Pilot Seismic Hazard Assessment of the Granite City, Monks Mound, and Columbia Bottom Quadrangles, St. Louis Metropolitan Area

Research Proposal

Submitted by

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A. PROJECT SUMMARY

The greater St. Louis metropolitan area is a densely populated urban zone, bounded by extensive deposits (up to 76 m deep) of unconsolidated sediment (mostly sands) underling well-defined flood plains. The severe curvature of the bedrock channel depressions at their edges may also be sufficient to trap seismic energy and cause incident body waves to propagate through the alluvium as surface waves, producing stronger shaking and longer durations than would be predicted by 1-D analyses. This phenomenon may explain the significant disparities in reported shaking in the channel fills as opposed to bedrock knobs during historic earthquakes. The ground-motions from New Madrid Seismic Zone and Wabash Valley Seismic zone have never included these basin effects and the scale and resolution of previous studies was of insufficient detail to ascertain such site-specific effects. The national USGS hazard maps (Frankel et. al., 2002) do not include the effects of local geologic structure or soil cover present in the St. Louis Metro Area. The range in expected site response for a wide spectrum of earthquake magnitudes and three potential source areas needs to be evaluated and distributed to the scientific and engineering communities concerned with assessing seismic hazards in the St. Louis Metro area because most of these municipalities (including the City of St. Louis) have recently adopted the 2003 International Building Code, which requires site-specific assessments of seismic shaking intensity based on the NEHRP soil classifications.

Seismic site response for the three pilot quadrangles will be evaluated: Granite City, IL; Monks Mound, MO-IL; and Columbia Bottom, MO-IL, which extend north and east of the downtown area, where the bedrock basement changes depth significantly. These evaluations would include assessments of the following attributes: 1) Probabilistic seismic hazard analysis -2%, 5% and 10% probability of exceedance in 50 years in predicting the peak ground accelerations [PGA]; 2) Two scenario earthquakes and their associated PGA, 0.2 sec-SA, and 1 sec-SA; 3) 0.2 second and 1.0 second spectral accelerations for 2%, 5% and 10% probabilities of exceedance in 50 years; and 4) Deterministic and probabilistic screening of liquefaction potential.

The objectives of this research will be the following: 1) Construction of realistic one-dimensional shake models, using geotechnical data such as $(N_1)_{60}$ SPT values, CPT soundings, and shear wave velocity measurements. 2) Develop probabilistic and deterministic protocols for earthquakes emanating from the three seismic source zones; 3) Choose suitable attenuation relationships applicable to East Central U.S.; 4) Apply site-specific analysis (DEEPSOIL v2.6) to determine amplification factors; 5) Compare results with 2-D analyses; and 6) Prepare seismic hazard maps which would follow the format established by the USGS for the Memphis seismic hazards study completed in 2004.

The overarching goal of this study will be to prepare credible seismic hazard maps for the three pilot quadrangles, so the St. Louis Area [Seismic] Hazard Mapping Project Technical Working Group (SLAHMP-TWG) can ascertain the reality of proceeding with the original goal of assessing 31 quadrangles in the greater St. Louis Metro area. At the end of this study, there will be total of 42 seismic hazard maps at a scale of 1:24,000 (7.5 minute quadrangles).

B. SEISMIC ZONES AFFECTING ST. LOUIS METRO AREA

Since 1973, a general awareness of the New Madrid Seismic Zone (NMSZ) emerged and became appreciated by most scientists working in the Midwest. Particular concern was expressed for the safety of Memphis, TN because of its close proximity to the southern end of the NMSZ (65 km). St. Louis is located about 200 km from the northern end of the NMSZ, causing most scientists and engineers to believe that it was at far less risk for seismic hazard than Memphis. Even though the great majority of research activity has focused on the NMSZ, in the past few years two additional seismic source zones have emerged, which are closer to St. Louis. Three seismic zones are now recognized as being capable of causing potentially damaging ground motions in the St. Louis Metropolitan area: the New Madrid Seismic Zone, Wabash Valley Seismic Zone, and South Central Illinois Seismic Zone. A brief review of these seismic zones is presented below.

The New Madrid Seismic Zone (NMSZ) is historically recognized for spawning periodic moderate to large size earthquakes. It is an old failed rift zone, believed by most seismologists to be an intraplate zone, within the interior confines of the North American tectonic plate. The NMSZ lies within a 70 km-wide, 200 km-long SW-NE trending graben (known as the Reelfoot Rift) which is interpreted to have formed during an episode of continental rifting that began in late Cambrian time (Hamilton, 1981). The NMSZ dominates central U.S seismicity (300 recorded tremors per year, on average) and, according to Johnson and Nava (1990), has the highest seismic moment release rate of any seismic zone in a stable continental region in the world.

A study by Johnston and Schweig (1996) identified seven candidate fault segments within the central fault system of the NMSZ: the Blytheville arch (BA), Blytheville fault zone (BFZ), Bootheel lineament (BL), New Madrid West (NW), New Madrid north (NN), Reelfoot fault (RF), and Reelfoot south (RS), shown in Figure 1. Historic seismicity of the region is summarized in Figure 2. Most of the active seismicity is concentrated in the northern embayment a south-plunging trough of Cenozoic and Upper Cretaceous age sedimentary rocks, which reach a depth of 1 km beneath Memphis. Figure 1 also shows three principal trends of seismicity; two northeast-trending arms with a connecting northwest-trending arm. This pattern of seismicity has been interpreted as a northeast-trending, right lateral strike-slip fault system with a compressional northwest-trending step-over zone (Bakun and Hopper, 2004).

Some of the largest historical earthquakes in Eastern North America occurred in the winter of 1811-1812. The 1811-1812 earthquake series had three main shocks and one large aftershock (the main shock of M_w 7.6 on December 16, 1811 was followed by a strong aftershock of M_w 7.0 later the same day). Each of the main shocks were followed by ~15 aftershocks greater than M_s=6 and ~1600 aftershocks large enough to be felt in the three months following the first event (Algermissen, 1983; Hamilton, 1981; Nuttli, 1987). The actual magnitudes of the 1811–1812 New Madrid events remain uncertain for a number of reasons. The 1811–12 earthquakes occurred before the region west of the Mississippi River was settled; so no credible information was recorded west of the River, only east of it. Shaking intensity contours for the 1811-12 events are, therefore, sparse and inconsistent. Another nagging uncertainty arises because of the low rate of seismic activity in the Midwestern U.S., as compared to other regions, like California.

