QuakeManager: A Software Framework for Ground Motion Record Management, Selection, Analysis and Modification

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ABSTRACT :

QuakeManager is an integrated software framework and database information system for the management, selection, modification and analysis of ground motion records. The QuakeManager Suite consists of a number of ground motion modification and analysis technologies built around a powerful ground motion database management system. The main objective of the QuakeManager Suite is to provide users with state-of-the-art ground motion selection, modification and analysis tools, while simultaneously providing utilities for file management, import and export of data, unit conversion, and other time-consuming tasks. By integrating several functionalities in one easy-to-use program, the process of ground motion selection and analysis can be performed more effectively. The framework was designed using modern software design concepts and makes heavy use of object-oriented software design and design patterns. This resulted in a clean design that is easy to maintain, modify and extend. The software has a highly interactive and configurable user interface that has a familiar feel and is easy to learn. These interactive features combined with the advanced capabilities of QuakeManager will make it easier for earthquake engineering professionals, students and researchers to find and utilize ground motion data.

KEYWORDS: 3-6 keywords for indexing purposes (spaced by commas)

1. INTRODUCTION

The use of ground motion data has been increasing worldwide due to several factors. These factors include the increasing availability of ground motion record due to increased instrumentation and dissemination, and increased interest from the earthquake engineering and education community in using linear and nonlinear response history analysis in seismic analysis and design. QuakeManager is a software framework that has been developed to address those needs and provide features for the management, selection, analysis and modification of ground motion records. A snapshot of the software can be viewed in Figure 1.

1.1. Ground Motion Record Formats

In recent years, a large number of records have been made publicly available through online databases in the United States, Japan and other countries (e.g. Cosmos and PEER online database). While these online databases vary tremendously in terms of supported features, number of available records, type of access -- some require user registration -- they collectively provide a wealth of ground motion records that can be searched, accessed, downloaded and used in ground motion studies and seismic analysis and design. One of the issues that a user is faced with when using records that come from various databases and multiple agencies in different countries is the fact that there is no standard ground motion format that is widely used. Many ground motion formats currently exist, that each have different header format and content, and different data format and units. This can become problematic when multiple records from multiple sources need to be opened, processed, analyzed or compared. While there are software utilities that can convert between some common file formats, this only provides a partial solution.

1.1. Available Computer Programs

The user of ground motion records typically needs to use a large number of specialized and general purpose applications in order to perform relatively simple tasks such as displaying and comparing ground motion histories, searching for records that satisfy certain criteria or match a spectral shape, processing records to perform baseline correction or filtering, and computing ground motion properties and linear and/or nonlinear spectra. While a large number of computer programs, public and commercial, are available, these programs do not provide users with the ability to perform all of these functions in an integrated fashion. The QuakeManager software was developed to address the above issues, and was designed as an extensible and modular software framework.

