Progress towards thesis:
Anthropogenic changes in Miller Creek and watershed:
a historical cartographic approach

Above: Miller Creek watershed; 62 years of change on an already altered landscape.

Micha Salomon       Geography 810       Davis
Abstract

This research seeks to determine the historical impacts of human activity in the study area. Through a detailed examination of a diverse set of historical and contemporary data sources, this research will generate a textual and cartographic narrative of human impacts at the local and landscape scale.

Research question

What have been the anthropogenic changes, or historical human impacts, on Miller Creek and Watershed in Marin County, CA?

Keywords: Miller Creek, Marin County, watershed, urban creek, landscape, environmental history, aerial photos, historical maps, GIS, orthorectification, remote sensing, steelhead
Introduction

The purpose of this paper is twofold. Foremost, it serves as a summary of my progress towards completing a thesis. This includes a preliminary review of the relevant literature, including topics and methods in geomorphology, remote sensing, landscape ecology and historical geography. Another marker of progress is the variety of data that has been compiled related to the research question. All of the data is implicitly geographic in that it relates the study area. That said, diverse data sources are used in this research. The primary data source is cartographic, consisting of recent and historical aerial photography and maps. In addition, other archival sources will be used. Historical maps and accounts, will serve to augment the usefulness of the cartographic data. Engineering documents related to roads, bridges, home construction will also serve as a form of historic data. Additionally, landscape photography from different historical periods will be examined and analyzed. Some professional and governmental reports of the study area contain photography wherein past conditions can be observed. In general, the data that has been gathered serves as evidence of historical conditions as well as of anthropogenic landscape change.

The second major purpose is the counterpoint to the first. It seeks to reveal gaps in the research done and data collected. As I code and organize the data that has been obtained, the missing pieces should become more apparent. Taking stock of what has been accomplished is a necessary step in moving forward with the research. Through the compilation, analysis and interpretation of the data, a new, more complete history of the study area will have been assembled. The end product will be a local historical environmental atlas for Miller Creek and watershed.
Background

Miller Creek is located in eastern Marin County. It is a moderately sized watershed, measuring only about 11 square miles (Figure 1). The eastern part of the county is the more urbanized portion. Miller Creek itself lies between the two largest towns in Marin, San Rafael and Novato, each with population of about 40,000. The Creek eventually drains into San Pablo Bay, after passing through anthropogenic tidal channels in anthropogenic diked marsh. Despite nearby urbanization, dairy ranching, and other modern and historical land uses in its watershed, Miller Creek maintains a steelhead population throughout a large portion of the perennial mainstem (Cox & O'Connor 2004).

This research reflects and includes some of the work I have performed at the San Francisco Estuary Institute (SFEI). Under Robin Grossinger, I have been working on the pending Miller Creek historical ecology study. Many of the historical maps of the area are archived digitally at SFEI. Historical ecology is a field which uses scientific and historical data to understand and map past ecosystems (Egan & Howell 2005). It uses methods from geomorphology, landscape ecology, historical geography, soil science and cartography so compile and analyze information about current and past landscapes and the processes which change them.
Significance

This study serves several purposes. That it will provide a detailed history of a local creek is an important end unto itself. It is of immediate interest to some local residents, as well as to historians and advocates of local creeks. A historical understanding of this watershed will also be a valuable tool for informing future land use decisions, and investments infrastructure such as roads, bridges, flood control or housing. Private property concerns include homeowners who may be threatened by bank erosion, flooding and landslides. Also, large property owners lower in the watershed desire development in what has historically been a non-built-up section between the bedroom communities of Novato and San Rafael.

Additionally, the study aims to provide a better understanding of “reference” or “natural” conditions of the area. These baseline conditions are important to consider, as portions of the landscape may be set aside for environmental or habitat restoration projects. By providing a better and more complete understanding about how past anthropogenic change has altered the landscape, this study may help inform steps that might be taken in order to improve local environmental conditions for human residents and wildlife. In terms of support for protection of open space, preservation, and ecological restoration, Marin is a special case (Gerhart 2002). Institutional and popular support for these environmental causes is strong and well informed. The Marin plan calls for a baylands corridor as an unfragmented conduit for wildlife to move between the protected natural landscapes of western Marin and the bayward, more urbanized and ecologically fragmented eastern side. Miller Creek watershed includes a portion of this corridor, and the adjacent Hamilton Air Force Base has already been slated for ecological restoration.

