# SUPPLEMENTAL PDF ATTACHMENTS

## Excerpts From The Kodiak Island Borough Seismic Vulnerability Assessment

## Attachment 1 – WLA Final Report Excerpt

The following attachment includes excerpts from the geologic and geotechnical portion of the seismic vulnerability assessment, generated by William Lettis & Associates (WLA). WLA was a subcontractor for the Kodiak Island Borough school facilities seismic vulnerability assessment project. Included herein are the 1) cover page, 2) table of contents, 3) introduction and scope of work, and 4) recommendations.

As part of the report, the consultant examined all possible seismic hazards, including ground motion, tsunamis, liquefaction, fault rupture, landslides and differential settlement at each site. Another important part of the report is that, instead of merely utilizing published code values for peak ground acceleration, a probabilistic seismic hazard assessment was completed using updated source models and updated attenuation relations. The results showed that peak ground accelerations could vary by a factor of three across Kodiak Island. These site specific values were tabulated and used by the structural engineer for analysis of the school buildings. A figure for the 475-year earthquake event spectra is included for reference.

The full report can be downloaded at: http://ak-kodiak.civicplus.com/index.asp?NID=108 and selecting “Seismic Vulnerability Assessment” or accessing the Kodiak Island Borough website (www.kodiakak.us) and searching for “WLA Final Report”.

# KODIAK ISLAND BOROUGH SCHOOL DISTRICT GEOLOGIC AND GEOTECHICAL SEISMIC VULNERABILITY ASSESSMENT

## FINAL SUMMARY REPORT

Submitted to:

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February 10, 2006

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## 1.0 INTRODUCTION AND SCOPE OF WORK

This Final Summary Report presents the results of the William Lettis & Associates, Inc. (WLA) Geologic and Geotechnical Seismic Vulnerability Assessment for the Kodiak Island Borough (KIB) School District, Kodiak Island, Alaska. This work was performed under subcontract to G&E Engineering Systems, Inc. (G&E) to support the preparation of the Seismic Implementation Plan (SIP) that addresses seismic hazards issues facing the KIB School District. The goals of the WLA study are to (1) identify any possible seismic hazards that may require retrofit or mitigation, (2) support the development of a risk-based management plan to address seismic vulnerabilities at all KIB schools and facilities, and (3) assist in the preparation of a FEMA Pre-Disaster Mitigation Competitive program (PDM-C) application.

The assessment performed by WLA included the following scope of work:

(1) Compile and evaluate existing data (maps, reports, and civil and structural drawings on file at KIB);

(2) Perform facility walkdown inspections for schools in and near Kodiak City (19 and 20 July 2005);

(3) Develop preliminary seismic hazards assessment of ground motions, liquefaction, landslide, faulting, and tsunami at each school site;

(4) Prioritize outlying school facilities for site inspections;

(5) Perform initial evaluation of ground motions using EZ-FRISK probabilistic seismic hazards analysis software and USGS hazard maps for Alaska;

(6) Preparation of a Technical Memorandum summarizing the initial geotechnical findings and seismic hazard assessment;

(7) Complete the geologic and geotechnical seismic hazards assessment for all 14 KIB Schools;

(8) Revise probabilistic ground motions using updated seismic source model and appropriate attenuation relations; and

(9) Preparation of this Summary Report.

The results of several separate geologic and geotechnical analyses are included as appendices to this summary report:

Appendix A: Facility Walkdown Geotechnical Data Sheets
Appendix B: Probabilistic Earthquake Ground Motions
Appendix C: Calculations of Active Lateral Loads

The WLA study was performed by a team of geologists including Robert Witter, P.G., William Lettis, C.E.G., Jeff Bachhuber, C.E.G., Scott Lindvall, C.E.G., and Rick Ortiz.

## 4.0 RECOMMENDATIONS

Recommendations for further investigation and mitigation of specific geotechnical and geologic hazards are included in the geotechnical data sheets in Appendix A. These recommendations are conceptual in nature, and should be implemented in an integrated way that considers the results of the final seismic vulnerability assessment. Recommendations that address the most significant issues identified in this geologic and geotechnical assessment are discussed in more detail below.

(1) Strong ground motions produced by moderate to large earthquakes in the Kodiak Island region present the principal hazard to all 14 KIB Schools. The results of our updated PSHA (Appendix B) incorporate site-specific parameters, were computed using the most up-to-date attenuation models, and indicate that PGAs may vary by a factor of 3 across the island. Therefore, we recommend using site-specific ground motions provided in Appendix B for the final seismic vulnerability assessments for all KIB schools.