The third uncertainty arises out of the extreme impedance contrast between the underlying Paleozoic age bedrock and the unconsolidated alluvial soils filling present-day river channels. The impedance contrast between the Paleozoic age bedrock (V_s = 3000 to 4000 m/sec) and Pleistocene age (V_s = 175 to 275 m/sec) or Holocene age (V_s = 150 to 200 m/sec) is rather severe when compared to other parts of the world. The impedance contrasts causes marked amplification of ground motion, especially low amplitude, long period motions. The severe impedance contrasts in Holocene alluvium along river valleys likely resulted in an overestimation of the magnitude of the 1811–12 earthquakes because the early American communities were situated along major rivers (Bakun and Hopper, 2004). Table 1 summarizes the range of estimated magnitudes for the 1811–12 earthquakes, over the past 30+ years.

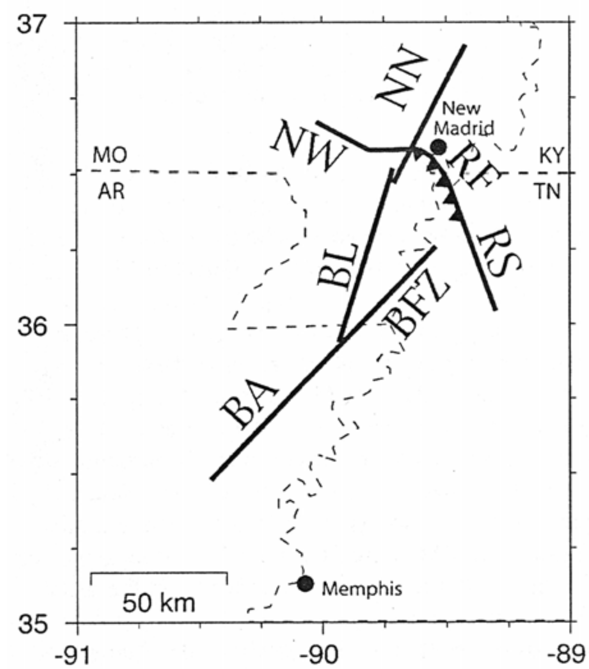

Figure 1: Fault segmentation of the NMSZ. The seven segments and their respective lengths are: Blytheville arch (BA-70 km), Blytheville fault zone (BFZ-55 km), Bootheel lineament (BL-70 km), New Madrid West (NW-40 km), New Madrid north (NN-60 km), Reelfoot fault (RF-32 km), and Reelfoot south (RS-35 km) (from Bakun and Hopper, 2004)

The locations of 1811–12 earthquakes have been resolved with a reasonable degree of certainty for the December 16, 1811 and February 7, 1812 events. Bakun et al. (2003) employed limited isoseismal area constraint method (Bakun and Wentworth, 1997) to fix the locations of the 1811-12 main shock events in the NMSZ. The pair of December 16, 1811 earthquakes are believed to have occurred on the southern arm of seismicity associated with the Blytheville Arch (Johnson and Schweig, 1996; Muller, Hough, and Bilham, 2004). Johnston and Schweig (1996) outline two alternative geometries for the main fault rupture for this quake; either BA and BL or BA and BFZ (see Figure 2). The February 7, 1812 M_w 7.8 earthquake occurred on Reelfoot fault (RF), possibly, including New Madrid north (NN) or Reelfoot south (RS) segments.

The January 23, 1812 earthquake has proven more difficult to constrain using the limited isoseismal area constraint method. Until recently, it was generally inferred to have occurred on the northern seismic arm of the NMSZ along segment NN (New Madrid north), according to Johnston and Schweig (1996); Tuttle, et al. (2002) and Cramer et al (2005). Hough et al. (2000), Hough et al. (2005), and Bakun and Hopper (2004), have presented an alternative scenario for this rupture in which New Madrid west (NW) is responsible, or even the Wabash Valley Fault Zone, 220 km northeast of the NMSZ (and 378 km from the assumed epicenter for this event). A major problem with this interpretation is the physical evidence gleaned from paleoseismic studies within the NMSZ, which show four major events that date from 1811-12 (Tuttle, et al., 2002, Tuttle et al., 2005; Cramer et al., 2005). To date, liquefaction features triggered by the 1811-12 earthquakes have not been documented at distances greater than 240 km (Street and Nuttli, 1984; Johnston and Schweig, 1996; Tuttle et al., 2002).

Paleoseismic investigations also suggest that the largest 1811-1812 earthquakes were not unique in magnitude because paleoliquefaction features provide convincing physical evidence that no less than four similar-size earthquake sequences have occurred in the last 2000 years, with an average recurrence of 500±300 years for the New Madrid Seismic Zone events (Tuttle *et al.*, 2002, 2005). Figure 1 shows the location of the New Madrid Seismic Zone.

A moderate size earthquake with a magnitude of 6 to 6.6 (Johnston, 1996 and Bakun et al., 2003) occurred in October 1895, with the greatest shaking intensity being recorded in Charleston, Missouri, towards then north end of the NMSZ.. It was the largest earthquake spawned by the NMSZ since the 1811-1812 earthquakes. Structural damage and liquefaction were reported along a line running from Bertrand, MO to Cairo, IL. Bakun *et al.* (2003) have suggested that the October 1895 quake may have been centered in southern Illinois, about 100 km north of Charleston, Missouri. However, given the distribution of reported shaking intensities, the loci of these data describe an energy release emanating from the Charleston, Missouri area.