Spatial framework

After preliminarily assessing the available data, it made sense to use a spatial framework to further divide the study area. Neither land uses nor natural processes are consistent across the entire study area. The spatial framework should reflect this fact, and assist in organizing the data and identifying gaps. While recognizing that this initial division is imprecise, and to some degree imposed artificially, I propose dividing the study area into four parts. The four parts are:

1. Tidal portion
2. Lower watershed
3. Middle watershed
4. Upper watershed

In both academic work (e.g. cite) and professional reports (e.g. Collins 2001), watersheds are frequently divided into sections. This framework is preceded in the existing literature. The divisions are made based on both geomorphic and historical land use reasons. Although the four divisions will be discussed in depth later, here is a brief summary of each:

The tidal portion extends from San Pablo Bay to approximately the abandoned tracks of the North Pacific Coast Railroad tracks. Drainage patterns are somewhat difficult to determine in this landscape of straight man-made channels bounding diked marshland.
Even the marshland which was diked to create the barely productive agricultural land is of anthropic origin. It was initially formed by sediment transported from the Sierra Nevada during the era of hydraulic mining in the 1800s. The historic stream had a tidal portion as well, perhaps much narrower.

The lower watershed includes the land west of railroad tracks up to US Highway 101. It includes the pasture of the Silveira dairy ranch. Also, it includes one of the older local landmarks. St. Vincent’s School was founded in 1855 on land donated by the original grantee, Timoteo Murphy. Evidence of earlier history, a shellmound persists on the St. Vincent’s site. Both properties have seen their plans for development and expansion opposed and thwarted by local anti-growth politics (Gerhart 2002).

The middle watershed is the most intensely urbanized. Virtually all of urbanization occurred between 1950 and 1980. During this time, suburban bedroom communities were built including: Marinwood in the 1950s, Upper Lucas Valley in the 1960s, and Lucas Valley Estates in the 1970s. For the most part, Miller Creek and its ephemeral tributaries were not buried. Another shellmound persists in this section.

The upper watershed is not urbanized. It consists of some private ranchland as well as an open space preserve.

**Historical framework**

History will be viewed through the lens of land use and land cover change. The historical data collected will serve two main purposes. It will be compared and cross referenced with the other data to add confidence to interpretation. Mutual comparison of the historic data sources, especially utilizing current GIS technology, has proved a powerful tool for understanding past landscapes and discovering spatial and temporal connections related to place. But it is important to note that not all historical data sources can be taken at face value without critical skepticism. All historical sources need to be understood by the context and purpose for which they were created, as well as for their purpose in the research. In her thesis, Ruth Askevold (2005) provides a good discussion on the uses and interpretations of several types of historical maps. Her discussion of the work of Harley (cite) and application of his ideas provide a concrete approach to historical maps and data.

Secondly, the historic background will situate this watershed in a regional historical context. For this purpose Barry Spitz’s *Marin: a History* (2006) has provided an excellent outline. Creating a land-use timeline creates an additional basis of comparison between this watershed and others, both locally and beyond.

The historical progression of land use practices both local and remote has had important effects on the study area. Utilizing the data compiled, some of these effects should be readily observable. It should not be ignored that important historical changes may not be observable at all with the given technology, data and expertise. While seeking to understand conditions further and further in the past, the spatial and temporal uncertainty of researcher assertions increases.

Despite these caveats, the historical record contains copious information. Where it has been accessible, some of this data has already proven indispensable to the research. Gathering data as a representative of SFEI has facilitated a level of access to information which might not have been as forthcoming had I presented myself as an independent student researcher.
In order to organize the historical data, a temporal framework is needed to complement the spatial framework outlined earlier. A preliminary timeline (Figure 2) has been developed that incorporates local land uses, key historical dates will be incorporated for the finished product. Similar approaches were used in a Wildcat Creek study (Collins et al. 2001) and on Coyote Creek in the south Bay Area (Grossinger et al. 2006).