(2) We recognize a high tsunami hazard at Old Harbor School on the basis that runup estimates for an extreme event would reach an elevation 7 feet higher than the gymnasium and within 3 feet below the main school building. Sustained flow of water depths greater than 2 feet caused by flooding during a tsunami can result in significant structural damage to buildings. Since there is no retrofit alternative to mitigate against tsunami inundation, we recommend that the Borough consider moving the school to higher ground in the northeastern part of the community near the airstrip or implementing a tsunami warning and evacuation procedure that evacuates all people from the gymnasium to higher ground behind the school, as described below.

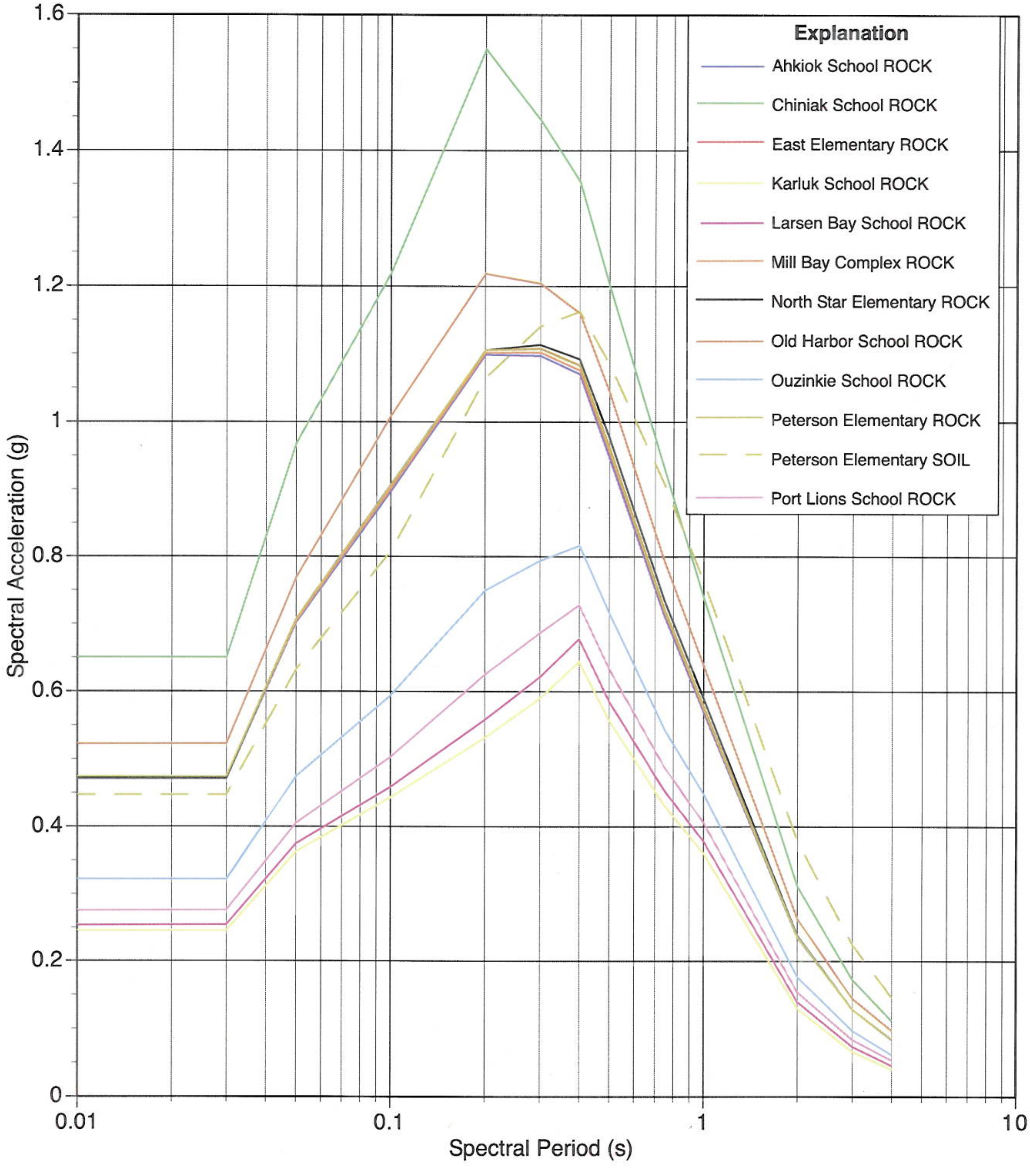
At all KIB Schools, including Old Harbor, Akhiok and Peterson, tsunami warning systems and evacuation plans should be developed to allow students, staff and visitors at the schools to quickly and safely reach higher ground. Evacuation routes should be shown on maps and clearly posted in the schools. The routes should be easily accessible by all people on foot, including disabled in wheelchairs, and lead to a designated evacuation center that is above the highest potential tsunami runup, seismically sound, and not vulnerable to earthquake-induced liquefaction, landsliding or surface fault rupture.