The Wabash Valley Seismic Zone (WVSZ) is located along the border between Illinois and Indiana. Paleoliquefaction features were initially reported in this area by USGS scientists in 1993, but was not universally accepted as its own seismic sources zone until a series of articles appeared in Seismological Research letters in 2004. Candidate active westward dipping thrust faults are suggested in seismic reflection profiles and recent paleoliquefaction studies have conformed that the zone is capable of producing repeated large-magnitude earthquakes from **M** 7.0 to 7.8, but **M** 6.0 events probably occur once every 1,000 years (McBride, 1997; McBride et. al 2002a; McBride et. al 2002b). The largest paleoearthquake event identified to date is known as the Vincennes-Bridgeport earthquake. It occurred about 6,011 ± 200 yr BP (Obermeier, 1998). Obermeier (2001) summarized that based on a suite of approaches (such as magnitude-bound, cyclic stress and energy stress methods) the magnitude of this earthquake was likely between **M** 7.5 to 7.8. The next-largest earthquake (known as Skelton-Mt Carmel earthquake) occurred 12,000 ± 1000 yr BP (Hajic et. al., 1995, Munson et al., 1997 and Obermeier, 1998). This earthquake size was estimated to be **M** 7.1 to 7.2 by Munson et al. (1997) and **M** 7.3 by Pond and Martin (1997). The investigators suggested that both of these earthquakes occurred close to one another, in the general vicinity of the largest historic earthquakes (**M** 4 to 5.5) in the lower Wabash Valley of Indiana-Illinois (Obermeier, 1998). Figure 2 shows the location of the Wabash Valley Seismic Zone.

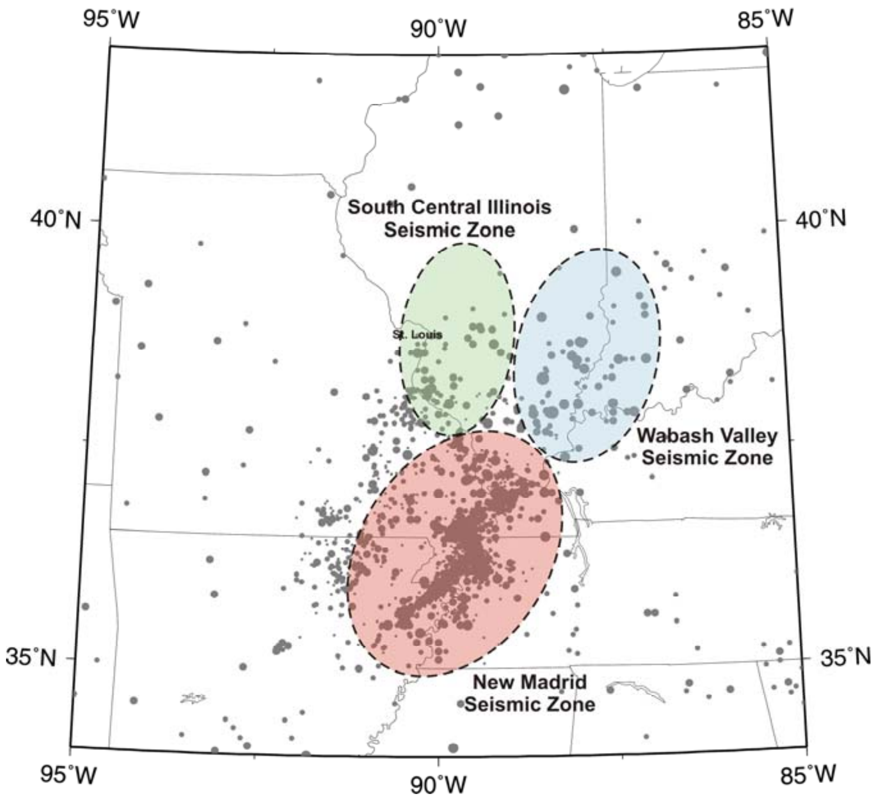

Figure 2 - Seismicity of Midwestern U.S and the areal extent of the three seismic zones: New Madrid Seismic Zone, Wabash Valley Seismic Zone, and South Central Seismic Zone. Dots represent the seismic activity recorded during historic time. The diameter of the circles represent epicenters of earthquakes, with increasing magnitude. Taken from Rogers, Karadeniz and Cramer (in press).

In 1999 paleoliquefaction data and basement faults identified in seismic-reflection data in south Central Illinois suggested this region is also capable of generating earthquakes with a maximum possible moment magnitude of 6 and 7, nucleating in the Paleozoic age basement (Su and McBride, 1999). This area has spawned two strong mid-Holocene events, known as the Springfield and Shoal Creek earthquakes, which have been identified in recent paleoliquefaction studies (McNulty and Obermeier, 1999). These investigators documented at least one moderate-size earthquake (**M** 6.2 to 6.8) and, probably, a second smaller event (~**M** 5.5) in the Springfield, IL region between 5,900 and 7,400 yr BP. The same study also documented evidence of paleoliquefaction caused by another strong earthquake (Shoal Creek), believed to have occurred in southwest Illinois around 4,520 BC ± 160 yr (McNulty and Obermeier, 1999). McNulty and Obermier (1999) believe that these earthquakes almost certainly exceeded M6.0. Tuttle et al. (1999) studied paleoliquefaction features in south St Louis and identified at least two generations of Holocene age earthquake-induced liquefaction features. Tuttle et al (1999) felt that these liquefaction features probably formed during the 1811-1812 New Madrid events, while other paleoliquefaction features likely formed during a mid-Holocene earthquake in 4,520 BC ± 160 yr. Figure 2 shows the areal extent of the proposed South Central Illinois Seismic Zone (SCISZ).

The USGS (2002) has assigned a probability of 15 to 30% for a Magnitude 6.0 to 6.8 event in the NMSZ within the next 50 years, making it the most probable destructive earthquake expected in the near term. The last two **M** 6.0+ earthquakes emanating from the NMSZ were the **M** 6.6 Charleston, MO quake of October 31, 1895 (discussed previously) and the **M** 6.3 Marked Tree, Arkansas quake of January 1843. Until recently, this M. 6.0+ event was believed to have a recurrence frequency of 70+/- 15 yrs.