![Figure 2: A timeline illustrating some land uses and land cover changes near Miller Creek. Dotted lined indicate uncertainty.](image)

There is evidence of Miwok settlement in Marin dating back over 5000 years. Europeans first made contact with the American in 1492, but the Spanish only discovered San Francisco Bay in 1579. Permanent European settlement in what is now northern California did not occur until around two centuries later, Mission Dolores being founded in San Francisco in 1776. At this time “an estimated 3000 Natives lived in Marin…the number once may have been higher, as European diseases had perhaps reached Marin” (Spitz 2006:5). If the was an extreme decline in population, it is probable that indigenous land use patterns, perhaps ecosystem management (cite) and land cover changed prehistorically. Of course without data, this is only speculation.

In the early years, cattle grazing was the predominant land use in the area. In some portions of the study area it has persisted to this day. Dairy ranching was introduced later (dates?). Mexican independence led to the end of the Mission system of land use, and instead granted land to elites. Timoteo (Timothy) Murphy, a well-connected Irish emigrant to Mexico, was granted the land encompassing most of the study area in 1844. The land grant was called San Pedro, Santa Margarita, y Las Gallinas. A small portion of the study area was granted to Ignacio Pacheco.

James Miller, after whom Miller Creek is named, purchased land in present-day Marinwood from Murphy in 1846. St. Vincent’s School was founded in 1855 on land willed by Murphy. John Lucas, after whom Lucas Valley is named, was a nephew of Murphy’s who was willed land by Murphy (Spitz 2006).

Hydraulic mining during the California gold rush left a lasting legacy on the landscape. From the 1850s until 1884, when hydraulic mining was banned, fine sediments accreted along the shallow edges of the San Pablo Bay. In the study area, this
anthropogenic deposition of sediment advanced the shoreline almost a mile bayward, with deposits 2 to 3 feet (~ 60 to 90cm) deep (Gilbert 1917). Over a period of decades the newly accreted marsh was diked to provide land for agriculture. While I suspect the land was not very productive, similar parcels around the bay were used to grow hay and beets.

In 1878 the North Pacific Coast Railroad connected Marin and Sonoma. The track is mostly intact and remains on the study area. The raised berm, or dike on which the tracks are built precludes the movement of water downslope into the tidal portion. The creek is routed under a railroad bridge, and into ditches where it follows an angled path into the bay.

Although the populations of neighboring San Rafael and Novato, the study area remained sparsely populated until the mid-1900s. Hamilton Field was built in 1930. The newly constructed officer housing can be seen in the earliest available set of aerial photos. Suburban home construction proceeded in parts of the lower watershed from about 1955-1975, two developments were designed by Eichler, a noted modernist builder.

Improvements on Lucas Valley Road have also been built by the county. These include minor improvements, bridge repairs as well as the construction of an entirely new segment for a portion of the route.

In recent years, efforts by two large landholders in the lower watershed to develop or expand have been opposed and stopped by local political forces that have been described as a “green versus growth” coalition.

The above summary should give a clear idea about how historical eras and developments can affect, and be affected by changing land use and changes in land cover. Along with the spatial framework, this local and regional timeline will assist in organizing the data, identifying gaps, and generating conclusions.
Literature review

The literature relevant to this study include topics and methods in geomorphology, remote sensing, landscape ecology and historical geography. Some relevant literature needs to be covered, specifically pertaining to soil science and oak biology and habitat.

Geomorphology

Anthropogenic change has long been an explicit subject of study in geomorphology. Gilbert’s hydraulic mining study conducted in 1917 is an example of this. Much more recently, Magilligan and Stamp (1997) conducted a study relevant to this research. In their study of reforestation of an anthropogenically disturbed watershed in Georgia, they classify predominant land uses into historical eras, similar to my historical framework. My study also seeks to identify any describe correspondences between land use change, geomorphic change and vegetation change.

