useful when driving to a site to track your path along the way.

Linking photographs to GPS position recorded in the track log is called geo-tagging, and many programs are available to process geo-tagging on Windows and Macintosh computers. The digital globe program Google Earth can directly import Garmin .GPX format files that include both waypoints and track log. Another feature of track logs is the ability to travel back along the same path using the TracBack feature. When activated, the unit will read in the track log and create a reverse route.

Track logs can be set up in either of two manual modes: (one) incremental time that separates measurements by a user specified number of seconds or minutes, or (two) incremental distance that separates measurements by a user specified number of meters. Because teams tend to stop and work at a site in detail and then move rapidly to another site, incremental time mode often captures many points at one location. We recommend using incremental distance for a vehicle, but setting the distance to a small number like 100 m. For closely spaced walking field surveys, select incremental time set to 5 to 20 seconds, depending on the storage capacity of your GPS unit. Ensure that the track log is transferred to Google Earth and save it on your GPS device. Saving it on your device typically reduces the number of points and the resolution of the resulting KMZ file is compromised. Thus, you should keep daily track logs and download each track log at the end of the day and save it on your computer.

(8) GEO-REFERENCING AND DATUMS

Summary: Geo-referencing

- Horizontal Datum WGS84
- Vertical Datum, ellipsoid values
- All measurements in meters and SI units.

A common source of confusion during a reconnaissance effort is the apparent mis-location of waypoints due to the misuse of datums. The datum is the underlying framework model of the earth that locations are referenced to in the model. Maps are grids created from a starting reference point called a datum. Using a map datum that does not match that reported by others can result in differences of position as much as several kilometers. There are scores of local and regional horizontal datum, global ellipsoid model datum, global Geoid model datum, as well as multiple epochs of these datum. *All GEER reconnaissance efforts, regardless of location on the earth, should be recorded and reported in the ellipsoid datum, the World Geodetic System of 1984 (WGS84)*. Elevations should be reported in ellipsoid heights.

GEER reconnaissance reports should report locations in decimal degrees, using the WGS84 World Geodetic System. One advantage to using decimal degrees is that the latitude and longitude can be put directly into the search window of Google Earth. A practical alternative to decimal degrees during the reconnaissance effort is to utilize UTM (Universal Transverse Mercator) an intuitive metric grid that is found on most USGS topographic quadrangle maps and available on your GPS. Because UTM northings and eastings are in a metric grid, it is easy to accurately determine distances and directions between sites. The US MGRS (Military Grid Reference System) is similar to UTM and used with military maps. However, all locations will be eventually reported in decimal degrees (using *WGS84*) in GEER reports.

