

GIS DATA CURATION AND WEB MAP APPLICATION FOR LA BREA TAR PITS  
FOSSIL OCCURRENCES IN LOS ANGELES, CALIFORNIA

by

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## **DEDICATION**

I dedicate this thesis to my husband, John, my parents, Guerry and Diane, and my sister, Angie, as well as my dog, Pinky, for their love and encouragement.

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## LIST OF ABBREVIATIONS

AGOL	ArcGIS Online
API	Application Programming Interface
APRMI	ArchaeoPaleo Resource Management, Inc
CSS	Cascading Style Sheet
CSV	Comma Separated Variable
GIS	Geographic Information System
GIST	Geographic Information Science and Technology
HC	Hancock Collection
HTML	Hypertext Markup Language
LACMA	Los Angeles County Museum of Art
MXD	Map Exchange Document
NHM	Natural History Museum of Los Angeles County
P23	Project 23
REST	Representational State Transfer
SSI	Spatial Sciences Institute
URL	Uniform Resource Locator
USC	University of Southern California
USGS	U.S. Geological Survey
WGS84	World Geodetic System 1984

## ABSTRACT

The occurrence of asphaltic fossil localities within and surrounding the Page Museum at the La Brea Tar Pits in Los Angeles, California is extensive and has been recorded for decades as non-spatial data collected in a non-spatial database. The motivation for this project stemmed from the author's time as a volunteer at the Page Museum over the course of one year. The Page museum staff requested an efficient way to cartographically display fossil data to assist staff with visualizing the taphonomy of fossils. At the time of this study, this thesis is the first GIS project that the Page Museum had ever supported for mapping of fossils. Most current literature describing fossil-related web GIS applications reports data displayed at small-scales, and exact locations of fossils are not generally provided through the applications. The main objectives of this thesis project were to design and implement a fossil excavation spatial database, digitally curate data that previously only existed in paper form, display fossil data in an interactive web GIS application, and develop a framework to support spatial analysis and live data feeds of fossil data in the future. As part of this thesis project, known fossil localities were digitized from a La Brea Tar Pits survey map maintained since 1913. The fossil specimen location records from the museum's existing database were then joined to those newly digitized features to support the development of the spatial database of existing fossil localities within the park. The fossil features contained in the spatial database were then published to the web through the web GIS application also developed as part of thesis research, as a proof of concept intended to guide future Page Museum GIS projects. Visualizing the location of fossils is intended to help better communicate the paleontology of the La Brea Tar Pits to the museum staff, and eventually to the general public. Lastly, it is anticipated that this web GIS application will contribute to the current literature on documentation and visualization of extensive fossil deposits.

## CHAPTER 1: INTRODUCTION

In the heart of Los Angeles the vast paleontological treasure of the George C. Page Museum of La Brea Discoveries, the La Brea Tar Pits, can be found nestled between high-rise buildings and busy streets (Page Museum 2015a). This pre-historic treasure consists of an exhumed collection of over 3 million fossils, and possibly millions more yet to be unearthed below the surface within the local asphalt and asphalt-rich sediments (Figure 1).

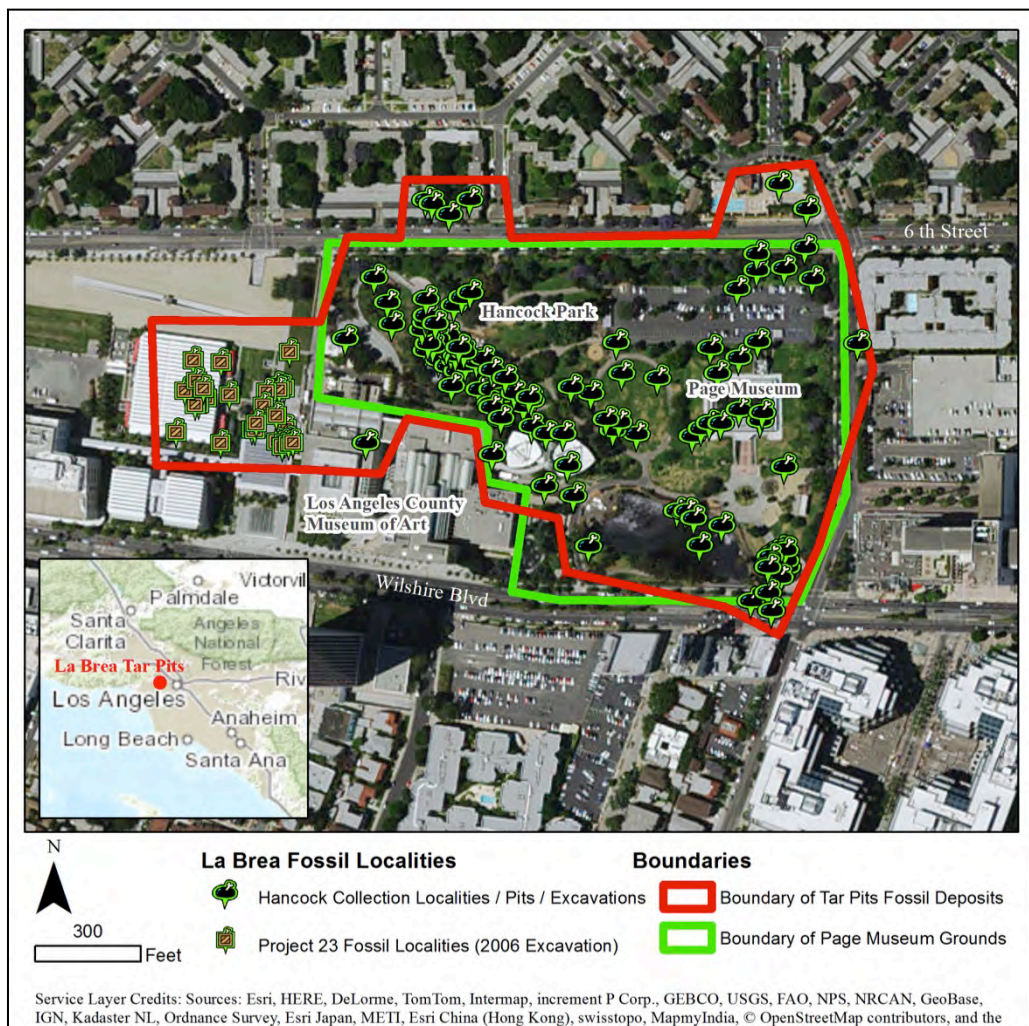


Figure 1 La Brea Tar Pits location map

The mission of the George C. Page Museum of La Brea Discoveries and the Natural History Museum (which manages the Page Museum) is to protect and study the fossils found at the La Brea Tar Pits (Page Museum 2015b). Since the early 1900's, paleontologists and volunteers at the museum have diligently recorded the locations, positions, and other relevant characteristics such as, age, gender, and condition of the fossils excavated at the La Brea Tar Pits. The fossil data is continuously compiled by museum staff into the non-spatial database KE EMu (KE Software 2015a), software, which is currently used by museums across the world (KE Software 2015b). At the time this study was initiated the location data associated with this non-spatial database was contained mostly on a single copy of a historical paper map maintained since 1913 (Noble 1913). It would be a profound loss if this paper map were to be damaged or lost. Thus, two of the author's primary goals were to create a spatial database design and implementation for the museum collection staff to support spatial visualization of the collections in GIS-related projects in a web application, and to preserve the geospatial data contained within the paper map within the new spatial database. Additionally, it is anticipated that spatial visualization of fossil excavation data may aid daily curation activities by helping staff easily view and check their data to spot trends and outliers. Significantly, this project has the distinction of being the first spatial database and interactive web mapping application of the La Brea localities and specimen data ever created (Aisling Farrell, per comm, 2013).

This chapter provides a description of this thesis project scope, motivation, and methodology for creating the La Brea Tar Pits web GIS application. Section 1.1 contains an overview of the web application project, and section 1.2 presents the motivation for the web application. Section 1.3 outlines the methodology for building the La Brea Tar Pits application,



while section 1.4 summarizes the chapters and structure of this remainder of this thesis manuscript.

## **1.1 Project Overview**

This thesis study consisted of two initiatives aimed specifically at supporting future La Brea Tar Pits fossil data collection and visualization by the Page Museum staff: (1) an Esri geodatabase was designed and implemented for efficient compilation of recorded locations of the La Brea Tar Pits fossil pits and individual fossil samples within specific pits, and (2) utilizing Esri ArcGIS version 10.2.1<sup>1</sup>, the fossil records within the new geodatabase were published as feature layers via Esri ArcGIS Server 10.2.1<sup>2</sup> and included in an innovative, interactive pilot web GIS mapping application.

At present, the geodatabase created for this project can be updated from the museum staff's current KE EMu database via SQL queries, providing the added benefit of digitally spatializing the fossil locations. The spatial support provide by a geodatabase allows fossils to be easily viewed in GIS layers as two dimensional (2D) or three-dimensional (3D) representations that provide a new way for the museum paleontologists to answer important questions about the taphonomy of the fossils and the shape of a given fossil deposit, as well as to easily track the extent of their subsurface excavations. In the context of this thesis, taphonomy is defined as how the individual specimens were fossilized, meaning the environmental conditions that affected the preservation (Shipman 1981, Spencer et al 2003).

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<sup>1</sup> Esri. 2015. "Mapping\_and\_visualization\_in\_ArcGIS\_for\_Desktop." Esri. Accessed August 22, 2015. [http://resources.arcgis.com/en/help/main/10.2/#/Mapping\\_and\\_visualization\\_in\\_ArcGIS\\_for\\_Desktop/018q000000400000/](http://resources.arcgis.com/en/help/main/10.2/#/Mapping_and_visualization_in_ArcGIS_for_Desktop/018q000000400000/).

<sup>2</sup> Esri. 2015. "What is ArcGIS for Server." Esri. Accessed August 22, 2015. [http://resources.arcgis.com/en/help/main/10.2/#/What\\_is\\_ArcGIS\\_for\\_Server/01540000037p000000/](http://resources.arcgis.com/en/help/main/10.2/#/What_is_ArcGIS_for_Server/01540000037p000000/).

Each record in the geodatabase corresponds to a unique fossil record. Each fossil record can be published as a point on a web map within the pilot web GIS mapping application, which also contains an overview of all fossil pits in the Page Museum park as well as other important local data, including topography, water bodies, streams, and gas and oil vents within the park in 1913 (Turner 2006, Quinn et al 2000, Noble 1913). Many older pits, water bodies, streams, and oil and gas vents today covered by grass, buildings, and parking lots can now be visualized in the web GIS mapping application. In its current stage of development, the main function of the web GIS application is to allow a museum staff user to select a pit and view information pertaining to the pit, such as age, number of fossils, and types of fossils, alongside a 3D visualization of the orientation of the fossil specimens before excavation. In the context of this thesis, a pit is defined as an asphaltic fossil deposit excavation and the terms pit and fossil excavation are “synonymous” (Woodard and Marcus 1973).

## **1.2 Motivation**

The main motivation for development of a spatial database (geodatabase) and the pilot web GIS application of the La Brea Tar Pits is to support the future development of a web GIS application that will keep visitors coming back to the museum by encouraging hands-on interaction with the application through visual exploration of the pits around the museum grounds. The Page Museum exhibits currently have no digital content. In order to appeal to future generations of visitors, it is important for the museum to start using the power of digital content such as interactive web maps. Moreover, as previously stated, this project has the distinction of being the first attempt at creating a spatial database (geodatabase) of fossil locations connected to a web GIS application (Aisling Farrell, per comm, 2013).

It is intended for this pilot web GIS application to be a starting point for future web applications that will be connected to a geodatabase updated nightly with the latest La Brea Tar Pit fossil finds from a given day. The intent is that this web application could eventually provide visitors with daily updates on the museum's predominantly 1970's era exhibits. The web application would be a method to communicate to the museum visitors the large numbers of fossils found on a daily basis. The main motto of the museum found on the Page Museum of La Brea Tar Pits home page is "discoveries made daily" (Page Museum 2015a). So with every visit it may be observed that the count of fossils has increased and view where the latest fossils came from in the live web GIS application. The timely communication of the La Brea Tar Pit finds to the public is very important to invigorate the public's interest in paleontology and the progress that this field of study has contributed to the understanding of climate change (Akersten, Shaw, and Jefferson 1983). The museum staff believe that future public, interactive GIS-based exhibits would greatly encourage museum visitors' interest in paleontology, geology, and even GIS, which ultimately might help the museum gain more funding opportunities from donors.

In turn, bringing awareness of the presence of the fossils in and around the park will emphasize the need to preserve these fossils. The web GIS application will show visitors that fossils can be found as far as a half-mile away in the heart of Los Angeles (Figure 2).

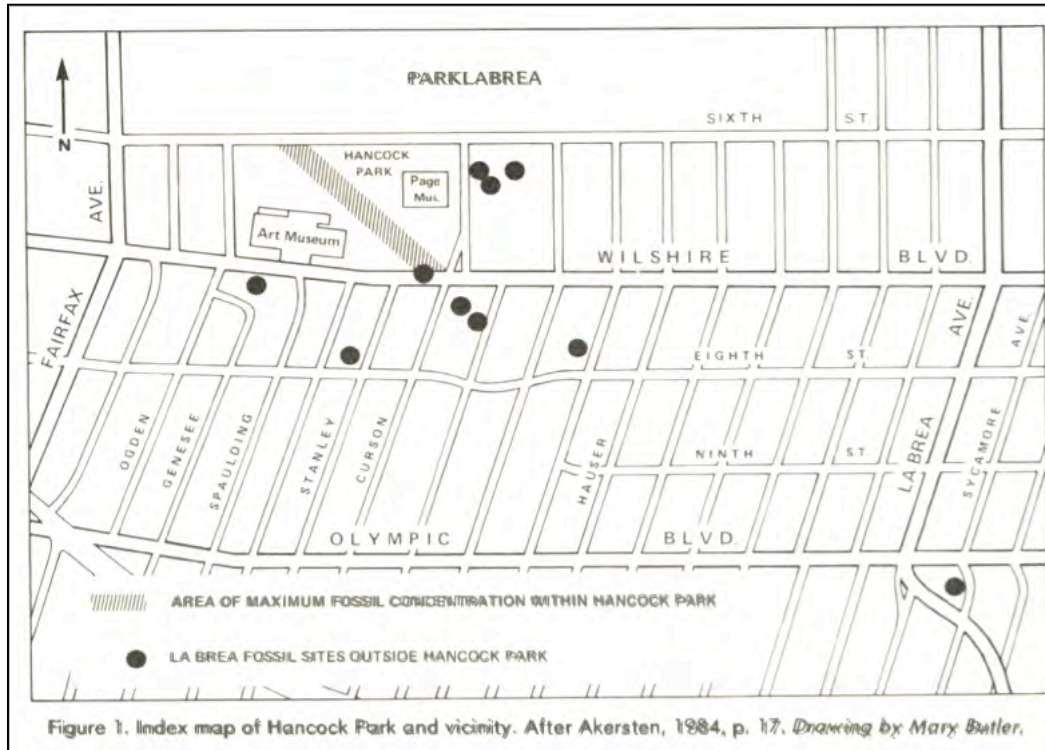


Figure 2 Areas with maximum fossil concentration and fossil sites that have been discovered during construction activities in the vicinity of Hancock Park (Shaw & Quinn, 1986)

Increasing public awareness of fossil locations in and surrounding the park will help ensure that the well-preserved asphalt covered fossils of the La Brea Tar Pits are protected from damage inherent at construction sites near fossil localities. As previously stated, the fossils of Rancho La Brea provide significant information on the climate in Los Angeles during the Pleistocene Epoch that is important for the understanding of past and present climates (Akersten, Shaw, and Jefferson 1983). For example, using the fossils scientists can conduct radiocarbon dating studies and isotopic studies to learn about the diet of the La Brea mammals, which offers important clues about the climate during the Pleistocene Epoch (Coltrain et al. 2004).

Another knowledge gap that this thesis study addresses includes the lack of development of large-scale GIS applications for visualizing fossil finds published in the literature. This web GIS application is relatively large scale and high resolution compared with previously published

studies, the intent being that fossil occurrence information can be visualized at the meter and centimeter scale.

### **1.3 Methodological Overview**

The geodatabase and web GIS application were created using the Esri ArcGIS suite of software including ArcGIS Desktop 10.2.1<sup>3</sup>, ArcGIS Server 10.2.1<sup>4</sup>, ArcGIS Online<sup>5</sup>, and ArcGIS for JavaScript API<sup>6</sup>. The geodatabase was designed and developed using Microsoft SQL Server 2008 R2<sup>7</sup>.

The schema for the geodatabase was developed based on the museum's collections database KE EMu (KE Software 2015a) and was minimally changed so that geodatabase updates from KE EMu can be easily made. It was a requirement of the Page Museum staff that the KE EMu database be kept as the main database and the geodatabase simply be an extension of the existing database. In addition, a museum staff member reviewed the database schema that was developed as part of this thesis effort.

The geodatabase creation step consisted of database schema development, database creation, fossil data editing, fossil data loading, and preparation for publishing fossil records as feature services to be integrated into the web GIS application. The museum's 1913 paper survey

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<sup>3</sup> Esri. 2015. "Mapping\_and\_visualization\_in\_ArcGIS\_for\_Desktop." Esri. Accessed August 22, 2015. [http://resources.arcgis.com/en/help/main/10.2/#/Mapping\\_and\\_visualization\\_in\\_ArcGIS\\_for\\_Desktop/018q00000004000000/](http://resources.arcgis.com/en/help/main/10.2/#/Mapping_and_visualization_in_ArcGIS_for_Desktop/018q00000004000000/).

<sup>4</sup> Esri. 2015. "What is ArcGIS for Server." Esri. Accessed August 22, 2015. [http://resources.arcgis.com/en/help/main/10.2/#/What\\_is\\_ArcGIS\\_for\\_Server/01540000037p000000/](http://resources.arcgis.com/en/help/main/10.2/#/What_is_ArcGIS_for_Server/01540000037p000000/).

<sup>5</sup> Esri. 2015. "ArcGIS Online Help." Esri. Accessed August 22, 2015. <http://doc.arcgis.com/en/arcgis-online/>.

<sup>6</sup> Esri. 2015. "ArcGIS API for JavaScript." Esri. Accessed August 22, 2015. <https://developers.arcgis.com/javascript/>.

<sup>7</sup> Microsoft. 2015. "SQL Server 2008 R2." Microsoft Developer Network. Accessed August 29, 2015. [https://msdn.microsoft.com/en-us/library/hh278297\(v=sql.10\).aspx/](https://msdn.microsoft.com/en-us/library/hh278297(v=sql.10).aspx/).

map, which is aged and showing significant signs of wear and tear, was scanned and manually digitized, then the resulting features were joined to the geodatabase. Also, geographic coordinates for the most recent Project 23 excavations of the Los Angeles County Museum of Art parking garage excavations were extracted from a pdf report authored by ArchaeoPaleo Resource Management, Inc. (Turner 2006). The Project 23 data was converted from the pdf report first to a .csv format table, then to a geodatabase table, and finally to a point feature class then merged with the manually digitized data. Next, the museum provided an extract of specimen data from the KE EMu database as a pilot data extract for this thesis project. The data extract was imported into SQL Server and transformed using SQL database queries before loading into ArcMap. Supporting tables such as radiometric dates and borehole geologic data were also loaded into the ArcMap map project (mxd), converted into geodatabase tables, then were related to the feature classes manually digitized from the paper map.

Next, the mxd was published as a map service using ArcGIS Server 10.2.1. Once published, the web GIS application development was accomplished by editing and customizing an ArcGIS Online web map and application template. The web GIS application template utilized for developing this study's web GIS application was an ArcGIS Online Web AppBuilder template, a JavaScript-based application<sup>8</sup>.

All customization of the web GIS application followed standards outlined after interviews with museum staff and research on La Brea fossils and fossil collections methodology (Aisling Farrell, per comm, 2015, Shaw 1982) in order to create basic requirements for a fossil database and web GIS application to be used in this museum. After the web application was

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<sup>8</sup> Esri. 2015. "Web AppBuilder for ArcGIS." Esri. Accessed August 22, 2015. <http://doc.arcgis.com/en/web-appbuilder/>.

finalized, museum staff users were given the opportunity to test the application and provide feedback before the final version was released.

#### **1.4 Thesis Structure**

The remainder of this thesis consists of four additional chapters. Chapter 2, Background and Related Work, provides a review of the La Brea Tar Pits' history and information regarding fossil excavations and also of other web-based applications supported by the Page Museum as well as other similar studies. Chapter 3, Methodology, describes in detail the methods used for developing both the geodatabase and the web GIS application, while Chapter 4, Results, presents the outcome and describes the user guides developed for the web GIS application as well as for updating the geodatabase. Lastly, Chapter 5, Conclusions and Future Work, describes the successes and challenges encountered during the project and explains the anticipated future direction of the La Brea Tar Pits geodatabase and web GIS application development.

## **CHAPTER 2: BACKGROUND AND RELATED WORK**

This chapter describes the background and related work reviewed before developing the La Brea Tar Pits geodatabase and web GIS Application. Section 2.1 gives an overview of the La Brea Tar Pits fossil localities. Section 2.2 provides a description of existing fossil and museum-centric databases found in the current literature. Lastly, section 2.3 describes the related web applications that were reviewed to establish the value and possible functionality such applications could add to museum database and fossil web application development communities.

### **2.1 Fossil Sites of the La Brea Tar Pits**

This section describes the history of the La Brea Tar Pits and provides background on fossil collection at the Page Museum. Section 2.1.1 reviews the history of the La Brea Tar Pits excavations. Section 2.1.2 gives a concise overview of the literature sources considered most pertinent to understanding the content of the KE EMu database fossil records accumulated to date. Section 2.1.3 provides background on fossil collection methodology currently in use at the museum.

#### ***2.1.1 La Brea Tar Pits Background***

The La Brea Tar Pits excavations began in 1913 (Figure 3) after the area was first discovered to have a rich deposit of asphalt (Stock and Harris 1992). During initial asphalt excavations, large fossils of startling proportions were discovered, including eccentricities such as mammoths and saber-toothed cats with 6-inch long teeth. After the significance of the discovery was understood, excavations soon began to recover fossils from the asphalt. The La Brea Tar Pits still continues to be excavated to this day and the richness of fossils still to be uncovered is assumed to be vast.





Figure 3 1913-1915 fossil excavations at the La Brea Tar Pits (Page Museum 2015c)

The latest excavations are called Project 23 (also referred to as P23) and consist of the 23 asphalt deposits that were discovered in 2005 while excavating to build an underground parking garage commissioned by the Los Angeles County Museum of Art (LACMA) (Aisling Farrell, per comm, 2015). For the purposes of this study, a deposit is defined as a concentration of fossils found below the surface (Woodard and Marcus 1973). In general, deposits' latitude, longitude, and depth are recorded; then the fossils are carefully wrapped and boxed in wooden crates (Figure 4), and finally removed by cranes and placed within the Page Museum grounds in Hancock Park. The origin location (pit) of each crate is recorded by the monitoring and recovery experts from ArchaeoPaleo Resource Management, Inc (APRMI) within Hancock Park near the Page Museum (Aisling Farrell, per comm, 2015, Turner 2006).



Figure 4 Project 23 crated fossil deposits (Page Museum 2015c)

To date, over 3 million fossils have been found in the La Brea Tar Pits and surrounding area, and more are discovered every day. However, of the over 1 million specimens that have been recovered from the La Brea Tar Pits, only around ~400,000 are digitally curated in the museum collections database (Aisling Farrell, per comm, 2015). In this collection, curation is defined as the collecting and cataloguing of fossils in as systematic manner so that the information collected can be available for future studies (Jones 2006). The museum began the initiative to database all specimens into a museum database system called KE EMu in 2006 (KE Software 2015). As mentioned in Chapter 1, the museum uses the KE EMu museum database software to digitally catalogue individual fossil specimens as well as create information (KE Software 2015). Pre-2006 excavations can only be used in an aggregate form due to the older data not being fully digital (entered into the KE EMu database) and data inconsistencies with older catalogued specimens, such as spelling errors in multiple database attributes. Encouragingly, post-2006 data such as Project 23 can be used for detailed studies involving multiple individual specimens, including 3D visualizations of fossils contained in entire deposits.

### ***2.1.2 La Brea Tar Pits Literature Review***

The La Brea Tar Pits is a subject that the author studied in depth in order to better understand fossil deposits at the La Brea Tar Pits and the content of the KE EMu fossil database. It was considered essential to obtain a good working knowledge of paleontology in order to successfully and accurately design an efficient spatial database (geodatabase) that could easily interface with KE EMu as well as support an interactive web GIS application.

The author used her background in geology and direct access to paleontologists at the Page Museum as resources for her research during her tenure as a Page Museum intern. Other sources on the geology and paleontology of the La Brea Tar Pits include an article by Woodard and Marcus (1973) that describes the stratigraphy and geology of La Brea Tar Pits fossil deposits in detail. Also, O'Keefe et al. (2009) and Friscia et al. (2008) discussed the bone distribution, density, and radiocarbon dates of Pit 91 at the La Brea Tar Pits. Lastly, at the time of this study, Stock and Harris (1992) was the most cited reference on La Brea fossils and contains a wealth of information on the fossil localities to be displayed in the web application. Shaw (1982) discussed excavation techniques developed for Pit 91 and used currently for Project 23 excavations and his paper was helpful for better understanding the excavation and curation process.

The Woodard and Marcus (1973) article provided context regarding the geology and stratigraphy of the La Brea Tar Pits, which helped inform the creation of the geodatabase and 3D fossil visualizations generated from the KE EMu database extract as a proof of concept of the spatial support provided by a geodatabase. The O'Keefe et al. (2009) and Friscia et al. (2008) articles also provided background and better understanding of the La Brea Tar Pits fossil deposits. The O'Keefe et al. (2009) article in particular was used as a model to create radiocarbon dating data tables for the geodatabase developed in this study. The Stock and Harris

(1992) book listed the common species found at the La Brea Tar Pits and was used as a source for common names of fossils that were requested by the museum staff to be added as a field to the geodatabase. Lastly, the Shaw (1982) article contributed to this study by providing a detailed description of the excavation process, including an explanation of how each excavation site is gridded and how the x, y, and z in situ position of fossils is measured.

### ***2.1.3 Fossil Collection Background***

Between March 2013 and June 2014, the author was a volunteer at the Page Museum at the La Brea Tar Pits and thus had the advantage of talking to museum staff members with firsthand information and accounts of fossil excavation and past salvage projects every working day.

From 1913 to present, a standard 1x1-meter grid pattern delineated by string is used to measure fossil locations when excavating fossils at the La Brea Tar Pits (Shaw 1982, Figure 5).



Figure 5 Example string laid out in 1x1 m grid at Pit 91 excavation site (Shaw 1982)

The grid system is set up with string stretched across the fossil site, forming a meter-by-meter grid pattern. This grid pattern is used to record the x, y, and z location of each fossil, but accuracy is a challenge due to improper placement of the string or string loosening over time. Individual fossil's dimensions are measured with rulers and recorded with pencil and paper, which contributes many additional potential sources of human error to the fossil collection process.

## **2.2 Review of Existing Museum Databases and Applications**

In Section 2.2.1 several existing museum and paleontological database schemas are presented. Section 2.2.2 provides a succinct literature review of the primary sources considered in preparation for designing the web GIS application. Existing applications found at the time of this study were reviewed in terms of their user interface, platform, and functionality. Due to the lack of fossil site web mapping applications discovered in this background research effort, applications created by museums for other subject areas were reviewed.

### ***2.2.1 Existing Database Review***

The first database reviewed was the KE EMu database, the software used by the Page Museum to catalogue their fossil specimen collection. KE EMu is a popular museum collections software used by many museums around the world (KE Software 2015b). The database has an easy to use form-based interface that is used to enter information about the specimen, such as the bone type, part, description, and taxonomical classification, and also relative location information such as deposit name and grid location and measurements (Figure 6).