Their data sources include Data sources include historical and modern aerial photography, US Soil Conservation Service soil maps and other government documents such as the agricultural census. As with my study, the historical period of most significant anthropogenic change, or devastation through rapid erosion and sedimentation, was the late 1800s. This study also reveals that there may different responses to change in various parts of the watershed, highlighting the need for a spatial framework. Magilligan and Stamp note that "Because of the complexity of … interactions, it is difficult to determine the exact causal links between hydrologic controls and geomorphic response" (615). This is an important consideration, and points in my case to a research product which is more a compilation of spatial and temporal data, rather then a convincing demonstration of causality in land cover change.

In contrast with Magilligan and Stamp, my study will focus more on the historical character of changes in land use and less on quantified hydrologic variables. For the most part, the analysis of hydrology will be limited to the existing research (perhaps Collins unpublished landslide data), government documents including as built bridge diagrams, and what can be observed on the landscape.

In his study of adjustment time to sediment resultant of hydraulic mining, Alan James (1999) laments that “Unfortunately, many scientists and engineers are reluctant to use historical methods because the evidence may be anecdotal, incomplete and less quantifiable than records derived from recent instrumental measurements. Nevertheless, placing modern processes into a long-term context requires knowledge of past process rates and changes which should be validated by historical data. The need for…validation grows rapidly...(in studies ranging) beyond a few decades"(268). He points out that since the time required for fluvial systems to readjust to anthropogenic change "is not well understood"(269) and that early quantitative data often post-dates historical alteration. Nontraditionally scientific, historic data sources can be useful or necessary to understand "channel adjustments and to identify multiple perturbations"(269).

Luna Leopold spent decades studying urban creeks. In a summary (Leopold et al 2005) of long term, repeated field measurements of urban and suburban creeks in Maryland, he provides several insights to this study. His difficulty of maintaining long term field markers, or monuments, in a system that is changing morphologically due to natural (e.g. erosion) and social processes (urbanization). He highlights the importance
of detailed and well preserved field notes. While they were generated for a different reason, detailed field notes from land surveys in the 1800s can contain data about the landscape and land cover can also be valuable sources. It goes to show that you never know what your field research may be used for down the line!

Leopold also quantifies urban expansion by counting houses on successive topo quads (353). He also notes that home construction corresponded with the cessation of grazing (356). Leopold is a field geomorphologist who specializes in quantitative measurement. Nevertheless, he highlights the important of social and economic factors. These factors relate to land use as well as to the changing morphology of the urban(izing) stream. He highlights five social-natural stages in the urbanization of creeks (359):

1 ~10 years early urbanization - little effect on the channel
2 ~10 years continued urbanization - increasing flows and sediment supply, "fish are decimated". This corresponds with Wolman’s (1967) observation that construction can exponentially increase sediment supply over the short term.
3 ~20 years towards complete buildout, streams sections are buried and culverted
4 ~10 years mature urban, growth of urban veg cover, sediment supply less but high peak flows common
5 ~unknown duration beginning of public demand for improved stream amenities, "Some reaches are exhumed at great expense...Some fish return"

Perhaps the four sections from my spatial framework, Tidal, Lower, Middle and Upper Reaches reached a particular stage of Luna’s classification in their own particular time. If that is the case, perhaps this study is a step towards bringing the entire creek to stage 5, where prior natural function is restored as per public demand and required mitigation.

Wolman’s (1967) observations are relevant to the suburbanized middle watershed. It applies to agriculture as well, which was historically practiced over the entire watershed. Construction can exponentially increase sediment supply, when large areas are under construction, such as during a rapid phase of urbanization this can significantly affect a watershed. Agricultural practices also increase sediment supply, but less than construction.

A review of geomorphic impacts of cattle and grazing was conducted by Trimble and Mendel in their 1995 article “The cow as a geomorphic agent”. Overgrazing can have profound effects on fluvial systems. Cows can have an impact in several ways. Soil compaction decreases infiltration and increases runoff, this can lead to greater peak flows and channel incision and gully formation upslope. Overgrazing can reduce vegetation cover and increase erodibility. Finally, cows can directly erode streambanks by trampling them.