(3) There is a high hazard for future debris flows at Old Harbor School, whether triggered by seismic shaking or by heavy rain during storms. The hazard has been generally mitigated by the

construction of a 10- to 15-foot high berm to direct potential flows around the school gymnasium. We recommend that it be monitored annually and following significant earthquakes and storms to assess the performance of the berm and measure the amount of debris flow deposition that may fill the channel. If debris in the channel begins to bury the berm, the material should be removed and the integrity of the berm repaired.

(4) The Old Harbor gymnasium has experienced a history of flooding caused by high ground water levels during heavy rain. The ground water appears to be freely flowing through the debris berm that is constructed of permeable sand and gravel. To mitigate this problem, we suggest installing a culvert in the channel behind the berm to collect water flowing down the gully and direct the flow around the gym.

(5) Wet to saturated fills in contact with flexible wood frame gymnasium walls at the Karluk and Akhiok Schools produce active soil pressures and resultant lateral loads that must be resisted by the building. It is not clear from geotechnical reports and structural and civil drawings whether the basement walls of the buildings were designed to withstand the potential lateral loads imparted on the wall by the adjacent soil column. In addition, despite design drawings that recommend the installation of a moisture barrier to protect exterior walls from ground water, evidence for recent repair of moisture barriers at Akhiok suggest the design may be ineffective and water damage to the building may have already occurred. Therefore, we suggest removing the soil and associated lateral loads to facilitate long-term maintenance and ensure satisfactory performance of the building.




| KODIAK ISLAND SCHOOLS | |
|---|---|
| **475-Year Uniform Hazard Spectra for All Kodiak Borough Island School Sites** | |
| WLA William Lettis & Associates, Inc. | Figure B-6 |

## Attachment 2 – Eidinger Final Report Excerpts

The following attachment includes excerpts from the structural portion of the seismic vulnerability assessment, generated by John Eidinger of G&E Engineering Systems, Inc. Mr. Eidinger was the prime contractor for the Kodiak Island Borough school facilities seismic vulnerability assessment project. Included herein are the 1) cover page, 2) table of contents, 3) and introduction with an executive summary.

An important element of this report was the use of compiling fragility and damage state figures for each structure for a given peak ground acceleration. The results showed the probability of damage ranging from slight to complete collapse for four scenario earthquakes varying (as a percentage of gravitational force) from 10%g to 56%g. These scenario analyses figures allowed the borough officials and the public to clearly understand the importance of retrofitting the schools to withstand probable earthquakes. These figures are included, herein.

Also included, is the benefit cost analyses. Benefit/cost ratios were provided so that projects could be prioritized and submitted to FEMA for co-funding under its Pre-Disaster Mitigation Program or Hazard Mitigation Grant Program. The higher the ratio, the more likely a project will qualify for grant funding. To date, every school mitigation project submitted under FEMA's grant mitigation programs by the Kodiak Island Borough has been approved.

The full structural seismic vulnerability assessment report can be downloaded at: http://ak-kodiak.civicplus.com/index.asp?NID=108 and selecting "Seismic Vulnerability Assessment" or accessing the Kodiak Island Borough website (www.kodiakak.us) and searching for "Eidinger Final Report".

# KIB
# Seismic Vulnerability Assessment

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*by:*


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*G&E Report 87.01.05, Revision 0*
*February 12, 2006*

# Table of Contents

# 1.0 Introduction

This report describes a Seismic Vulnerability Assessment for all of the Kodiak Island Borough school buildings.

## *1.1 Executive Summary*

A Seismic Vulnerability Assessment was performed of the Kodiak Island Borough school buildings. The assessment included all the buildings for 13 schools as well as the Learning Center. Several of the schools include multiple buildings, and each building was included in the assessment.

For each site / building, we evaluated six seismic hazards: ground shaking, surface faulting, liquefaction, tsunami, landslide and differential settlement. Given these seismic hazards, we evaluated how each building might perform in various size earthquakes.

The geologic hazard studies show that the level of earthquake motion that should be used for design of new facilities, to modern (2006) standards, should be about 18% to 40% larger than what was used for the design of most of the schools built since the mid-1960s. The 18% increase would reflect design using the seismic concepts in the Uniform Building Code (1997), which are set at providing for life safety for earthquakes that occur once every 475 years. The 40% increase would reflect design for even rarer earthquakes, as would be required if KIB adopts the latest provisions of the International Building Code, which are set at designing for life safety for 2/3 of an earthquake that might occur once every 2,475 years.

For those buildings where we recommend structural seismic upgrades, the upgrades should be designed to meet the intent of providing life safety service for earthquakes that occur once every 475 years.