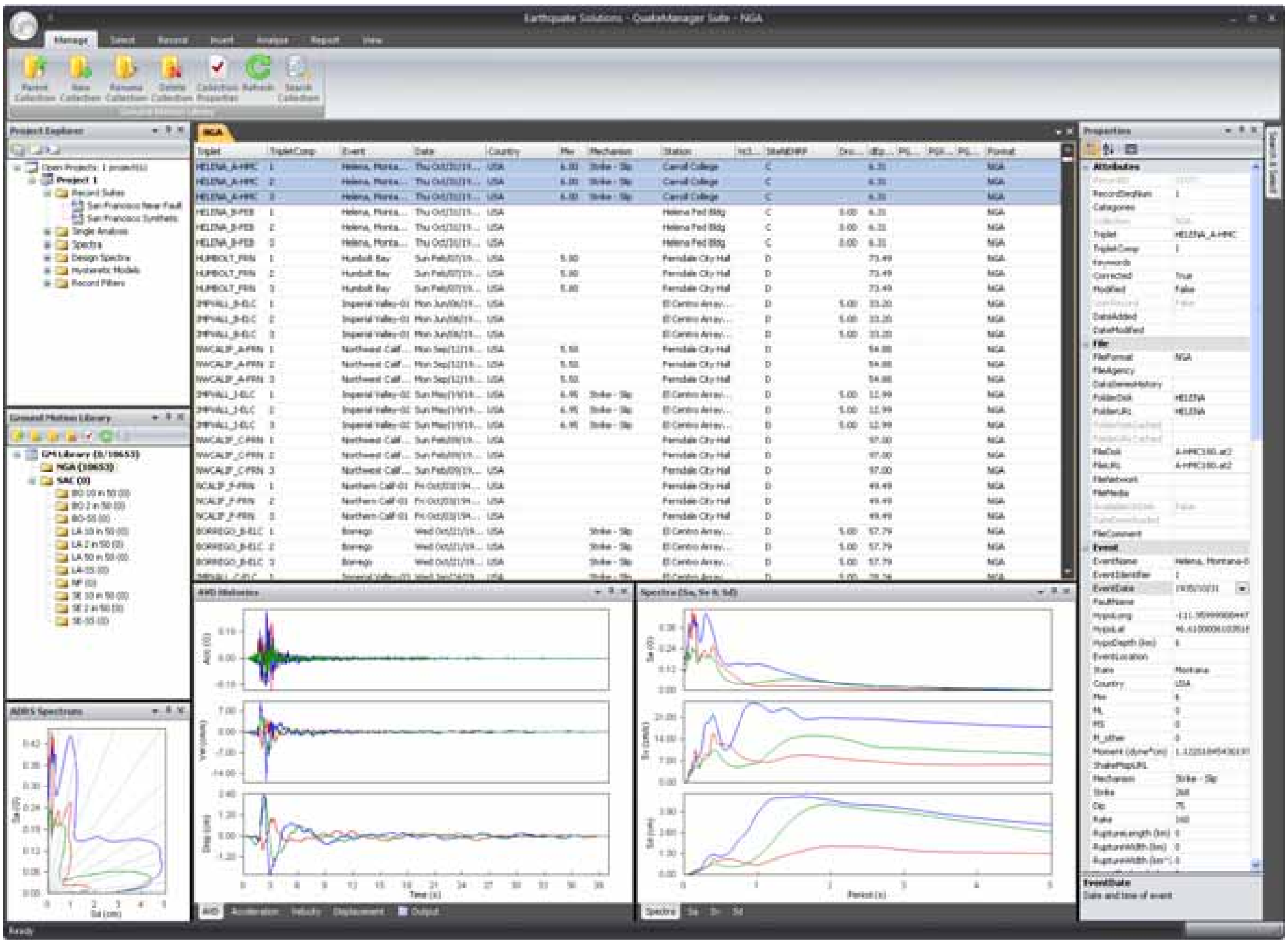


Figure 1 Main QuakeManager user interface window

2. MAIN SOFTWARE COMPONENTS

QuakeManager was designed as a framework that supports common functions and operations needed for the management and analysis of ground motion records. This provides a basic infrastructure that supports more advanced functions that can be added over time. The software was fully developed in C++ under Microsoft Visual C++ 2005. The design of the framework was conceptually and functionally separated into several components. This has several benefits in conceptual design as well as actual software development. Several components have already been developed. In the future, these components will be developed further, and more components will be added. The following is a the list of current components:

2.1. QuakeManager

The QuakeManager component provides most of the infrastructure that is needed by other components for accessing and manipulating ground motion records. It includes a database for management of ground motion records, and a set of infrastructure technologies that are used by other components.