Since grazing and pasturing have been ongoing in the study area, the evidence of impact of these land use activities are highly relevant to this study. If historical records can provide an estimate of cattle grazed in various areas, the impacts might be quantitatively estimable. The sharp decrease in number of trees in the lower watershed is probably an impact of the continued presence of cattle.

Trimble also wrote a chapter in Egan & Howell’s Historical Ecology guide (2005) about the role understanding “Geomorphology, Hydrology, and Soils” can play in
mapping and understanding past land cover and ecology. He describes the use of several historical data sources. The specific government surveys and reports he recommends include: 1) geological surveys, 2) soil surveys, 3) soil erosion surveys, 4) storm discharge and water quality, 5) stream, valley, and coastal surveys, 6) bridges, mills and riparian features, 7) irrigation and wetland records. He points out that while early geologic surveys may not be accurate or useful for the study of geology, but that the agents who performed them may have included other relevant observations on the landscape, land uses, or vegetation. Of Trimble’s list of recommended sources, this study will make use of geological, soil and coast surveys as well as bridge and road diagrams.

Relevant to the tidal portion of the study area are two studies supported by the US Geological Survey (USGS). These include a recent study of historical sedimentation sediment deposition and movement in the San Pablo Bay (Jaffe et al. 1998) and Gilbert’s classic 1917 study entitled “Hydraulic Mining Debris in the Sierra Nevada” By Jaffe et al.’s estimation, a full two thirds of the sediment delivered to San Pablo Bay since 1850 was a result of the period of intensive hydraulic mining.

Gilbert’s report article is of interest both as a descriptive geomorphology paper and as an historic document. The introduction provides the historical context in which the report was written. He described the development of the industrial process of hydraulic mining. As the hillsides were blasted away, sediment supply increased precipitously. Both large and small sediment were deposited in stream channels, floodplains. The term “slickens” evokes a stream that runs thick with fine sediment, some quantity of which was deposited in the tidal portion of the study area. Gilbert describes how "About Suisun and San Pablo Bays the marsh lands have grown at the expense of the open water, the growth being closely associated with the deposition of mining debris on the shoals" (p21). He uses USCS (1850s) and USCGS (1890s) maps as key evidence. More recent diking of marshlands, and the expansion of bayfill have greatly reduced the area of the tidal marsh around the bay in general. In the study area, the accreted tidelands were diked but not filled.

Gilbert’s discussion of subsidence as evidenced by sinking shellmounds also leads one to wonder if there are not indeed additional shellmounds, and perhaps archeological evidence which has sunk beneath the current level of the bay.

**Local history**

There is evidence of Miwok settlement in Marin dating back over 5000 years. Europeans first made contact with the American in 1492, but the Spanish only discovered San Francisco Bay in 1579. Permanent European settlement in what is now northern California did not occur until around two centuries later, Mission Dolores being founded in San Francisco in 1776. At this time “an estimated 3000 Natives lived in Marin…the number once may have been higher, as European diseases had perhaps reached Marin” (Spitz 2006:5). If the was an extreme decline in population, it is probable that indigenous land use patterns, perhaps ecosystem management (cite) and land cover changed pre-historically. Of course without data, this is only speculation.

Changing notions of land ownership, and the changing economy of land use are key to understanding landscape history in general and the Miller Creek area in particular. In the early years, cattle grazing was the predominant land use in the area. Cattle grazed in “the canadas of Las Gallinas,” according to the description of Mission San Rafael
lands in 1828. (Teather 1986:36). In some portions of the study area grazing has persisted to this day. Dairy ranching was also introduced in the mid 1800s.

Mexican independence led to the end of the Mission system of land use, and instead granted land to individual owners. In 1837 Timothy Murphy (Don Timoteo) arrived in San Rafael, where he eventually becomes mission administrator and justice of the peace (Teather 1986). Murphy was a well connected Irish emigrant to Mexico, was granted the land encompassing most of the study area in 1844 by Californio governor Micheltoreno (Spitz 2006). Described as huge, measuring six feet six inches and weighing 300 pounds, Murphy comes across as quite a historical character. Although he was rejected, he sought to wed the daughter of General Vallejo, started the rowdy St. Raphael day rodeo, learned the local Miwok dialect and unsuccessfully lobbied the US Land Commission for Native land rights in nearby Tincasia (Spitz 2006).