C. SIGNIFICANCE OF THE PROPOSED PROJECT

This past winter the USGS-CEUS office organized a St. Louis Area [Seismic] Hazard Mapping Project Technical Working Group (SLAHMP-TWG). The SLAHMP-TWG is convening four times a year to discuss mutual goals and assignments for the 5-year NEHRP Earthquake hazards program (EHP) study focusing on evaluating relative seismic risks and ground shaking hazards posed to the St. Louis Metropolitan area, which encompasses an area of about 4,000 km^2 on 29 USGS 7.5-minute quadrangles (Figure 3).

The principal short-term goal of the SLAHMP-TWG is to use the available geodata generated on three or four pilot quadrangles to ascertain what level of effort and cost will be required to prepare seismic hazard maps of all 29 quadrangles in the St. Louis Metro area, using a similar format to that established by the USGS CEUS office for the Memphis/Shelby County Seismic Hazard Maps project, completed in 2004. The Memphis/Shelby County project covered six USGS 7.5-minute quadrangles. This project will seek to create seismic hazard maps for three pilot quadrangles in the central St. Louis metropolitan area: Columbia Bottom, Granite City, and Monks Mound.

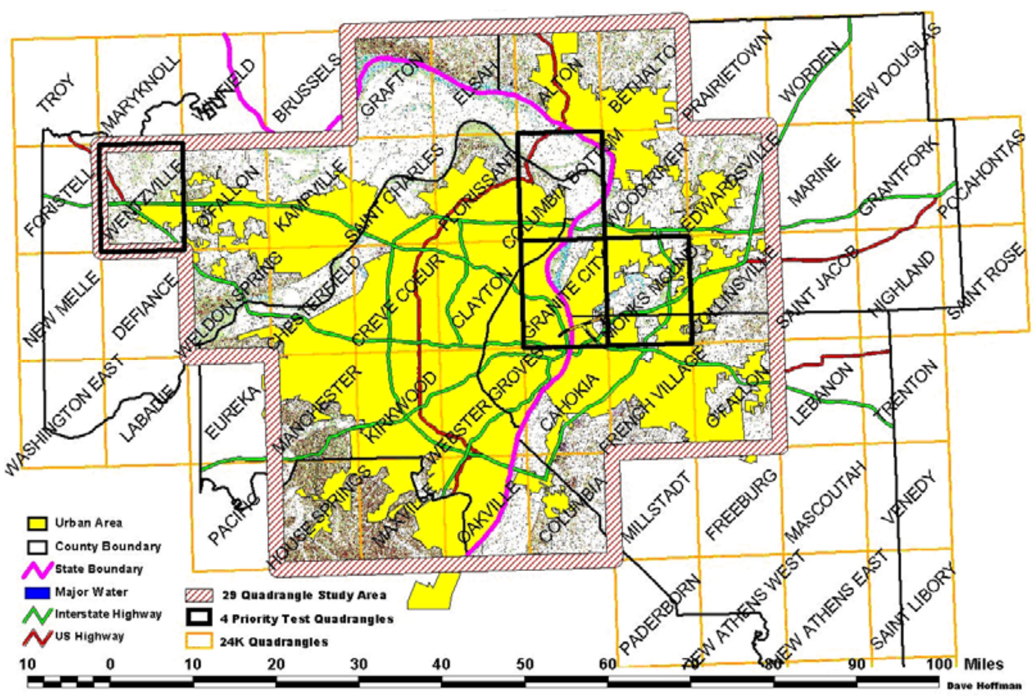

Figure 3 - 29 quadrangles comprising the St. Louis metropolitan area. The pilot quadrangles for the multi-year EHP are highlighted. They include the Monks Mound, Granite City, and Columbia Bottom quadrangles. The solid black lines are county boundaries.

These maps should also serve as an example work products for what the 5-year NEHRP-EHP in St. Louis will prepare over the foreseeable future, to allow geoscientists and engineers in the greater St. Louis (STL) metropolitan area to use the 1997 NEHRP Provisions in the 2003 International Building Code (IBC), recently adopted by the Cities of St. Louis and St. Charles, and under consideration in 11 other municipalities in the immediate area.

The 1997 NEHRP provisions incorporated into the 2000 and 2003 IBC require geoscientists to classify soil profiles at each site for potential site amplification; using one of 10 different soil categories (soil types A through F_4). In FY99 a grant from USGS-NEHRP to the Central United States Earthquake Consortium (CUSEC) State Geologists was used by the ISGS and MoDGLS to construct large scale maps of surficial materials in Illinois and Missouri. These maps were compiled at a scale of 1:250,000. These data were combined to construct the NEHRP Soil Amplification Class map reproduced in Figure 4. This map is presently used by scientists, engineers, peer reviewers, and planners for the St. Louis Metro area. It was prepared before any shear wave velocity measurements were actually made in the region, based on simplified assumptions. The flood plains highlighted in orange were denoted as Soil/Site Class E, with assumed shear wave velocities of less than 180 m/sec. Recent reviews of well logs and geotechnical borings in the area of the proposed pilot quadrangles reveals that the Mississippi flood plain actually exhibits a wide array of soil profiles and depths, ranging from as little as 2 to as much as 76 m in depth, with a range of materials types, ranging from peats and fat clay to dense gravelly sands.