A relational database is used to store important information about each record. The database has several tables that reflect the properties of each record, and currently collectively contain about 130 different fields, which may increase since the database is still under development. Those properties are displayed in the "Properties Pane" whenever a record is selected. The property categories reflect the different tables and consist of:

1. Record Attributes: General record attributes
2. File: Information and attributes of the actual data file
3. Event: Event information
4. GeoLocation: Station information
5. EventGeoLocation: Relationship between Event and Station such as epicentral distance, azimuth, etc.
6. Sensor: Recording sensor information
7. Array: Information about seismic array to which this sensor belongs.
8. Processing: Record processing information
9. Data Series: Data series properties (PGA, PGV, PGD, in addition to many other record parameters including intensity measures).
10. Raw Series: Information about the raw (uncorrected) data.
11. Spectral Values: Spectral acceleration, velocity and displacement values stored for quick searching and selection of ground motion records.

The QuakeManager component includes multiple technologies that are essential for the proper management and manipulation of ground motion records. These include:

1. Ground motion database
2. Data structures for representing ground motion records. The data structure used is based on the Cosmos tagged data format (*Evans et al 2007*).
3. Support of different ground motion formats. Several ground motion formats are fully supported, which means that the whole file is interpreted and imported into the program. All of the header fields are automatically imported into the database, which makes it possible for QuakeManager to automatically generate ground motion database by parsing the file headers. This is particularly useful when metadata information about the records is not separately available. The Cosmos XML format is also supported.
4. Unit awareness/conversion capability. In order to manipulate and process records and data of various units seamlessly and uniformly, a unit type is affiliated with each data field or series. This allows the conversion of data to any unity system on the fly, and allows the user to select the preferred working unit system irrespective of the original units.
5. Infrastructure code for manipulating data series and performing algebraic and data and signal processing operations.

2.2. QuakeSelect

Provides database search and selection tools. This functionality can be accessed from the "Search & Select Pane", which provides the ability to search for records based on numerous criteria including event name, magnitude and distance, in addition to numerous other event, station and record parameters. It is also possible to search for records that best match a certain target spectrum. Several criteria can be used to determine the way the spectral match is computed.

2.3. QuakeSpec

Includes a set of technologies for computing linear and nonlinear spectra of a ground motion record. Several types of nonlinear spectra can be computed including constant strength, constant ductility and constant damage spectra. These capabilities are similar to those provided by the computer program Bispec (*Hachem 1999*, and *Hachem 2004*), but with more extended features, hysteretic models and types of spectra.

2.4. QuakeMatch

This component performs spectral modification of a record to match a design spectrum. This component is currently under development.

3. USER INTERFACE

In order to fully utilize the software capabilities and maximize user productivity, a significant effort was invested in designing a graphical user interface that is modern, powerful, efficient, yet is intuitive and easy to use. The user interface draws on the latest developments in user-interface design, such as using moveable and resizable panes, using an Office-like Ribbon interface, providing the ability to browse record database information and display record histories, as well as the ability to instantly compute record properties including spectral values (Figure 2). The workspace is fully configurable and the various panes can be arranged and sized in a multitude a ways. Panes can be docked, floated or hidden, which maximizes space use and allows the use of multiple screens if desired (Figure 3). An emphasis was placed on visual output and immediate feedback from the user interface. Multiple docked panes allow the instantaneous plotting of the selected records' acceleration, velocity and displacement histories. Other panes show the various spectral quantities in various formats, or other analytical quantities such as Fourier spectra and Power Spectral Density.

The main pane displays a list of current records, which can be all the records belonging to a given database collection, a filtered set of records, or the result of a search for specified parameters or to best match a target spectrum. The columns headers contain a number of commonly used fields, which can be customized by adding or removing columns from an available list of about 100 different fields. Figure 4 shows two different ways for choosing the column fields, a field chooser dialog, and column selection pop-up menu.

Figure 5 shows the ability to group the records by any available column field. The grouping can be nested and each field can be sorted in an ascending or descending order.

The search capability is available through the "Search & Select" pane, which is hidden by default (set to Auto Hide), but can be easily displayed when needed. A snapshot of typical search criteria and results is shown in Figure 6.