Murphy’s land grant was called San Pedro, Santa Margarita, y Las Gallinas. “Las Gallinas (“The Hens”) was part of Timothy Murphy’s 1844 land grant” encompassing most of the study area and including the Gallinas Creek watershed to the south. “(B)ut the name pre-dates (the grant) by several decades. Gallinas is mentioned in a manuscript at the Bancroft Library, Noticia de un Viaje a San Rafael (“News of a Voyage to San Rafael”) by Father Mariano Payeras, who visited the area in 1818. Cattle grazed in “the canadas of Las Gallinas,” according to the description of Mission San Rafael lands in 1828. Marinwood and John F. McInnis County Park are among areas in old Las Gallinas today.” (Teather 1986:36). “During the mission years a specific area, perhaps a rancho or a cattle range under supervision of the priests, was named Santa Margarita, as shown on an 1834 map of mission lands. Areas in the valley today include Terra Linda, Northgate, and Lucas Valley.” (Teather 1986:71). Unlike grantees in other parts of the San Francisco Bay Area, such as Alviso (Askevold 2005), the Murphy grant was not reinterpreted and truncated after an extended court case. His holdings were passed onto his chosen heirs intact.

It bears noting that a small northeastern portion of the study area was granted to Ignacio Pacheco.

James Miller, after whom Miller Creek is named, purchased land in present-day Marinwood from Murphy in 1846. “Miller (had) arrived with his family in 1845 by wagon train and became one of Marin’s most prominent dairy ranchers. He built a mansion called Miller Hall in the present Marinwood. His holdings also included land on Tomales Bay (see Millerton). Miller’s oldest son, William J., also became a prominent resident and landowner. (see Nicasio).” (Teather 1986:46).

St. Vincent’s School was founded in 1855 on land willed by the bachelor Murphy on his deathbed in 1853. It was “founded… by the Daughters of Charity of St. Vincent de Paul, who named it for their patron. Formerly an orphanage, the school is now a residential treatment center for boys with adjustment problems. New buildings were dedicated in 1930 and new residential cottages in 1977.” (Teather 1986:63)

John Lucas, after whom Lucas Valley is named, was a nephew of Murphy’s who was willed land by Murphy (Spitz 2006). “Lucas, his wife Maria, and their children lived in a large house on their 2,340-acre Santa Margarita Ranch, now Lucas Valley and Terra Linda. The property was purchased by M. T. Freitas in the 1890’s.” (Teather 1986:38).

In 1948 the annexation of California by the United States was formalized in the treaty of Hidalgo. The next year saw the gold rush and the massive influx of migrants
that rapidly propelled California from sleepy hinterland to its first economic and population boom.

Hydraulic mining during the California gold rush left a lasting legacy on the landscape. From the 1850s until 1884, when hydraulic mining was banned, fine sediments accreted along the shallow edges of the San Pablo Bay. In the study area, this anthropogenic deposition of sediment advanced the shoreline almost a mile bayward, with deposits 2 to 3 feet (~ 60 to 90cm) deep (Gilbert 1917). Over a period of decades the newly accreted marsh was diked to provide land for agriculture. While I suspect the land was not very productive, similar parcels around the bay were used to grow hay and beets. A series of historical, spatially accurate maps (USCS 1854; USGCS 1897-8; USGS 1914-16; USGS 1942), documents the successive diking of newly accreted (1850s-1884) marshland.

In 1878 the North Pacific Coast Railroad connected Marin and Sonoma. Two stations were used on the study area: Miller Creek and St. Vincent’s (Spitz 2006). The location of these stations should be determined if possible. The track is mostly intact and remains on the study area. The raised berm, or dike on which the tracks are built precludes the movement of water downslope into the tidal portion. The creek is routed under a railroad bridge, and into ditches where it follows an angled path into the bay.