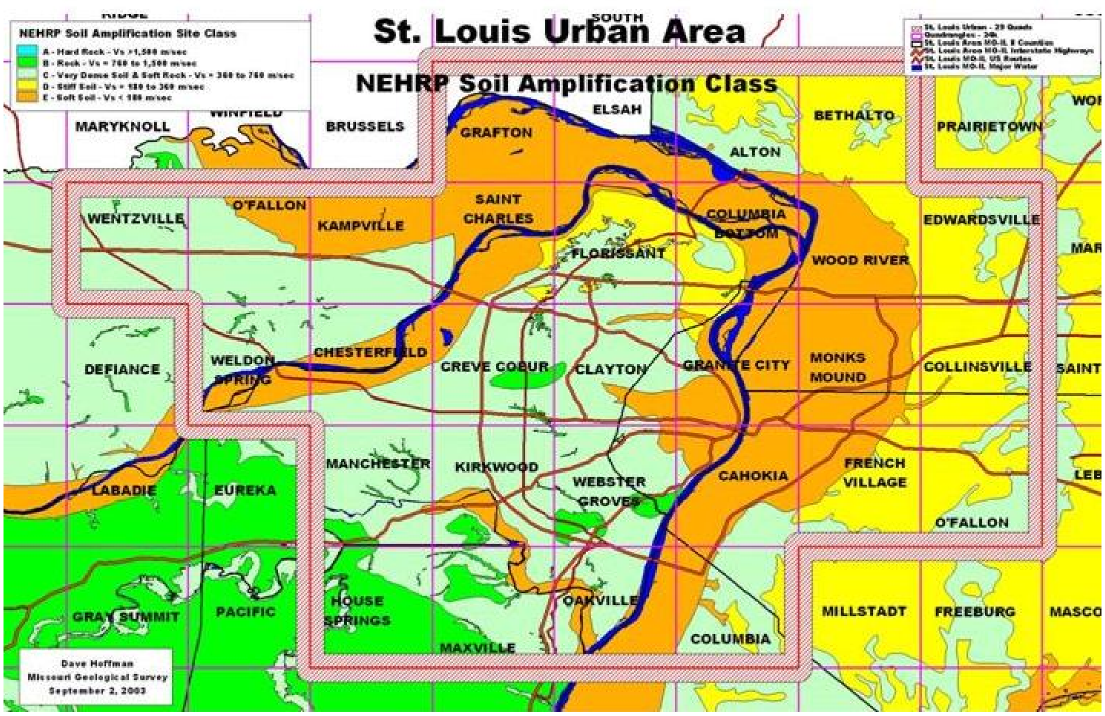

Figure 4 - NEHRP Soil Amplification Class map prepared by the Central U.S. Earthquake Consortium State Geologists. This map was prepared in 1998-99 before any shear wave velocity measurements were actually made in the area. The flood plains highlighted in orange are denoted as Soil/Site Class E, with assumed shear wave velocities of less than 180 m/sec.

Recent studies (Rogers, Karadeniz and Kaibel, in press; and Rogers, Karadeniz and Cramer, in press) show that the depth of unconsolidated soil cover exerts enormous influence on site magnification, especially for long period motions emanating from > 100 km distance. Figure 5 shows the effect of surficial soil thickness on peak spectral accelerations for a Magnitude 6.0 to 6.8 quakes at an epicentral distance of 210 km for the Creve Coeur Bridge site in northwestern St Louis (on the Missouri River flood plain). Figure 6 shows the predicted impacts of soil cover thickness on spectral acceleration for M 6.0 earthquake at an epicentral distance of 110 km. These preliminary results reveal the absolute need for more site-specific analyses, which attempt to model the approximate relationships between depth and consistency of the soil cover with site response, for an array of the most expected earthquakes (not just so-called “maximum events” emanating from the NMSZ).

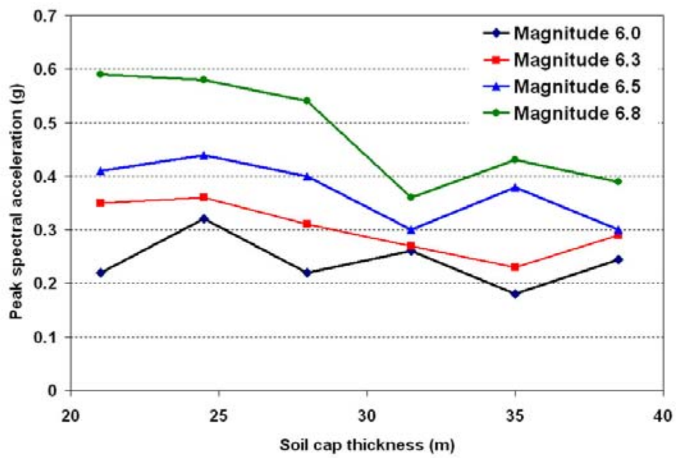

Figure 5 - Variation of peak spectral acceleration with soil cap thickness for Magnitude 6.0 to 6.8 earthquakes at an epicentral distance of 110 km at the Creve Coeur Bridge site in St. Louis.

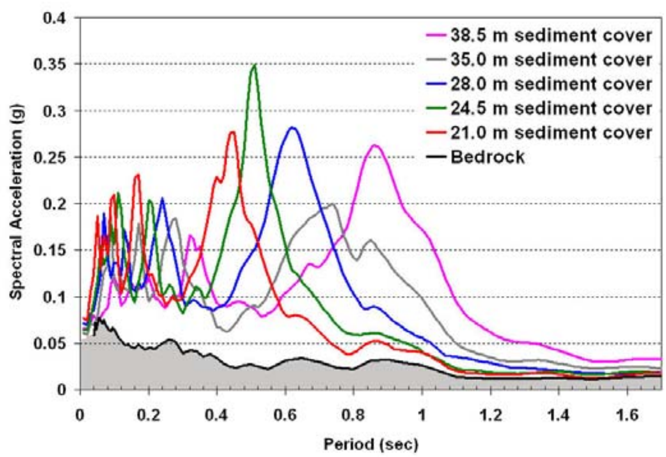

Figure 6 - Effect of sediment thickness on the response spectra for Creve Coeur Bridge for M 6.0 at a distance of 110 km (from Rogers, Karadeniz, and Cramer, in press).

In figure 7, the soil cover of these three quadrangles (Columbia Bottom, Granite City and Monks Mound -only two is visible) can be seen. These quadrangles are located on the alluvial valley; therefore, the soil thickness is expected to change with the basin geometry, being thicker near the center of the flood plain. The curvature of the bedrock depression underlying the flood plain can trap body waves and cause some incident body waves to propagate through the alluvium as surface waves (Kramer, 1996). These waves can produce stronger shaking and longer durations than would be predicted by one-dimensional analyses that consider only vertical propagating s-waves. Silva (1988) demonstrated that one-dimensional analyses are valid out in the middle of gently sloping bedrock depressions, but may under-predict the response due to generation of surface waves near the edges of such basins, such as exist along the bluffs of the Missouri River flood plain. This limitation of one-dimensional analyses is recognized and the differences in shaking intensity with decreasing thickness of soil cover are presented in Figures 5 and 6. The change in peak ground acceleration with the soil cover thickness is provided in Figure 8. The peak spectral accelerations, periods and peak ground accelerations are markedly different for different soil thicknesses. In order to minimize or eliminate any of all of the above-cited concerns, I would try to apply 2-D analysis and compare my results with 1-D analysis. If the results are within acceptable range, I will continue applying 1-D dynamic analysis.