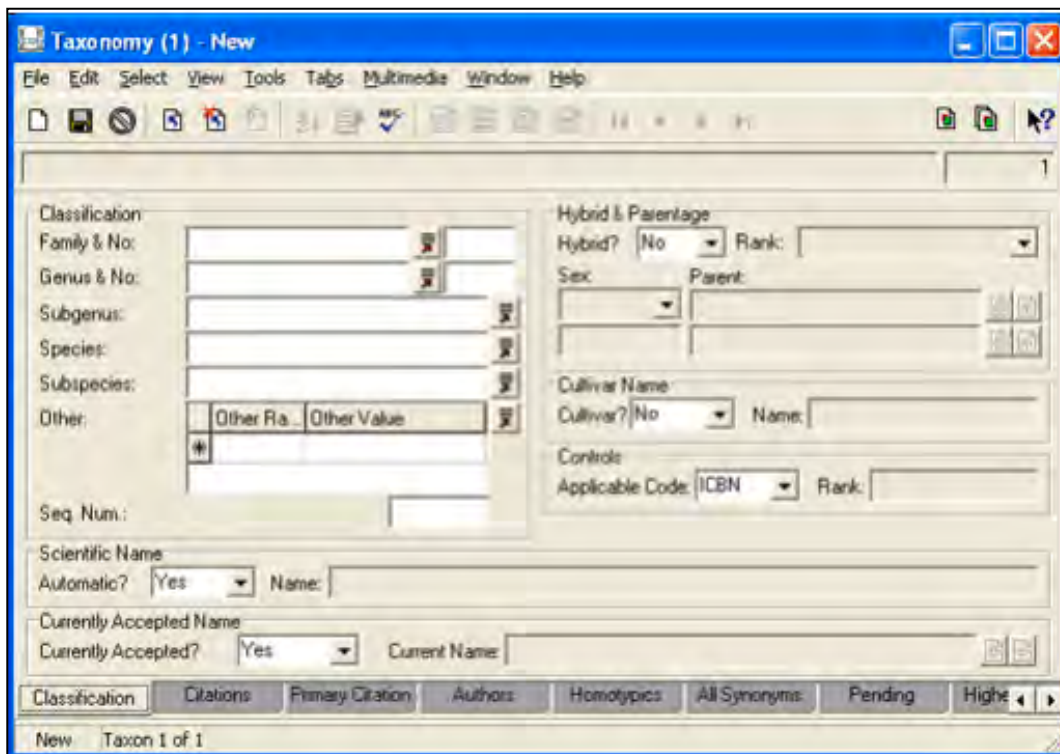


Figure 6 KE EMu taxonomy module (KE Software 2015c)

The author reviewed the use of the database software by the museum staff and found that the three primary modules used were the taxonomy, site, and fossil element modules. The site information collected is not georeferenced in the form of coordinates. The location information collected is the name of the deposit and the x, y, and z (depth of the fossil in situ, from surface) in reference to the origin of the excavation grid. According to online documentation, the KE EMu database can collect coordinates and display them as a report using a connection to the desktop ArcExplorer software but the museum does not use this module. Collecting coordinates is not part of their current workflow, and moreover, coordinate locations were not documented for the historical excavation sites until the author of this study digitized a paper survey map of the 1913-1915 excavation sites. However, the ArcExplorer capabilities as outlined in the KE Software documentation are for small-scale use cases such as displaying sites on a global scale

(KE Software 2015d, Figure 7). In this study, the author's database and web application design are for the large scale needs of the La Brea Tar Pits study area.

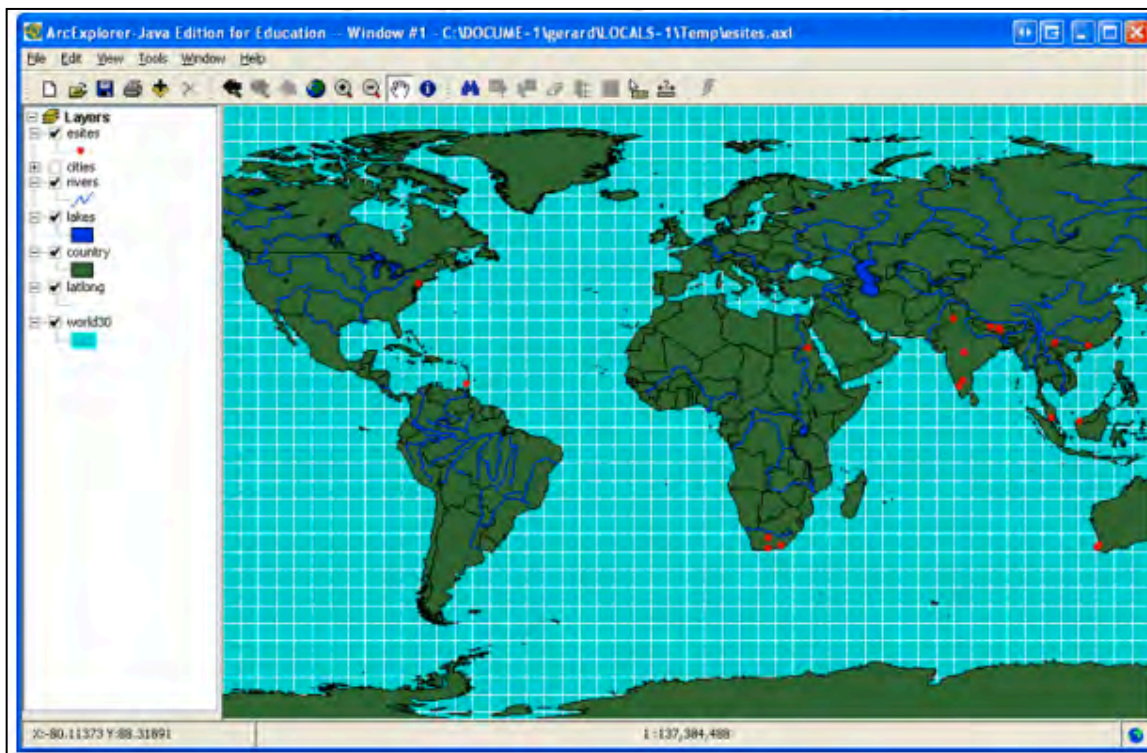


Figure 7 KE EMu ArcExplorer report (KE Software 2015d)

The next database to be reviewed was the database of the MioMap application (University of California 2015, Carrasco et al 2005). The database structure of the MioMap database is similar to the Page Museum KE EMu database structure in the inclusion of an age table, also in the requirements of the geodatabase discussed in Chapter 3. Fossil age data is included in the geodatabase structure developed as part of this study.

The structure of the MioMap database consists of a Locality table which is linked to an Age/Deposit table, Absolute Age table, Faunal table, Synonymy table, and Reference table. There are interrelationships between the Faunal table and Synonymy table connected by a Taxon ID. Also there is a relationship between the Reference table and the Electronic Bibliography (Figure 8).

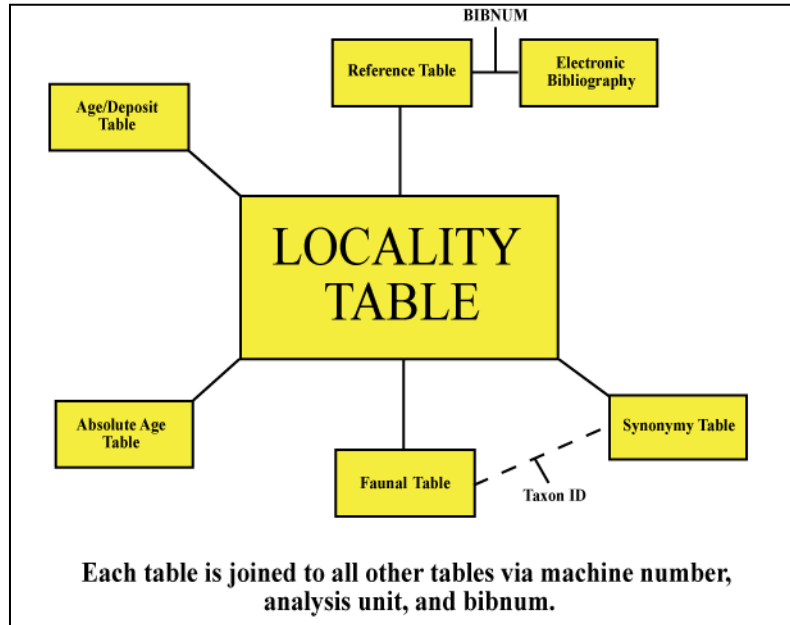


Figure 8 MioMap data structure (University of California 2015)

The attributes of the Locality table (Figure 8) include coordinates, altitude and precision information. The database structure includes data on township location as per a USGS quadrangle map encompassing the site. Reviewing this data structure was helpful but the same attributes did not translate well to this project’s geodatabase design, because the fossil locations are recorded at a different scale than those from the La Brea Tar Pits. Also, in the Faunal table (Figure 8) each fossil specimen is only recorded as a species and does not include information about the actual bone. In the context of this thesis, a species is defined as an individual animal of the most specific taxonomical classification. For example, a saber-tooth cat (*Smilodon fatalis*) is of the genus “*Smilodon*” and at a more specific level, classified as the species “*fatalis*” (Stock and Harris 1992). In the La Brea Tar Pits deposits, whole specimens are not often found so bones are recorded in the KE Emu database as “elements” and not recorded as the entire individual (i.e., skeleton), as the MioMap database structure suggests.



The second database reviewed is the Fossilworks Paleobiology Database (Behrensmeyer et al 2013). The structure of the database consists of six tables: (1) references, (2) taxonomic names, (3) taxonomic synonymies and classifications, (4) primary collection data, (5) taxonomic occurrences, and (6) re-identifications of occurrences. Tables are linked via Record ID numbers and additional lookup tables are included in the database structure. This database is also not designed to search on elements (individual bones) and instead searches the taxon name only.

The geodatabase design developed as part of this thesis addressed gaps found in the other fossil databases considered, including adding precise location components for individual fossils (bones). In addition, the other databases do not contain information that would allow detailed searches, other than by species name. Lastly, the geodatabase is intended to display data at more precise geographic locations than the databases reviewed in this study, as well as interface or connect seamlessly with the existing KE EMu database maintained by the Page Museum staff.

### ***2.2.2 Existing Museum Collection Application Platforms and Functionality***

An extensive internet search for web GIS mapping applications similar to that envisioned for the Page Museum found four applications that contained relevant functionality, including the ability to search for specific fossils, visualize the fossil location on a map, and view related information to add context such as photos or related data (Smithsonian 2015, National Science Foundation 2015, Harbert 2014, and University of California 2015). A summary of each application and the relevance to this study is provided in the section.

The first application reviewed was the Smithsonian Institution's application displaying the most populated as well as unpopulated places in the world (Smithsonian 2014, Figure 9). The

Smithsonian site uses a customized ArcGIS Online storytelling shortlist application<sup>9</sup> template. The user interface features a numerical guide through different web page panels that describe each numbered point on the map. The application combines media such as photos with text that describes each location on the map in detail. Since features such as fossil deposits displayed in the Tar Pits application are numbered, the storytelling shortlist template could possibly be a good option for this project.

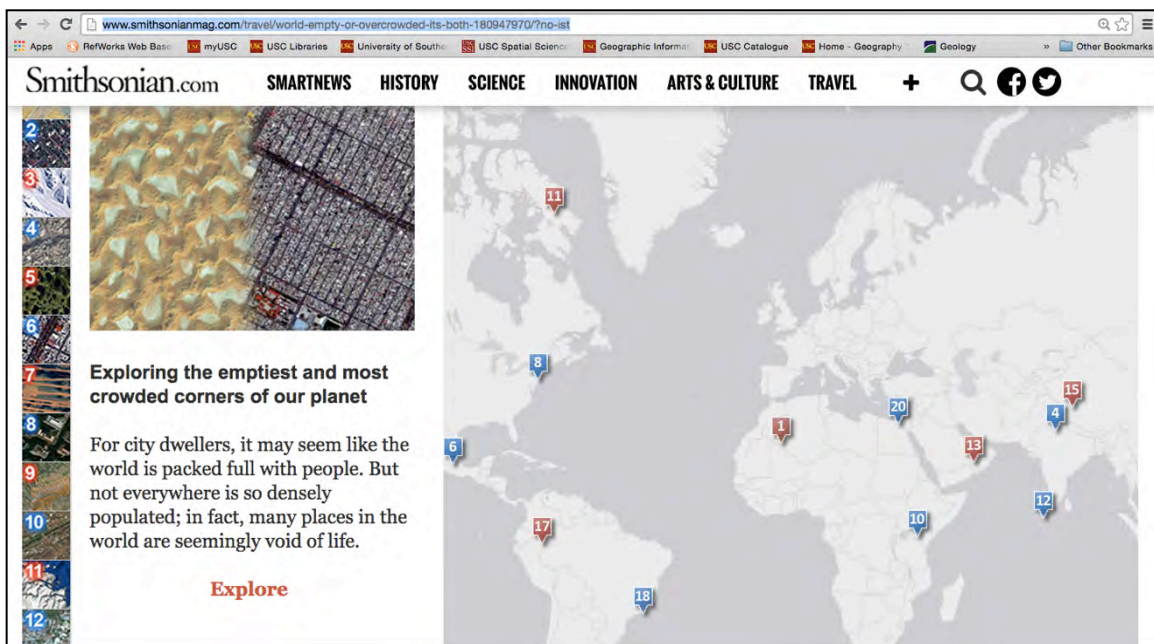


Figure 9 Is the World Full or Empty (Smithsonian 2015)

Another web GIS application reviewed was VertNet, which is an initiative between several universities and institutions to create a portal to connect to all museum and university fossil collections (National Science Foundation 2015, Figure 10). The VertNet application is developed using the Google Maps API as the web mapping technology. The user interface of VertNet is straightforward, however the web map visualization is basic and lacks richness in

<sup>9</sup> GitHub. 2015. "Shortlist Storytelling Template JS." Accessed August 29, 2015. <https://github.com/Esri/shortlist-storytelling-template-js/>.

symbolology. The website overall is robust and the information that can be found when searching for a specific specimen is very helpful for the research community. In comparison, the web GIS application developed as part of this research is intended to be more focused on the specific needs of the La Brea Tar Pits and would not need to display information such as language, institution code, name recorded by, and modified date found in the VertNet application (Figure 10).

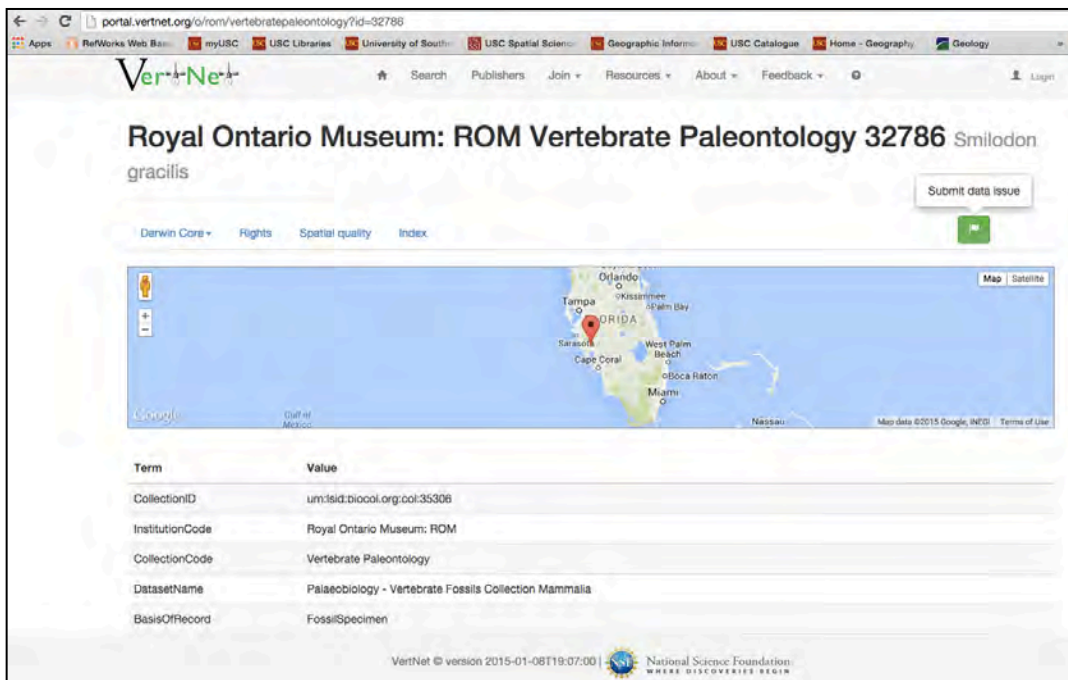


Figure 10 VertNet showing specimen from the Royal Ontario Museum (National Science Foundation 2015)

The third application reviewed, the MioMap: Miocene Mammal Mapping Project, is an interactive web mapping application similar to the web GIS application developed as part of this thesis (Carrasco et al 2005, Figure 11). This application employs a table and popup combination, as outlined in the user requirements for this application developed as part this study (Chapter 3). It is also interesting to note that this application includes records of fossils reportedly found in the La Brea Tar Pits, yet only shows nine records and the locations of those records are

inaccurate. For example, one location is almost a mile south of the true location of the museum grounds that contain the pits.

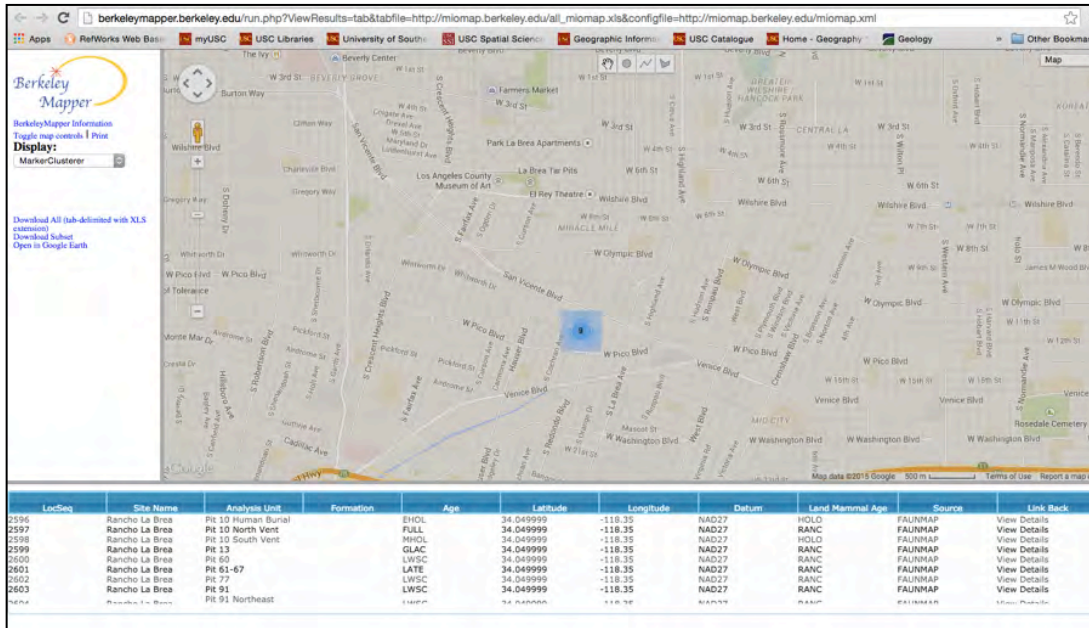


Figure 11 MioMap: Miocene Mammal Mapping Project (University of California 2015)

The four similar web map applications reviewed herein indicate that there may be a gap in publicly available robust fossil web GIS applications. The majority of GIS web applications found in this research effort display data at very small-scale extents. For example, the VertNet example and MioMap application web maps are low resolution, at the state and city level. In the MioMap example, coordinates are not accurate for locations and vary by at least a mile. In contrast, the La Brea Tar Pits web GIS application is a larger-scale application with data displayed at a near meter accuracy. For example, the La Brea Tar Pits web GIS application is designed to allow the user to zoom into locations in the park and with a subset of data, specifically the data extract from Project 23, have the ability to view fossil x, y, and z orientation to the centimeter.

The background research on the La Brea Tar Pits history, current processes, and excavation methodology gave the author the necessary knowledge and context to proceed with the thesis work. Moreover, the review of existing web application and databases helped the author to identify the current research gaps. The knowledge gained from the research carried out in this chapter greatly helped to inform the database and web development described next in Chapter 3 Methodology.

## **CHAPTER 3: METHODOLOGY**

This chapter describes the methodology for developing the La Brea Tar Pits geodatabase and accompanying web GIS application. Section 3.1 provides an overview of the methodology, while section 3.2 describes the data sources including spatial and non-spatial data intended to interface with the Page Museum's KE EMu database. Section 3.3 explains the data processing performed and geodatabase creation methodology. The functional and nonfunctional requirements as well as the development approach for the database and web GIS application are described in section 3.4. Lastly, section 3.5 discusses the application development environment, development process, and requirements review.

### **3.1 Method Overview**

The methodology in this thesis initiated from a final project completed under the direction of Dr. Jennifer Swift in the SSI MS GIST Program, the SSCI 591 Web GIS course at the University of Southern California. Additional ideas were garnered from a GIST master's thesis on the topic of web application development (Milholland 2014), and from my own experience as a GIS Analyst at International Medical Corps where I participate as part of the Information Technology Business Services development team (International Medical Corps 2015).

A general overview of the development of the web GIS application is provided in Figure 12. The first two steps included data collection and geodatabase and web application requirements gathering. The last requirements gathering step was determining the most appropriate web GIS software and production environment. For this project, the author chose the ArcGIS Server GIST Virtual Machine environment (Figure 12, step 2).

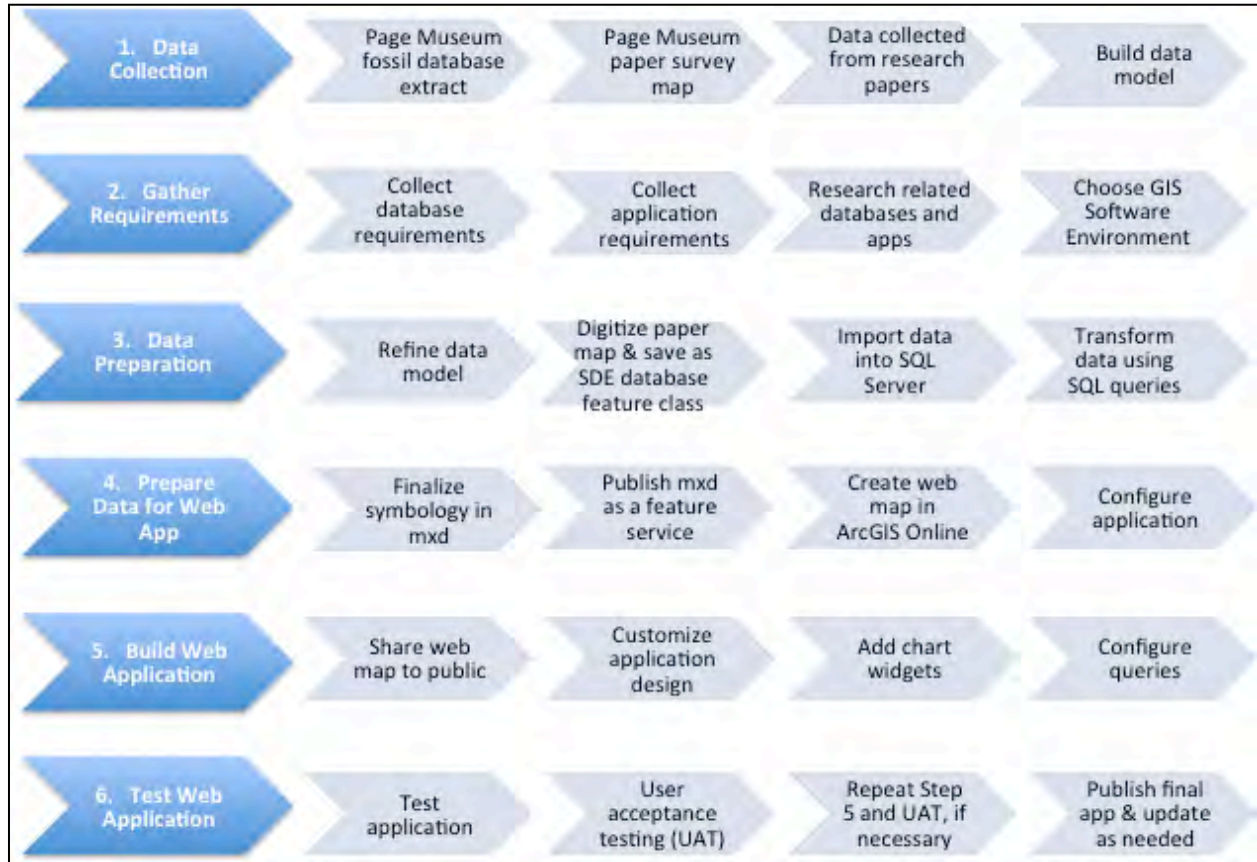


Figure 12 La Brea Tar Pits web GIS application methodology

The third step in this study was data preparation, in which the data model was refined based on user requirements and the data extract from KE EMu was transformed into a geodatabase (Figure 12). In Step 4 the data was prepared for the web GIS application by publishing the feature classes from the mxd to ArcGIS Server (Figure 12, step 4). Step 5 describes the building of the web application, which began with choosing a web application template for functionality, look and feel. For the last step (Figure 12, step 6), the author tested the application and fixed all errors found. Finally, users tested the application for usability and to confirm that requirements were met. The required research skills that were necessary to complete this project are described in Appendix A: Required Research Skills.

The remainder of this chapter covers the data methodology, spatial database and application development. Specifically, section 3.2 covers data sources, section 3.3 discusses data processing and data considerations, section 3.4 describes the web GIS application development approach and user requirements, and section 3.5 explains the ArcGIS Server and Online application development process.

## **3.2 Data Sources**

This section describes the data sources used in this project and divides the data into two categories: spatial and non-spatial. Non-spatial and spatial data source descriptions are provided in sections 3.2.1 and 3.2.2, respectively. A detailed table of all data sources described in this section can be found in Appendix B: Data Sources and Description.

### ***3.2.1 Spatial Data***

One of the most important input spatial data for this thesis project was a paper survey map on paper (40 x 70") that was provided by the Collections Manager, Aisling Farrell, of the George C. Page Museum of La Brea Discoveries (Figure 13, Noble 1913). The map contains locations for all excavation sites at the La Brea Tar Pits, from 1914 to present. The paper survey map was originally made by the Los Angeles County Surveyor in 1914 and was updated in 1983 by Page Museum staff (Aisling Farrell, per comm, 2013; Noble 1913).





The second critical spatial data input was geologic borehole data, which included latitude and longitude information. This data came from a USGS report written by Jim Quinn, a geologist and former Curatorial Assistant at the Page Museum (Quinn et al 2000). Two of the 403 boreholes contain detailed sediment descriptions by elevation and depth (from sea level) as well as the asphalt content of the sediment by elevation and depth (from sea level).

The third highly significant spatial data input was the Project 23 deposit locations. Project 23 is the name of the newest deposits to be found during the excavation of an underground parking structure for LACMA (see section 2.1.1 La Brea Tar Pits Background). The latitude and longitude information for the deposits (crates) were transcribed from the ArchaeoPaleo Resource Management, Inc. report (Turner 2006).

### ***3.2.2 Non-Spatial Data***

The non-spatial data for this research came from two sources: (1) the museum's KE EMU database (KE Software 2015a, La Brea Tar Pits Collections KE Emu database 2015) and (2) a publication by O'Keefe et al (2004). The Page Museum uses KE EMu as their curatorial relational database that contains records describing the fossil specimen excavated from a La Brea deposit and the positional information about the specimen. The extract provided by Museum staff consisted of two tables, named Ecatalogue.csv (408,234 records) and SitSiteR.csv (408,203 records). The Ecatalogue.csv table contained the catalogued specimens' taxonomical and osteological information and the SitSiteR.csv contained the specimen location information in three dimensions.

In addition to the survey map, Museum staff provided an extract from June 2015 of the entire fossil database as two csv files (Appendix C: KE EMu Data, Table C-1 and Table C-2). The attributes found in the database extract provided are described in detail in section 3.2.2, and

are not inclusive of every attribute that can be found in the KE Emu database. Instead the attributes included from the Project 23 extract represent those that were chosen by the museum staff as the attributes they deemed necessary for the geodatabase, specifically for the creation of summary tables (described in section 3.3 and also found in Appendix E and F).