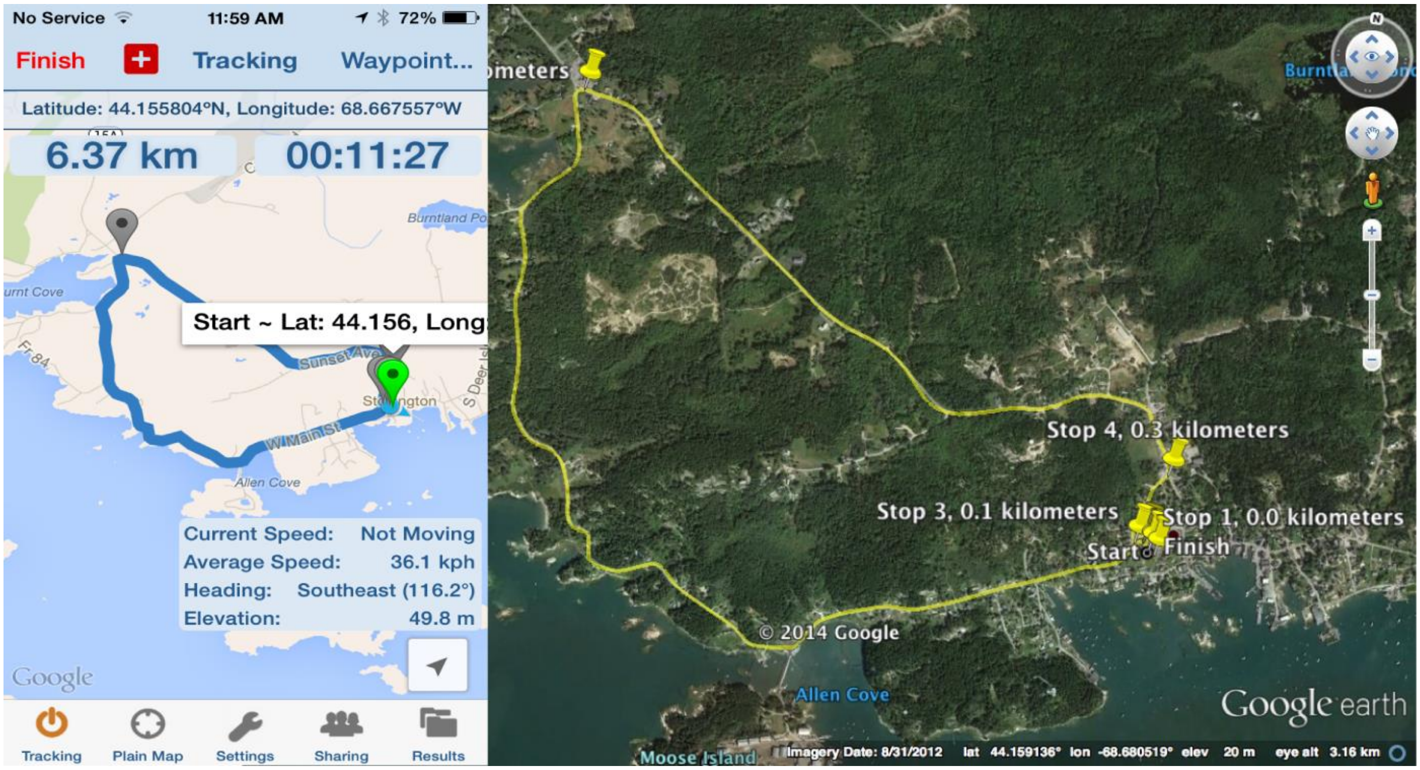

Figure 6. Track logs from smartphones can directly output Google Earth KML files for GPS location and geotagging photos

[9] SITE NAMING CONVENTIONS

Summary: Site naming

- Sequential site naming with each of the investigators initials followed by the sequential site number (i.e., JB14).

Systematic naming of sites is a critical part of organizing observations in the report and the Google Earth map. One approach that has worked successfully to organize and segregate the observations of different members is to sequentially number the sites using the Observer's initials. For example, JSS1 is the first site visited by J. S. Smith, and site JSS40 would be the 40th site J. S. Smith visited, several days later. This site may coincide with the visit of another teams site log JAD04 (J. A. Doe, site 04). It will be apparent when visualizing the sites in Google Earth, that there have been multiple visits to the same location. It is a good idea to keep the site IDs separate, as these two parties may have focused on, and observed different damage aspects. An alternative approach to site naming, is to assign sequential site-numbers for each vehicle.

A Microsoft Excel file record of each waypoint should be maintained by the individual team members, or for each vehicle. An example record is found in Appendix 2. The record includes the site number identifier; latitude; longitude; photographer; notes and description; and a list of damage aspects that when selected will become radio buttons in the Google Earth map.

[10] FIELD PHOTOGRAPHY TECHNIQUES

Summary: Photography

- Synchronize camera clock to GPS track log times for geo-tagging.
- Always have a scale in the image
- Include background scenery for reference
- Collect GPS waypoints or track logs at all picture locations

Several simple techniques can make a photographic dataset of an extreme event more valuable to other researchers and to the team member compiling observations of performance. Set the digital camera clock to the time displayed on the GPS device you are using so as to synchronize the picture taking time with the GPS track log. Take a picture of the GPS time at the start and end of each daily reconnaissance to insure that the clocks are synchronized and to recalibrate photo times if a time error occurs.