For construction of future new buildings, we recommend that the higher standard (2/3 of 2,475 year earthquake) be used. This should provide immediate occupancy for the buildings should a 475-year earthquake occur, while still providing life safety reliability in larger but rarer events.

For most of the buildings, the existing structural systems were designed with a reasonable capability to resist medium to quite large earthquakes. However, for portions of the three oldest buildings (Middle School, Ouzinkie, Peterson), we found there were significant deficiencies in the existing lateral force resisting system, such that a structural upgrade appears warranted. We also found some deficiencies at the High School Library Wing and Gym, largely through strength and stiffness discontinuities that were apparently overlooked in the original design.

In addition, we found that at essentially every school there are a number of non-structural components that require anchorage or bracing. These components range from furnaces, heating and ventilation equipment, water tanks, library bookshelves, suspended ceilings, windows, etc. The cost to upgrade the essential items needed for building services is $348,480 (all schools except Middle School), plus $10,966 for Middle School. The cost to upgrade suspended ceilings just over main egress areas would be an additional

$302,000. The cost to upgrade all suspended ceilings would be $1,189,000. The cost of upgrading suspended ceilings has not been included in Table 1-1.

The complete seismic upgrade program would cost $3,132,290. Table 1-1 summarizes the costs and benefits and the Benefit Cost Ratios (BCR) for the recommended upgrades.

| School Building | Seismic Upgrade Cost[1] | Project Benefits | Benefit Cost Ratio |
|---|---|---|---|
| Middle School | $1,251,510[2] | $8,132,160 | 6.50 |
| Ouzinkie (1969 portion) | $149,000 | $975,410 | 7.55 |
| Peterson (1946 portion) | $508,500 | $1,862,173 | 3.66 |
| High School Library Wing | $464,500 | $4,452,695 | 9.59 |
| High School Gym (Alternative 1[3]) | $410,300 | $416,768 | 1.02 |
| Non Structural Items | $348,480 | | |
| Total | $3,132,290[4] | $15,839,206 | 5.06[5] |

*Table 1-1. Summary of Recommended Seismic Upgrades and BCRs*

We performed a series of benefit cost analyses, to examine how cost effective it is to perform the above upgrades. Using a discount rate of 7% and applying the FEMA-approved methodologies to perform such analyses we found that the BCR varies from 1.02 to 9.59 for the recommended six projects when ranked individually, or 5.06 when considered as one large project. Any project with a Benefit Cost Ratio of 1 or larger is deemed cost effective on an economic basis; in other words, the capital cost spent today is less than the benefits accrued from reduction in building damage, injury to people and other economic impacts from all future earthquakes over the remaining lifetime of the schools.

It is our opinion that all of the above listed projects are eligible for co-funding under FEMA's Pre-Disaster Mitigation program. We therefore recommend that KIB consider submitting a proposal to FEMA under its PDM-C 2006 program. The availability of funds under FEMA's 2006 program are uncertain, and it is possible that FEMA will not have sufficient funds in 2006 for all eligible projects.

Should co-funding from FEMA not be available under the FEMA 2006 PDM-C program, we recommend that KIB still implement all of the above projects as soon as funds are available. The work should be prioritized to do early implementation of the projects with the highest BCRs, consistent with permitting, and coordinated with complementary operations and maintenance projects. All work should be completed by 2016 (ten years), reflecting the ongoing risk to the community. If resources are available, it is possible that all upgrades could be completed in four years (by end of summer 2010).

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[1] Includes relocation costs during construction.

[2] Includes $10,966 for upgrade of essential non-structural items.

[3] Alternative 1 denotes an upgrade of the Gym to provide improved performance after a design basis earthquake (PGA = 0.47g). See Section 4.5 for a further description.

[4] Budget would be based on rounded figures to the nearest $1,000.

[5] Benefits from upgrade of the non-structural items would modestly increase this value.

## 1.2 Other Improvements

During the course of our field visits, a few other maintenance related improvements were noted. These include:

- Install new roof at Old Harbor Gym building (improve roof drainage)
- Install new roof at Larsen Bay Gym Building (improve roof drainage)
- Remove soil backfills on walls at Karluk and Akhiok (reduce wall loading, long term water damage to building)

These upgrades would not likely be eligible for FEMA co-funding.

## 1.3 Report Outline

The outline of the report is as follows:

- Section 2 describes the structural systems for each building where structural retrofits are recommended.
- Section 3 presents the seismic hazards for each building.
- Section 4 describes the Seismic Vulnerability Assessment for each building and describes recommended seismic retrofits for those buildings where upgrades are warranted and cost effective.
- Section 5 describes the fragility and damage states for each building selected for seismic upgrade. Section 5 also presents risk summaries for all buildings, even those not recommended for seismic upgrade.
- Section 6 describes the benefit cost analyses in context of FEMA's PDM-C program.