### **3.3 Data Background and Processing Methods**

The first part of the data processing was to scan and digitize the 1914/1983 paper survey map in order to bring the paper survey map's data into a GIS. For this project and, more importantly, to preserve the map and the history it contains, Aisling Farrell and the author of this study had the paper map professionally scanned and output in TIFF format at a blueprint shop. Due to the map being over three decades old, there were many worn areas, smudges, and slight tears. Thus, it was also important to scan the map before more wear and tear could occur.

The geotechnical report borehole data provided by Jim Quinn et al. (2000) was copied and reformatted into Microsoft Excel and displayed in ArcMap as NAD 1927 UTM Zone 11N because the data was collected in that datum. Both USGS borehole data and Esri imagery were used to georeference the scanned survey map, after projecting the borehole data to WGS 1984 Web Mercator Auxiliary Sphere to match the Esri Imagery Basemap (Figure 14).

Next in ArcMap, contours, survey markers, La Brea Tar Pit excavation sites, exposed fossil pits, creeks, water bodies (lakes and ponds), and oil and gas vents were manually digitized from the georeferenced survey map. After digitizing the La Brea Tar Pit locations from the survey map as polygons, the Feature to Point tool in ArcMap was used to convert the polygons to points. This was done because some pits appeared so small on the original surveyed map that it was determined that they should be represented as points. Converting to points made it easier to

represent the features as marker symbols that can be easily enlarged, and all pits are thus uniformly represented.

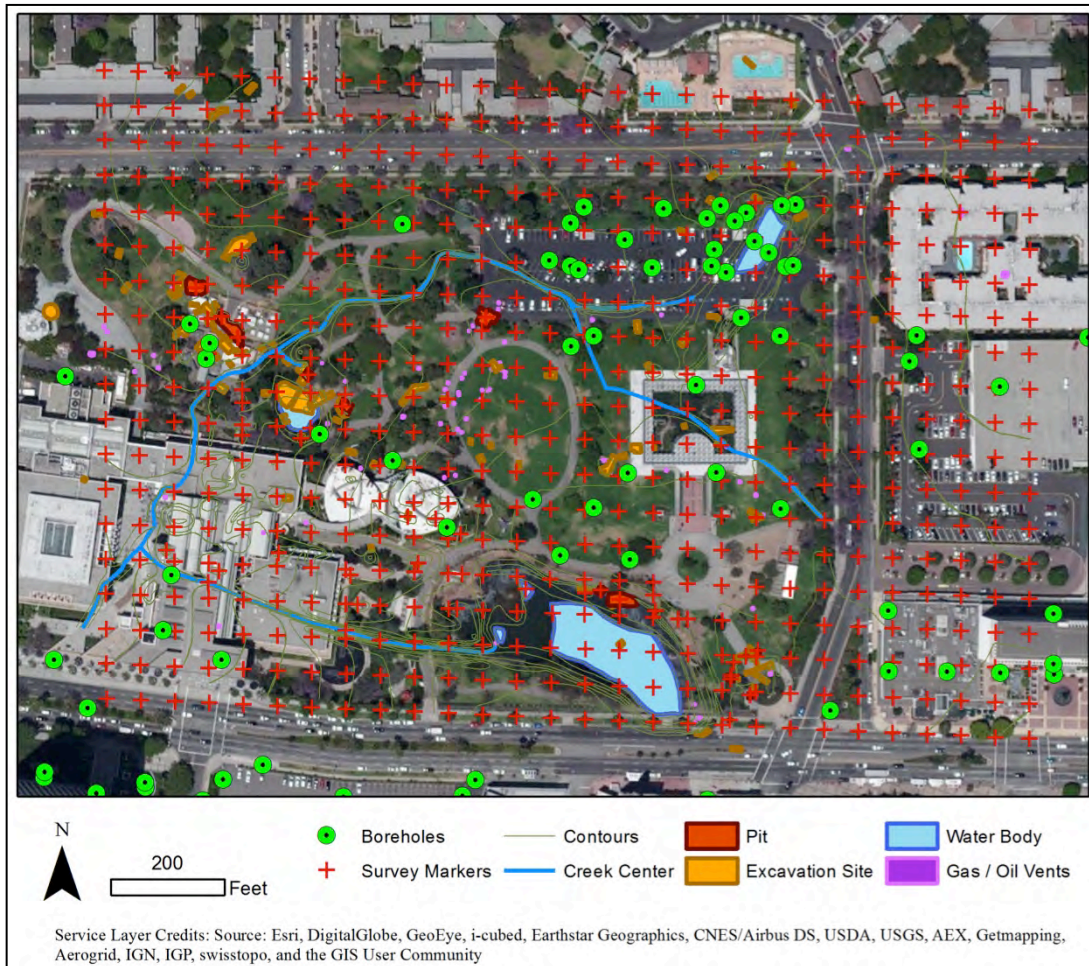


Figure 14 Esri Basemap and boreholes (green circles) used to georeference the survey map

Also, the more recent excavation locations referred to as Project 23 were added to the GIS map project from an Excel table of latitude and longitude locations extracted from the ArchaeoPaleo Resource Management, Inc (APRMI) mitigation report (Turner 2006). The data were added to ArcMap and the x,y coordinates were used to convert the data in the Project 23 table into a feature class. Appendix E: Geodatabase Creation Notes and SQL Queries provides more information on the geodatabase creation process. In order to simplify the data migration from the KE EMu database, the digitized La Brea Tar Pits data (known as the Hancock

Collection data in the KE EMu database) and the Project 23 data were merged into one feature class. Additionally, the depth fossil measurements were converted to the survey map measurements in feet, since the APRMI depth recorded in both meters and feet.

Next, the KE EMu data extract from June 2015 was directly converted into a geodatabase. Appendix E outlines the process of transforming the database extract csv tables into a SQL Server 2008 geodatabase. To summarize, two files were imported into SQL Server as flat files and then transformed into one table. Those fields that had multiple values were parsed into multiple fields in order to preserve the data.

In order to capture key information from the Specimen Site Catalogue entity without exposing its records as a feature service (the Page Museum requested that the granular data not be shown), summary tables were generated from the SpecimenSiteCatalogue table. The summary tables were calculated using SQL queries in anticipation that in the future the queries can be used as stored procedures if the KE EMu database is directly linked to a SQL geodatabase instance within ArcGIS Server. The SQL queries used to create the summary tables can be found in Appendix F: SQL Queries for Specimen Summary Tables.

A small subset of fossil location data from the KE EMu database captured to the centimeter level from Project 23, Deposit 1 was provided for this project as well. The data extract consisted of 59 *Panthera atrox* specimens and 108 *Smilodon fatalis* specimens. These specimens were chosen because while the large majority of specimens at the museum cannot be attributed to one individual animal, these particular specimens have been deemed by paleontologists to possibly belong to identifiable individuals (Aisling Farrell, per comm, 2015). For example, the *Panthera atrox* specimens are thought to represent one individual while the *Smilodon fatalis* specimens are thought to represent at least three individuals. The museum staff

considered these to be representative data samples well suited as a guide for development of the geodatabase schema.

ArcMap and ArcScene were then used to visualize the specimen records of the *Smilodon fatalis* and *Panthera atrox* individuals in 3D, as a preliminary test of the geodatabase design. To prepare the original data for 3D visualization using ArcScene, the data had to be significantly transformed in Microsoft Excel by the author. Multiple values found in one cell had to be parsed using Text to Columns in Microsoft Excel, and the catalogue number or identification number for a given fossil was replicated in each new record corresponding to each point on a bone at which measurements were taken (Figure 15). When a fossil is excavated, northing (y- direction), westing (x-direction) and, below depth (z-direction) measurements from one to three points of the bone are recorded depending on the type of bone.

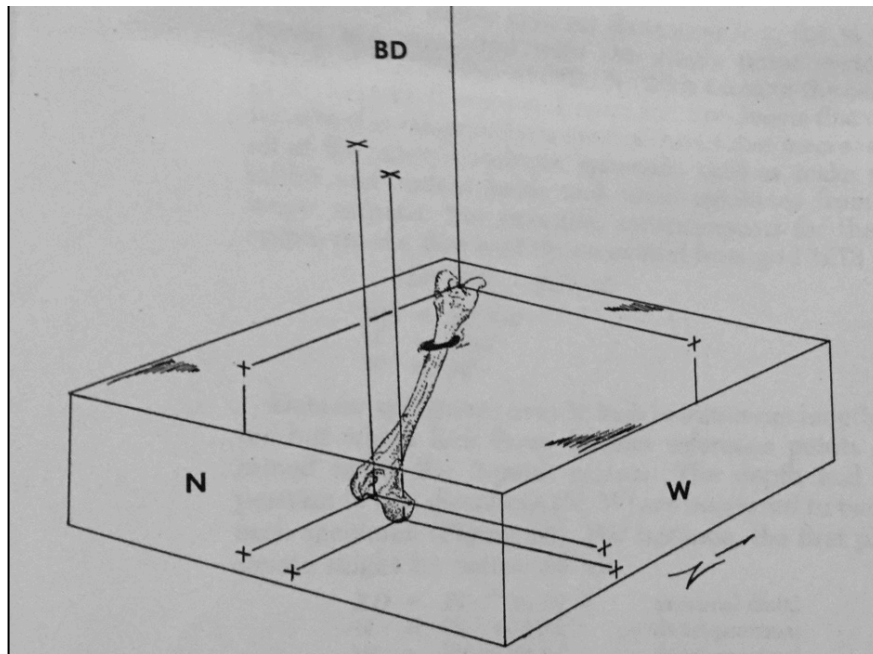


Figure 15 Below depth (BD), northing (N), and westing (W) measurements taken for a mammal femur (Shaw 1982)



the Page Museum to better understand deposit shapes and the distribution of different specimen types, to thus inform research questions. In the future, 3D models would allow a museum visitor to visualize fossil orientations pre-excavation. In the final application, a video of Figure 17 is displayed as in a link from the application, as an example. The linked web pages containing the 3D renderings were created using Adobe Dreamweaver as simple html pages with video tags hosted on the USC web server.

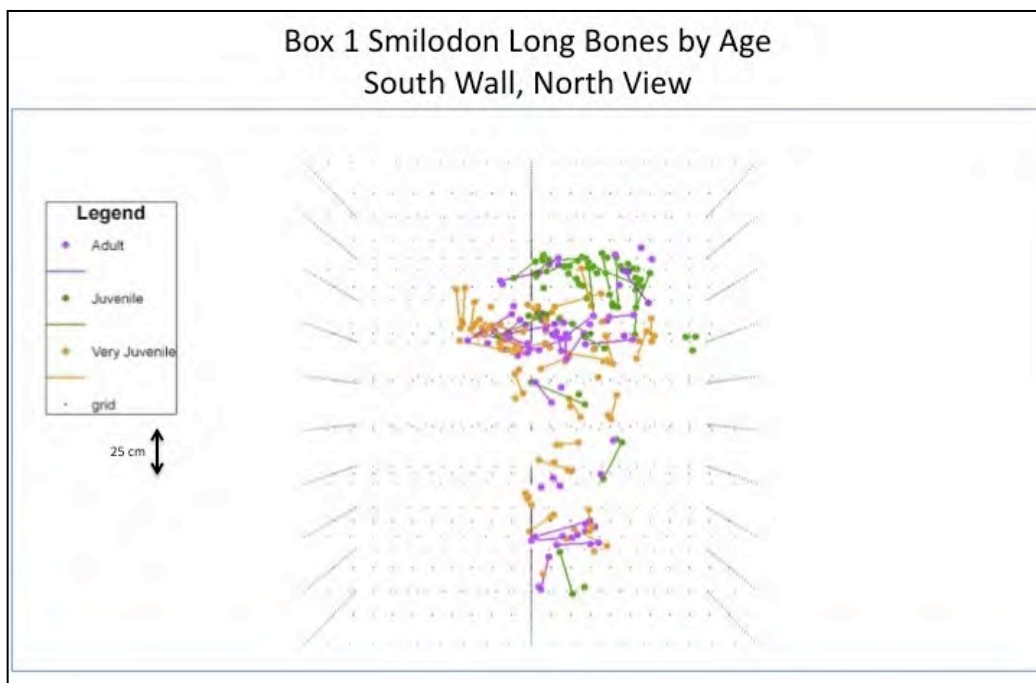


Figure 17 *Smilodon fatalis* long bone specimens classified by ontogenetic age

### 3.3.1 Specimen Data

A major disclaimer concerning the fossil data received from the Page Museum KE EMu database is that the data extract is in no way representative of the entirety of the Page Museum's collection, nor is it an accurate picture of the true number, type, and distribution of fossils found in the many pits. Many specimens from early excavations were never entered in the KE EMu database nor have all specimens been completely recovered from every pit (Aisling Farrell, per



comm, 2013). Thus, fossil type aggregate totals for each pit provided for this study are considered proof of concept purposes only, in order to visualize what information the museum currently has recorded.

It is important to further define the word specimen to provide additional context. Specimen does not refer to an individual animal. Specimen refers to any bone, bone fragment, tooth, claw, etc. from a fossilized animal. Note that specimens also include plants, but for the scope of this project plants were not included in the GIS application. Also, it is essential to note that the majority of specimens at the museum cannot be assembled together as an individual. In fact, specimens on display at the museum are primarily a mix of many different individuals. The reason that individuals are not found at the Tar Pits is because of the geology and mechanics of an asphalt fossil locality. As asphalt rose through cracks in the geologic layers below the museum, they were mixed together and the process damaged most fossils.

### ***3.3.2 Spatial Data Accuracy***

It is expected that there may be errors due to the inherent lack of accuracy when rubber-sheeting the survey map since there were only 54 actual measured latitude longitude measurements (boreholes) that could be used as locational references. In addition, the pits were mapped in 1913 and last updated in 1983 by field survey without the help of today's sub-meter digital GPS units. The park has changed greatly over the years since this map was first created, and pits, water features, elevation, and other attributes have also changed due to land development. Also, there may be errors in the manual digitization of the map because of the human error endemic to using a mouse.

The original source of this data is considered high quality in terms of accuracy because the survey map was created by a professional surveyor, albeit in 1914, and updated in 1983 by

professional geologists and paleontologists. Nevertheless, there is always the possibility of human error inherent with hand drawn maps that must be noted. The depth measurements on the survey map have an additional margin of error because those data were recorded in 1914 by fossil excavators working in the inhospitable environment of asphalt pits subjected to frequent cave-ins, asphalt and water infiltration, and methane exposure (Stock and Harris 1992). Moreover, the pits measured at that time have been covered by rapid development in the Los Angeles area. There is now an art museum built on top of ten of the pits, a parking lot and a lake (Figure 18), as well as the Page Museum covering nine pits. Unfortunately it is not possible to visually field check the accuracy of the map by surveying those parts of the park grounds.

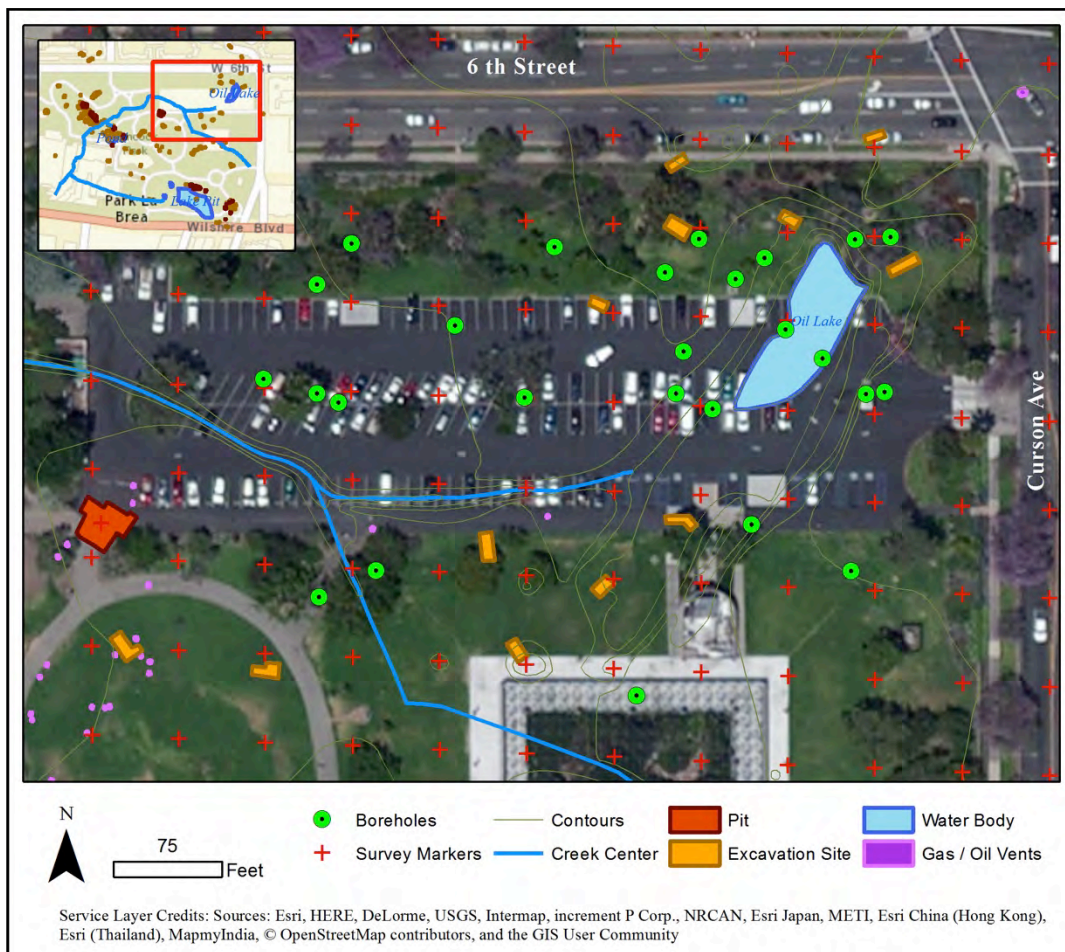


Figure 18 A parking lot was built over Oil Lake and several pits during the 1970s

### ***3.3.2.1 Fitness of Use for Spatial Analysis***

The borehole data from the 1970s to 1990s and at depth is considered accurate, though the condition near the surface has changed over the years due to landscaping and the building construction discussed above. Predictions made from analyzing the data should be carefully considered since the pit data dates back to 1914 while the geologic data spans the last 30 years.

As for the distribution of the data, the pit polygons are clustered in the southwest part of the map extent (Figure 19). The polygons for the fossil pits represent between 25 and 1000 square feet and it is unlikely that the fossils are homogenous within pits. This could affect future spatial analyses because the distribution of and number of fossils in each pit cannot be analyzed because of a lack of data. Some pits included in the dataset used in this study may not have had more than a few fossils in them, while other pits contained thousands. Eventually it would be advantageous to attempt to estimate the number of fossils in each pit with the help of the Page Museum staff by reviewing old museum documents from the early 1900's. Another primary issue for this dataset is that there is no nonoccurrence data, only occurrence, because the excavation sites were not chosen systematically. If GIS analysis is carried out using this data in the future, archival documents from the 1914 survey should be reviewed to determine if any nonoccurrence pit data is available.

If this data is to be used for spatial analysis in the future the author recommends that the digital data be re-projected into NAD 1927 State Plane California VII FIPS 0407. Web Mercator, although projected, is not recommended for spatial analysis in California because area and distance are distorted as distance from Equator increases. State Plane coordinate systems preserve area, directions, distance, and shape with minimal distortion so it is the best choice for spatial analysis in a large-scale mapping project for a 0.25 by 0.35 square mile extent.

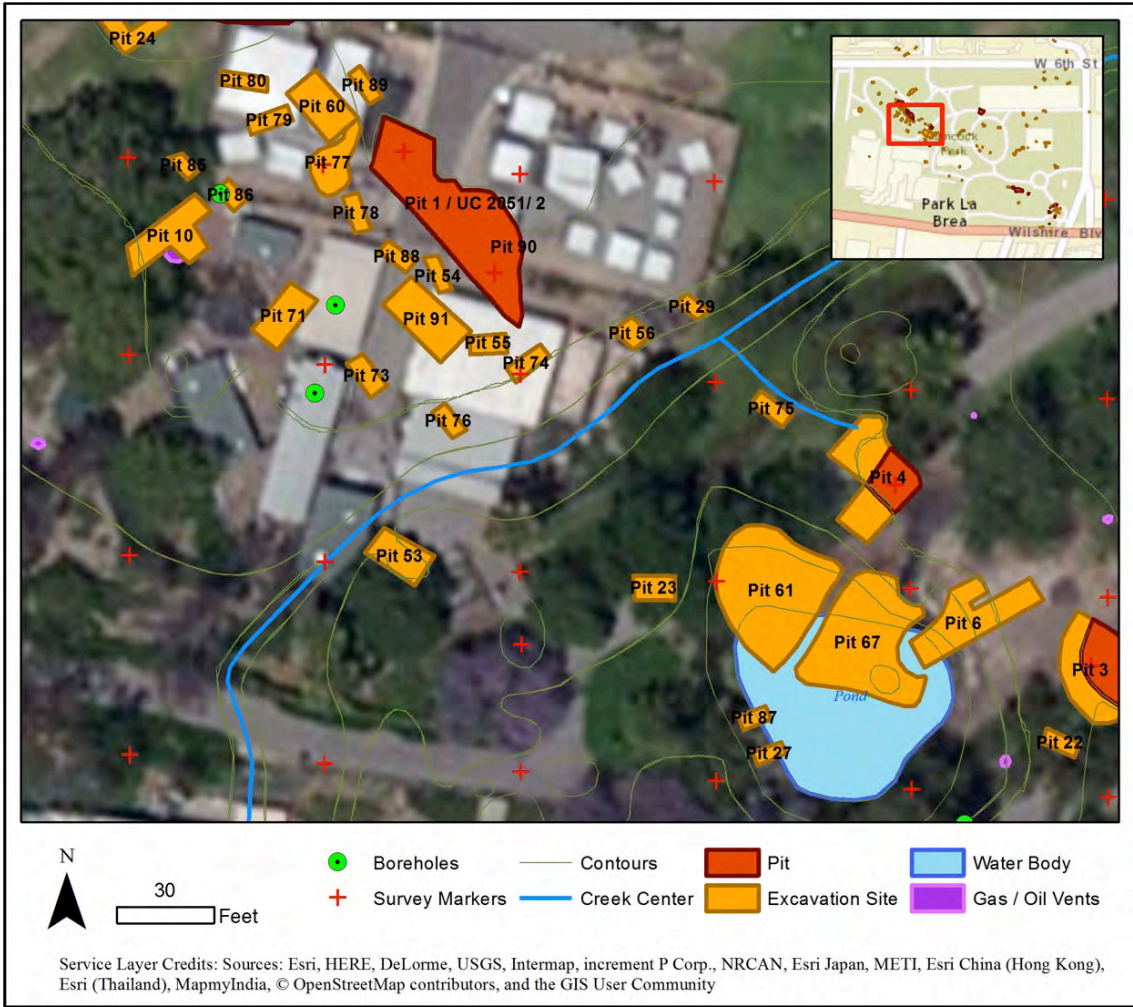


Figure 19 Clustering of fossil pits and fossil excavation sites

### **3.4 Development Approach and User Requirements for the Web GIS Application**

The following sections describe the development approach and the user requirements gathered from the museum staff for the web GIS application.

#### ***3.4.1 Development Approach***

An Agile programming approach was used to continuously make changes to the application until the requirements are met, with the acceptance that requirements may change during the development process (Deewan and Jain 2012). The geodatabase and web GIS application were tested for functionality and troubleshooting was accomplished as needed. After the web GIS application was completed, during Spring and Summer semesters of 2015 museum staff participated in user acceptance testing (UAT) to ensure that the Page Museum requirements had been met by the application, detailed in the next sections of this chapter.

#### ***3.4.2 User Requirements***

To summarize, the primary requirements for this project include the following: 1) the digitized survey data must be contained within a spatial database (geodatabase), 2) the data must be linked to specimen information in a web GIS application, 3) summary database tables must aggregate data by attributes such that many details of each specimen are not available to the general public. The next section describes the application-specific functional requirements.

##### ***3.4.2.1 Functional Requirements***

Functional requirements are requirements that are necessary for the desired user experience for the web GIS application. These describe the minimum requirements of the application in terms of the user experience. Appendix G: Requirements for the Web GIS Application, Table G-1 lists and describes the requirements and the viewing mediums recommended.

### ***3.4.2.2 Nonfunctional Requirements***

Nonfunctional requirements identify how the web application and underlying system should perform. Appendix G: Requirements for the Web GIS Application, Table G-2 describes the nonfunctional requirements for each medium (server/web system and web/mobile interface).

## **3.5 ArcGIS Server and ArcGIS Online Application Development**

Section 5.5.1 describes the software environment, section 3.5.2 outlines the steps performed in the ArcGIS Server environment to create and publish the data as a map service to the web, section 3.5.3 reviews the steps performed in the ArcGIS Online environment to create the web GIS application, and lastly a review of the web application to determine if user requirements were met is provided in section 3.5.4.

### ***3.5.1 Development Environment***

Database, server, and web development were performed on a MacBook Air (OS X Yosemite 10.10.4) using a GIST ArcGIS Server virtual machine (VM) running Microsoft Windows Server 2008 R2, ArcGIS for Server 10.2.1, and SQL Server 2008. The html code to create the linked web pages containing the videos of 3D data was edited with Adobe DreamWeaver on a MacBook Air desktop and transferred to the USC web server via the FTP application Fetch.

#### ***3.5.1.1 Web GIS Software and Environment***

The web GIS software environment chosen for this project was Esri ArcGIS Desktop, ArcGIS Server, Microsoft SQL Server Express, ArcGIS Online, and ArcGIS JavaScript API (Figure 20).

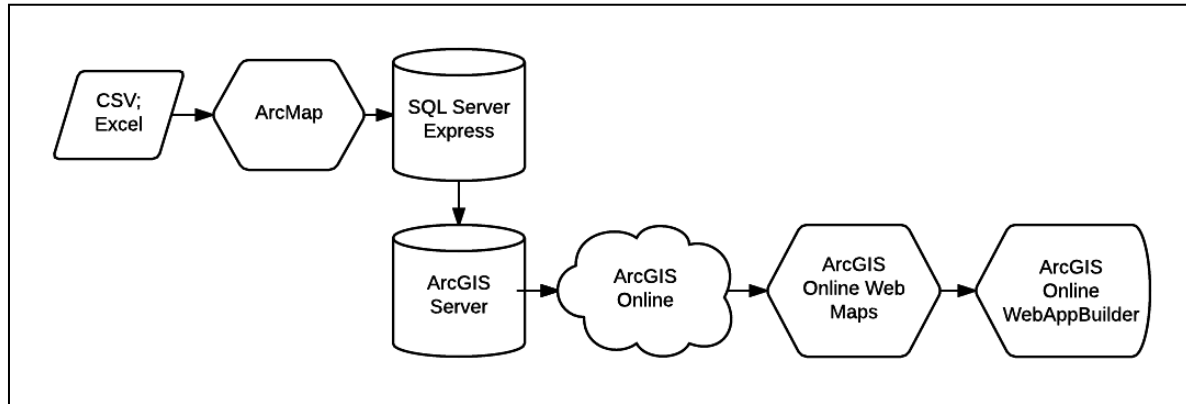


Figure 20 Flow Diagram of ArcGIS development process from raw data to web GIS application

### ***3.5.1.2 ArcGIS Server Environment***

The development and production environments both reside on a Windows Server 2008 R2 SP1 virtual server. At the time of this study, the server was hosted at the University of Southern California (USC). Feature services were created in ArcMap 10.2.1 using Microsoft SQL Server 2008 database feature classes.

### ***3.5.1.3 ArcGIS Online Environment***

ArcGIS Online (AGOL) provides a convenient technology for customizing the symbology and basemaps used in web GIS applications easily in a user-friendly environment that does not require programming. Thus, by using AGOL, a web application developer can quickly customize the look of REST endpoint feature layers by editing the pop-up text, basemaps, layer order, and other stylistic elements. The ease of development in ArcGIS Online allows the developer to quickly move on to more complex customization of the application by speeding up the feature layer customization process. The ArcGIS Online environment used in this project is the USC Spatial Sciences Institute (SSI) ArcGIS Online for Organizations.