Linking digital photographs with the GPS track log is called geo-tagging, and several software programs can perform this function (RoboGeo for the PC is an excellent product). Geo-tagged photographs can be brought into Google Earth directly, or through the web applications to Flickr or Panoramio. Calibrate the clock on your camera to the GPS unit clock time received from the NAVSTAR satellites.

When possible, insert a reference scale in the form of a meter stick or some other recognizable object into the photograph scene so that crude dimensions can be estimated from the image. Each evening, download the photographs onto a computer and separate the images into Waypoint-specific folders. Finally, when taking a photograph of an object, try to include background scenery that may be useful for follow-on researchers to reoccupy the same location. Consider taking photographs at a distance of the entire site (or with a wide-angle lens) and then taking photographs at closer distance (or with a narrow-angle [zoom] lens) so that the overall context of the area can be assessed as well as details within the area.

Figure 6. Geo-tagged photo in Google Earth.

Photographing an image from two locations separated by 50 cm-to-several meters can create a parallax effect that allows for stereo viewing of the scenery. Stereoscopic pairs of images can be converted to anaglyphs false-colored in cyan-magenta, or displayed in polarizing digital displays, to allow for future stereoscopic viewing for analysis of damage. No-cost software called *StereoPhotoMaker* is convenient for making anaglyphs rapidly for viewing with cyan-magenta glasses. As digital photogrammetric technology and software improves, it will be possible to extract digital terrain models from digital images collected this way. Currently available systems require specialized commercially available software and calibrated camera-lens combinations (3GSM), knowledge about the position of the camera and its characteristics (Sirovision), or knowledge about the position of the subject in the image (Adam Technology).

[11] GOOGLE EARTH (GE) MAPPING

Summary: Google Earth (GE)

- Prepare the cache and images
- Know how to map on GE
- Know how to enter overlays
- Organize the report map

The advent of new and innovative technologies like Google Earth for post-event reconnaissance has revolutionized these investigations in the area of spatial information organization and presentation. Google Earth is a mapping software tool that allows for visualization of detailed data, imagery, and hyperlinked overlays, through traditional geographic information system tools and an innovative digital globe format. The real-time application of this program in the field allows for the spatial organization of extreme-event damage data in the form of geographic coordinates, text, and imagery and field measurements. Google Earth is a software product that allows for viewing of Earth satellite imagery, maps and user-defined overlays of geospatial information. For the purposes of organizing data on the reconnaissance, the free version of Google Earth is adequate. Paid versions of the software (Google Earth-Plus, -Pro, and –Enterprise) allow for varying degrees of ability to overlay and control data including GPS device input of data and the creation of data layers. These higher end versions of the software are useful in setting up the final Google Earth report of the extreme event.

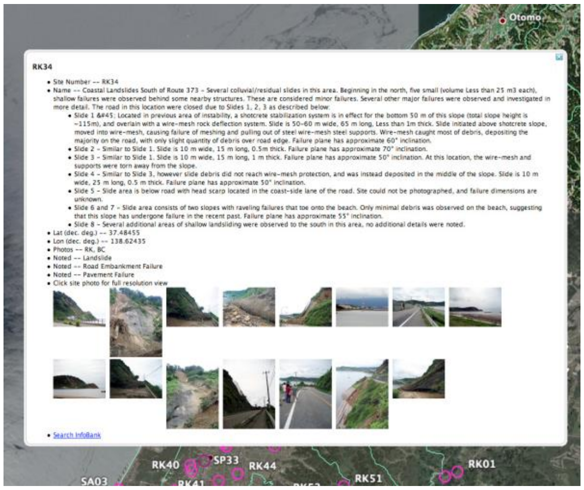

Figure 7. Detail of thumbnails of damage imagery and damage observations for a landslide-damaged site.