Although the populations of neighboring San Rafael and Novato, the study area remained sparsely populated until the mid-1900s. Hamilton Field was built in 1930. The newly constructed officer housing can be seen in the earliest available set of aerial photos. Suburban home construction proceeded in parts of the lower watershed from about 1955-1975, two developments were designed by Eichler, a noted modernist builder.

Improvements on Lucas Valley Road have also been built by the county. These include minor improvements, bridge repairs as well as the construction of an entirely new segment for a portion of the route.

In recent years, efforts by two large landholders in the lower watershed to develop or expand have been opposed and stopped by local political forces that have been described as a “green versus growth” coalition. In terms of support for protection of open space, preservation, and ecological restoration, Marin is a special case (Gerhart 2002). Institutional and popular support for these environmental causes is strong and well informed. Indeed, “By 1908, Marin had its first National Monument – the beginning of a long tradition whereby the county was able to martial (sic) federal resources to meet its local conservation goals” (Gerhart 2002:27).

In direct relevance to the study area, Gerhart notes “Perhaps most telling of the tight tolerances to which Marin’s landscape is now engineered is a battle that has raged for over a decade around the last community separator between San Rafael and Novato. Since the late 1980s the St. Vincent’s School for Boys and the Silveira dairy ranch have sought to develop much of their bayland property, yet have seen their plans frustrated by an environmentalist direct action campaign, a county referendum, and two consensus-based planning processes in which developers, community members, environmentalists, and property owners have labored fruitlessly to determine appropriate development densities for the land. Despite popular support for preservation (largely because of traffic increases associated with the new building), in the end it may take direct purchase of development rights – at enormous prices – to fully conserve the lands.” (2002:91-2).
In other words, private property and the economics of development are no longer the strongest driver of land cover change as they were in the preceding historical period. Suburban housing development did not continue unabated, as it did during the same period in other parts of the Bay Area and around the country. Across the bay during this period, neighboring cities expanded into a continuous urbanized space. In this part of Marin, the suburbanizing processes were at work, but were also limited.

Gerhart identifies four distinct periods of land conservation in Marin in general: 1) In the 1800s-1908 private landholders consolidate large tracts, engage in extractive resource production and eventually establish an elite suburban community. “For many early residents, the county’s majestic and imposing hillsides seemed a defensive barrier, protecting an isolated region beyond the reach of capital.”(9). From 1908 to 1938, urban recreationists and local elites fought development, and defended an “emerging vision of place”. 2) 1934-58 witnessed the development of conservation institutions, and the increasing bureaucratic sophistication of land use policy. 3) The 1960s and early 70s represent the most contentious massive wave of urban development. Rapid suburbanization pushes local conservationists to secure a comprehensive plan to protect open spaces and parkland. 4) From 1973 to the present, local politics often trumps urban development. However, this method of conservation has its limitations.

Perhaps reflecting Luna et al’s (2005) fifth stage of urban streams, Gerhart points toward “A new series of coordinating bodies (that) have arisen...(namely) local watershed groups. These seek to bring together interested property owners in a watershed and work out land management issues that bridge property lines. In Marin such problems have involved endangered and threatened species, particularly ones tied to the county’s fragile water supplies. In particular, Coho salmon and steelhead trout have been focal points for managers seeking to salvage stream systems on the verge of collapse.”(89). This scenario fits the Miller Creek area, where a local watershed group is beginning to form. The county has been assisting in this effort through seed funding an expertise. The research I am performing at SFEI is being funded by the county as part of this process.

Methodology

The primary data sources used in this research will be cartographic. Historical maps of the area date back to the mid-1800s. Early maps include spatially inaccurate diseños from the Mexican period, the highly accurate USCS and USCGS coastal topographic sheets (T-sheets), historical USGS quadrangles, Railroad Maps, and County property maps. Care must be taken when georectifying, comparing, and verifying these historical maps (Askevold 2005). Trimble’s chapter in Egan & Howell (2005) lists many data sources which might be useful in studies of landscape change. Egan and Howell illustrate the spatial and temporal scales and ranges of available data (Figure 3).
Additionally, orthorectified historical aerial photos will be a key component to this study. Systematic aerial photo surveys of the United States began in the late 1930s under the Federal Agricultural Adjustment Administration (AAA). The AAA was later folded into the US Department of Agriculture (USDA). The photos were originally used for quantitative measurements of farm field size in order to monitor compliance with New Deal subsidies for agriculture (Monmonier 2002). That said, the 1943 photos taken in the vicinity of Hamilton Field have the word “CONFIDENTIAL” printed on and crossed off indicates that the military uses of aerial surveillance was a another key factor in the development of this Federal Program.