### 3.5.2 ArcGIS Server Development

On the GIST VM, the feature classes were compiled in ArcMap 10.2.1 for preparation for publishing using ArcGIS Server 10.2.1. In ArcMap, the feature class fields were given user-friendly aliases to remove underscores and to better describe what the fields represent by adding details in parentheses, such as “Depth (in meters)” to alert the user of the units of measure of the depth field. Also, in ArcMap, the symbology was set using custom made symbols (Figure 21) created by cartoonist John Pham (John Pham, per comm, 2015).



Figure 21 Custom symbols

Next, the finalized ArcMap map project (mxd) was published as a read-only map service as a REST endpoint. Appendix H lists the layers that make up the feature services.

### 3.5.3 ArcGIS Online Development

The REST Service endpoint was added to a new blank web map in ArcGIS Online. The web map created for this project was shared to the USC ArcGIS Online organization and the web map was customized based on user requirements.

The “Streets” basemap was chosen to provide a neutral backdrop for the data with some labeling, yet minimal coloring to compete with the map data. The pop-ups were edited in the ArcGIS Online web map before publishing as a web application. In the pop-up it should again be



noted that specimen counts and most abundant values are based on specimens recorded in the geodatabase and do not represent the entirety of the collection. The pop-up text was written as a custom attribute display using text and attributes html tags in the ArcGIS Online pop-up text editor. For example, the La Brea Fossil Deposit pop-up was edited to display:

“There are a total of "{NumberOfSpecimens}" databased specimens in Deposit {locality} as of June 2015. The top elevation of the deposit is {top\_elev\_ft} feet and the bottom elevation is {bottom\_elev\_ft} feet.  
The calibrated age range for this deposit is "{relationships/0/Min\_Calibrated\_Age} {relationships/0/Max\_Calibrated\_Age}". Note: If Total Number of Specimens is blank (""), there are no recorded data for this deposit.”

In the web GIS application, feet was chosen as the unit of measurement since all elevations, pits, and water depths are recorded in feet on the original survey map, which allows for consistency within the application for the user.

The web application was built using an ArcGIS Online template and the JavaScript API version 3. The out-of-the-box WebAppBuilder technology hosted on ArcGIS Online was also used (Esri 2015c). The color of the overall application was changed from the default blue color to an orange color similar to the orange used on the Page Museum’s main website. An image of a saber-toothed cat (*Smilodon fatalis*) was also added to the interface as well as a link to the Page Museum website. Additionally, the visible scale of the application was extended to 100 as the maximum zoom level with 800, 400, and 200 added as zoom levels in between. The zoom level was extended due to this application being large scale for a very small extent of Hancock Park (0.25 by 0.35 square mile).

An “About” section was added to explain the web application to the public. In the “About” section, a URL to the original paper survey map was included to give the application

user insight into the development of the geodatabase and web GIS application<sup>10</sup>. Also URLs of the 3D representations of the *Smilodon fatalis* and *Panthera atrox* elements (bones) were added to display the future potential of mapping fossils to the centimeter level in 3D<sup>11 12</sup>.

Also, queries and charts were added per the user requirements of the web GIS application. The queries were requested by the museum staff because there are about 145 deposits, so searching the data would otherwise be difficult. As a proof of concept, one may search for most abundant deposits by deposit, by species, and by element. As this web GIS application evolves in the future these queries can be added or edited as the museum staff requires. The queries added include the following: (1) Search by Deposit #, (2) Search for Most Abundant Deposits, (3) Search for Deposit by Most Abundant Species, and (4) Search for Deposit by Most Abundant Element (Figure 22 - Figure 25 display the chart configurations).

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<sup>10</sup> Pham, K.P. 2015a. "Tar Pits Survey Map." Accessed August 29, 2015. <http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/TarPitsSurveyMap.html/>.

<sup>11</sup> Pham, K.P. 2015b. "P23 Box 1 Fluffy Video." Accessed August 29, 2015. [http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/P23\\_Box1\\_Fluffy\\_video.html/](http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/P23_Box1_Fluffy_video.html/).

<sup>12</sup> Pham, K.P. 2015c. "P23 Box 1 Smilodon by Age Video." Accessed August 29, 2015. [http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/P23\\_Box1\\_SmilodonbyAge\\_video.html/](http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/P23_Box1_SmilodonbyAge_video.html/).

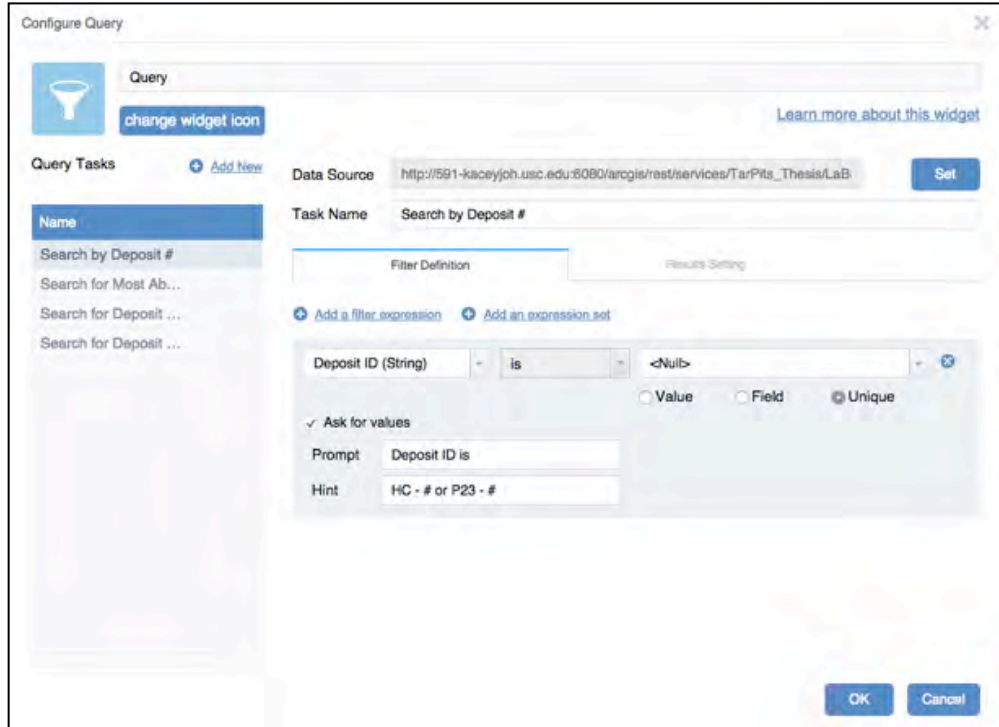


Figure 22 Search by Deposit # Query widget configuration

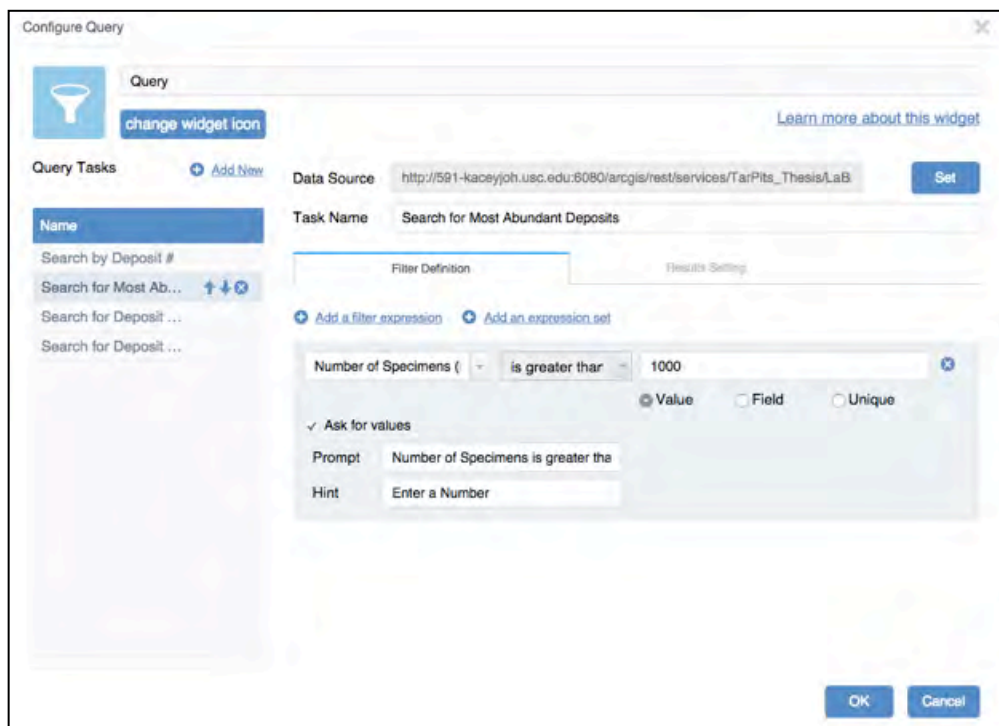


Figure 23 Search for Most Abundant Deposits Query widget configuration

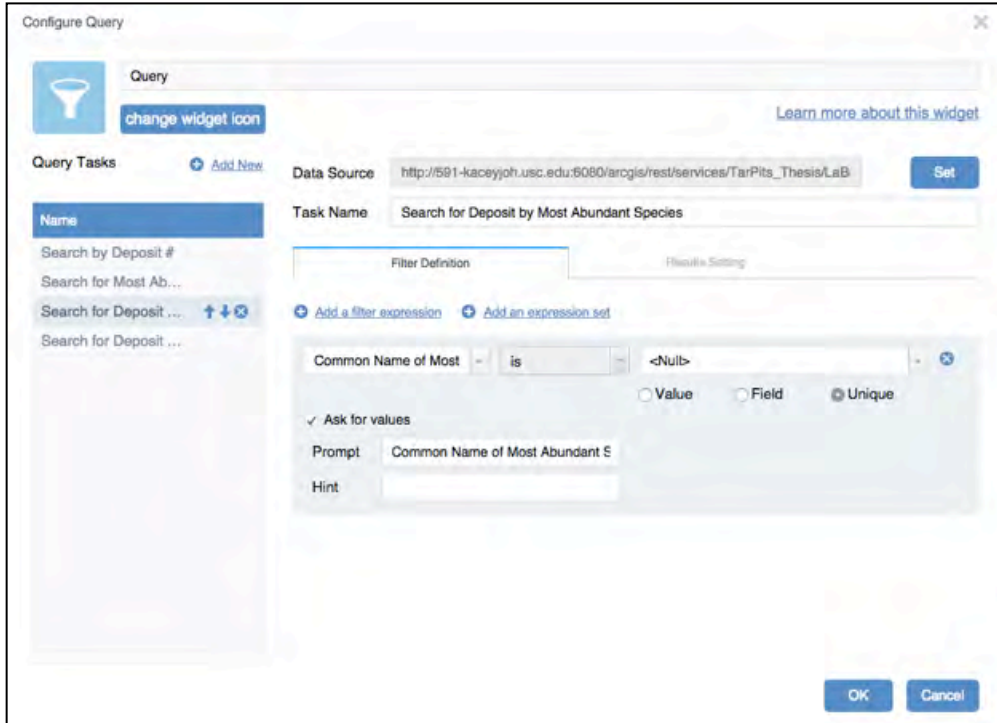


Figure 24 Search for Deposit by Most Abundant Species Query widget configuration

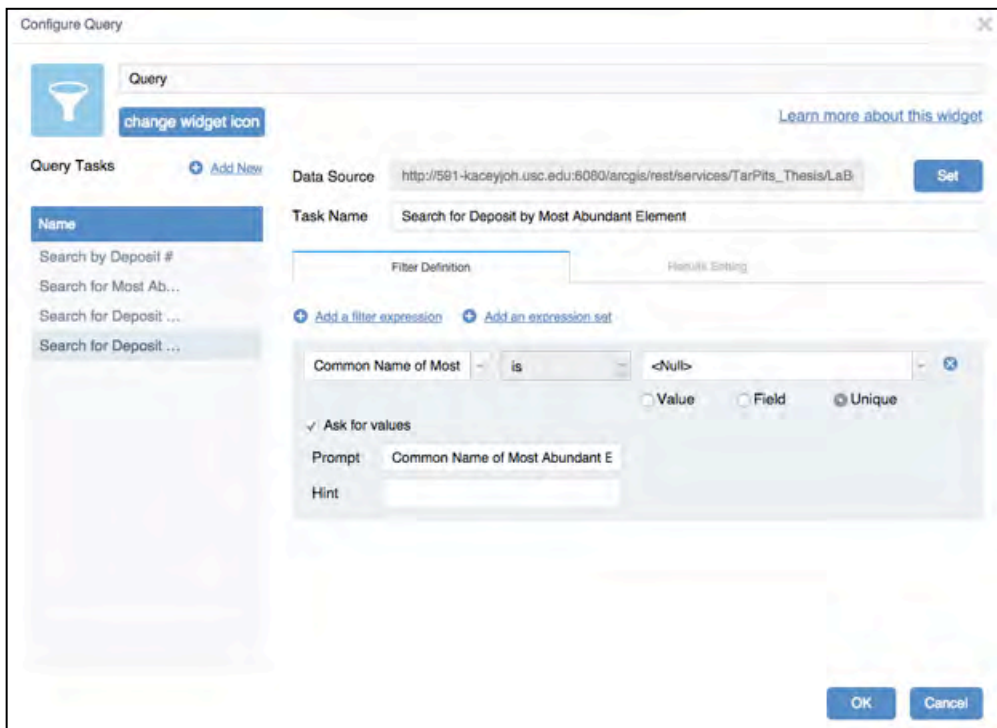


Figure 25 Search for Deposit by Most Abundant Element Query widget configuration

The charts were requested to show an added dimension to the data visualization by showing abundance of deposits and certain taxonomical classes by using pie and column charts. The charts that were added include: (1) Number of Specimens by Deposit, (2) Total Number of Mammals, Reptiles, Birds, and Amphibians in Collection (associated with a deposit), (3) Number of Mammals by Deposit, (4) Number of Reptiles by Deposit, (5) Number of Birds by Deposit, and (6) Number of Amphibians by Deposit (see Figure 26 - Figure 31 for chart configurations).

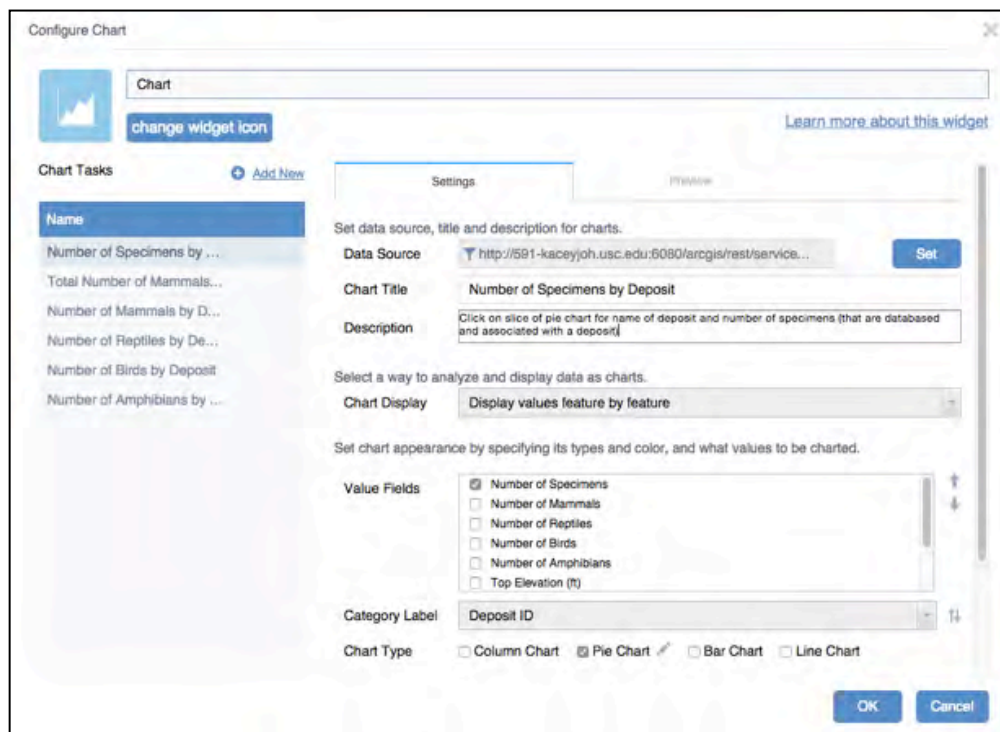


Figure 26 Number of Specimens by Deposit Chart widget configuration

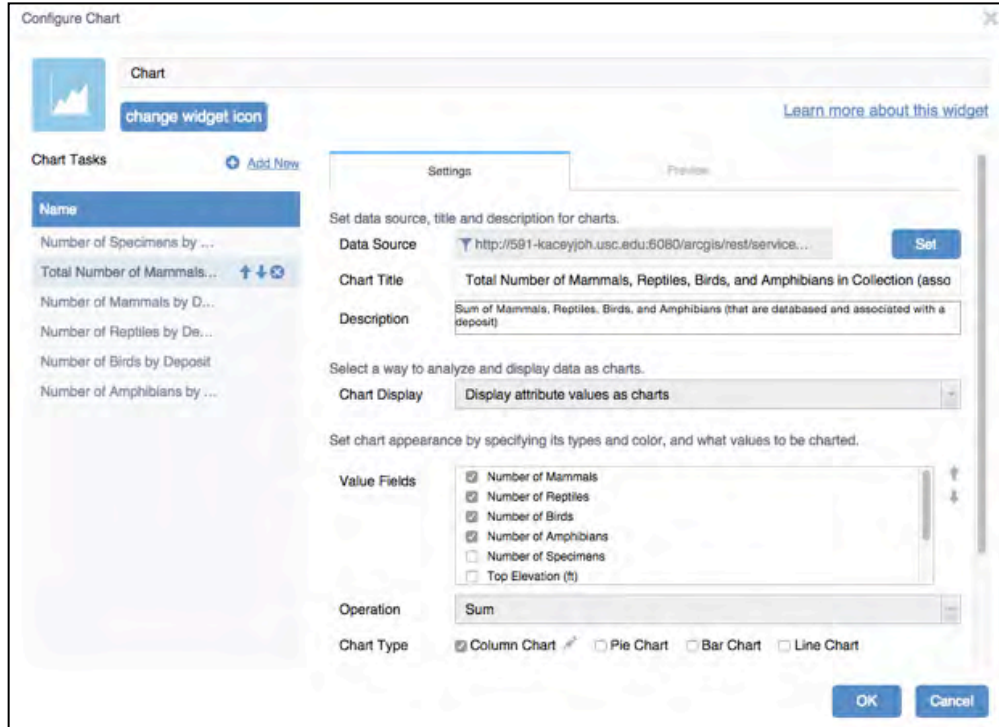


Figure 27 Total Number of Mammals, Reptiles, Birds, and Amphibians in Collection (associated with a deposit) Chart widget configuration

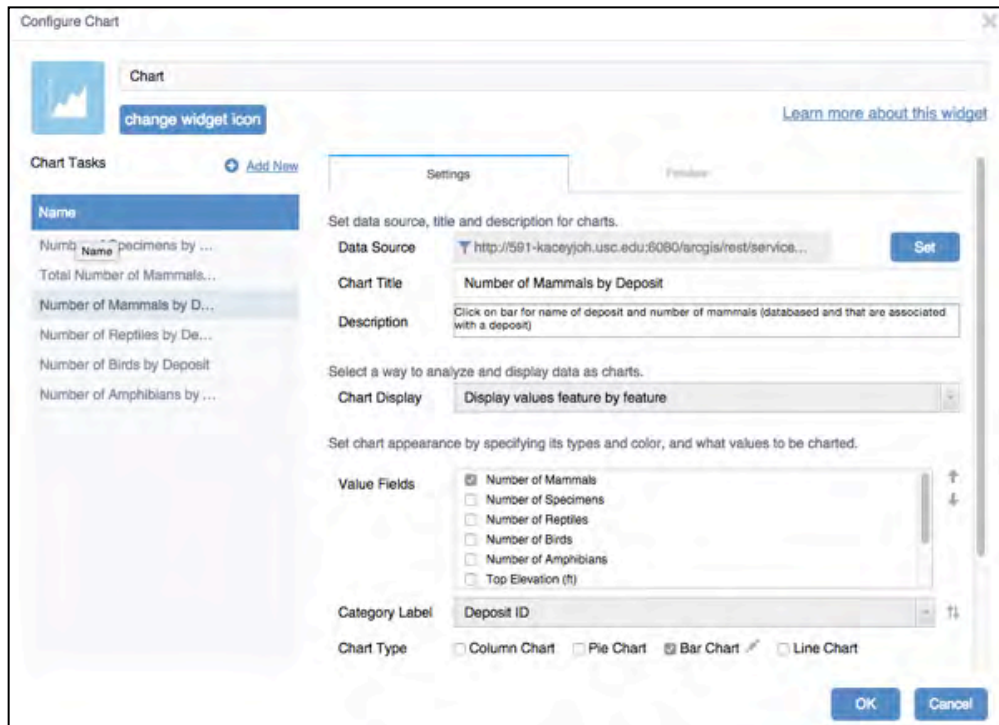


Figure 28 Number of Mammals by Deposit Chart widget configuration

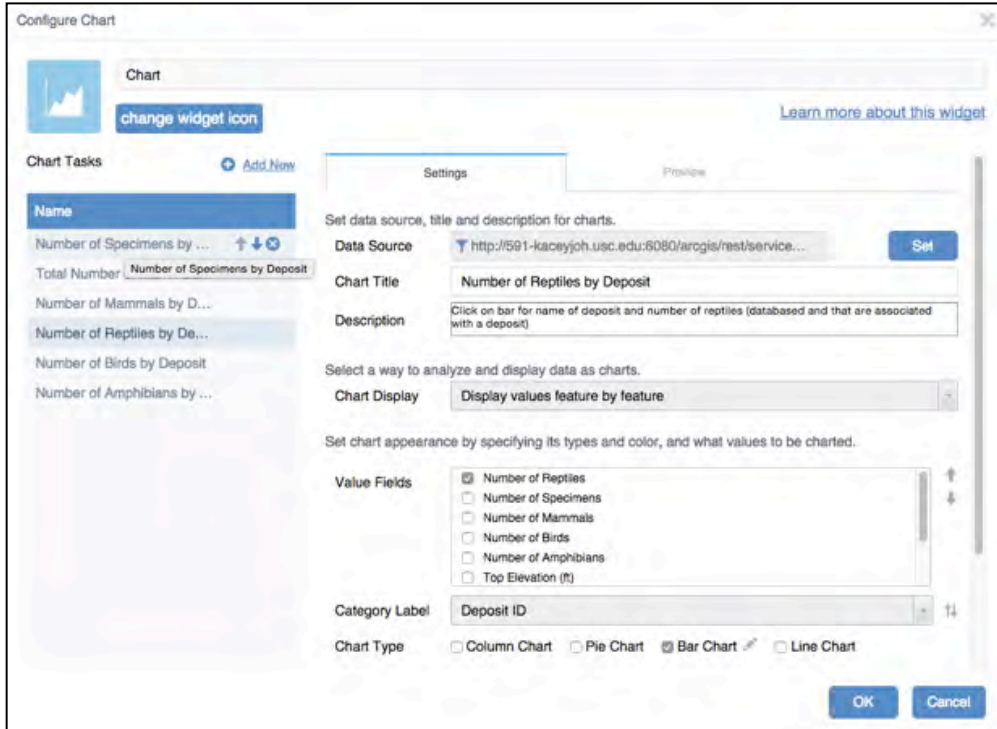


Figure 29 Number of Reptiles by Deposit Chart widget configuration

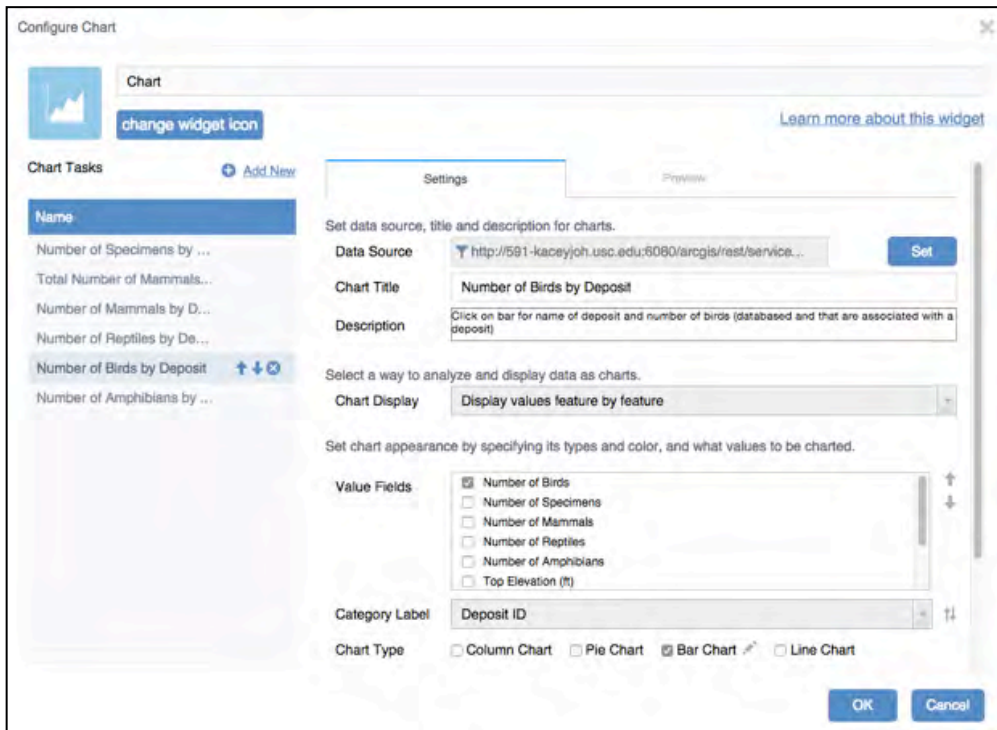


Figure 30 Number of Birds by Deposit Chart widget configuration

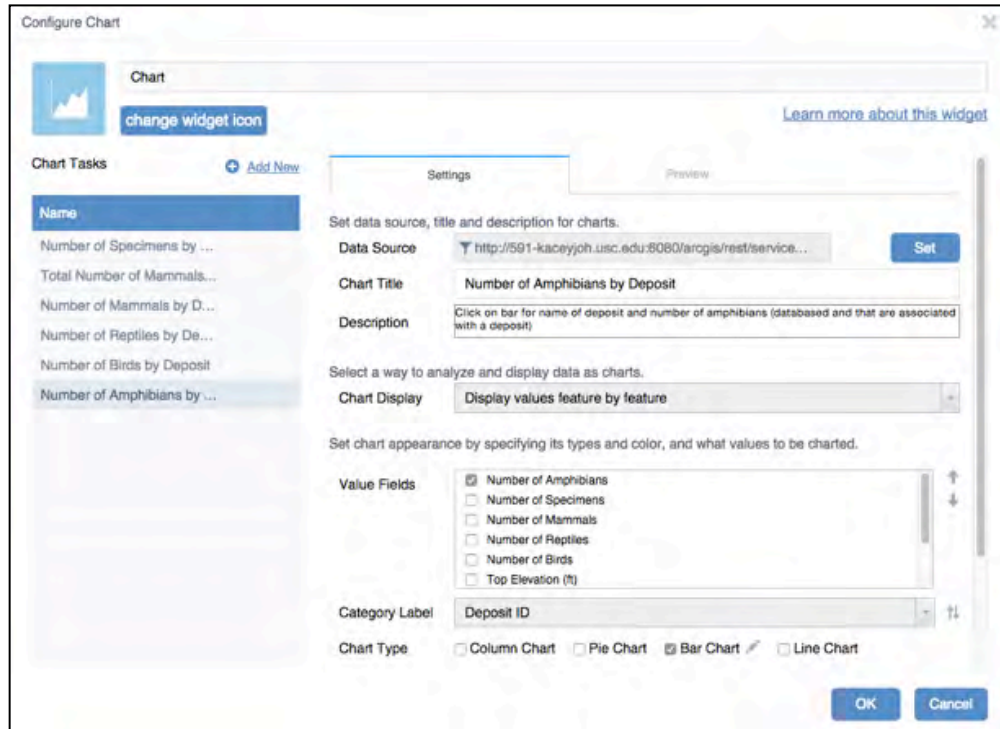


Figure 31 Number of Amphibians by Deposit Chart widget configuration

### 3.5.4 Web Application Requirements Review

The following section outlines the web application review results from a meeting that took place between the author and museum staff on July 13, 2015. The results of the review can be found in Appendix G: Requirements for the Web GIS Application, Table G-3 and G-4. Additionally, a review of feedback received and changes requested can be found in Appendix G, Table G-5.