Prior to the field reconnaissance, Google Earth should be loaded onto a laptop or table computer that will be used in the field. In the software preferences (tools…/options…/cache), the memory cache should be set to the maximum stetting (currently, hard disk cache limit is 2000 MB; RAM cache is limited by the physical memory installed on the computer being used; check before going to the field and select a computer that will allow at least 500 MB). While connected to the internet in the evening, Google Earth should be used to view in detail the study areas that will be visited the next day. Then the program can be turned off. Doing this allows for the last images cached on the hard disk to be accessible without Internet connection when the computer is used in the field. Once the team is in the field, the Google Earth program can be used to annotate the map with locations of varied damage aspects and intensities, and new image overlays can be brought into the program. As the map is populated with observations, it becomes the primary tool for planning each day's studies.

It is useful to have a projector to project the Google Earth map during team meetings; many hotels have flat-panel monitors to which computers can be connected directly, but some require HDMI connectivity capabilities of the computer. During these meetings, the reconnaissance team should task one participant with a responsibility of merging GPS data, digital site logs and digital images into a spreadsheet. From these data, daily Google Earth (*.kml* mark-up language) files are generated to display the written observations and locations. By observing the extent of the damage in Google Earth, the team can identify unexplored areas for the next day's reconnaissance focus; spatial trends in the damage observations; and any errors that might have been included in the GPS logs and hand-typed observations. The daily *.kml* files can be put on everyone's laptop for the next day's reconnaissance, and *KML* files can also be sent by email to other GEER participants who are working virtually on or monitoring the reconnaissance effort.

> *[KML is a file format used to display geographic data in an Earth browser such as Google Earth, Google Maps, and Google Maps for mobile. KML uses a tag-based structure with nested elements and attributes and is based on the XML standard. KMZ stands for KML-Zipped.*
>
> *It is the default format for KML because it is a compressed version of the file. One of the more powerful features of KMZ is that it allows any images and custom icons used to be zipped within the KMZ file. That way the reconnaissance team can share these details without having to reference the files through some link to the Internet. See: http://code.google.com/apis/kml/documentation/kml_tut.html*

Conventions:

Photos are taken by different photographers at same sites visited by groups, and sometimes at different sites visited by individuals. Each photographer should assign their own ID to the site, and record its latitude and longitude. The photographer should record which photos were taken at each site.

From each photographer, the team needs a copy of their full resolution photographs and two spreadsheets. List each photo file name in a spreadsheet with the site ID to which it belongs in two columns: Site ID (see below), and Photo Name.

On the second worksheet list each site ID in a spreadsheet, the location of the site, and note the damage aspects and any other observations. Spreadsheet columns should be: Site ID (e.g. JSS12), Latitude (decimal degrees), Longitude (decimal degrees), and Site Name (e.g., Sendai

Airport).

The subsequent columns are to check (Y) characteristics/features observed by the team member. These could include the following observations:

"Day"
"Time"
"Elevation (m)"
"Photos"
"Geologic Material Type"
"Geologic Formation", "Location"
"Distance from USGS Epicenter (km)",
"Landslide Type", "Volume > 1000 m",
"Volume 100 to 1000 m", "Volume < 100 m"
"Liquefaction"
"Lateral Spreading"
"Bearing Offset"
"Ground Settlement"
"Severe Structural Damage"
"Moderate Structural Damage"
"Minor Structural Damage"
"No Structural Damage"
"Landslide"
"Landslide Location"
"Road Embankment Failure"
"Pavement Failure"
"Railway Deformation"
"Bridge Approach Deformation"
"Bridge Approach Offset"
"Toppled Monument"
"Fine-Grained Soil Failure"
"Retaining Wall Deformation"
"Earth Embankment Deformation"
"% red-tag structures"
"Business Continuity & Industrial Facility",
"Structure & Ground Interaction?"
"Collapse Direction"
"Surface Fault"
"Tsunami Effects"

These are just possible observations. Some are (Y/N) values. Some are text descriptions. The information provided by each team member will be combined into a consolidated spreadsheet once for a report Google Earth map.