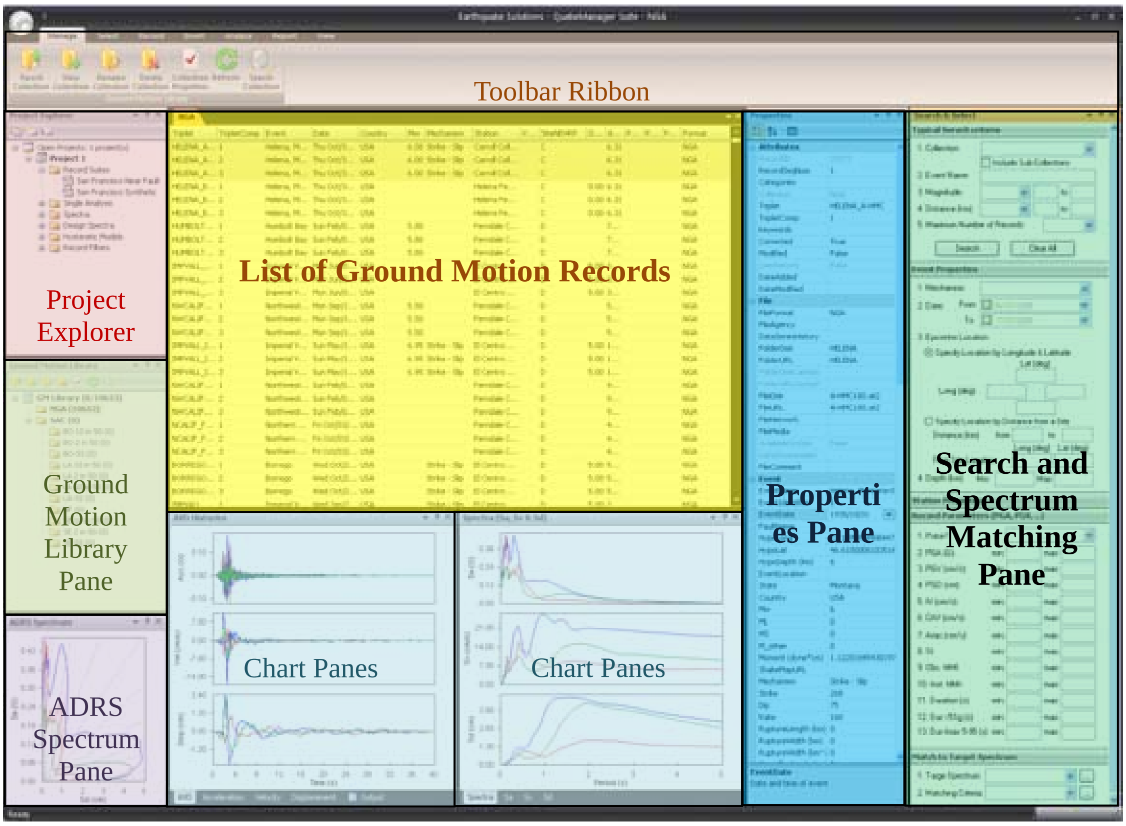


Figure 2 Main QuakeManager interface components including the search panel