### 3.6 Chapter Summary

The methodology implemented consisted of data collection, requirements gathering, geodatabase design, data preparation for entry into the geodatabase and use in the web GIS application respectively, web GIS application creation, and testing of the final pilot web GIS application. Steps were repeated as necessary using an Agile approach after museum staff user review. The results of the final geodatabase and web GIS application created by following the method



outlined in this chapter are presented in the next chapter, Chapter 4 Results, including geodatabase and web GIS application user guides citing typical use cases for the web application.

## CHAPTER 4: RESULTS

This chapter describes the results of the development of the La Brea Tar Pits database and web application. Section 4.1 presents the final geodatabase model, and section 4.2 provides examples illustrating the web GIS application functionality. Section 4.3 includes user manuals for use and updating of the web GIS application, and section 4.4 outlines typical use cases for museum staff for the web GIS application. Lastly, section 4.5 presents a preliminary field data collection schema.

### 4.1 Data Model: Geodatabase Diagram and Schema

The structure of the La Brea Tar Pits database is visualized in a geodatabase Entity Relationship Diagram (ERD) in Figure 32 and Figure 33. The design of the geodatabase ERD is based on all data fields captured in the KE EMu database, though not all of the original data fields were captured in the web GIS application pop-ups. To best focus the scope of this project as well as follow the requirements gathered from the Page Museum staff, only some of the fields and aggregated versions of the fields were implemented in the geodatabase and thus also in the resulting web GIS application. A detailed description of the resulting interrelationships between database entities is provided herein.

The design of the geodatabase ERD was created to follow KE EMu database structure as closely as possible, to facilitate creating queries to extract, transform, and load records from the KE EMu database to the La Brea Tar Pits geodatabase as part of a regular maintenance and updating plan for future work (Figure 32). Thus the geodatabase was built based on an ideal structure for a “live” geodatabase in which records could be updated to the SQL Server geodatabase nightly using stored procedures.

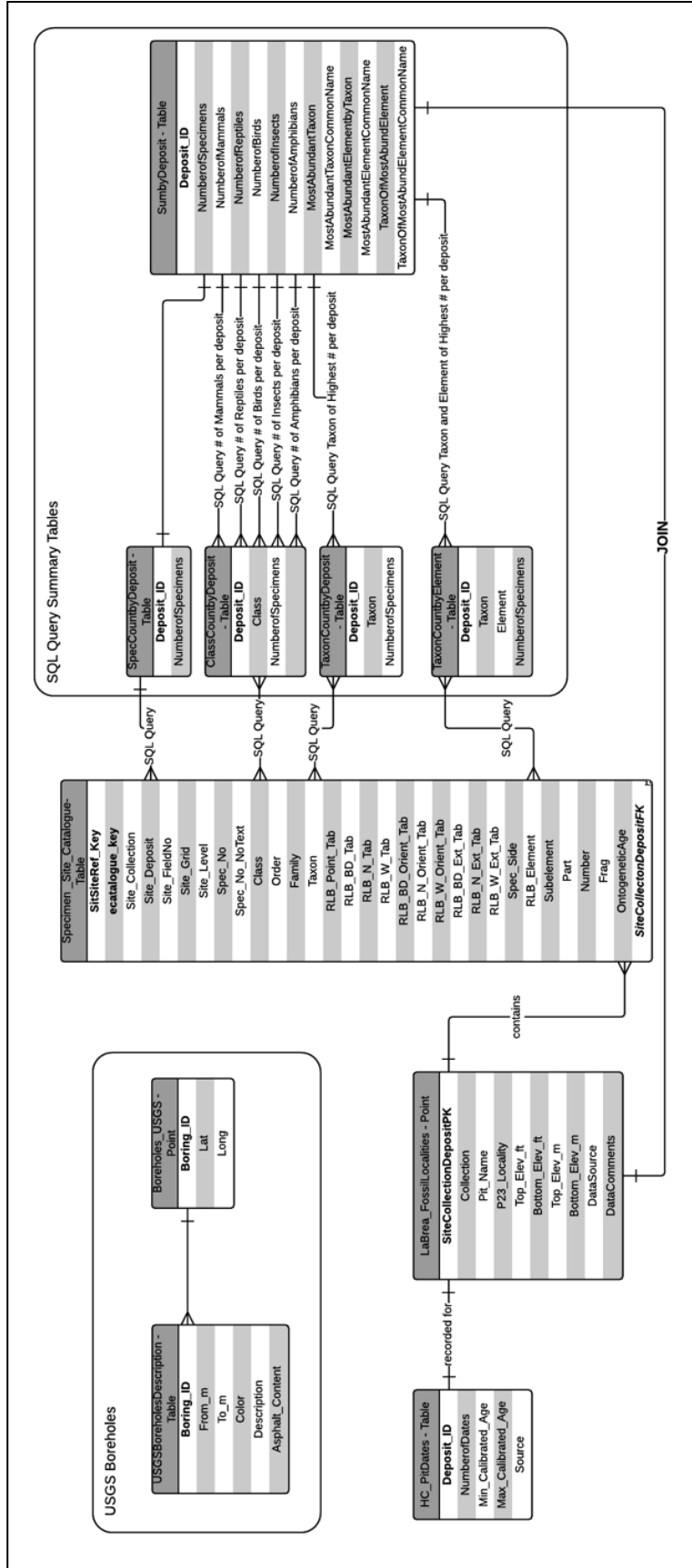


Figure 32 La Brea Tar Pits geodatabase ERD detailed view

The La Brea Tar Pits geodatabase ERD begins with the LaBrea\_FossilLocalities point feature class entity and describes the survey site in which the fossils are found. The LaBrea\_FossilLocalities includes dates recorded for some pits in the HC\_PitDates table, and contains many fossil specimens from the Specimen\_Site\_Catalogue indicated in Figure 33. The LaBrea\_FossilLocalities feature class is related to both the HC\_PitDates entity and the Specimen\_Site\_Catalogue entity by the Deposit ID. The Specimen\_Site\_Catalogue entity describes the paleontological specimen found at the survey site, using a common attribute key. The Specimen\_Site\_Catalogue entity contains all attributes found in the extracted tables from the KE EMu database. Some specimens contained in the table may have null deposit IDs or IDs that do not match to a locality in the LaBrea\_FossilLocalities entity.

The LaBrea\_FossilLocalities table possesses a one-to-many relationship with the Specimen\_Site\_Catalogue entity, and the LaBrea\_FossilLocalities table has a one-to-one relationship with the HC\_PitDates entity (Figure 33). The SQL query summary table SumbyDeposit is related in a one-to-many relationship to the Specimen\_Site\_Catalogue table via intermediate entity tables. The intermediate tables are related to the Specimen\_Site\_Catalogue entity as a many-to-many relationship for all entities except for the SpecCountByDeposit entity, which is related one-to-one because there is only one total specimen count per deposit. The many-to-many relationships exist because there are many species per deposit. The SumbyDeposit table was created via multiple SQL queries to extract totals from the intermediary tables. Lastly, the SumbyDeposit table was joined one-to-one to the LaBrea\_FossilLocalities entity feature class.

The geodatabase ERD also contains the borehole entities from the data collected from the USGS and the Quinn technical report (Quinn et al 2000, Figure 33). The Boreholes\_USGS point feature class is related to the USGSBoreholesDescription entity in a one-to-many relationship because each borehole location is related to many depth measurements with associated sediment descriptions.

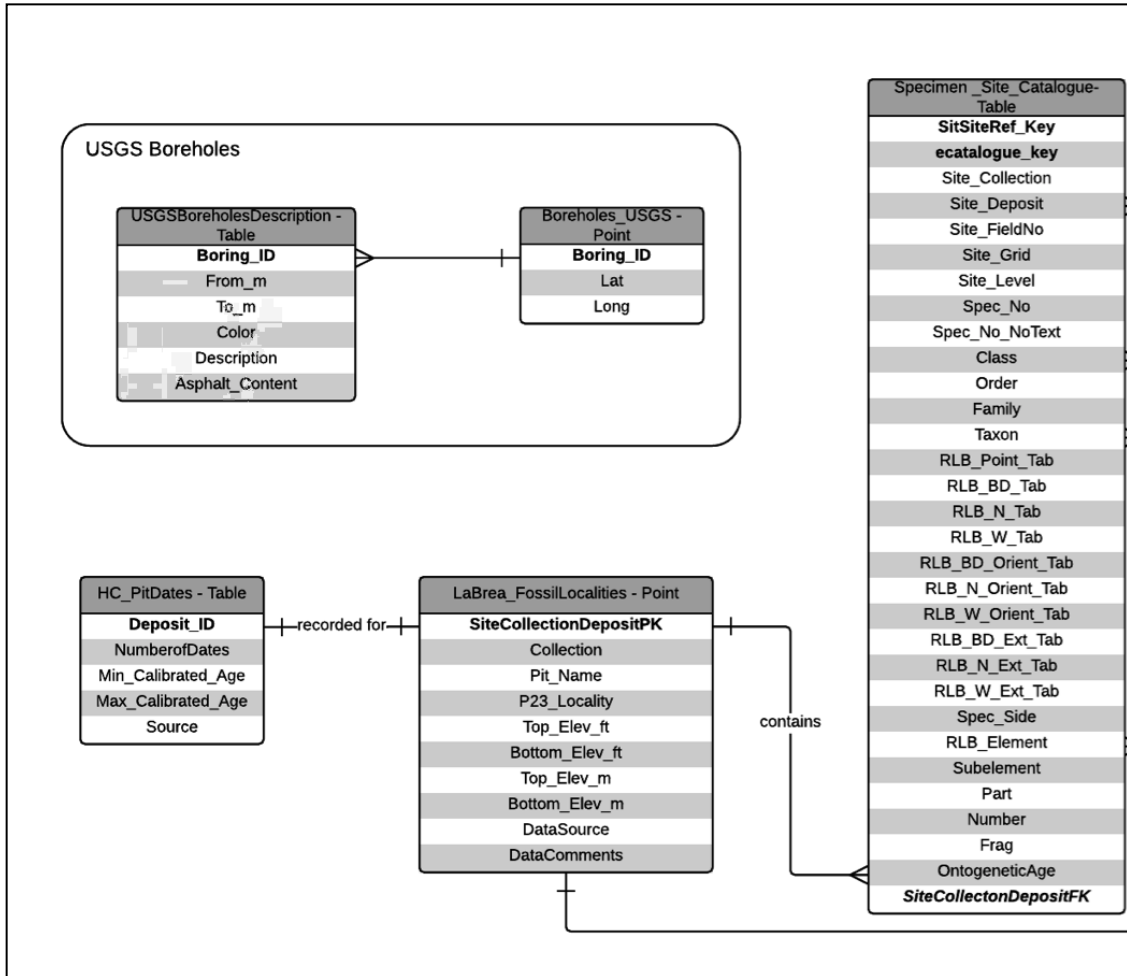


Figure 33 Enlarged view of main structure of the La Brea Tar Pits geodatabase ERD showing the relationships between the point feature classes and tables

#### ***4.1.1 Geodatabase Tables, Fields, and Properties***

Appendix I: La Brea Tar Pits Geodatabase contains tables that describe the fields, attributes, and relationship classes in the La Brea Tar Pits geodatabase.

#### ***4.1.2 Data Model Review***

The data model was reviewed and accepted by museum staff on July 13, 2015. As previously stated, the main requirements were that the new geodatabase be as similar to, or as consistent as possible with the basic schema of the KE EMu data extract provided in June of 2015. The data entered into the geodatabase was minimally changed for the purpose of better visualizing in a GIS. The key requirement that highly detailed information on individual specimens not be exposed in the geodatabase and hence in the web GIS application required that some data be summarized was accomplished, and checked and accepted by museum staff. The museum staff's major concern was sustainability and the ease of maintenance of the geodatabase in the future (Aisling Farrell, per comm, 2015). These concerns are addressed in Appendix K in the form of geodatabase update user guide, and in Chapter 5 Future Work, regarding long term database development and implementation.

#### ***4.1.3 Database Update User Guide***

To update the database, in the future it is anticipated that the KE EMu database will be directly connected to the SQL Server and stored procedures, based on the SQL queries found in Appendix E and F. It is intended that the queries be set to run as nightly automated updates. Until a connection is set up between the two databases, a manual update procedure is still necessary. Appendix K: Geodatabase Update User Guide contains the steps required for performing manual updates of the new geodatabase from the KE EMu database.

## 4.2 Web Application Screenshots and Functionality

When the user first opens the application, the interface appears as shown in Figure 34. Note that the application is not public so an ArcGIS.com Organizational account will need to be provided in order to view the application.

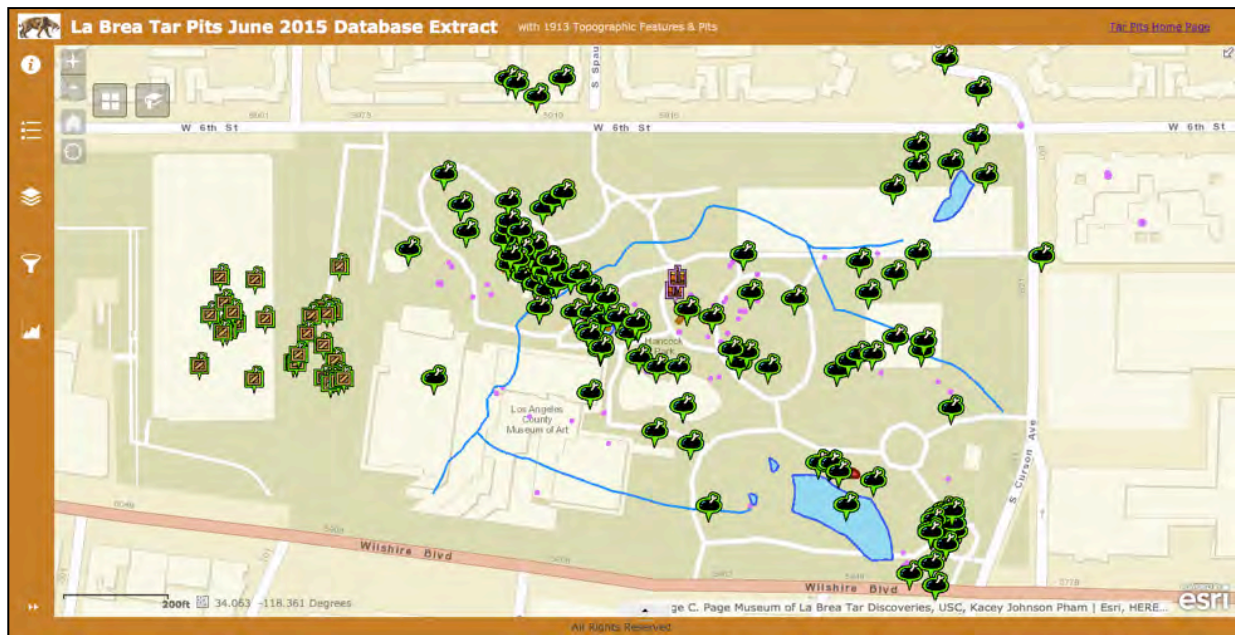




Figure 34 The final version of the La Brea Tar Pits web application as of August 2015  
There is a left side panel of widgets that can be clicked on and will automatically expand the side panel to a full pane. The widgets are follows: About the App, Legend, Table of Contents, Queries, and Graphs. Within the map frame in the top left corner, are zoom in/out controls, return to home extent, and find the user's location buttons. Additionally, in this same left upper area, the bookmarks  and basemaps  widgets can be found.

## 4.3 Web Application User Guides

User guides were developed to help the museum staff use and update the web GIS applications. Appendix L is a guide for use of the application, which follows a standard user workflow. The user guide shows the staff how to navigate to the various menus and widgets in the application,

with emphasis on how to use the query and chart functionalities. Appendix M: Web GIS Application Update User Guide contains a guide to assist the staff in the update of the application when necessary. The guide outlines how to change the web map, the layout, the colors, and edit the widgets in the web application using the ArcGIS Online Web AppBuilder interface.

#### **4.4 Use Cases**

The anticipated current use cases are for the museum staff, to check the web GIS application daily to view how the total distribution of different taxonomical classes had changed based on recent excavations. Also, the web GIS application itself can be used to search for locations of pits as a simpler way to find current or new pit locations. This is the first map view of any kind displaying both Project 23 and Hancock Collection pits together on the same map. The web GIS application also provides an extremely efficient way for the museum staff to monitor and compare locations across the park. Visually, staff members can easily see trends in abundance of specific types of fossil deposits that could hopefully lead to answering many present and future research questions related to paleontology and climate change.

The web GIS application offers a way to view selected collection data spatially that cannot be achieved by viewing through the medium of the KE EMu database. The new way of viewing the specimen data can lead to new data curation workflows that allow the museum staff to catch errors in data entry that may not have otherwise gone undetected using the interface of the KE EMu database.

#### **4.5 Field Data Collection Geodatabase Prototype**

This section describes additional work that was done to support the thesis project, but has not been reviewed by the museum staff. The proposed field data collection geodatabase could be



created by updating the current geodatabase design described in section 4.1. It is important to note that this is a draft schema that has not yet been implemented as a backend to a mobile field data collection application.

#### ***4.5.1 Field Data Collection Geodatabase Diagram and Schema***

The original design of the geodatabase ERD was created with the help of Cynthia Burrows, Jennifer Titus, and Dr. Jordan Hastings in SSCI 582 Spatial Databases Spring 2014 course as part of a final project (Cynthia Burrows, Jennifer Titus, and Dr. Jordan Hastings, per comm, 2014). Cynthia and Jennifer designed a geodatabase ERD for archaeology and the author focused on paleontology and combined these efforts into an Archaeo-Paleo database design. For this thesis project, the author then adapted the Archaeo-Paleo database design to be focused on paleontological use specific to the project requirements of the Page Museum at the La Brea Tar Pits (Figure 35 – Figure 36).

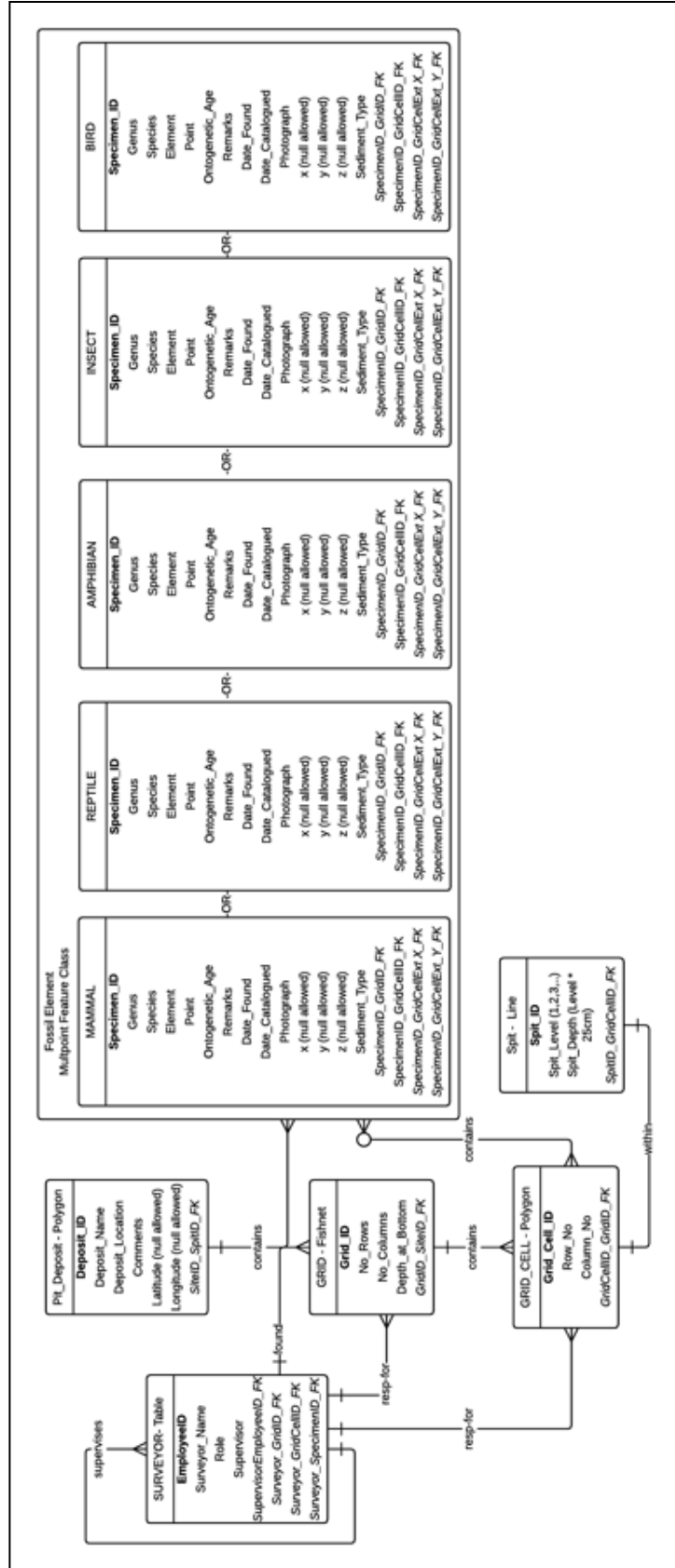


Figure 35 La Brea Tar Pits field data collection geodatabase ERD detailed view featuring all Fossil Element Subtypes

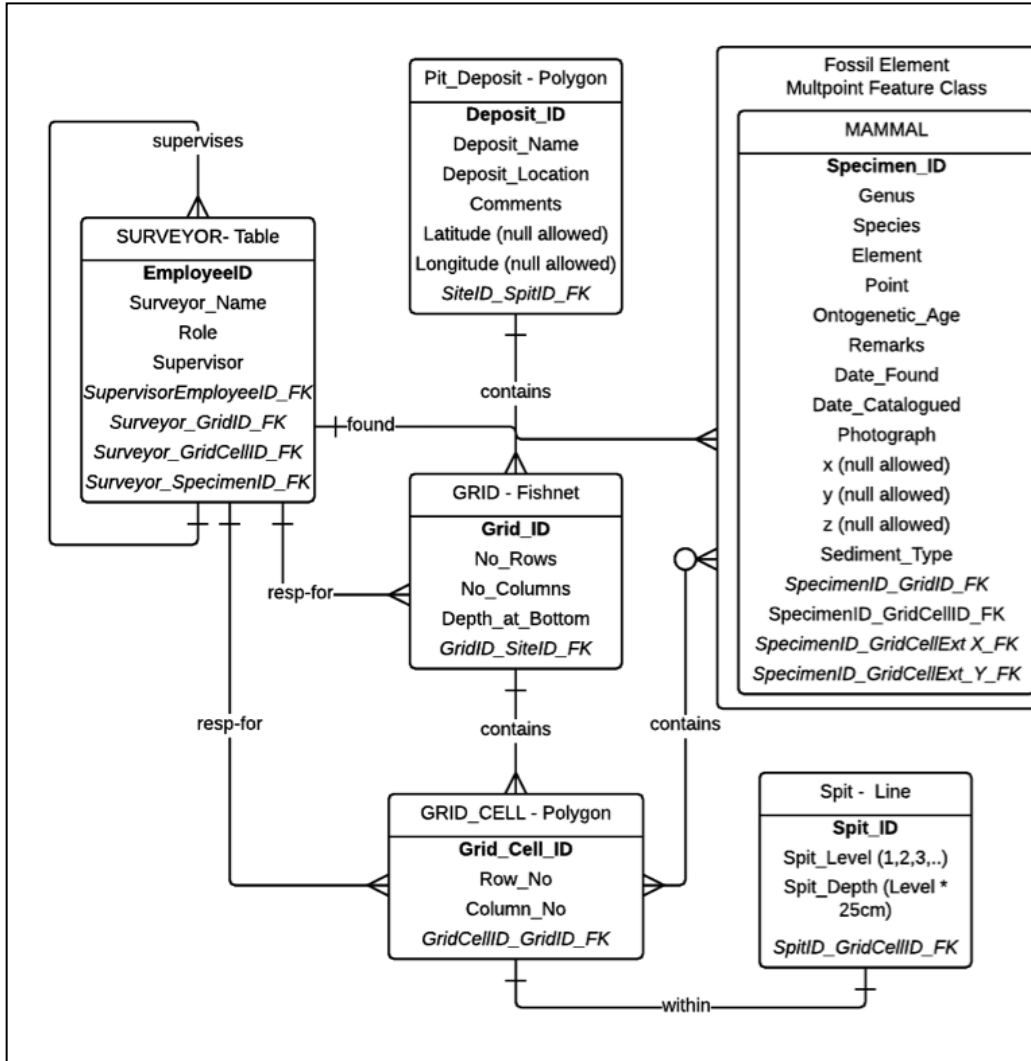


Figure 36 Enlarged view of main structure of the La Brea Tar Pits field data collection geodatabase ERD showing the relationships between attributes and the feature class type of each entity

Appendix J: La Brea Tar Pits Field Data Collection Geodatabase Table J-1 through Table J-9 describe the tables, fields, relationship classes, topology, and domains, in the La Brea Tar Pits field data collection geodatabase. The La Brea Tar Pits field data collection geodatabase ERD starts with the Surveyor entity. The surveyor is responsible for finding and documenting the specimens (fossils or fossil elements) that they discover in an assigned grid cell. An individual surveyor may find one or many specimens. The Fossil Element entity describes the

paleontological specimen found at the survey site. The fossil element entity is made up of subtypes of the most common types of fossil element found for each entity. The Pit Deposit entity describes the survey site in which the fossils are found. Each Pit Deposit entity contains a Grid entity, which is the outline of the gridded survey site within the larger Pit Deposit entity. The Grid entity contains the Grid Cell entity, which is made up of rows and columns. Each grid has depth levels that are measured in units of 25cm called “spits.” A fossil’s element entity must be found within one or many grid cells.

The following is a description of the envisioned interrelationships between geodatabase entities. The surveyor has a one-to-many relationship with itself to account for the supervisor role in the hierarchy of surveyors. The surveyor is responsible for one-to-many grids and grid cells, and the surveyor finds one-to-many cultural or natural artifacts. The pit deposit has a one-to-many relationship with the grid(s) that it contains and also has a one-to-many relationship with the spit levels that are found within the pit deposit. Lastly, the grid cell has a many-to-many relationship with the fossils that are found within its bounds. There may be multiple grids that contain the same fossils and there may be multiple fossils in one grid. If the same fossil exists in many grids, this is called a grid extension, which can be in the x- and/or y- direction. Grid extensions are represented in the geodatabase by the attributes `Artifact_ID_GridCellExt_X_FK` and `Artifact_ID_GridCellExt_Y_FK`.

There are no interrelationships between individual fossil specimens in this geodatabase ERD because in practice, paleontologists at the Page Museum consider each fossil in a database to be its own entity. If relationships between specimens require study, at present a researcher may query the KE EMu database for specimens that occur within a certain distance from the

fossil specimen in question. The definition of a relationship between artifacts may be different for each researcher, so it is best for the database to make no fossil relationship assumptions.

#### **4.6 Chapter Summary**

In summary, the work produced for this thesis project consisted of a geodatabase, a GIS web application, and a prototype field data collection geodatabase. The following chapter will describe how this work can be maintained and also discuss future work and considerations for this project.

## **CHAPTER 5: DISCUSSION AND CONCLUSIONS**

This chapter describes the maintenance considerations and future work for the La Brea Tar Pits database and web GIS application. The author and her committee chair, Dr. Jennifer Swift met with Aisling Farrell and Luis Chiappe, Director of the Dinosaur Institute at the Natural History Museum of Los Angeles County, on August 27<sup>th</sup> 2015 (Aisling Farrell and Luis Chiappe, per comm, 2015) and discussed many of the points that informed this chapter. Section 5.1 describes the long-term maintenance of the geodatabase and application. Section 5.2 discusses future work including an envisioned museum exhibit, future field data collection opportunities, and 3D data visualization potential. Lastly, section 5.3 provides final thoughts about furthering this thesis work.