For a similar presentation of the Niigata 2007 Earthquake see:

http://walrus.wr.usgs.gov/infobank/n/nii07jp/kml/n-ii-07-jp.sites.kmz

or for the Miyage-Iwate Japan 2008 Earthquake see:

http://walrus.wr.usgs.gov/infobank/t/toh08jp/kml/t-oh-08-jp.sites.kmz

Using the Google Earth 3D-buildings display, where available, enables the team to identify the locations of critical facilities such as the wastewater plants, municipal waste incinerators, schools, and other municipal buildings for inspection. Another feature, Google Earth Street-View, where available, enables the team to view structures and facilities in their condition prior to the earthquake. Google Maps Street-View, where available, also provides an opportunity to observe pre-damage conditions and details that may have been modified by rescue/recovery operations, as was used effectively in the August 9, 2013, Manitou Springs, Colorado Flood reconnaissance

(http://www.geerassociation.org/GEER_Post%20EQ%20Reports/Manitou_Springs_2013/index.html).

[12] SPECIALIZED RECONNAISSANCE TOOLS

Summary: Specialized Reconnaissance Tools

- Can be critical in elevating the quality of data the investigation.

Ground-based terrestrial laser scanning (lidar), Vs-measurement equipment (e.g., SASW, MASW, ambient arrays), and UAV photographic drones, and other advanced reconnaissance tools can capture much data at a high resolution, and do so quickly. Their potential use on GEER reconnaissance activities should be carefully considered.

Team leaders should add researchers who have these advanced tools and the skill to deploy them to capture perishable data. Though the use of these tools is beyond the scope of this guidance document, the team should consider these critical tools at the onset of planning.

[13] SERVER FILE STRUCTURE FOR THE

FINAL REPORT.

Summary: Server files structure

- Establish clear protocols for acceptable data
- Link photos and locations to damage types
- Use a server from organizations that mandate permanent data delivery.

After the reconnaissance, we have found that using three relatable spreadsheets provides better flexibility in producing the **.kml* file than the single large spreadsheet used in the field. The three spreadsheets are 1) Location, which includes Site ID, Latitude, Longitude; 2) Photos, which includes Site ID, Absolute Pathname (a URL network linkage to the photos that removes the necessity of hosting all the photos on one server); and 3) Observations, which includes Site ID and observation categories that will be used to make radio buttons (e.g., site amplification, tsunami effects, liquefaction, ground settlement, landslide, road embankment failure, pavement failure, bridge approach offset, severe structural damage, moderate structural damage, minor structural damage, no structural damage, % red tag structures, business continuity, levee erosion). The spreadsheets were saved as tab delimited files and USGS FORTRAN program '*sites4kml.for*' is used to merge the data from these three files into the Google Earth-ready *kml* file.

GOOGLE EARTH MAP FEATURES

Different symbol types should populate the general site map of the reconnaissance area. Default icons are available for use. To change the icon, get information on a place mark (command-I on a Macintosh computer; control-I on a Windows computer) and click the icon in the upper right corner. Select available icon, or import a customized icon. In this dialog box, the icon size, color, and associated text size and color can be customized. When normally viewing the icon, double clicking on a symbol will let the viewer fly to the site, single-clicking on icon opens a dialog box with detailed information about the earthquake magnitude, mechanism, and timing, and any associated graphics placed with this 'Placemark' (Google Earth's term for a location or waypoint). Other icons that are useful for a reconnaissance reporting are directional arrows (e.g., N, NE, E, SE, S, SW, W, NW) to signify the direction of collapsed structures.

Choosing 'All Sites' selects all of the locations in the **.kml* file. Specific sites with particular characteristics can be selected as well. A researcher interested in studying sites of bridge- and bridge-approach-damage can select the appropriate radio button and filter only those relevant sites. This is a powerful tool as some of the sites have multiple damage aspects and prior to the use of Google Earth could not be easily cross-referenced in a visual manner.