## 1.4 Abbreviations and Definitions

| | |
|---|---|
| BCR | Benefit Cost Ratio |
| CMU | Concrete masonry unit |
| FEMA | Federal Emergency Management Agency |
| KIB | Kodiak Island Borough |
| KMS | Kodiak Middle School |
| g | acceleration (1g = 32 feet / second / second) |
| M | Magnitude (moment) |
| PDM-C | Pre Disaster Mitigation - Competitive |
| PGA | Peak Ground Acceleration (units in g) |
| psf | pounds per square foot |
| UBC | Uniform Building Code |
| V | Code based term for seismic base shear forces |
| W | Code based term for weight of the building used in seismic evaluations |

In this report, we generally use the term "Kodiak" or "Kodiak Island" to refer to the entire island, and "Kodiak City" to refer just to the geographic area of the city.

## 1.5 Limitations

The findings in this report are meant as a structural / earthquake condition assessment of each building for purposes of developing a cost effective seismic retrofit program for the Kodiak Island Borough. These evaluations are also used to perform benefit cost analyses as part of the FEMA PDM-C.

## 1.6 Acrobat File Format

If you are viewing a .pdf version of this report, you should use Acrobat Reader version 7 (free from www.adobe.com) or the full version of Acrobat 7. Prior versions of Acrobat may scramble some fonts.

## 1.7 Acknowledgements

This report was written by John Eidinger and Donald Duggan of G&E Engineering Systems Inc. Benefit cost analyses were developed by Ken Goettel of Goettel & Associates, Inc. Geologic and geotechnical hazards were developed by William Lettis, Rob Witter, Jeff Bacchuber, Scott Lindvall and Rick Ortiz of William Lettis and Associates, Inc.

Many KIB staff and Kodiak residents participated in this effort, providing project coordination, access to schools, attendance and review of presentations and draft reports, including: Bud Cassidy, Ken Smith, Sharon Lea Adinolfi, Robert Tucker, Gregg Hacker, Gary Carver (Carver Geologic Inc.), Rick Gifford, Duane Dvorak, Scott Arnot, Brent Watkins and Larry Ledoux.

## 5.6 Scenario Analyses

Each building in the KIB was evaluated as to how it might perform in four different scenario earthquakes. By "scenario" earthquake, it is meant that an earthquake that produces a specific PGA at the site has occurred. The four scenario earthquakes are:

- PGA = 0.1g. This is representative of small local or larger distant earthquakes that might affect the school. Most of KIB's schools have already experienced earthquakes with this approximate level of shaking.
- PGA = 0.4g. This is representative of a large nearby earthquake. Up until the mid-1990s, this is what was meant as being in "seismic zone 4" per the UBC.
- PGA = 475 years. Using modern seismic hazard analyses, the 475-year earthquake PGA represents the best estimate of an earthquake that has 10% chance of occurring in the next 50 years. The UBC (1994 edition) and many other codes base seismic design on this concept.
- PGA = 2/3 of 2,475 years. Using modern seismic hazard analyses, the 2,475-year earthquake PGA represents the best estimate of an earthquake that has 2% chance of occurring in the next 50 years. The IBC (2000 and 2003 editions) code bases seismic design on this concept.

Figures 5-1 through 5-4 summarize the results for each building. The results are presented for each building for each of four levels of earthquake, for four possible damage states:

- Slight
- Moderate
- Extensive
- Complete

Sections 5.1 through 5.5 describe what is meant by each damage state for the buildings with the greatest chance of significant damage in large earthquakes. For example, Figure 5-4 shows that the High School Library wing has about a 25% chance of being in the complete damage state, given an earthquake that produces PGA = 0.56g at that site. For that same level of earthquake, the nearby Vocational Wing has a 2% chance of being in the complete damage state.

When interpreting the results in Figures 5-1 to 5-4, the following factors should be kept in mind:

- For Figures 5-3 and 5-4, the actual PGA values are based on the data in Table 3-1. The listed PGA value are specific for the Mill Bay Complex.
- These analyses are based on a number of assumptions and address uncertainties and randomness. By randomness, it is meant that although a scenario earthquake might most likely produce PGA = 0.56g at a site, there is considerable variation in ground motions in a given earthquake over short distances, generally on the order

of ±50%. This accounts for about half the total variation in predicting the actual damage state of the building. By uncertainty, it is meant that the strength of construction materials is generally unknown (some steel might be specific as having a minimum strength, and actually have just that strength, while another heat of steel might have 50% more strength); there is uncertainty as to the quality of construction; there is uncertainty as to the actual weight of the building at the time of the earthquake, etc.