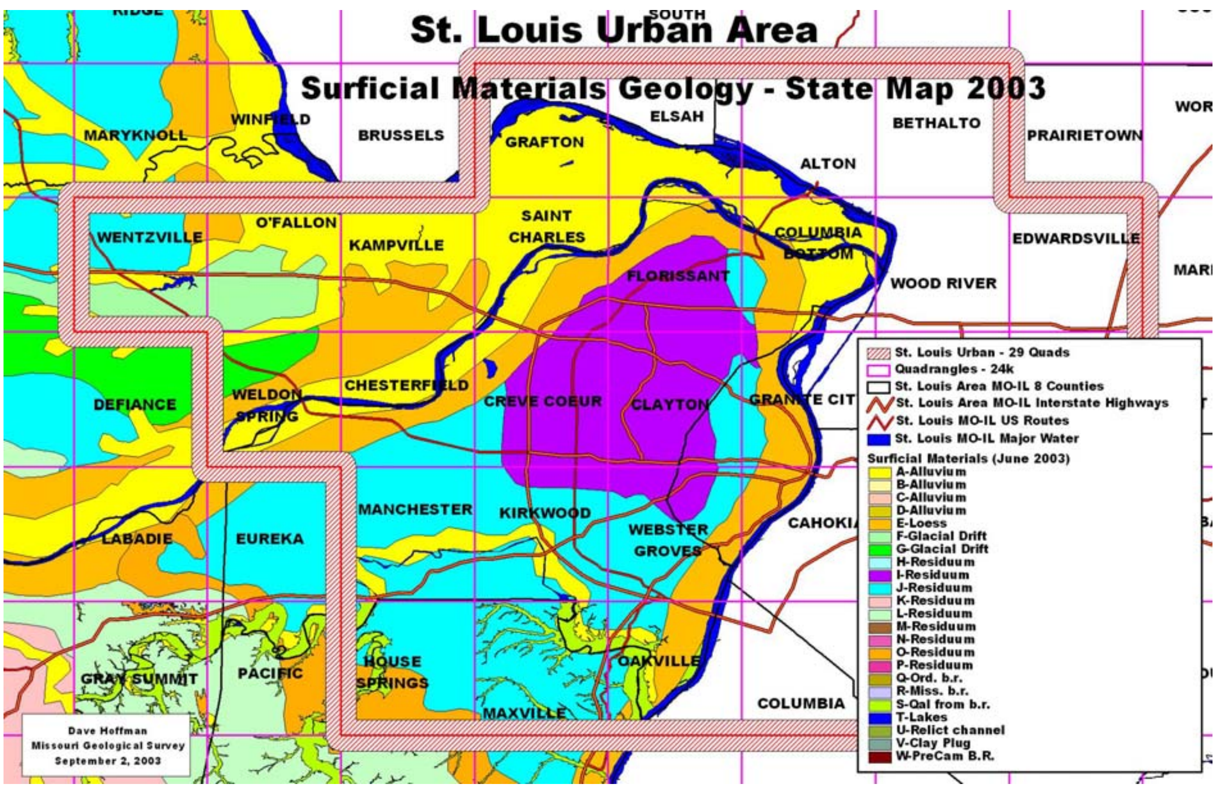

Figure 7 – Soils types and their distribution in St. Louis Metro Area

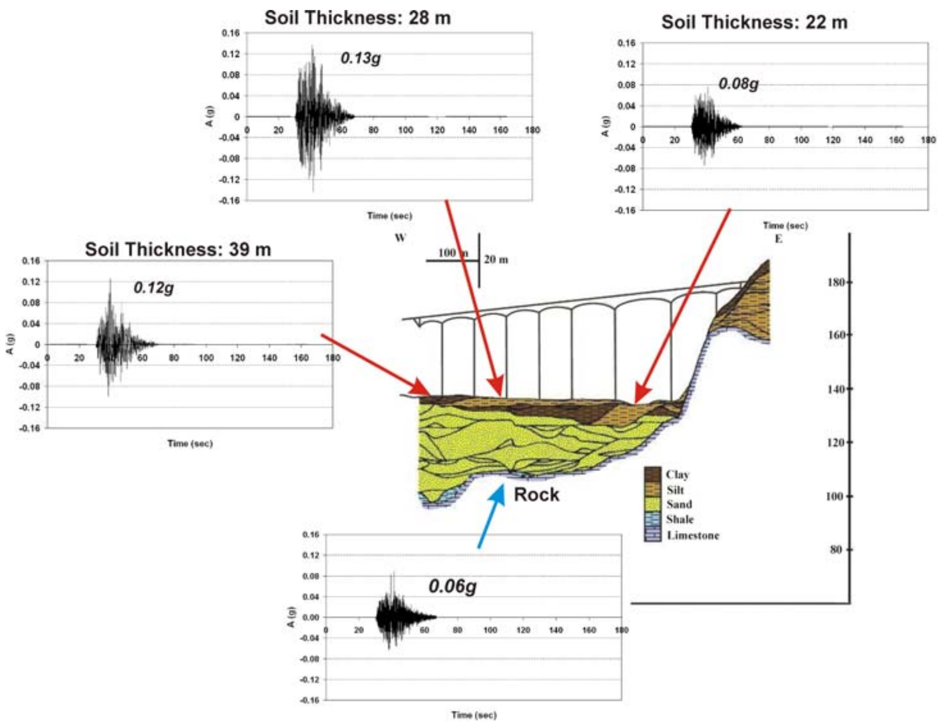

Figure 8: The affect of soil thickness on the peak ground acceleration

After calculating the soil response using 1-D or 2-D dynamic analysis, the corresponding site amplifications will be estimated. These amplification factors will be combined with the rock acceleration to estimate the ground motions on the surface. A recent study estimated that the site amplification in St. Louis area may range from 5.5-9.0 X for 6.0-6.8 magnitude earthquakes emanating from any of the three seismic zones. An example calculation of site amplification is given in Figure 9.