### **5.1 Long-Term Geodatabase and Application Maintenance**

At present the application will be hosted on the USC GIST VM. It is anticipated that the Natural History Museum will host the database and application at some time in the near future. In Appendix N: Recommendations for Technology Transfer, the author provides recommendations to Page Museum staff for the transfer of the geodatabase to an ArcGIS environment hosted by the Natural History Museum. Also, recommendations for the skillset needed to carry out the work will be similar to the required research skills possessed by the author as described in Appendix A. The geodatabase, web GIS application and all associated files were backed up to external media in anticipation of this future transfer.

Procedures written for the Page Museum staff for updating the database and application are outlined in Chapter 4. The author may facilitate technology and knowledge transfer sessions to the staff to assist in learning how to maintain the database. The La Brea Tar Pits 1913/1983 map feature classes are static for the foreseeable future. Nevertheless, if the museum uncovers

new deposits that need to be added to the paper survey map, the procedure for updating the feature classes can be found in Chapter 4 as well.

Furthermore, it is anticipated that future USC GIST students will continue working on this project. It is envisioned that the geodatabase will one day be directly connected live to the KE EMu museum collections database. For example, a student intern or a consultant to the museum could set up a database connection and stored procedures to push nightly updates of the KE EMu database to the geodatabase. If this endeavor happens, the student or consultant can refer to the SQL queries (as described in Appendix E: Geodatabase Creation Notes and SQL Queries and Appendix F: SQL Queries for Specimen Summary Tables) to re-generate the tables in the geodatabase.

## **5.2 Future Work**

This section describes long-term aspirations for the evolution of this project. Section 5.2.1 discusses the possibility of this application evolving into a museum exhibit while section 5.2.2 explains how the geodatabase can be adapted in the future to support field data collection using a mobile GPS collection device. Finally, section 5.2.3 discusses the potential of 3D GIS visualization of fossils.

### ***5.2.1 Interactive Museum Exhibit***

This thesis project geodatabase design and web GIS application efforts will hopefully one day evolve into a resource available to visitors of the Page Museum in the form of a hands-on interactive public exhibit within the museum. This exhibit could have the distinction of being updated every day to support the museum's website which states that "discoveries are made daily" (Page Museum 2015a). It is envisioned that the interactive map will be housed in a wall with a large touch sensitive monitors to allow visitors to directly query different pit locations to

learn about the daily discoveries in the deposits. Also, it is imagined that a museum guest could search for a pit and view interactive graphs of the most abundant types of fossils found.

### ***5.2.2 Field Data Collection***

There is a strong potential for adaptation of the geodatabase into a new schema to support field data collection at excavation sites in Hancock Park. The geodatabase designed in this thesis could be adapted to be used with a digital, spatial field data collection tool. For example, the GPS data collection device could be a mobile phone using the ArcGIS Collector application<sup>13</sup>, or it could be a more precise GPS collection device with sub-centimeter accuracy to precisely map the location of fossils discovered, which would support mapping the elements found in a 3D model (see section 5.2.3 for further discussion).

### ***5.2.3 Three-dimensional (3D) Data Visualization***

A small extract of data was used in the example 3D visualization in order to map the x, y, and z (depth) of fossil elements found in Project 23 Deposit 1 for large cats. The methodology is described in Chapter 3 and involved significant data preparation after the original data was obtained from the KE EMu database. Future work will be necessary to develop a SQL query to automate the transformation of the data fields to convert specimen location data to a format that can be viewed in 3D in GIS. Additionally, the implementation of a new geodatabase design to capture the x, y, and locations of elements found during future excavations would make the visualization of elements in 3D space more easily automated without requiring significant database transformation and queries.

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<sup>13</sup> Esri. 2015. "Collector for ArcGIS: Get Started." Esri. Accessed August 22, 2015. <http://www.esri.com/software/arcgis/collector-for-arcgis/>.



A benefit of 3D display is that it could enhance the capabilities of the La Brea Tar Pits web GIS application and possible future museum exhibits by allowing visitors to see how fossil deposits appear below the surface and to better comprehend the vast collection of fossils contained in each pit. Currently, the web application contains simple hyperlinks to two 3D videos of large cat specimens in Project 23, Deposit 1<sup>14</sup> <sup>15</sup>.

It is desired by the museum staff that 3D data be incorporated into the web application as live data in the future. Accordingly, the museum exhibit could be enhanced to allow the visitor to select a fossil deposit location and zoom into the grid layout of the excavation site. Then the user could choose to display, for instance, all mammals, predatory birds, or highlight specific species. It is also hoped that previously scanned bone images could also be rendered within the 3D visualization so that bones can be more easily identified, rather than viewing dots and lines as in the current version of the 3D proof of concept visualization. This would allow the museum visitors to truly see the remarkably abundant assortment of fossils that are found at each excavation site.

### **5.3 Next Steps**

To continue this project, it is recommended that the museum hire volunteers, student interns or consultants with the same or similar qualifications as the author. In this way the new geodatabase could continue to be developed and linked to the KE Emu database, and the 3D visualizations could be implemented directly from the geodatabase. Lastly, the web GIS application could be extended to include 3D visualizations as well as live web maps updated daily, which could also become part of new, interactive, public exhibits at the museum.

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<sup>14</sup> Pham, K.P. 2015b. "P23 Box 1 Fluffy Video." Accessed August 29, 2015. [http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/P23\\_Box1\\_Fluffy\\_video.html/](http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/P23_Box1_Fluffy_video.html/).

<sup>15</sup> Pham, K.P. 2015c. "P23 Box 1 Smilodon by Age Video." Accessed August 29, 2015. [http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/P23\\_Box1\\_SmilodonbyAge\\_video.html/](http://www-scf.usc.edu/~kaceyjoh/LaBreaTarPits/P23_Box1_SmilodonbyAge_video.html/).

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## APPENDIX A: REQUIRED RESEARCH SKILLS

This appendix contains an overview of the research skills possessed by the author of this study, also necessary for those who will continue this work.

Table A-1 Required Research Skills

	<b>Proficiency (novice, intermediate, expert)</b>	<b>Experience/Training</b>
<b>ArcGIS Server</b>	Intermediate	Web GIS coursework; ArcGIS Server experience
<b>SQL Server</b>	Intermediate	A SQL Server geodatabase experience and access to SQL subject matter experts
<b>ArcGIS Desktop</b>	Expert	Over 5 years experience with ArcGIS Desktop
<b>ArcGIS API for JavaScript</b>	Novice/Intermediate	Review of Lynda.com courses, Esri for Developers ArcGIS for JavaScript reference guide; ArcGIS WebAppBuilder was used so JavaScript development was not necessary
<b>HTML &amp; CSS</b>	Novice/Intermediate	Review of Lynda.com courses, other online resources, access to subject matter experts
<b>Paleontology</b>	Intermediate	Working knowledge from volunteering at the Page Museum, access to subject matter experts

## APPENDIX B: DATA SOURCES AND DESCRIPTIONS

This appendix contains a table of all datasets used in this thesis including data sources, contents, preparation, size, representation, attributes, and accuracy.

Table B-1 Data Sources and Descriptions

<b>Dataset</b>	<b>Source</b>	<b>Contents</b>	<b>Preparation</b>	<b>Size</b>	<b>Representation</b>	<b>Attributes/ Accuracy (If relevant)</b>
La Brea Tar Pit Locations	The dataset describes the locations of asphalt fossil pits (i.e., the tar pits) digitized from a paper map of the park. (Noble 1913)	Historical pit locations from 1913.	Digitized in ArcMap and saved as feature class	114 rows	Point and Polygons	Pit Name, Bottom elevation of bottom of the pit (ft) *Accuracy may be off by 10 + ft due to digitization error.
La Brea Tar Pits Pit Dating	O'Keefe et al. (2009) Rancho La Brea Dating. Contributions in Science, Number 518 (O'Keefe et al 2009)	Radiometric dates of pits	Import table from txt file and relate to location layer by pit number	43 rows	Table	Pit, Age Range Calibrated, Mean Age Calibrated, Carbon Years, St Dev, Number of Dates
Project 23 Pit Locations	ArchaeoPaleo Resource Management Inc report via Page Museum (Turner 2006)	Project 23 pit locations from 2006 parking lot salvage	Display xy events layer in ArcMap and saved as feature class	23 rows	Point and Polygons	Location name, lat, long, fossil count, fossil types
Water Bodies	Paper survey map of park from 1913 (Noble 1913)	Map of the water body boundaries digitized from the survey map.	Digitized in ArcMap and saved as feature class	6 rows	Polygon	Type (Lake or Pond), Name, Water Elevation (feet).
Creeks	Paper survey map of park from 1913 (Noble 1913)	Map of the creeks digitized from the survey map.	Digitized in ArcMap and saved as feature class	4 rows	Line	Name
Oil and gas vents	Paper survey map of park from 1913 (Noble 1913)	Map of the oil and gas vents digitized from the survey map.	Digitized in ArcMap and saved as feature class	91 rows	Polygon	Name
Contours	Paper survey map of park from 1913 (Noble 1913)	Elevation contours in feet (contour interval = 2 ft)	Digitized in ArcMap and saved as feature class	129 rows	Line	Elevation

Dataset	Source	Contents	Preparation	Size	Representation	Attributes/ Accuracy (If relevant)
Survey Markers	Paper survey map of park from 1913 (Noble 1913)	Survey points from original 1913 survey using stakes and lathes, points are 18 ft apart, elevation range is 154 -180 ft.	Digitized in ArcMap and saved as feature class	568 rows	Point	Elevation
Boreholes / Core data	USGS Geotechnical Report (Quinn et al 2000)	Exploratory boreholes – only 2 boreholes in the Hancock Park extent have sediment descriptions	Display xy events layer in ArcMap and saved as feature class	403 rows	Point	Boring ID, Investigator, Boring Type (General Geotechnical, Geotechnical Standard Penetration Test (SPT), or Geologic Exploration), Elevation (interval, meters), Total Depth (interval, meters), Latitude, Longitude
Borehole Sediment Descriptions	USGS Geotechnical Report (Quinn et al 2000)	Sediment descriptions by depth in meters for two USGS boreholes within Hancock Park	Import table from txt file and relate to location layer by Boring ID	80 rows	Table	Boring ID, From depth (m), To Depth (m), Color, Description, Asphalt Content
Fossil x,y,z location of <i>Smilodon fatalis</i> and <i>Panthera atrox</i> in Box 1 of Project 23 fossil localities	Page Museum staff provided extracts from their KE EMu specimen database	The x, y, z coordinates of where each element of <i>S. fatalis</i> or <i>P. atrox</i> was found in a pit to be represented in 3D	Display x,y events layer with z value in ArcMap and saved as feature class, and edited in ArcScene	253 rows ( <i>S. fatalis</i> ); 161 rows ( <i>P. atrox</i> )	3D Point	Specimen Number, Taxon ( <i>S. fatalis</i> or <i>P. atrox</i> ), Comments, Group (hindlimb, forelimb, etc), Element Part (proximal, distal, etc), element (fibula, humerus, etc), ontogenetic age (adult, juv, etc), North (y-direction in cm), West (x-direction in cm), BD (z-direction in cm), grid (A1, B2, etc), Level (1,2,3,..) *Grid surveyed: accurate to the centimeter

## APPENDIX C: KE EMU DATA

This appendix contains the schemas of the KE EMu database extract obtained from the Page Museum in June 2015.

Table C-1 KE EMu Extract - Ecatalogue

<b>Ecatalogue.csv</b>		
<b>Field Name</b>	<b>Description</b>	<b>Notes</b>
ecatalogue_key	Unique ID for ecatalogue table from KE EMu extract	PK (Combined two tables- this is PK of second table)
Spec_No	First part Specimen ID or Catalogue Number	Letter or # key denoting the catalog system and collection
Spec_No_NoText	Second part Specimen ID or Catalogue Number	
Taxon	Taxonomical hierarchy (Taxon, Family, Order, Class)	
RLB_Point_Tab	Point of bone	
RLB_BD_Tab	Depth of specimen pre-excavation	
RLB_N_Tab	Y-direction of specimen pre-excavation	
RLB_W_Tab	X-direction of specimen pre-excavation	
RLB_BD_Orient_Tab	Orientation of BD point measured	
RLB_N_Orient_Tab	Orientation of Y point measured	
RLB_W_Orient_Tab	Orientation of X point measured	
RLB_BD_Ext_Tab	Grid that BD measurement extends into	
RLB_N_Ext_Tab	Grid that Y measurement extends into	
RLB_W_Ext_Tab	Grid that X measurement extends into	
Spec_Side	Side of bone	
RLB_Element	Osteological element (type of bone)	
SubElement	Sub classification of bone	
Part	Identifiable part of bone found to base measurement on	Ex. (Px=proximal, Dt=distal, etc)
Number	Number of element	For numbered bones such as vertebrae and toes
Frag	Is the specimen a fragment?	
OntogeneticAge	Maturity of specimen	If the specimen be identified as juvenile, or very juvenile



Table C-2 KE EMu Extract - SitSiteR

<b>SitSiteR.csv</b>		
<b>Field Name</b>	<b>Description</b>	<b>Notes</b>
SitSiteRef_Key	Unique ID for SitSiteR table from KE EMu extract	Primary Key
ecatalogue_key	Unique ID for ecatalogue table from KE EMu extract	Primary Key (Combined two tables- this is PK of second table)
Site	Locational information for the specimen	Collection, Deposit, Field No, Grid, Level

## APPENDIX D: FOSSIL POSITIONAL DATA FOR 3D DISPLAY

This appendix provides an example of a specimen record from the KE EMu database before and after the author transformed one record to three records and shifted data values to flip the axis and depth measurements. The acronyms used in the column names are RLB (Rancho La Brea), BD (Below Depth), N (North), and W (West).

Table D-1 Example of fossil positional data before transforming for 3-dimensional display

Catalogue_No	RLB_Point	RLB_BD	RLBBD_Extension	RLBN	RLBW	RLBWExtension	RLBCoordinates_tab_all	RLBLevel_all
Catalog Number	Rancho La Brea (RLB) Specimen - Point Measured on Bone	Below Depth Measurement	Below Depth Measurement Spit Level Extension	Northing	Westing	Westing Grid Extension	Grid (1x1 m)	Spit Level (25 cm increments)
P23 16107	Dt Px RT	181 172 174	L7 L7	3.5 4 5.5	1 88.5 90.5	B-2	B-1	8

Table D-2 Example of fossil positional data after transforming for 3-dimensional display

Catalogue_No	RLB_Point	RLB_BD	RLBBD_neg	RLBBD_Extension	RLBN	RLBW	RLBW_neg	RLBWEExtension	RLBCoordinates_tab_all	RLBLevel_all
P23 16107	Dt	181	-181		3.5	1	-1	B-2	B-1	8
P23 16107	Px	172	-172	L7	4	88.5	-88.5		B-1	8
P23 16107	RT	174	-174	L7	5.5	90.5	-90.5		B-1	8

## APPENDIX E: GEODATABASE CREATION NOTES AND SQL QUERIES

This appendix documents the data processing steps and SQL queries used to create the geodatabase described in section 3.3 Data Background and Processing Methods.

### Processing in ArcMap:

- Merged P23 points from Archaeo Paleo report with HC Points from Survey map using ArcMap.

#### *Fields From P23*

[OBJECTID]  
,[Locality]  
,[Latitude\_N]  
,[Longitude\_]  
,[UTM\_Northi]  
,[UTM\_Eastin]  
,[TopElev\_m]  
,[BottomElev\_m]  
,[TopElev\_ft]  
,[BottomElev\_ft]  
,[Notes]  
,[Field\_No]  
,[P23\_Deposit]  
,[Shape]

#### *Fields From HC*

[OBJECTID]  
,[LocalityID]  
,[Name]  
,[BottomElev\_ft]  
,[lat]  
,[long]  
,[Pit\_No]  
,[SHAPE]

#### Notes:

- Added Field [Bottom\_Elev\_m] used field calculator with expression  $[Bottom\_Elev\_m] = [BottomElev]/3.2808$
- Field Calculator  $Top\_Elev\_ft = TopElev\_m * 3.2808$
- Add Column called “DataSource”, “DataComments” to capture the difference in accuracy and data processing between the two tables
- Create SiteCollectionDepost field in point feature class for Join to SiteCollectionDepositFK in table
- Add “Collection” field to specify whether “Project 23” or “Hancock Collection” in order to draw by unique values category in ArcMap
- Export final table to SQL as LaBrea\_FossilLocalities

## Processed in MS Excel:

Received two extract tables from Museum staff in June 2015

*Ecatalogue.csv (408,234 records)*

ecatalogue\_key  
SpeSpecimenNo  
SpeSpecimenNoText  
Taxon -> Text to Columns in MS Excel to create (Taxon, Family, Order, Class)  
SpeSide  
RLBElement  
RLBSubElement  
RLBElementPart  
RLBElementNo  
RLBFragment  
RLBOntogeneticAge  
RLBPoint\_tab  
RLBBD\_tab  
RLBN\_tab  
RLBW\_tab  
RLBBDOrientation\_tab  
RLBNOrientation\_tab  
RLBWOrientation\_tab  
RLBBDExtension\_tab  
RLBNExtentsion\_tab  
RLBWExtension\_tab

*SitSiteR.csv (408,203 records)*

SitSiteREf\_Key  
Ecataloguekey  
Site -> Text to Columns in MS Excel to create ( Site\_Collection, Site\_Deposit, Site\_Field  
No, Site\_Grid, Site\_Level)

## Processed in MS SQL:

- Imported ecatalogue.csv to SQL as Specimen\_Catalogue and SitSiteR.csv as Specimen\_Site\_Deposit
- Parsing values from site\_collection and site\_deposit, editing, and combining the columns to create foreign key to match to location feature class

### *Query 1: Script to create table*

```
USE TarPits_kaceyjoh
SELECT [SitSiteRef_key]
    ,[ecatalogue_key]
    ,[Site_Collection]
    ,[Site_Deposit]
    ,[Site_FieldNo]
    ,[Site_Grid]
```

```

    ,[Site_Level]
    ,[ObjectID]
INTO Specimen_Site_Deposit
FROM [TarPits_kaceyjoh].[dbo].[SiteSiteR]
-----
ALTER TABLE [TarPits_kaceyjoh].[dbo].[Specimen_Site_Deposit]
ADD collection_short VARCHAR(5)
,deposit_short VARCHAR(50)
,SiteCollectionDepositFK VARCHAR(100)
-----

```

**Query 2: find all possible values for Site\_Collection**

```

SELECT [Site_Collection]
FROM [TarPits_kaceyjoh].[dbo].[Specimen_Site_Deposit]
Group by Site_Collection

```

**Results:**

```

Site_Collection
Pit 91 Collection
Birds-HC
Project 23 Collection
Shinenkan
Deposit General locality
Deposit 14
Deposit 91
Hancock Collection

```

Note:

- For purposes of GIS, all values that are not equal to Project 23 Collection will be changed to HC in order to join to HC feature class. This avoids duplicate, stacked point locations for collections that come from the same deposits.

```

USE TarPits_kaceyjoh
Update Specimen_Site_Deposit_new2
Set Collection_Short = 'HC'
Where Site_Collection <> 'Project 23 Collection'

```

```

USE TarPits_kaceyjoh
Update Specimen_Site_Deposit_new2
Set Collection_Short = 'P23'
Where Site_Collection = 'Project 23 Collection'
Query to find all possible values for Site_Deposit
SELECT [Site_Deposit]
FROM [TarPits_kaceyjoh].[dbo].[Specimen_Site_Deposit]
Group by Site_Deposit

```

Notes:

- To insert contents of Site\_Deposit into new column and replace deposit with '-' to result in "-#"
- Note – Cannot map to pits or boxes by grid number because the same grid number can be found in multiple deposits. Field number can be matched to deposit, but for purpose of this project, field number values are not included in the query. The resultant column of only "deposit -" values has only 385 nulls. The majority are grid values that cannot be parsed. With specific update statements, cleaned up the remaining values.

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
SET deposit_short = REPLACE(site_deposit, 'Deposit', '- ')
WHERE site_deposit like '%Deposit%'
SELECT * from specimen_site_deposit_new2
```

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
SET deposit_short= replace(site_deposit, ' Field No. GJM295 ','- 91')
WHERE site_deposit like '%Field No. GJM295%'
```

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
SET deposit_short = replace(site_deposit, ' Field No. RLP914 ','- 91')
WHERE site_deposit like '% Field No. RLP914 %'
```

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
SET deposit_short = replace(site_deposit, ' Field No. GJM584 ','- 91')
WHERE site_deposit like '% Field No. GJM584 %'
```

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
SET deposit_short = replace(site_deposit, ' Field No. GJM596 ','- 91')
WHERE site_deposit like '% Field No. GJM596 %'
```

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
SET deposit_short= replace(site_deposit, ' Field No. GJM550 ','- 91')
WHERE site_deposit like '% Field No. GJM550 %'
```

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
SET deposit_short = replace(site_deposit, ' Field No. MJB060607 ','- 14')
WHERE site_deposit like '%Field No. MJB060607%'
```

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
```

```
SET deposit_short = replace(site_deposit, ' Field No. KOK060501 ','- 9')
WHERE site_deposit like '% Field No. KOK060501%'
```

- There is no 'KOK060501' but there is 'KOK060510' which is Deposit 9
- Manually updated P23 box 14 values to 'P23' because site\_collection value set to "Deposit 14" and query to shorten collection name to 'HC' or 'P23' defaulted non 'Project 23' values to "HC"

```
USE TarPits_kaceyjoh
Update Specimen_Site_Deposit
SET collection_short = 'P23'
WHERE sitsiteref_key = '406880' or sitsiteref_key = '406908' or sitsiteref_key = '406911'
```

***Query 3: Script to create collection and deposit FK ID to match to point feature class of Tar Pit deposits:***

```
Use TarPits_kaceyjoh
update specimen_site_deposit
set SiteCollectionDepositFK= Collection_short+ Deposit_short
```

**ArcMap Processing:**

**Query 4: Creation of Aggregate Tables in ArcMap**

Joined Specimen\_Catalogue and Specimen\_Site\_Deposit into SPECIMEN\_SITE\_CATALOGUE because tables have almost the same amount of records (-31 nulls). In order to aggregate, the catalogue table required location information so joining by ecatalogue\_key with site\_deposit table added the necessary location information.

## APPENDIX F: SQL QUERIES FOR SPECIMEN SUMMARY TABLES

This appendix contains the queries used to create the geodatabase SQL summary tables described in section 4.1 Data Model: Geodatabase Diagram and Schema.

### *Query 1: Select Counts of Taxonomic Classifications*

```
/****** Script for Select Count of Taxon per Locality *****/  
USE TarPits_kaceyjoh  
SELECT SiteCollectionDepositFK, taxon, COUNT(taxon)as NumberofSpecimens  
INTO TaxonCountByDeposit  
FROM dbo.SPECIMEN_SITE_CATALOGUE  
WHERE SiteCollectionDepositFK is NOT NULL  
GROUP BY SiteCollectionDepositFK, Taxon  
order by SiteCollectionDepositFK ;
```

```
/****** Script for Select Count of Class per Locality *****/  
USE TarPits_kaceyjoh  
SELECT SiteCollectionDepositFK, class, COUNT(class)as NumberofSpecimens  
INTO ClassCountByDeposit  
FROM dbo.SPECIMEN_SITE_CATALOGUE  
WHERE SiteCollectionDepositFK is NOT NULL  
GROUP BY SiteCollectionDepositFK, Class  
order by SiteCollectionDepositFK ;
```

```
/****** Script for Select Count of Taxon by Element per Locality *****/  
USE TarPits_kaceyjoh  
SELECT SiteCollectionDepositFK, taxon,RLBElement, COUNT(RLBElement)as  
countoftaxonbyelement  
INTO TaxonByElement  
FROM dbo.SPECIMEN_SITE_CATALOGUE  
WHERE SiteCollectionDepositFK is NOT NULL  
GROUP BY SiteCollectionDepositFK, Taxon,RLBElement  
order by SiteCollectionDepositFK ;
```

```
/****** Script for Select Count of Specimens per Locality *****/  
USE TarPits_kaceyjoh  
SELECT SiteCollectionDepositFK, COUNT(ecatalogue_key)as NumberofSpecimens  
INTO SpecimenCountByDeposit  
FROM dbo.SPECIMEN_SITE_CATALOGUE  
WHERE SiteCollectionDepositFK is NOT NULL  
GROUP BY SiteCollectionDepositFK  
order by SiteCollectionDepositFK ;
```

Notes:

- Register with gdb in arcmap after table creation (Adds an ObjectID)
- Clean up summary tables to remove nulls



- Add values to table and join to site\_deposit FC (ie, NumberofSpecimens, Number of Mammals, Most Abundant Taxon, etc)

```
/****** Script for Select Number of Mammals per Locality *****/
```

```
NumberofMammals,
USE TarPits_kaceyjoh
SELECT [SiteCollectionDepositFK]
      ,[class]
      ,[NumberofSpecimens] as NumberofMammals
      ,[ObjectID]
INTO MammaliaClassCountByDeposit
FROM dbo.ClassCountByDeposit
Where class like '%Mammalia%'
```

```
/****** Script for Select Number of Reptiles per Locality *****/
```

```
NumberofReptiles,
USE TarPits_kaceyjoh
SELECT [SiteCollectionDepositFK]
      ,[class]
      ,[NumberofSpecimens] as NumberofReptiles
      ,[ObjectID]
INTO ReptiliaClassCountByDeposit
FROM dbo.ClassCountByDeposit
Where class like '%Rep%'
```

```
/****** Script for Select Number of Birds per Locality *****/
```

```
NumberofBirds,
USE TarPits_kaceyjoh
SELECT [SiteCollectionDepositFK]
      ,[class]
      ,[NumberofSpecimens] as NumberofAves
      ,[ObjectID]
INTO AvesClassCountByDeposit
FROM dbo.ClassCountByDeposit
Where class like '%aves%'
```

```
/****** Script for Select Number of Amphibians per Locality *****/
```

```
USE TarPits_kaceyjoh
SELECT [SiteCollectionDepositFK]
      ,[class]
      ,[NumberofSpecimens] as NumberofAmphibians
      ,[ObjectID]
INTO AmphibiaClassCountByDeposit
FROM dbo.ClassCountByDeposit
Where class like '%amphi%'
```

/\*\*\*\*\*\* Script for Select Number of Insects per Locality \*\*\*\*\*/

```
USE TarPits_kaceyjoh
SELECT [SiteCollectionDepositFK]
      ,[class]
      ,[NumberofSpecimens] as NumberofInsects
      ,[ObjectID]
INTO InsectaClassCountByDeposit
FROM dbo.ClassCountByDeposit
```

/\*\*\*\*\*\* Script for Select Most Abundant Taxon per Locality \*\*\*\*\*/

```
USE TarPits_kaceyjoh
SELECT sitecollectiondepositfk, taxon, numberofspecimens
INTO MostAbundTaxonByDeposit
FROM TaxonCountByDeposit
WHERE numberofspecimens = (SELECT max(numberofspecimens)
FROM TaxonCountByDeposit as f
WHERE f.sitecollectiondepositfk = TaxonCountByDeposit.sitecollectiondepositfk);
```

Note:

- Some deposits with low values have repeat highest number of taxon bc taxon count = 1 for several taxons but for demo purposes, those low, repeated values will be ignored.