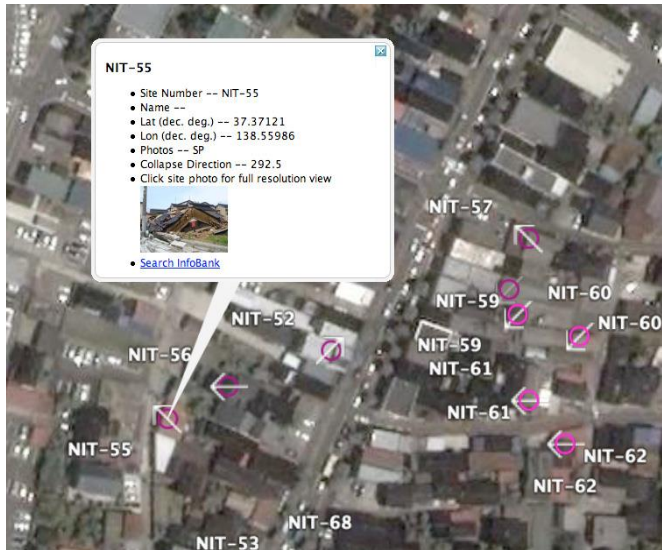

Figure 9. Example of how structural collapse directions can be plotted in Google Earth (Kashiwazaki, Japan, collapse NIT-55, 37.37121, 138.55986).

Appendix 1:

AMERICAN RED CROSS FIRST AID ESSENTIALS

First Aid Kit:
• Sterile adhesive bandages in assorted sizes
• 2-inch sterile gauze pads (4-6)
• 4-inch sterile gauze pads (4-6)
• Hypoallergenic adhesive tape
• Triangular bandages (3)
• 2-inch sterile roller bandages (3 rolls)
• 3-inch sterile roller bandages (3 rolls)
• Scissors
• Tweezers
• Needle
• Moistened towelettes
• Antiseptic
• Thermometer
• Tongue blades (2)
• Tube of petroleum jelly or other lubricant
• Assorted sizes of safety pins
• Cleansing agent/soap
• Latex gloves (2 pair)
• Sunscreen
• Nonprescription drugs
• Aspirin or non-aspirin pain reliever
• Anti-diarrhea medication
• Antacid (for stomach upset)
• Syrup of Ipecac (use to induce vomiting if advised by the Poison Control Center)
• Laxative
• Activated charcoal (use if advised by the Poison Control Center)
• Needles, thread
• Medicine dropper

This first aid kit is only one element in your emergency kit. Your reconnaissance team vehicle emergency kit should include the following:

• A supply of bottled water (one gallon per person per day).
• A supply of nonperishable packaged high energy foods such as granola bars, raisins and peanut butter
• Plastic cups, utensils, napkins, and
• A change of clothing, rain gear and sturdy shoes
• First aid kit and manual
• Prescription medications
• hand sanitizer
• Paper, pencil
• Whistle
• Toilet paper, towelettes
• Personal hygiene items
• Plastic garbage bags, ties
• Utility knife
• Pliers
• Tape

• A list of Hospitals in at the epicentral area.

Reconnaissance Team Members Are Personally Responsible For:

• An extra pair of eye glasses
• A cell phone, mobile radio (walkie-talkie), flashlight and extra batteries
• Credit cards and cash
• An extra set of car keys (duplicate the rental car key!)
• Hat and gloves, appropriate field clothing for Sun protection, hot and cold weather, and exposure to rain or snow.
• Sunglasses
• Sturdy shoes or work boots
• Rain gear