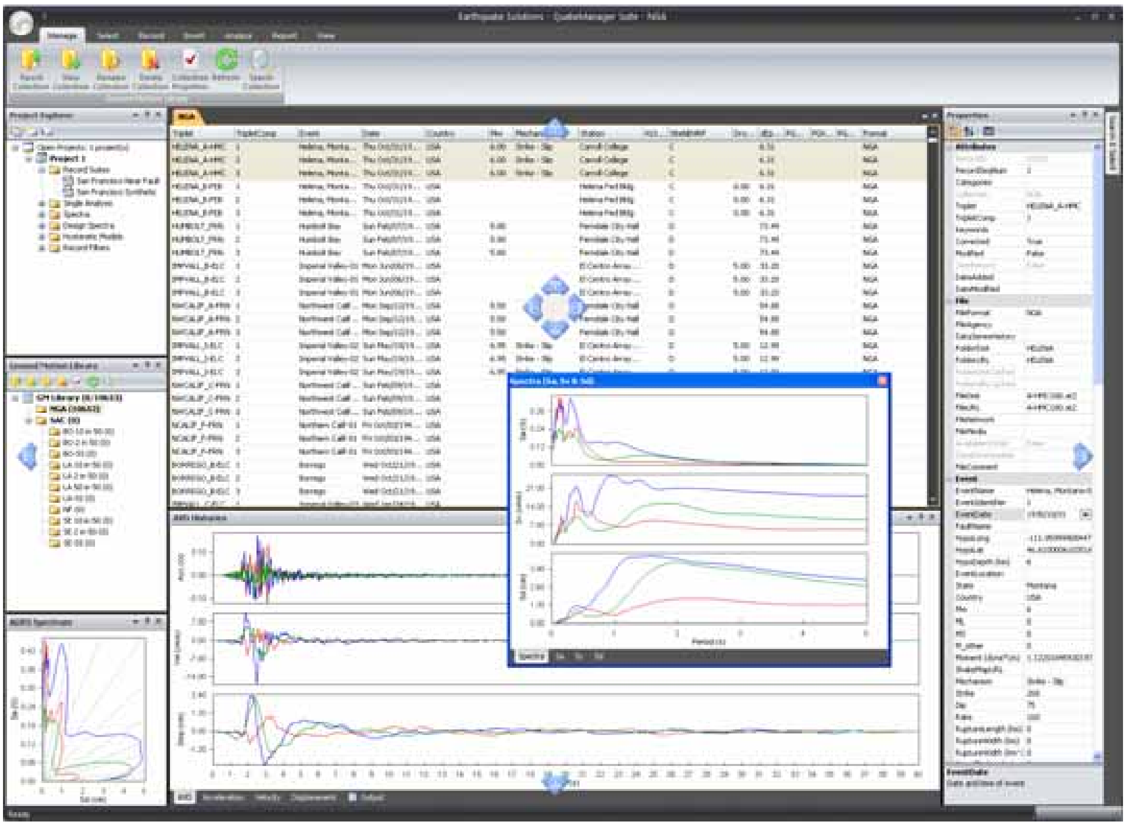


Figure 3 QuakeManager pane floating and advanced