/\*\*\*\*\*\* Script for Select Most Abundant Taxon per Locality \*\*\*\*\*/

```
USE TarPits_kaceyjoh
SELECT[sitecollectiondepositfk]
      ,[taxon]
      ,[numberofspecimens]
      INTO MostAbundTaxonByDepositGreaterthan5
FROM [TarPits_kaceyjoh].[dbo].[MostAbundTaxonByDeposit]
WHERE NumberofSpecimens > 5
```

/\*\*\*\*\*\* Script for Select Most Abundant Element by Taxon per Locality \*\*\*\*\*/

```
USE TarPits_kaceyjoh
SELECT sitecollectiondepositfk, taxon, RLBelement, countoftaxonbyelement
INTO MostAbundElementByTaxonByDeposit
FROM TaxonByElement
WHERE countoftaxonbyelement = (SELECT max(countoftaxonbyelement)
FROM TaxonByElement as f
WHERE f.sitecollectiondepositfk = TaxonByElement.sitecollectiondepositfk);
```

Note:

- some deposits with low values have repeat highest number of taxon bc taxon count = 1 for several taxons but for demo purposes, those low, repeated values will be ignored and only numberofspecimens > 8 will be included in final table

```

Use TarPits_kaceyjoh
SELECT [sitecollectiondepositfk]
      ,[taxon]
      ,[RLBelement]
      ,[countoftaxonbyelement]
INTO MostAbundTaxonByElementGreaterthan8
FROM [TarPits_kaceyjoh].[dbo].[MostAbundElementByTaxonByDeposit]
WHERE countoftaxonbyelement > 8

```

/\*\*\*\*\*\* Script for Join All Temp Summary Tables Together By DepositID \*\*\*\*\*/

```

USE TarPits_kaceyjoh
SELECT MammaliaClassCountByDeposit.SiteCollectionDepositFK
      ,MammaliaClassCountByDeposit.NumberofMammals
      ,SpecimenCountbyDeposit.NumberofSpecimens
      ,SpecimenCountbyDeposit.SiteCollectionDepositFK as DepositID
INTO Temp1
FROM MammaliaClassCountByDeposit
RIGHT JOIN SpecimenCountbyDeposit
ON
MammaliaClassCountByDeposit.SiteCollectionDepositFK=SpecimenCountbyDeposit.SiteColle
ctionDepositFK

```

```

USE TarPits_kaceyjoh
SELECT ReptiliaClassCountByDeposit.SiteCollectionDepositFK
      ,Temp1.NumberofSpecimens
      ,Temp1.NumberofMammals
      ,ReptiliaClassCountByDeposit.NumberofReptiles
      ,Temp1.DepositID
INTO Temp2
FROM ReptiliaClassCountByDeposit
RIGHT JOIN TEMP1
ON ReptiliaClassCountbyDeposit.SiteCollectionDepositFK=Temp1.DepositID

```

```

USE TarPits_kaceyjoh
SELECT AvesClassCountByDeposit.SiteCollectionDepositFK
      ,Temp2.NumberofSpecimens
      ,Temp2.NumberofMammals
      ,Temp2.NumberofReptiles
      ,AvesClassCountByDeposit.NumberofAves as NumberofBirds
      ,Temp2.DepositID
INTO Temp3
FROM AvesClassCountByDeposit
RIGHT JOIN TEMP2
ON AvesClassCountByDeposit.SiteCollectionDepositFK=Temp2.DepositID

```

```

USE TarPits_kaceyjoh
SELECT AmphibiaClassCountByDeposit.SiteCollectionDepositFK
    ,Temp3.NumberofSpecimens
    ,Temp3.NumberofMammals
    ,Temp3.NumberofReptiles
    ,Temp3.NumberofBirds
    ,AmphibiaClassCountByDeposit.NumberofAmphibians
    ,Temp3.DepositID
INTO Temp4
FROM AmphibiaClassCountByDeposit
RIGHT JOIN TEMP3
ON AmphibiaClassCountByDeposit.SiteCollectionDepositFK=Temp3. DepositID

```

```

USE TarPits_kaceyjoh
SELECT InsectaClassCountByDeposit.SiteCollectionDepositFK
    ,Temp4.NumberofSpecimens
    ,Temp4.NumberofMammals
    ,Temp4.NumberofReptiles
    ,Temp4.NumberofBirds
    ,Temp4.NumberofAmphibians
    ,InsectaClassCountByDeposit.NumberofInsects
    ,Temp4.DepositID
INTO Temp5
FROM InsectaClassCountByDeposit
RIGHT JOIN TEMP4
ON InsectaClassCountByDeposit.SiteCollectionDepositFK=Temp4.DepositID
Order by NumberofInsects

```

```

USE TarPits_kaceyjoh
SELECT MostAbundTaxonByDepositGreaterthan5.SiteCollectionDepositFK
    ,Temp5.NumberofSpecimens
    ,Temp5.NumberofMammals
    ,Temp5.NumberofReptiles
    ,Temp5.NumberofBirds
    ,Temp5.NumberofAmphibians
    ,MostAbundTaxonByDepositGreaterthan5.Taxon as MostAbundTaxonWithGreaterthan5
    ,Temp5.DepositID
INTO Temp6
FROM MostAbundTaxonByDepositGreaterthan5
RIGHT JOIN TEMP5
ON MostAbundTaxonByDepositGreaterthan5.SiteCollectionDepositFK=Temp5.DepositID

```

```

USE TarPits_kaceyjoh
SELECT MostAbundTaxonByElementGreaterthan8.SiteCollectionDepositFK
    ,Temp6.NumberofSpecimens
    ,Temp6.NumberofMammals

```

```

        ,Temp6.NumberofReptiles
        ,Temp6.NumberofBirds
    ,Temp6.NumberofAmphibians
    ,Temp6.MostAbundTaxonWithGreaterthan5
    ,MostAbundTaxonByElementGreaterthan8.RLBelement as
MostAbundElementGreaterthan8
, MostAbundTaxonByElementGreaterthan8.Taxon as TaxonOfMostAbundElement
    ,Temp6.DepositID
INTO Temp7
FROM MostAbundTaxonByElementGreaterthan8
RIGHT JOIN TEMP6
ON MostAbundTaxonByElementGreaterthan8.SiteCollectionDepositFK=Temp6.DepositID

```

***Query 2: JOIN TO LABREA\_FOSSILLOCALITIES FC***

```

USE TarPits_kaceyjoh
SELECT
    LABREA_FOSSILLOCALITIES.OBJECTID
    ,LABREA_FOSSILLOCALITIES.SiteCollectionDeposit_PK
    ,LABREA_FOSSILLOCALITIES.Collection
    ,LABREA_FOSSILLOCALITIES.PitNo
    ,LABREA_FOSSILLOCALITIES.Name
    ,LABREA_FOSSILLOCALITIES.Locality
    ,LABREA_FOSSILLOCALITIES.Field_No
    ,LABREA_FOSSILLOCALITIES.Notes as P23Notes
    ,LABREA_FOSSILLOCALITIES.Bottom_Elev_m
    ,LABREA_FOSSILLOCALITIES.Bottom_Elev_ft
    ,LABREA_FOSSILLOCALITIES.TopElev_m
    ,LABREA_FOSSILLOCALITIES.Top_Elev_ft
    ,LABREA_FOSSILLOCALITIES.DataSource
    ,LABREA_FOSSILLOCALITIES.DataComments
    ,LABREA_FOSSILLOCALITIES.Shape
        ,Temp7.NumberofSpecimens
        ,Temp7.NumberofMammals
        ,Temp7.NumberofReptiles
        ,Temp7.NumberofBirds
    ,Temp7.NumberofAmphibians
    ,Temp7.MostAbundTaxonWithGreaterthan5
    ,Temp7. TaxonOfMostAbundElement
    ,Temp7.MostAbundElementGreaterthan8
    ,Temp7.DepositID
INTO LABREA_FOSSILLOCALITIES_SUMS_JOIN
FROM Temp7
RIGHT JOIN LABREA_FOSSILLOCALITIES
ON Temp7.DepositID=LABREA_FOSSILLOCALITIES.SiteCollectionDeposit_PK

```

### **ArcMap Processing:**

- Added Columns for common names of taxon and elements
  - MostAbundTaxGreat5CommonName
  - MostAbundElemtGreat8CommonName
- Use field calculator to enter common names from Stock and Harris 1992
- Calculate common name for taxons and element

## APPENDIX G: REQUIREMENTS FOR THE WEB GIS APPLICATION

This appendix lists and describes the recommended requirements and viewing mediums for this project. Tables G-1 and G-2 detail the functional and nonfunctional requirements for each medium (server/web system and web/mobile interface), respectively. Tables G-3 and G-4 provide the subsequent review the functional and nonfunctional requirements. Additionally, a review of feedback received and changes requested can be found in Table G-5.

Table G-1 Functional Requirements

Requirement	Description	Viewing mediums	
		Web	Mobile
Navigation	The user will have the ability to pan and zoom the map	X	X
Search	The user will have the ability to search by pit location, fossil type, date, abundance	X	X
View detail	The user will have the ability to view further information about the map contents and map functionality	X	X
Show/hide layers	The user will have the ability to show or hide layers using check boxes	X	X
Change basemap	The user will have the ability to switch between the Esri Light Gray, Esri Dark Gray, Esri Satellite, Esri Topographic, Esri World Street Map, or a custom hillshade DEM created from the Page Museum survey map from 1913	X	X
Show/hide table	The user will have he ability to show or hide feature tables	X	
Feature pop-ups	The user will have the ability to click or touch the map to view feature pop-ups	X	X
Link to tarpits.org	The user will have the ability to navigate to the Page Museum home page for more information about the La Brea Tar Pits	X	X
Charts	The user will have the ability to view charts based on the number of specimens found in the fossils deposits	X	X

*Source:* Table adapted from Milholland (2014)

Table G-2 Nonfunctional Requirements

Requirement	Description	Mediums	
		Server/Web System	Web/Mobile Interface
Display	The display extent will be zoomed to the Page Museum grounds at Hancock Park in Los Angeles, CA		X
	Individual specimen record will not be exposed as a feature service; Data shall only be used in aggregate form via summary tables	X	X
Customize template for La Brea Tar Pits	The template's design will reflect the subject of paleontology		X
	The web application will be hosted on the USC GIST ArcGIS Server environment	X	
Security	Users will have read-only access to feature layers	X	X
	Administrator will have the ability to add, delete, or edit features	X	X

*Source:* Table adapted from Milholland (2014)

Table G-3 Functional Requirements Review

Requirement met?	Requirement	Description	Viewing mediums	
			Web	Mobile
Yes; as of 7/13/2015	Navigation	The user will have the ability to pan and zoom the map	X	X
Yes; as of 8/10/2015	Search/ Query	The user will have the ability to search by pit location, fossil type, date, abundance	X	X
Yes; as of 7/13/2015	View detail	The user will have the ability to view further information about the map contents and map functionality	X	X
Yes; as of 7/13/2015	Show/hide layers	The user will have the ability to show or hide layers using check boxes	X	X
Yes; as of 8/10/2015	Change basemap	The user will have the ability to switch between all available Esri basemaps	X	X
Yes; as of 7/13/2015	Show/hide table	The user will have the ability to show or hide feature tables	X	
Yes; as of 7/13/2015	Feature pop-ups	The user will have the ability to click or touch the map to view feature pop-ups	X	X
Yes; as of 7/13/2015	Link to tarpits.org	The user will have the ability to navigate to the Page Museum home page for more information about the La Brea Tar Pits	X	X
Yes; as of 8/10/2015	Charts	The user will have the ability to view charts based on the number of specimens found in the fossils deposits	X	X

Source: Table adapted from Milholland (2014)

Table G-4 Nonfunctional Requirements Review

Requirement met?	Requirement	Description	Mediums	
			Server/Web System	Web/Mobile Interface
Yes; as of 7/13/2015	Display	The display extent will be zoomed to the Page Museum grounds at Hancock Park in Los Angeles, CA		X
Yes; as of 8/10/2015		Individual specimen record will not be exposed as a feature service; Data shall only be used in aggregate form via summary tables	X	X
Yes; as of 7/13/2015	Customize template for La Brea Tar Pits	The template's design will reflect the subject of paleontology		X
Yes; as of 7/13/2015		The web application will be hosted on the USC GIST ArcGIS Server environment	X	
Yes; as of 7/13/2015	Security	Users will have read-only access to feature layers	X	X
Yes; as of 7/13/2015		Administrator will have the ability to add, delete, or edit features	X	X

Source: Table adapted from Milholland (2014)



Table G-5 Feedback and Changes Requests - July 13, 2015 Review

Number	Feedback/Change requested	Fixed as of Date
1	Troubleshoot why video is not working in linked html pages from About widget	8/10/2015
2	Confirm pop-up text – some attributes may not be necessary or do not make sense in the context of the application	8/10/2015
3	Add basemaps selection widget	8/10/2015
4	Add source for O’Keefe and Quinn papers to About widget	8/10/2015
5	Make oil/gas vents feature brighter and easier to see on map	8/10/2015
6	Do not use mean age for pit dates – use calibrated age range instead	8/10/2015
7	Pit 10 should have dates associated with it	8/10/2015
8	Pit 3 and 4 are incorrectly showing no specimens associated with them	8/10/2015

## APPENDIX H: WEB APPLICATION GIS SERVICES

The following table lists the layers that make up the feature services in the web GIS application developed as part of this thesis work.

Service	Layer ID	Capabilities	Database Feature Class/Table Name	Description
La Brea Fossil Localities	0	Select	TarPits_kaceyjoh.DBO.LABREA_FOSSILLOCALITIES	The merged HC and P23 deposit locations joined to the SumByDeposit table (see Tables 4 & 7)
Boreholes w/ Sediment Descriptions	1	Select	TarPits_kaceyjoh.DBO.BOREHOLES_USGS	Boreholes within the park with relate to sediment description table
Boreholes	2	Select	TarPits_kaceyjoh.DBO.BOREHOLES	Boreholes within and surrounding the park without sediment descriptions
Survey Markers	3	Select	TarPits_kaceyjoh.DBO.SURVEYMARKERS	Survey markers digitized from the paper survey map
Contours	4	Select	TarPits_kaceyjoh.DBO.CONTOURS	Contours digitized from the paper survey map
Creek Center	5	Select	TarPits_kaceyjoh.DBO.CREEK_CENTER	Creeks digitized from the paper survey map
Pit	6	Select	TarPits_kaceyjoh.DBO.PIT	Pit polygons digitized from the paper survey map
Excavation Site	7	Select	TarPits_kaceyjoh.DBO.EXCAVATION_SITE	Excavations site polygons digitized from the paper survey map
Water Body	8	Select	TarPits_kaceyjoh.DBO.WATER_BODY	Water bodies digitized from the paper survey map
Gas / Oil Vents	9	Select	TarPits_kaceyjoh.DBO.GAS_OIL_VENTS	Gas and oil vents digitized from the paper survey map
Hancock Collection Pit Dates	10	Select	TarPits_kaceyjoh.DBO.HC_PITDATES	Pit Dates Table for HC Deposits related to LABREA_FOSSILLOCALITIES feature service
USGS Boreholes Description	11	Select	TarPits_kaceyjoh.DBO.USGS_BOREHOLESDESCRIPTION	USGS Borehole sediment descriptions related to BOREHOLES_USGS feature service

*Source:* Table adapted from Milholland (2014)

## APPENDIX I: LA BREA TAR PITS GEODATABASE

The following tables (Table I-1 through Table I-7) describe the tables, fields, and relationship classes in the La Brea Tar Pits geodatabase.

Table I-1 Relationship Class

<b>RELATIONSHIP CLASS</b>		
<b>Feature Class/Attribute Origin</b>	<b>Table/Attribute Destination</b>	<b>Relationship</b>
LaBrea_FossilLocalities_Sum_Join/SiteCollectionDepositPK	Grid_Cell_ID	One-to-one
Boreholes_USGS/ Boring_ID	USGSBoreholesDescription/Boring_ID	One-to- many

Table I-2 LaBrea\_FossilLocalities Entity

<b>LA BREA FOSSIL LOCALITIES – Point Feature Class</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
ObjectID	Unique ID	Object ID	Not Null	Unique	Primary Key
SiteCollectionDeposit PK	Pit / Deposit ID	Text	Null	Unique	Foreign Key
Pit_Name	Pit Deposit Name	Text	Null		Noble 1913
P23_Locality	P23 Locality Name	Text	Null		Turner 2006
Top_Elev_ft	Top Elevation of P23 Locality (calculated from meters)	Double	Null		Turner 2006
Bottom_Elev_ft	Bottom Elevation of HC an P23 Deposits (calculated from meters)	Double	Null		Noble 1913, Turner 2006
Top_Elev_m	Top Elevation of P23 Deposits	Double	Null		Turner 2006
Bottom_Elev_m	Bottom Elevation of HC (calculated from feet) and P23 Deposits	Double	Null		Noble 2013, Turner 2006
DataSource	Source of data	Text	Null		Citations
DataComments	Data creation notes	Text	Null		

Table I-3 HC\_PitDates

<b>HANCOCK COLLECTION (HC) PIT DATES</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
DepositID	Deposit ID	Text	NotNull	Unique	Primary Key
NumberofDates	Number of Dated Specimens	Long Integer	Null		O'Keefe et al 2009
Max_Calibrated_Age	Calibrated YBP min	Long Integer	Null		O'Keefe et al 2009
Min_Calibrated_Age	Calibrated YBP min	Long Integer	Null		O'Keefe et al 2009
Source	Supervisor Employee ID Foreign Key	Text	Null		O'Keefe et al 2009

Table I-4 Specimen\_Site\_Catalogue Entity

SPECIMEN SITE CATALOGUE					
Field Name	Description	Type	Not Null	Unique	Notes
SitSiteRef_Key	Unique ID for SitSiteR table from KE EMu extract	Double	NotNull	Unique	Primary Key
ecatalogue_key	Unique ID for ecatalogue table from KE EMu extract	Double	NotNull	Unique	Primary Key (Combined two tables- this is PK of second table)
Site_Collection	Collection that specimen belongs to	Text	Null		From SitSiteR Table: Site -> Text to Columns in MS Excel to create (Site_Collection, Site_Deposit, Site_FieldNo, Site_Grid, Site_Level)
Site_Deposit	Deposit ID	Text	Null		*See notes for "Collection"
Site_FieldNo	Filed Locality ID	Text	Null		*See notes for "Collection"
Site_Grid	Grid (Letter-Number)	Text	Null		*See notes for "Collection"
Site_Level	Levels (25 cm intervals)	Text	Null		*See notes for "Collection"
Spec_No	First part Specimen ID or Catalogue Number	Text	Null		Letter or number key denoting the catalog system and collection
Spec_No_NoText	Second part Specimen ID or Catalogue Number	Double	Null		
Class	Taxonomical hierarchy	Text	Null		From ecatalogue table: Taxon -> Text to Columns in MS Excel to create (Taxon, Family, Order, Class)
Order	Taxonomical hierarchy	Text	Null		*See notes for "Class"
Family	Taxonomical hierarchy	Text	Null		*See notes for "Class"
Taxon	Taxonomical hierarchy (Genus species)	Text	Null		*See notes for "Class"
RLB_Point_Tab	Point of bone	Text	Null		
RLB_BD_Tab	Depth of specimen pre-excavation	Text	Null		
RLB_N_Tab	Y-direction of specimen pre-excavation	Text	Null		
RLB_W_Tab	X-direction of specimen pre-excavation	Text	Null		
RLB_BD_Orient_Tab	Orientation of BD point measured	Text	Null		
RLB_N_Orient_Tab	Orientation of Y point measured	Text	Null		
RLB_W_Orient_Tab	Orientation of X point measured	Text	Null		
RLB_BD_Ext_Tab	Grid that BD measurement extends into	Text	Null		
RLB_N_Ext_Tab	Grid that Y measurement extends into	Text	Null		
RLB_W_Ext_Tab	Grid that X measurement extends into	Text	Null		
Spec_Side	Side of bone	Text	Null		
RLB_Element	Osteological element	Text	Null		type of bone

SPECIMEN SITE CATALOGUE					
Field Name	Description	Type	Not Null	Unique	Notes
SubElement	Sub classification of bone	Text	Null		
Part	Identifiable part of bone found to base measurement on	Text	Null		Px=proximal, Dt=distal, etc
Number	Number of element	Text	Null		For numbered bones such as vertebrae and toes
Frag	Is the specimen a fragment?	Text	Null		
OntogeneticAge	Maturity of specimen	Text	Null		If the specimen be identified as juvenile, or very juvenile
SiteCollectionDepositFK	Deposit ID	Text	Not Null	Unique	Foreign Key

Table I-5 SumbbyDeposit (Joined to LaBrea\_FossilLocalities Feature Class)

SUMMARY BY DEPOSIT					
Field Name	Description	Type	Not Null	Unique	Notes
Deposit_ID	Deposit ID	Text	NotNull	Unique	Primary Key
NumberofSpecimens	Total count of specimens in deposit	Long Integer	Null		
NumberofMammals	Total count of mammals in deposit	Long Integer	Null		
NumberofReptiles	Total count of reptiles in deposit	Long Integer	Null		
NumberofBirds	Total count of birds in deposit	Long Integer	Null		
NumberofAmphibians	Total count of amphibians in deposit	Long Integer	Null		
MostAbundTaxonWithGreaterthan5	Most Abundant Species with > 5 Count	Text	Null		
MostAbundTaxGreat5_CommonName	Common Name of Most Abundant Species with > 5 Count	Text	Null		
MostAbundElementGreaterthan8	Most Abundant Element with > 8 Count	Text	Null		
MostAbundElemtGreat8_CommonName	Common Name of Most Abundant Element with > 8 Count	Text	Null		
TaxonOfMostAbundElement	Species w/ Most Abundant Element with > 8 Count	Text	Null		
TaxonOfMostAbundElementCommonName	Common Name of Species w/ Most Abundant Element with > 8 Count	Text	Null		

Table I-6 Boreholes\_USGS Entity

<b>USGS Boreholes – Point Feature Class</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
Boring_ID	Boring ID	Text	NotNull	Unique	Primary Key
Lat		Double	NotNull		Quinn et al 2000
Long		Double	NotNull		Quinn et al 2000

Table I-7 USGSBoreholesDescription Entity

<b>UGS Borehole Descriptions - Table</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
Boring_ID	Boring ID	Text	NotNull	Unique	Primary Key
From_m	From depth in meters	Double	Null		Quinn et al 2000
To_m	To depth in meters	Double	Null		Quinn et al 2000
Color	Color of sediment	Text	Null		Quinn et al 2000
Description	Description of sediment	Text	Null		Quinn et al 2000
Asphalt_Content	Asphalt content	Text	Null		Quinn et al 2000

## APPENDIX J: LA BREA TAR PITS FIELD DATA COLLECTION GEODATABASE

The following tables (Table J-1 through Table J-9) describe the tables, fields, relationship classes, topology, and domains, in the La Brea Tar Pits field data collection geodatabase developed as part of this thesis work.

Table J-1 Topology

TOPOLOGY		
Rule	Feature Class/Attribute	Description of Relationship
Must not overlap	Grid Cell	Grid cells must not overlap

Table J-2 Domains

DOMAINS			
Domain Name	Domain Type	Domain Definitions	Description
Element	Coded Values	rib, femur, radius, scapula, sacrum, thoracic vertebra, cervical vertebra, tibia C/, frontal, maxilla, metatarsal, vertebra, ...	Osteological element (type of bone)
Point	Coded Values	Px, Dt, Tub, FC, MC, LC ,RT, AC. PC, NS, ...	Identifiable part of bone found to base measurement on (Px=proximal, Dt=distal, etc), e.g., the proximal end of the humerus bone was found at location x,y at depth z
Spit	Coded Values	1, 2, 3, 4, ... , 9	Levels (25 cm intervals)

Table J-3 Relationship Class

RELATIONSHIP CLASS		
Feature Class/Attribute Origin	Feature Class/Attribute Destination	Relationship
Specimen_ID	Grid_Cell_ID	One-to-many
Grid_Cell_ID	Grid_ID	One-to-one
Grid_Cell_ID	Spit_ID	One-to-many
Deposit_ID	Gird_ID	One-to-many
Employee_ID	Specimen_ID	One-to-many

Table J-4 Surveyor Entity

<b>SURVEYOR</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
EmployeeID	Employee ID	Text	NotNull	Unique	Primary Key
Surveyor_Name	Surveyor Name	Text	NotNull		
Role	Role	Text	NotNull		
Supervisor	Supervisor	Text	NotNull		
SupervisorEmployeeID_FK	Supervisor Employee ID Foreign Key	Text	Null		
Surveyor_GridID_FK	Surveyor Grid ID Foreign Key	Text	Null	Unique	Foreign Key
Surveyor_GridCellID_FK	Surveyor Grid Cell ID Foreign Key	Text	Null	Unique	Foreign Key
Surveyor_ArtifactID_FK	Surveyor Artifact ID Foreign Key	Text	Null	Unique	Foreign Key

Table J-5 Spit Entity

<b>SPIT</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
Spit_ID	Strata ID	Text	NotNull	Unique	Primary Key
Spit Level (1,2,3,...)	Strata Number	Short Integer	NotNull		
Spit_Depth	Strata Depth	Short Integer	NotNull		
SpitID_GridCellID_FK	Strata Type	Text	NotNull		

Table J-6 Pit Deposit Entity

<b>Pit_Deposit</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
Deposit_ID	Pit / Deposit ID	Text	NotNull	Unique	Primary Key
Deposit_Name	Pit / Deposit Name	Text	NotNull		
Deposit_Location	Pit / Deposit Location	Text	NotNull		
Latitude	Latitude	Long Integer	Null		
Longitude	Longitude	Long Integer	Null		
DepositID_Spit_ID_FK	Deposit ID Spit ID Foreign Key	Text	Null	Unique	Foreign Key



Table J-7 Grid Entity

<b>GRID</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
Grid_ID	Grid ID	Text	NotNull	Unique	Primary Key
No_Rows	Number of Rows	Short Integer	NotNull		
No_Columns	Number of Columns	Short Integer	NotNull		
Depth_at_Bottom	Depth at Bottom	Short Integer	NotNull		
GridID_DepositID_FK	Grid ID Deposit ID Foreign Key	Text	Null	Unique	Foreign Key

Table J-8 Grid Cell Entity

<b>GRID_CELL</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
Grid_Cell_ID	Grid Cell ID	Text	NotNull	Unique	Primary Key
Row_No	Row Number	Short Integer	NotNull		
Column_No	Column Number	Short Integer	NotNull		
GridCellID_GridID_FK	Grid Cell ID Grid ID Foreign Key	Text	Null	Unique	Foreign Key

Table J-9 Fossil Element Entity

<b>FOSSIL ELEMENT – (MAMMAL, BIRD, REPTILE, INSECT, AMPHIBIAN)</b>					
<b>Field Name</b>	<b>Description</b>	<b>Type</b>	<b>Not Null</b>	<b>Unique</b>	<b>Notes</b>
Specimen_ID	Artifact ID	Text	NotNull	Unique	Primary Key
Genus					
Species	Species	Text	NotNull		
Element	Bone Type	Text	NotNull		
Point					
Ontogenetic_Age	Ontogenetic Age	Text	NotNull		
Remarks	Condition	Text	Null		
Date_Found	Date Found	Date	NotNull		
Date_Catalogued	Date Archived	Date	Null		
Photograph	Photograph	BLOB	Null		
X (null allowed)	X	Long Integer	Null		
Y (null allowed)	Y	Long Integer	Null		
Z (null allowed)	Z	Long Integer	Null		
ArtifactID_GridID_FK	Artifact ID and Grid ID Foreign Key	Short Integer	Null	Unique	Foreign Key
ArtifactID_GridCellID_FK	Artifact ID and Grid Cell ID Foreign Key	Short Integer	Null	Unique	Foreign Key
ArtifactID_GridCellExt_X_FK	Artifact ID and Grid Cell ID Foreign Key	Short Integer	Null	Unique	Foreign Key
ArtifactID_GridCellExt_Y_FK	Artifact ID and Grid Cell ID Foreign Key	Short Integer	Null	Unique	Foreign Key

## APPENDIX K: GEODATABASE UPDATE USER GUIDE




The following guide provides an outline of the steps necessary to manually update the La Brea Tar Pits geodatabase created as part of this thesis work.

1. Use “Text to Column” in Microsoft Excel to parse the values in the records or fields and columns by space. It is intended that this task will be updated to a SQL script in the future. Microsoft Excel was used in the early stages in the development of the database while the author gained experience in SQL query writing.
2. Import the Ecatalogue.csv as Specimen\_Catalogue and SitSiteR.csv as Specimen\_Site\_Deposit in SQL Server Management Studio as flat files.
3. Using the SQL queries in Appendix E Query 3, parse values from Site\_Collection and Site\_Deposit in the Specimen\_Site\_Deposit, which will combine the columns to create a foreign key to match the same attribute in the location feature class.
4. Insert contents of Site\_Deposit into new column and replace deposit with ‘-’ to result in “-#”. Note that it is not possible to map pits or crates by grid number because the same grid number can be found in multiple deposits. For example, the resultant column of only “deposit –” values has 385 nulls. The majority are grid values that cannot be parsed. With specific update statements, the remaining values can be cleaned (see Appendix E).
5. In ArcMap join Specimen\_Catalogue and Specimen\_Site\_Deposit into one table called Specimen\_Site\_Catalogue. This prepares the table and adds all necessary fields needed to perform the SQL summary queries.
6. In SQL Server Management Studio, follow the queries found in Appendix F to create the temporary summary tables. Then join all temp summary tables together by Deposit ID. Lastly, join to the LaBrea\_FossilLocalities feature class.