Appendix 2: Example EXCEL template for logging observations

Site Number	Lat (dec. deg.)	Lon (dec. deg)	Name	Photos	Liquefaction	Lateral Spreading	Bearing Offset	Ground Settlement	Structural Settlement	Severe Structural Damage	Moderate Structural Damage	Minor Structural Damage	No Structural Damage	Landslide	Road Embankment Failure	Pavement Failure	Railway Deformation	Bridge Approach Offset	Toppled Monument	Fine-Grained Soil Failure	Retaining Wall Deformation	Earth Embankment Deformation	% red-tag structures	Business Continuity & Industrial Facili	Structure & Ground Interaction?
SD1	37.38868	138.56413	Sea Wall - 13 cm Wide separation at sea-wall to buttress connection.	SD, SB	x	x		x		x			x									x			
SD2	37.38507	138.56907	Bridge on route 352 over Sabaishi River - Five-span steel bridge with steel piers	SB				x								x									
SD3	37.36093	138.52027	Kashiwazaki Marina - Settlement and separation of concrete slabs. A few sand	SD, SB	x	x		x			x														
SD4	37.35928	138.51990	Top of hill over closed tunnel - Tunnel was open on 7-21-07, but closed on 7-22-	SB				x						x					x						
SD5	37.36532	138.53213	Kashiwazaki of Beautiful Sea - About 1 m of lateral spreading on south side and	SD, SB	x	x		x		x															
SD6	37.36668	138.53565	Wharf structure with military vehicles (temporary) and steel scrap storage. Settl	SD, SB	x	x		x		x															
SD7	37.36593	138.53692	Kashiwazaki Port - Quay wall between SD6 and SD8	SD	x	x		x																	
SD8	37.36680	138.53825	Kashiwazaki Port - Coast Guard/Navy Berths	SD	x	x		x																	
SD9	37.36665	138.53983	Kashiwazaki Port - Taiheiyo Cement Facility	SD	x			x																	
SD10	37.42252	138.64122	Pavement damage and settlement and fill at bridge approaches on expressway.	SD												x		x							
SD11	37.36650	138.58868	Liquefaction of fill around buried utility. Uplifted manholes and trench settlement	SB, SD	x											x									
SD12	37.36663	138.59223	Midorigaoka Creek Overcrossing - Buckled brace across creek. No sign of liqu	SB, SD		x																			
SD13	37.37253	138.59468	Spherical green gas tanks. Some damage to skirt where pipe connects under tl	SB, SD								x													
SD14	37.37115	138.59488	A few red tagged buildings. No signs of ground failure. Less than 5% red tags.																				Less than 5		
SD15	37.37443	138.55550	No signs of ground failure. 5-10% red tagged buildings. One zone with liquefac																				5-10		
SD16	37.38403	138.56972	Red-tagged temple with stones toppled primarily in N-S direction. Some large c	SB						x						x			x						
SD17	37.36715	138.56293	Some bending in railway track beneath bridge.														x								
SD18	37.36598	138.55830	1-2" settlement at base of tank. Tank looks good.					x																	
SD20	37.36847	138.55813	NTT Building Telecom Tower - Tower looks fine from the road, but a thorough re	SB																					
SD21	37.36905	138.56530	Railway bridge with some spalling of concrete at abutment.									x													
SD22	37.32318	138.56428	A few collapses but not much damage. Less than 5% of buildings collapses in s	SB																			Less than 5		
SD23	37.35207	138.56953	Very little damage.																						
SD24	37.35355	138.54923	Some roof damage. No ground failure.																						
SD25	37.33863	138.55305	Expressway bridge with no discernible damage.																						
SD26	37.33700	138.47327	Landslide at road. About 3 m vertical drop of road at head scarp over length of a	SD, SB										x	x	x									
SA1	37.43903	138.73292	Drive to Kashiwazaki - Hokuriku Expressway goes to one lane approximately 8k													x									
SA2	37.42819	138.60896	Route 352, due east of Nuclear Power Plant - Approximately 30 cm of settlemer															x							
SA3	37.40872	138.57962	Lunch stop near Nuclear Power Plant - No information documented. Many TV v										x												