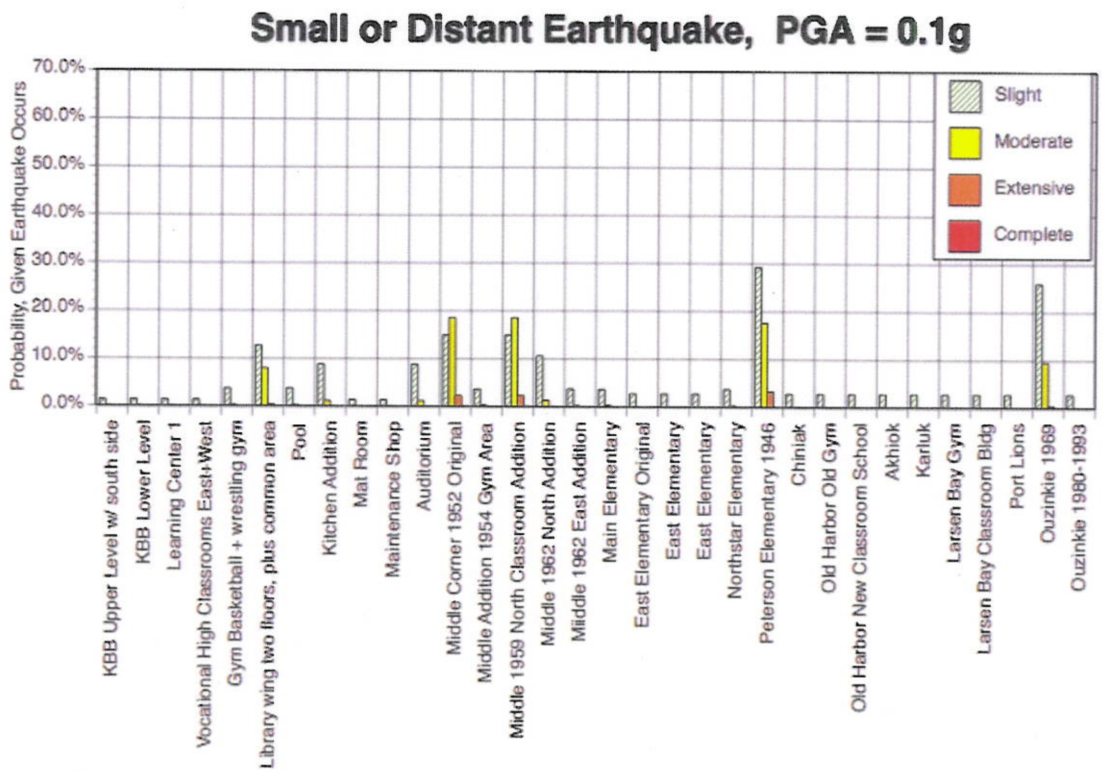


*Figure 5-1. Building Performance: PGA = 0.1g Scenario Earthquake*

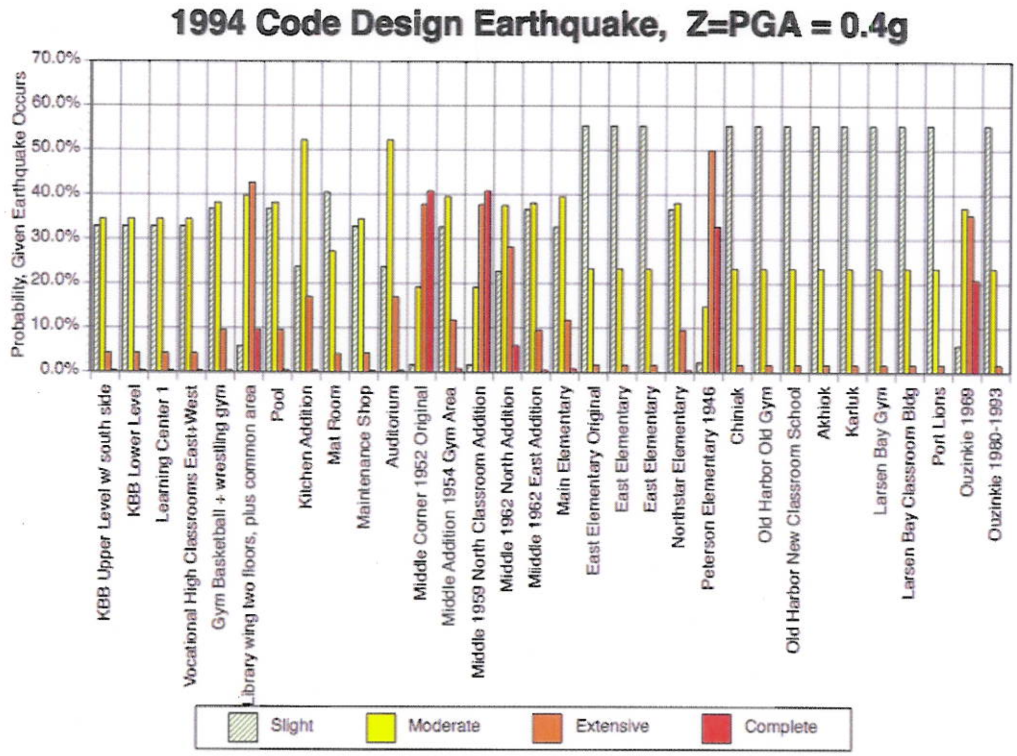


*Figure 5-2. Building Performance: PGA = 0.4g Scenario Earthquake*

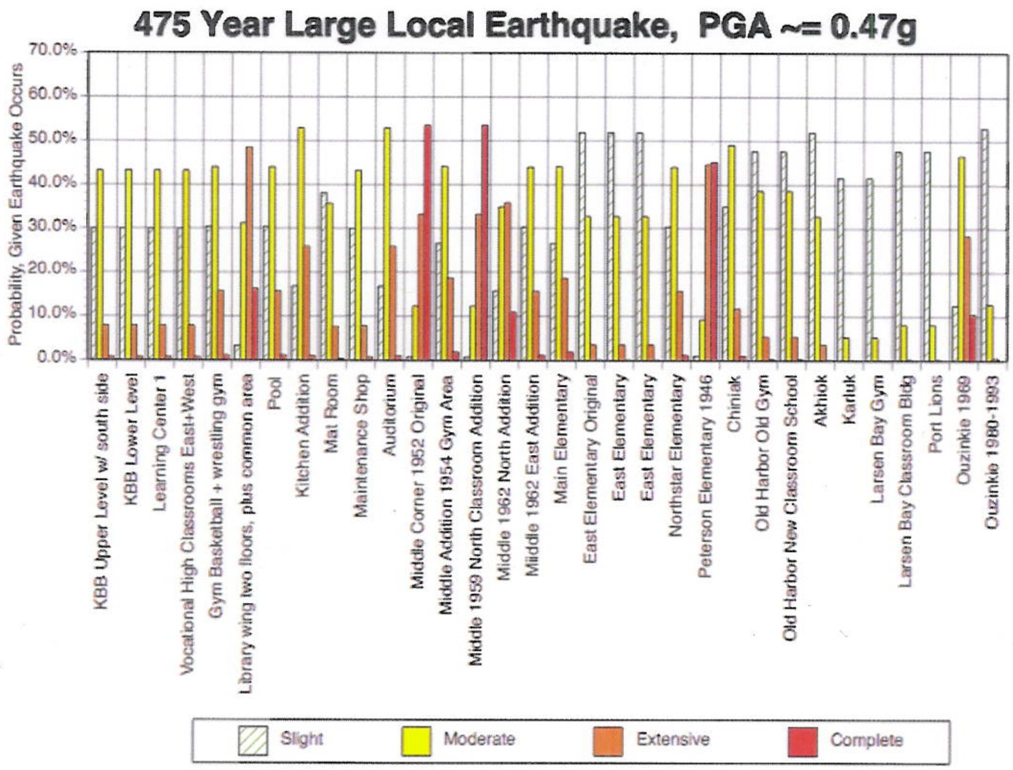


*Figure 5-3. Building Performance: 475 Year Scenario Earthquake*

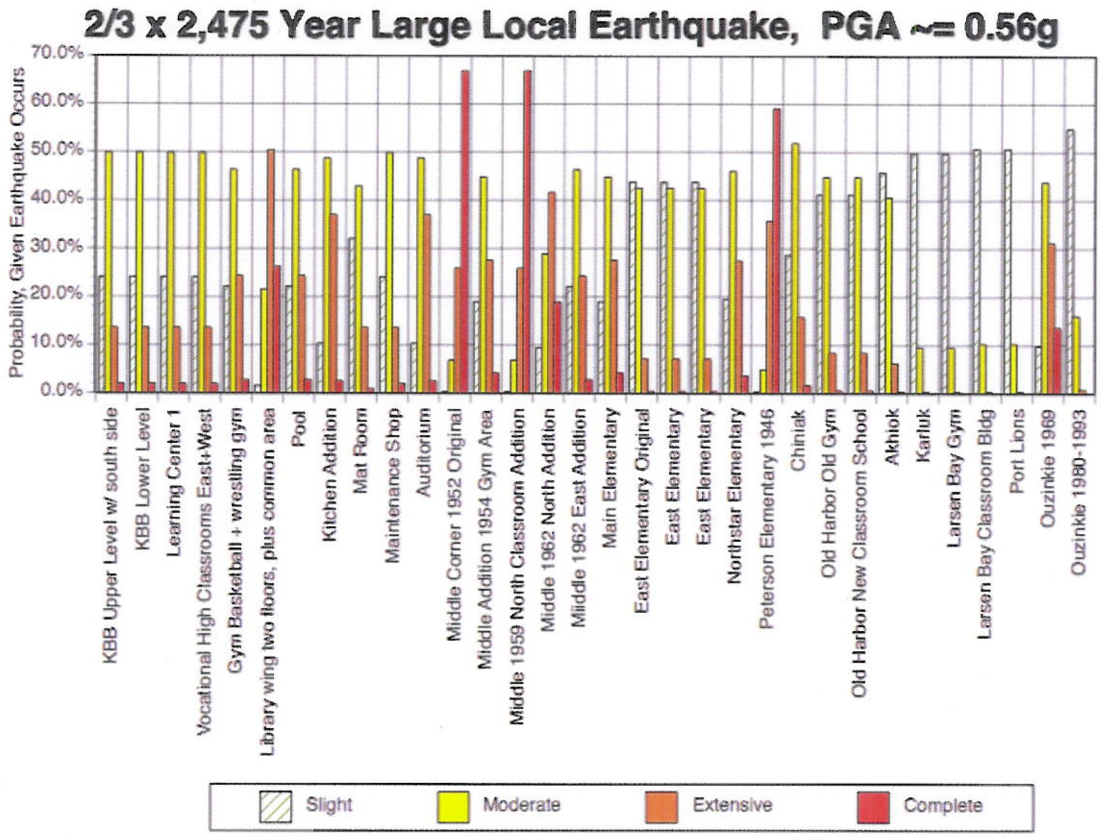


*Figure 5-4. Building Performance: 2/3 of 2.475 Year Scenario Earthquake*

# 6.0 Benefit Cost Analyses

Based on the structural engineering evaluations and cost estimates in this report, benefit cost analyses were performed to examine the cost effectiveness of the proposed seismic mitigation projects.

The analyses were performed using the analytical tools and models required by FEMA (FEMA Benefit Cost Toolkit 2.0, January 2005). A description of these models and results for the upgrade of the Middle School are provided in Goettel (2006).

Analyses were performed for each of the five building structural upgrades described in this report. For the High School gym, two alternatives were examined (upgrade the complete building for PGA = 0.47g, or just decouple the non-structural masonry walls from the rest of the building). The results for each of the five analyses are provided in Table 6-1.