docking features

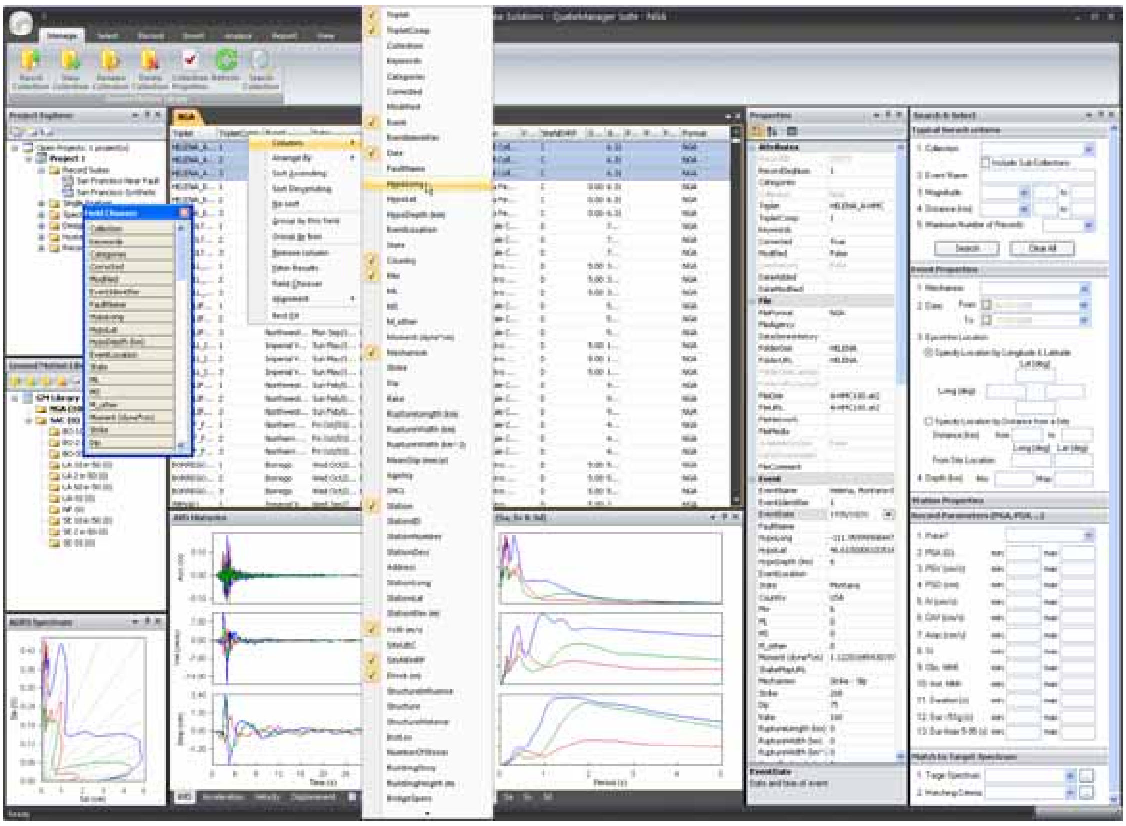
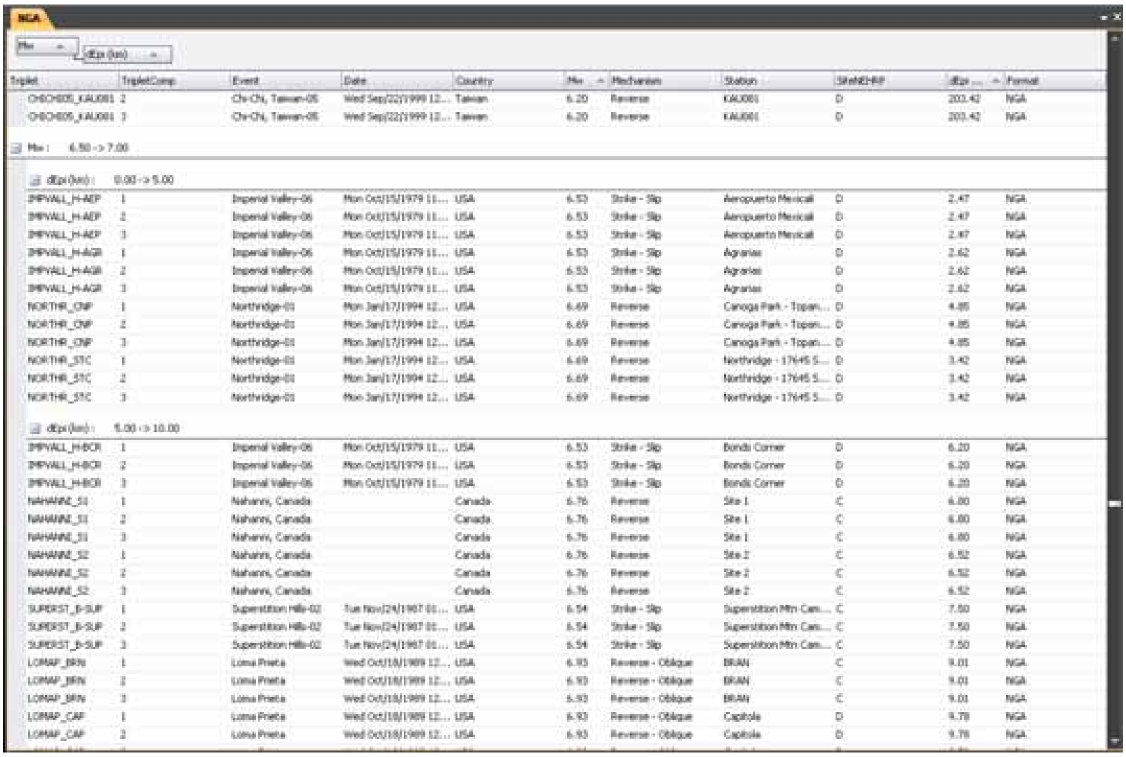