7. Two procedures may be used to update the 1913/1983 survey map feature classes.
  - a. The first method is to copy to the feature class as a new name and edit the feature class in ArcMap. A copy must be used because ArcGIS Server locks the original published feature class. Then, for instance, a point can be copied and moved to the desired location.
  - b. The second method is to add a table with the same schema as the feature class and include the latitude and longitude in separate columns corresponding to the location where each data (fossil or other) was originally found. Then, right click the table and choose “display XY data” and save the resultant layer as a feature class and merge the new feature class with a copy of the old feature class.

## APPENDIX L: WEB GIS APPLICATION USER GUIDE

The following guide is designed to help the museum staff as well as other users navigate the web GIS application and follow a typical user workflow.

1. The first step to using the application is to click on the information symbol  in the left panel to open the “About the Application” widget.
  - a. This widget provides a summary of the application, including data sources, data methodology, fitness for research use, and links to the pilot project (example) dataset, 3D videos of Project 23 Box 1 *Panthera atrox* and *Smilodon fatalis* specimens.
2. Open the Legend widget  to view the data layers and identifying symbology to become familiar with the data displayed.
3. Open the Layer List widget  to view all layers and have the ability to turn layers off and on.
  - a. To expand the layers click on the small arrow next to the name of the map service “La Brea Tar Pits June 2015 Database Extract” (Figure L-1).

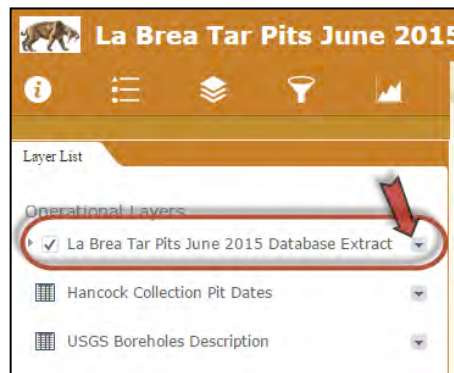


Figure L-1 How to expand the Layer List

- b. The layer names will now be displayed and you can turn them off and on by check  and unchecking  the checkboxes next to the layer names (Figure L-2).

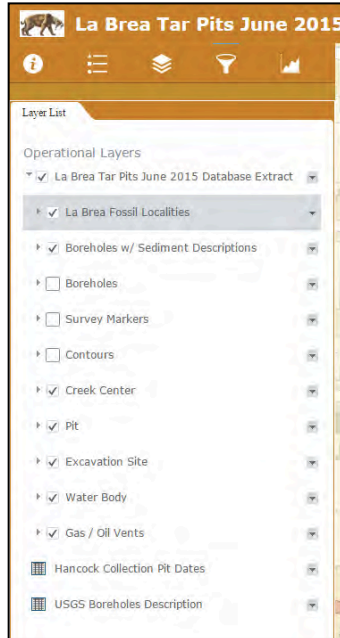





Figure L-2 The Layer List after expanding in Step 3a

- Next, navigate the map by clicking and dragging the mouse to pan and use the + and – tool  to zoom in and out of the map, and the home tool  to return to the original extent of the map. Choose an area to zoom into (Figure L-3) and explore by double clicking on the map to zoom in or by using the zoom icon 

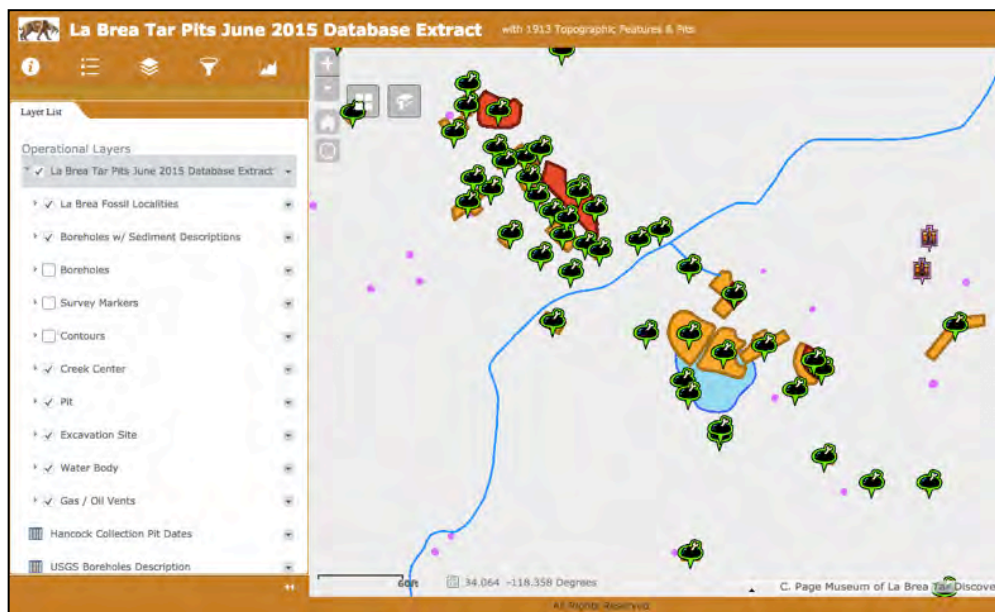


Figure L-3 Example zoomed in area of the map focusing on a cluster of pits

5. Click on icons on the map in order to open pop-up windows to display detailed information about the points on the map (Figure L-4).
  - a. The orange and red polygon layers represent the perimeter of each pit and excavation site as designated in the 1913 survey map. The orange and red areas have pop-ups that contain the bottom elevation as recorded on the 1913 survey map (Figure L-4).



Figure L-4 Example pop-up contents for a pit perimeter showing the bottom elevation recorded on the 1913 survey map

- b. If several icons are layered on top of each other, all will be selected when clicking on that location on the map. To scroll through to the next pop-up to see the desired map feature, click the arrow pointing to the right on the top right of the pop-up (Figure L-5).



Figure L-5 How to scroll to the next layer's pop-up when several map layers are selected at once

- c. Figure L-6 shows an example of the information contained in the pop-up for a fossil deposit.

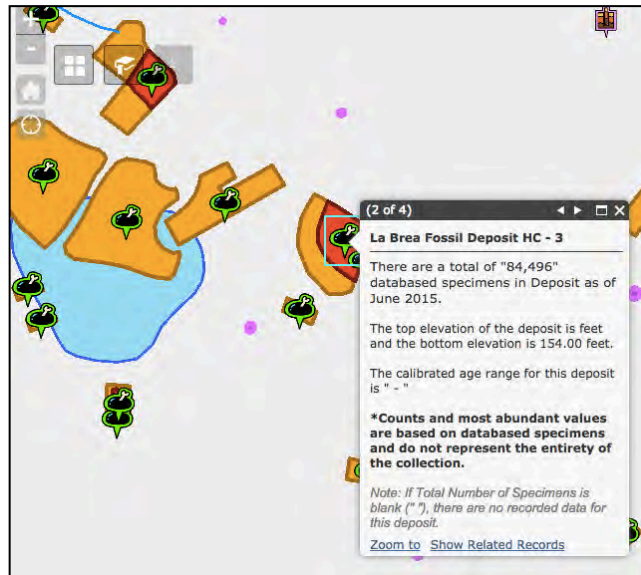


Figure L-6 Example pop-up contents for Hancock Collection deposit 3 (HC - 3)

- d. Scroll down to see the complete contents of the pop-up (Figure L-7). Note that a graph is also included that shows the distribution of taxonomical classes in the selected deposit.

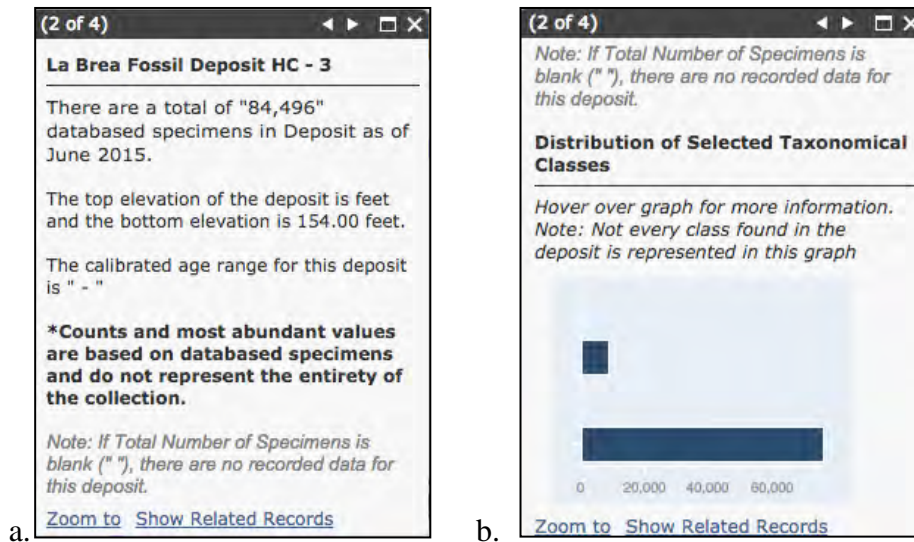


Figure L-7 Example pop-up contents for Hancock Collection deposit 3 (HC - 3) in detail shown the top of the pop-up contents (a) and the bottom of the pop-up contents (b)

6. In the pop-ups, the blue text “Show Related Records” can be clicked to open an attribute table immediately below the map view, which will show radiometric dating for some HC pit locations, and borehole sediment descriptions for select boreholes (Figure L-8).

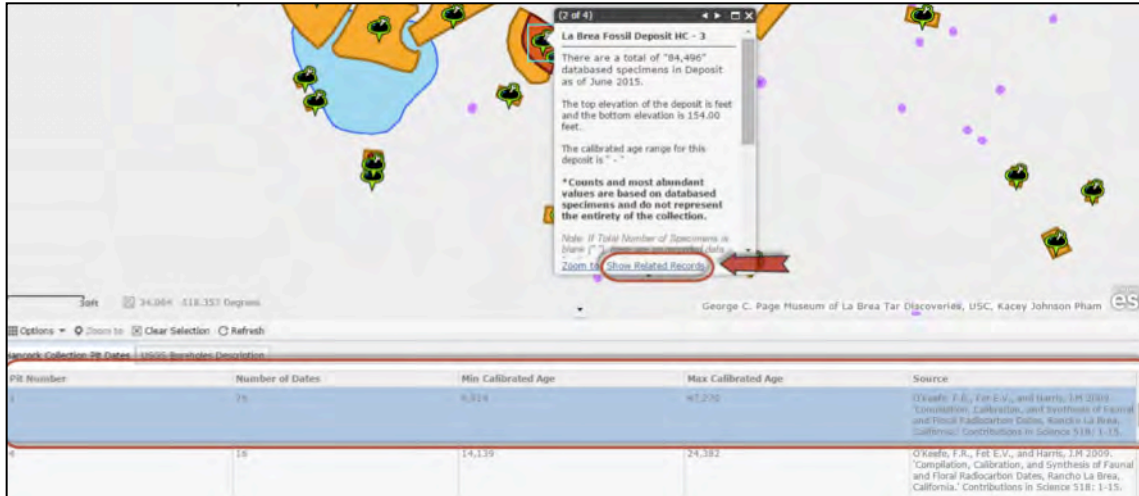


Figure L-8 Example radiometric dating table appears after clicking “Show Related Records” for Pit 3

- a. Fields can be sorted in the attribute table by clicking the column names once to sort ascending and twice to sort descending (Figure L-9).

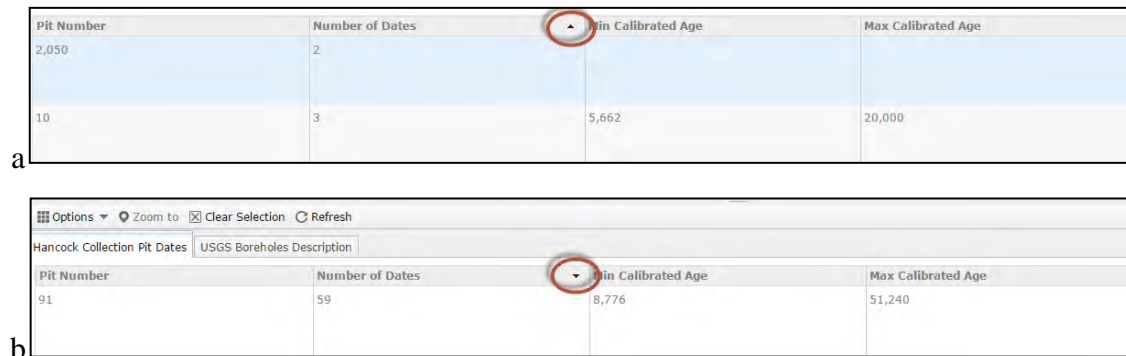


Figure L-9 Sorting of Pit Dates by “Number of Dates” ascending (a) and descending (b) order



- b. Clicking the down arrow will close the attribute table (Figure L-10).

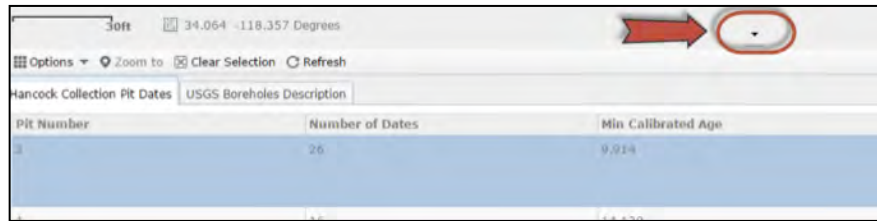



Figure L-10 Closing the attribute table

7. To further explore the map’s capabilities, open the Query widget  (Figure L-11). The Query widget contains pre-defined queries that allow the user to:
- search the map for a particular deposit,
  - search for the most abundant deposits,
  - search for a deposit by the most abundant species, and
  - search for a deposit by the most abundant fossil element.

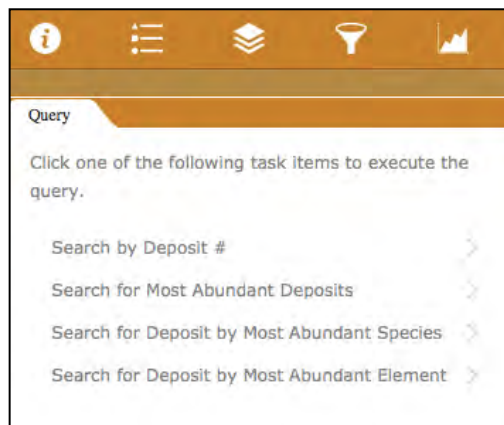


Figure L-11 Queries

8. For example, to search for deposit # 4, click on “Search by Deposit” and click on the drop down menu to see a list of all deposits. Or type a leading character into the field according to the gray “hint” below the box that describes the character format of deposit numbers (HC - # or P23 - #) (Figure L-12).

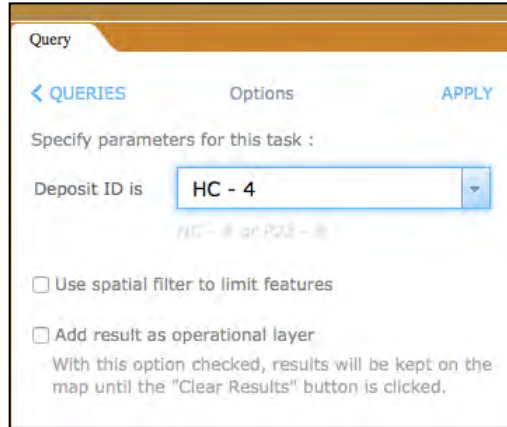


Figure L-12 Query example

9. Next, click “apply” and the query searches for deposit 4. When the results are returned, the deposit will be highlighted in blue.
  - a. Click on the result or a pop-up that appears next to the highlighted deposit and click on “Attributes from related table: Hancock Collection Pit Dates” to view radiometric dates (note: this table will not appear for Project 23 deposits) (Figure L-13).

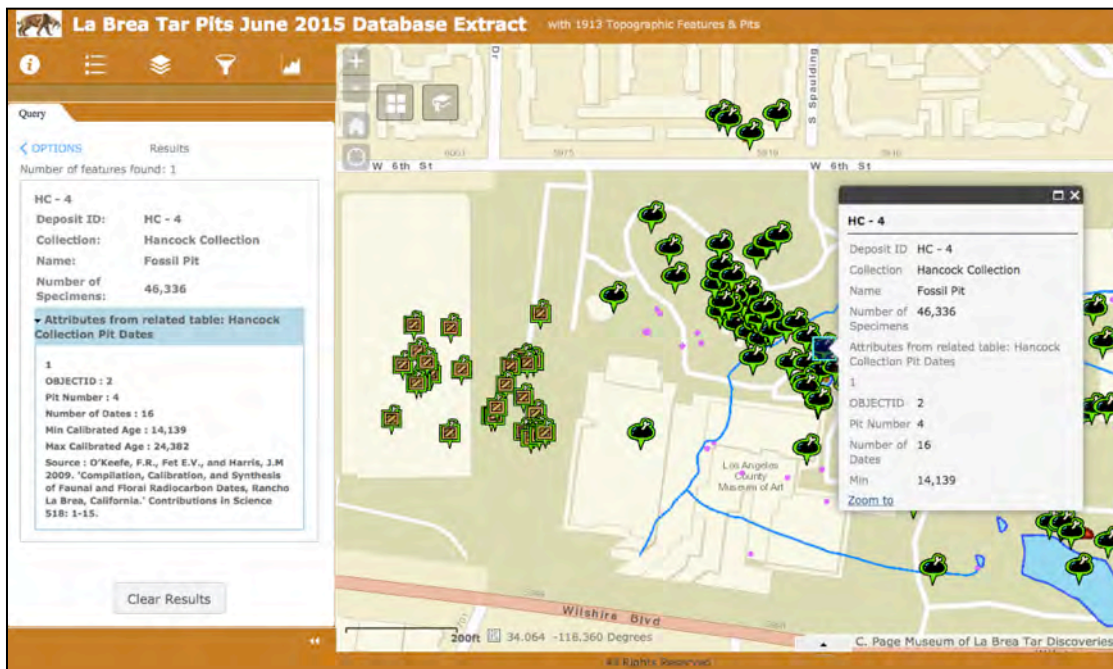




Figure L-13 Example query results and pop-up display results

10. The following is an overview of how to use the chart widget. First, choose the Charts widget icon  to explore pre-defined charts set up for the La Brea Tar Pits application.

- a. The available charts are:
  - i. Number of Specimens by Deposit,
  - ii. Total Number of Mammals, Reptiles, Birds, and Amphibians by Deposit,
  - iii. Number of Mammals by Deposit,
  - iv. Number of Reptiles by Deposit,
  - v. Number of Birds by Deposit, and
  - vi. Number of Amphibians by Deposit.

11. Next, choose a chart from the list in the left side panel after opening the Chart Widget by clicking the name of the chart or the arrow  (Figure L-14).

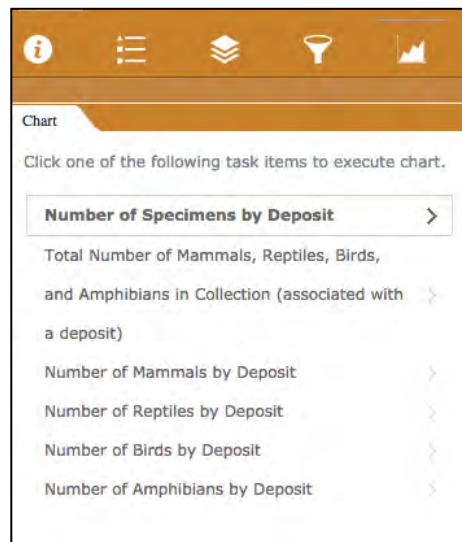


Figure L-14 List of available charts

12. Then, choose “Apply” to generate the chart. After the chart is generated, all selected data points in the chart will be highlighted on the map as yellow circles. The charts are interactive; Click on the chart to view a specific chart data point, which will be panned to and highlighted on the map as a red square outline (Figure L-15).

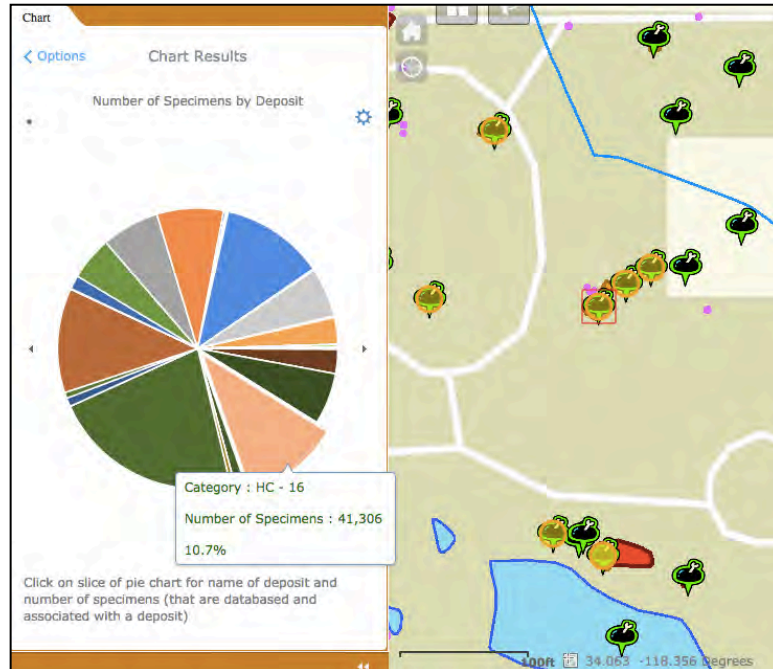


Figure L-15 Example Number of Specimens by Deposit chart with Deposit HC – 16 highlighted in the chart and on the map

## APPENDIX M: WEB GIS APPLICATION UPDATE USER GUIDE

The following guide is designed to help the museum staff to update the web GIS application developed as part of this thesis work.

1. Open the web mapping application item “La Brea Tar Pits Map” in ArcGIS Online.
2. Click the down arrow in the blue box labeled “Open” and choose “Edit Application” and the Web AppBuilder for ArcGIS editing interface will open.
  - a. The layout can be changed to several different themes and i.e. the color can be changed within the Theme tab (Figure M-1).

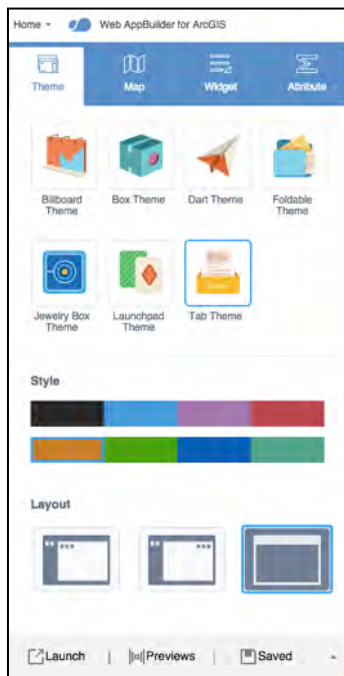


Figure M-1 Web AppBuilder editing interface Theme Tab

3. By choosing the Map tab, options are presented that allow the user to choose a different web map, change the extent of the map and customize the visible scales (Figure M-2).

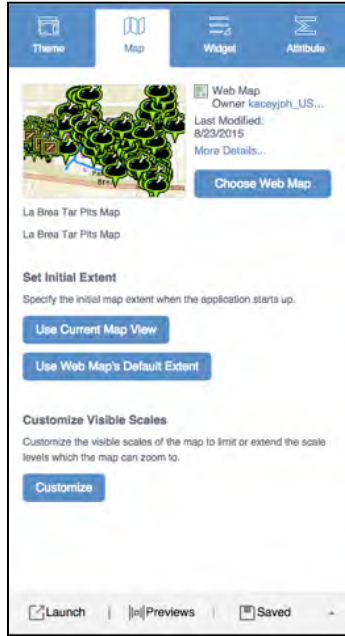


Figure M-2 Web AppBuilder editing interface Map Tab

4. Within the Widget tab, all widgets can be edited and new widgets can be added (Figure M-3).

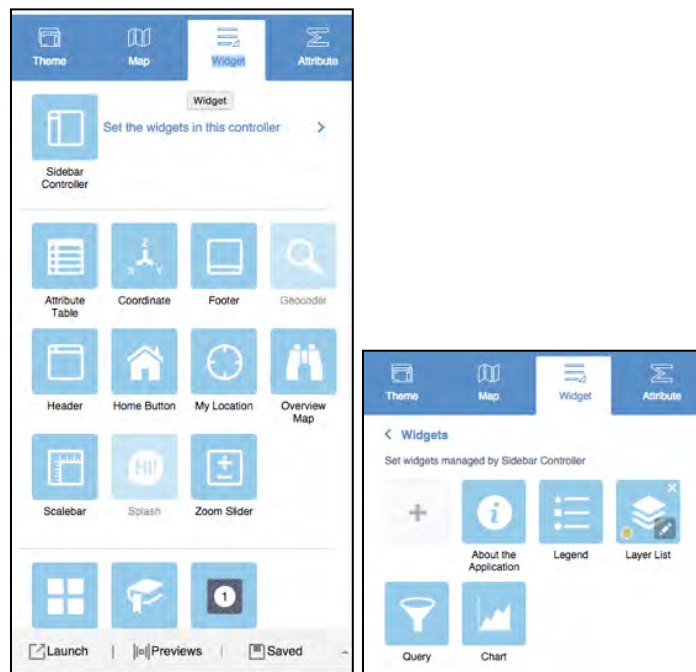


Figure M-3 Web AppBuilder editing interface Widget Tab

5. For more information, please see the Web AppBuilder for ArcGIS user guide (Esri 2015e).
6. To view original widget settings, see Chapter 3, section 3.5.3 ArcGIS Online Development.
7. Lastly, to change the logo, title, or to change/add URLs to the map, open the Attribute tab (Figure M-4).

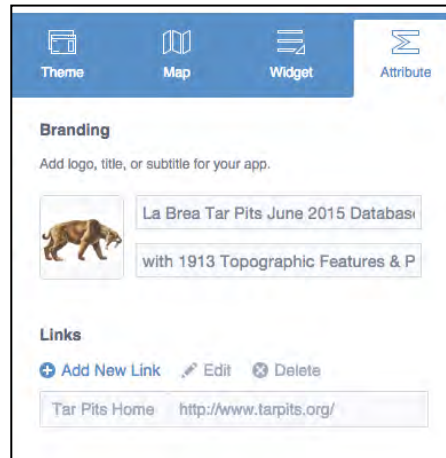


Figure M-4 Web AppBuilder editing interface Attribute Tab

For additional information, the most current version of Web AppBuilder online help documentation should be accessed on the Esri.com website.

## **APPENDIX N: RECOMMENDATIONS FOR TECHNOLOGY TRANSFER**

This appendix describes the process for the Page Museum to host this database and application in their environment.

1. A server machine running at least Windows Server 2008 R2
2. Installation of ArcGIS Server 10.2.1 or later on the server machine
3. SQL Server installation on the ArcGIS Server machine and SQL Server Native Client installation
4. ArcGIS Desktop installed on at least one machine
5. Backup media of mxds and SQL Server geodatabase will be provided by the author
6. These files should be transferred to the server machine
7. Restore SQL database using SQL Server Management Studio

\* If museum staff desire a “live” connection from the SQL Server geodatabase to the KE EMu database, a person with the experience listed in Appendix A will be required in order to set up a connection between the two databases. It is recommended that this individual use the SQL queries found in Appendix F: SQL Queries for Specimen Summary Tables, to create stored procedures in SQL Server Management Studio, for example to run nightly updates from the KE EMu database to update the La Brea Tar Pits geodatabase.