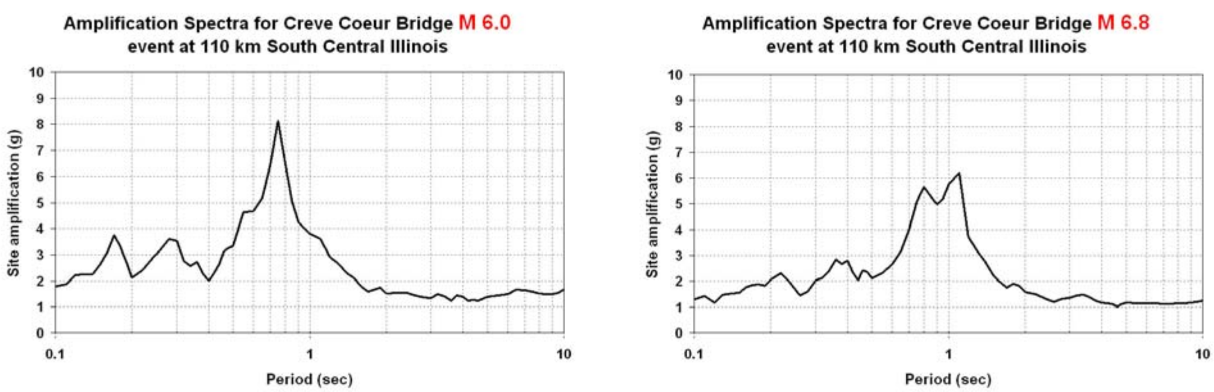

Figure 9: Site amplification factors for M6.0 and M6.8 earthquakes emanating from South Central Illinois at a distance of 110 km.

Until recently, scant shear wave velocity data existed for the St. Louis Metro area, but recent efforts have focused on collection of data within and adjacent to the three pilot quadrangles proposed for evaluation in this study, shown in Figure 10.

A GIS geo database for the St. Louis Metro Area is being prepared by a Ph.D. Candidate in Geological Engineering. He is using existing data archived by the Illinois State Geological Survey (ISGS), Illinois Department of Transportation (IDOT), Missouri Division of Geology and Land Survey (MoDGLS), Missouri Department of Transportation (MoDOT), Metropolitan Sewer District of St. Louis (MSD), St. Louis University (SLU), and the University of Missouri-Rolla (UMR). Theses GIS layers will include: 1) Surficial geologic materials; 2) Loess thickness; 3) Underlying bedrock geology; 4) Surficial materials thickness; 5) depth to groundwater; 6) shear-wave velocity data; and 7) engineering properties (density, water content etc.) of soils (where available). These information layers will be used to construct one-dimensional models of various sites in the three pilot quadrangles.

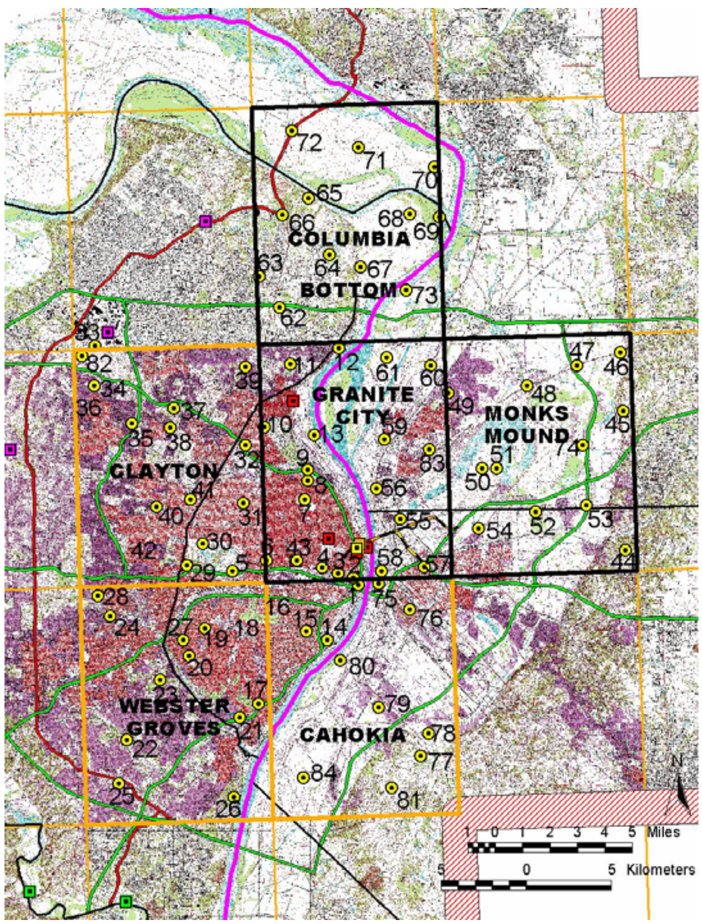

Figure 10 - Recently completed shear wave velocity tests in vicinity of the Columbia Bottom, Granite City, Monks Mound, Cahokia, Clayton and Webster Groves quadrangles. Seismic site response is expected to vary markedly with thickness of late Quaternary cover, which dips easterly crossing the Mississippi River into Illinois. The three pilot quadrangles are outlined in solid black lines.

D. PROJECT PLAN

Task 1 – Comprehensive Literature Review. A thorough literature review will be made (which is almost completed) of all the recent studies addressing historic seismicity, paleoseismicity, and faulting in the New Madrid Seismic Zone, the Wabash Valley Seismic Zone and the South Central Illinois Seismic Zone.

Task 2 – Collection of Geologic Data. The five principal geodata repositories are the Missouri Geological Survey (MoGS), Missouri Department of Transportation (MODOT), Illinois State Geological Survey (ISGS), the Illinois Department of Transportation (IDOT) and the University of Missouri Rolla. I will also contact consulting firms working in the region and try to use some of their data. The Missouri and Illinois Geological Surveys are in the process of acquiring the geodata generated by their respective DOTs in the St. Louis metro area. The following data will be collected: 1) Surficial geologic materials; 2) Loess thickness; 3) Bedrock geology; 4) Surficial material thickness; 5) depth to groundwater; 6) shear-wave velocity profiles; and 7) engineering properties (density, water content etc.) of soils.