Figure 4 Column field selections and field chooser features



Mw | dEpi (km)

Triplet	TripletComp	Event	Date	Country	Mw	Mechanism	Station	SiteNEHRP	dEpi ...	Format
CHICHI05_KAU081	2	Chi-Chi, Taiwan-05	Wed Sep/22/1999 12...	Taiwan	6.20	Reverse	KAU081	D	203.42	NGA
CHICHI05_KAU081	3	Chi-Chi, Taiwan-05	Wed Sep/22/1999 12...	Taiwan	6.20	Reverse	KAU081	D	203.42	NGA
Mw : 6.50 -> 7.00										
dEpi (km) : 0.00 -> 5.00										
IMPVALL_H-AEP	1	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Aeropuerto Mexicali	D	2.47	NGA
IMPVALL_H-AEP	2	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Aeropuerto Mexicali	D	2.47	NGA
IMPVALL_H-AEP	3	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Aeropuerto Mexicali	D	2.47	NGA
IMPVALL_H-AGR	1	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Agrarias	D	2.62	NGA
IMPVALL_H-AGR	2	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Agrarias	D	2.62	NGA
IMPVALL_H-AGR	3	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Agrarias	D	2.62	NGA
NORTHR_CNP	1	Northridge-01	Mon Jan/17/1994 12...	USA	6.69	Reverse	Canoga Park - Topan...	D	4.85	NGA
NORTHR_CNP	2	Northridge-01	Mon Jan/17/1994 12...	USA	6.69	Reverse	Canoga Park - Topan...	D	4.85	NGA
NORTHR_CNP	3	Northridge-01	Mon Jan/17/1994 12...	USA	6.69	Reverse	Canoga Park - Topan...	D	4.85	NGA
NORTHR_STC	1	Northridge-01	Mon Jan/17/1994 12...	USA	6.69	Reverse	Northridge - 17645 S...	D	3.42	NGA
NORTHR_STC	2	Northridge-01	Mon Jan/17/1994 12...	USA	6.69	Reverse	Northridge - 17645 S...	D	3.42	NGA
NORTHR_STC	3	Northridge-01	Mon Jan/17/1994 12...	USA	6.69	Reverse	Northridge - 17645 S...	D	3.42	NGA
dEpi (km) : 5.00 -> 10.00										
IMPVALL_H-BCR	1	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Bonds Corner	D	6.20	NGA
IMPVALL_H-BCR	2	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Bonds Corner	D	6.20	NGA
IMPVALL_H-BCR	3	Imperial Valley-06	Mon Oct/15/1979 11...	USA	6.53	Strike - Slip	Bonds Corner	D	6.20	NGA
NAHANNI_S1	1	Nahanni, Canada		Canada	6.76	Reverse	Site 1	C	6.80	NGA
NAHANNI_S1	2	Nahanni, Canada		Canada	6.76	Reverse	Site 1	C	6.80	NGA
NAHANNI_S1	3	Nahanni, Canada		Canada	6.76	Reverse	Site 1	C	6.80	NGA
NAHANNI_S2	1	Nahanni, Canada		Canada	6.76	Reverse	Site 2	C	6.52	NGA
NAHANNI_S2	2	Nahanni, Canada		Canada	6.76	Reverse	Site 2	C	6.52	NGA
NAHANNI_S2	3	Nahanni, Canada		Canada	6.76	Reverse	Site 2	C	6.52	NGA
SUPERST_B-SUP	1	Superstition Hills-02	Tue Nov/24/1987 01...	USA	6.54	Strike - Slip	Superstition Mtn Cam...	C	7.50	NGA
SUPERST_B-SUP	2	Superstition Hills-02	Tue Nov/24/1987 01...	USA	6.54	Strike - Slip	Superstition Mtn Cam...	C	7.50	NGA
SUPERST_B-SUP	3	Superstition Hills-02	Tue Nov/24/1987 01...	USA	6.54	Strike - Slip	Superstition Mtn Cam...	C	7.50	NGA
LOMAP_BRN	1	Loma Prieta	Wed Oct/18/1989 12...	USA	6.93	Reverse - Oblique	BRAN	C	9.01	NGA
LOMAP_BRN	2	Loma Prieta	Wed Oct/18/1989 12...	USA	6.93	Reverse - Oblique	BRAN	C	9.01	NGA
LOMAP_BRN	3	Loma Prieta	Wed Oct/18/1989 12...	USA	6.93	Reverse - Oblique	BRAN	C	9.01	NGA
LOMAP_CAP	1	Loma Prieta	Wed Oct/18/1989 12...	USA	6.93	Reverse - Oblique	Capitola	D	9.78	NGA
LOMAP_CAP	2	Loma Prieta	Wed Oct/18/1989 12...	USA	6.93	Reverse - Oblique	Capitola	D	9.78	NGA