| School Building | Seismic Upgrade Cost | Project Benefits | Benefit Cost Ratio |
|---|---|---|---|
| Middle School | $1,251,510[11] | $8,132,160 | 6.50 |
| Ouzinkie (1969 portion) | $149,000 | $975,410 | 7.55 |
| Peterson (1946 portion) | $508,500 | $1,862,173 | 3.66 |
| High School Library Wing | $464,500 | $4,452,695 | 9.59 |
| High School Gym (Essential upgrade) | $410,300 | $416,768 | 1.02 |
| High School Gym (Decouple walls) | $40,000 | $250,369 | 7.26 |
| Non structural equipment and items | $348,480 | - | - |
| Total (with HS essential upgrade) | $3,132,290 | $15,839,206 | 5.06 |

*Table 6-1. Results of Benefit Cost Analyses – Structural Upgrades*

An upgrade with a BCR greater than 1 has more benefits than costs and should be pursued by KIB. With this in mind, all of the upgrade projects are cost effective, although some clearly more so than others.

With regards to the High School Gym upgrade, two options were considered. In the first option, the existing non-structural masonry walls are substantially upgraded into reinforced concrete shear walls, and the building's existing steel braced frame and roof are upgraded to make it stiffer and stronger to resist smaller earthquakes, and provide about 20% more capacity than the existing building to resist larger earthquakes. By ignoring the benefits that accrue that the Gym could be considered an emergency shelter post-earthquake for people displaced from other damaged structures, the BCR is 1.02. This shows that modest upgrades (about 20% more strength) provide only modest improvement, even given the very high seismicity in Kodiak. The alternative choice, which is to decouple the weak non-structural walls from the main lateral force resisting system, appears to offer a better BCR (7.26 versus 1.02), but would provide no improvement in using the Gym as an emergency shelter. We selected the more expensive

[11] Includes relocation costs during construction where occupancy will likely be impacted during construction.

"essential upgrade" for the recommended upgrade of the Gym, and this is listed in the Executive summary of this report.

A cost of $348,480 is listed for the non-structural upgrades at all the schools except the Middle School, and an additional $10,966 included in the Middle School cost estimate (covers 990 items). Table 6-2 lists the items needing anchorage / restraint at each school, including upgrade costs. The BCR in the Totals in Table 6-1 includes the costs for these non-structural upgrades but no benefits for schools without structural upgrades, so the Total BCR is actually somewhat higher than those listed in Table 6-1.