Task 3 – Characterization of Surficial Geologic Materials. Shear wave propagation values and impedance contrasts between underlying rock and the soil cover combine to exert the greatest influence on seismic site response. In addition to shear wave velocity information, bulk density, water content, and dynamic soil properties are also required for dynamic analysis of site response at each location. The basin geometry and the curvature of the bedrock depression underlying the flood plain may also exert significant impacts on the site response; so it is crucial to ascertain the distribution of the soil types and their respective thicknesses (Figures 3, 4 and 5). Some of the soil density and shear wave velocities will be correlated from corrected Standard Penetration Test (SPT) data.

Task 4 – Determination of Site Specific Amplification and Attenuation. Seismic site amplification is also influenced by the ground motion characteristics, such as the fundamental period of the site, which shifts with earthquake magnitude and epicentral distance. I will employ most recent CEUS ground-motion attenuation relations to estimate the distribution of ground motions for a specified magnitude and distance. Some of the accepted attenuation relations for the Central U.S. are Atkinson and Boore (1995), Frankel and others (1996), Campbell (2003), and Somerville and others (2001). I attended the NEHRP CEUS Hazard Workshop which was convened in Boston in May 9-10, 2006. New and Updated relationships are discussed in this workshop and I am planning to use these relationships as soon as they are published.

I will combine all the available information (unit density, thickness, shear-wave velocity, shear modulus, and damping) and employ the software program DEEPSOIL v2.6 or SHAKE2000 to analyze and identify those factors promoting site amplification. To understand the effects of the basin geometry I also hope to employ 2-D analyses using QUAD4M and compare the results. After making these comparisons, I will proceed with the selection of the appropriate amplification factors and move on to the next task.

The 1-D DEEPSOIL Version 2.6 site response program was developed by Hashash and Park [2002] at the University of Illinois, Urbana. DEEPSOIL was developed to model the effects of thick soil profiles in the American Midwest, allowing 30 layers of soil to be modeled above a bedrock interface. The depth of unconsolidated "soil" cover within the NMSZ varies from zero on the margins of St. Louis to more than 1000 m at Memphis, about 450 km downstream. DEEPSOIL can analyze soil profiles using linear, equivalent linear, and/or nonlinear methods. The equivalent linear approach usually provides an acceptable response for preliminary screening analyses of seismic site response, which seek to estimate the likely range of site amplification and assess liquefaction potential.

DEEPSOIL provides two methods for the input of dynamic soil properties: 1) modified hyperbolic model; and 2) discrete points, to define the modulus reduction and damping curves.

Task 5 – Hazard Map Preparation.

I will prepare seismic hazard maps for the three pilot 1:24,000 scale quadrangles (Granite City, Monks Mound, Columbia Bottom) in St. Louis Metro area, including: 1) 2%, 5% and 10% probability of exceedance in 50 years in terms of PGA; 2) 2 scenario earthquakes and their associated PGA and 0.2 sec-SA and 1 sec-SA; 3) 0.2 second and 1.0 second spectral accelerations for 2%, 5% and 10% probabilities of exceedance in 50 years; and 4) Deterministic and probabilistic screening of liquefaction potential.

My principal project goal is the preparation of "baseline" seismic hazard maps useful for codified seismic design (using the 2003 IBC) and planning that can be easily understood by end users. These end users should include: state and federal agencies; academic researchers; public agencies (including regulators), local agencies, private sector business, and the general public.

E. FINAL REPORT AND DISSEMINATION

A final report will be prepared at the end of the project. The report will document the following maps separately for each quadrangle:

1) 2% probability of exceedance in 50 years in terms of PGA;
2) 5% probability of exceedance in 50 years in terms of PGA;
3) 10% probability of exceedance in 50 years in terms of PGA;
5) 2 scenario earthquakes and their associated PGA and 0.2 sec-SA and 1 sec-SA;
6) 0.2 second spectral accelerations for 2%, 5% and 10% probabilities of exceedance in 50 years;
7) 1 second spectral accelerations for 2%, 5% and 10% probabilities of exceedance in 50 years;
8) Liquefaction potential analysis;
9) Probabilistic liquefaction analysis.

In summary, I will prepare total of 42 seismic hazard maps (1:24,000 scale 7.5 minute quadrangle maps). A CD-ROM copy of the digital maps will be included with my final report. Results of my research will also be disseminated to the scientific and engineering communities through publications in archival journals, public presentations, and the maps will be made available to the earthquake science and engineering community through mass e-mailings using the Central US Earthquake Information Server, the U.S. Universities Council on Geotechnical Engineering (USUCGER), the Association of Engineering Geologists (AEG) list server, the

Seismological Society of America (SSA) list server, and through the Earthquake Engineering Research Institute's (EERI) monthly newsletter. In addition, I will make presentations at appropriate conferences and professional society meetings in the Midwest, including the Center for Earthquake Information and Research (CERI), EERI New Madrid Chapter, AEG, and SSA.

F. TENTATIVE PROJECT TIMELINE

Phase 1: Evaluate all the recent studies addressing historic seismicity, paleoseismicity, and faulting in the New Madrid Seismic Zone, the Wabash Valley Seismic Zone and the South Central Illinois Seismic Zone (August 2005-August 2006 –almost completed).

Phase 2: Collect all the available geologic, geotechnical and geophysical data (January 2006-August 2006).

Phase 3: Characterize shallow geologic materials for dynamic analysis (May 2006-August 2006).

Phase 4: Determine rock accelerations employing the recent attenuation relationships (May 2006-September 2006).

Phase 5: Determine the site amplification using DEEPSOIL or SHAKE 2000 (August 2006-October 2006). Any new geological, geophysical and geotechnical data will be added at this stage.

Phase 6: Establish probabilistic protocols (October 2006).

Phase 7: Disseminate the hazard maps (November 2006-February 2007).

Phase 8: Compile the Ph.D. dissertation (August 2006-April 2007).

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