Figure 5 Grouping and sorting of ground motion records by various fields

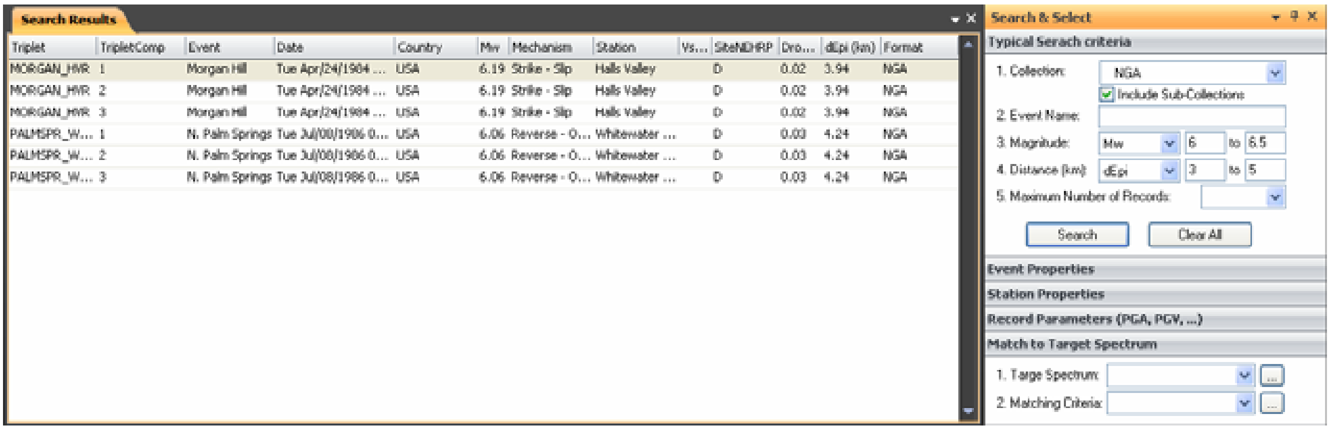


Figure 6 Example of a search operation and the resulting records

4. CURRENT STATUS AND FUTURE PLANS

The development of the QuakeManager component and the major infrastructure components is essentially completed. This makes the software fully useable for managing, browsing, and searching for records. Development is continuing on other components in order to introduce higher-level functionality that takes advantage of the developed infrastructure.

5. CONCLUSION

A software framework and user interface was developed for the management, selection, modification and analysis of ground motion records. This software introduces a integrated and dynamic approach for using ground motion records that increases productivity and provides new capabilities that are not available in other ground motion analysis software. The major infrastructure and user interface components have been developed, and development is continuing on more higher-level record modification and analysis features.

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