The historical aerial photos were taken from a vertical, rather than oblique, vantage point. The vertical vantage point limits geometric distortion of the image, making in useful for quantitative measurement (Jensen 2000). Using digital photogrammetry techniques, the aerial photos can be merged together and digitally resampled into ortho-images, which are even more spatially accurate. In addition, ortho-images can be used in a GIS where they can be combined and compared with other spatial data (Baltsavias 1996).

Cousins’ (2001) research utilizes both historical maps and aerial photographs to study land cover change in Sweden. Sweden has cadastral maps dating back to the 1600s which were used in conjunction with aerial photos to study land cover change. Both the maps and the photos were georectified. Cousins studied "semi-natural grasslands...the remnants of traditional agriculture" and the effects of past land uses on biodiversity. Different land use and land cover areas were measured over time to detect change. Although they are not the primary object of this paper, soil types are mentioned in the appendix as well.
Toutin (2004) describes the many systematic sources of geometric distortion in remotely sensed images. Images need to be orthorectified to remove significant geometric distortions so they can be used in a GIS. According to Toutin, the rapid spread and utility of GIS applications and a greater quantity of fine spatial resolution data have rendered orthorectified, geometrically corrected layers more necessary than in the past. Most of the examples presented by Toutin are of satellite platform sensors. Nevertheless, many of the same principles apply to raw aerial photographs. The orthorectification process follows the same principles and mathematical reprojection models. I’m not sure, however, whether Leica Photogrammetry Suite (LPS) uses a 3D polynomial or a 3D rational function to reproject the raster based on a horizontal and vertical reference, and manually and automatically generated control points.

The geographic correction of historical photos can be accomplished through technical means. These will be described in greater detail in the methods section. Through a process of digitization (scanning), image processing, and using the Leica Photogrammetry Suite (LPS) software package, 1943 historical aerial photos (USDA) were corrected with 14.3 meter root mean square error (RMSE) from a horizontal reference (NAIP 2005). A series of 9”x9” black and white photographs can be scanned, transformed and mosaicked into a single continuous, spatially correct layer.

In addition to their somewhat limited role in geomorphology, historical aerial photos and maps have been used in landscape ecology for studying changes in land cover. Kadmon & Harari-Kremer (1999) compared manual and automated approaches to classifying vegetation in historical aerial photographs. They calculated an RMSE of 15m for both sets of images they used, although they don’t describe the method they used to derive the statistic. In another important pointer, the article describes how differences in brightness between images were corrected using an empirically derived regression equation described in Hall et al. (1991). This enabled a supervised single spectral classification whose results were comparable to manual classification after they adjusted the grey level for the images prior to mosaicking. In their analysis, spatial error was mainly attributed to inaccuracies in the DEM and in the determination of control point coordinates. To improve spatial accuracy, after initial rectification the images were re-registered to each other.

The Kadmon & Harari-Kremer article also discusses how spatial errors and classification errors both can detract from final map accuracy. These are concerns that I will bear in mind as I work towards the cartographic end product of this research. I having been trying to work out a method of histogram correction similar to the one described by Kadmon & Harari-Kremer so that the maps created through this research will not contain visible markers of where two individual ortho-photos were mosaicked.

Touminen and Pekkarinen’s (2004) observations point out a potential pitfall in Kadmon & Harari-Kremer’s single-spectral classification approach. They point out that spectral reflectance properties of objects are dependent on sun angle and sensor viewing angle.

Collins et al.’s (2003) report in Washington State studies changes in both vegetation and channel form. The study eses multiple historic maps (GLO plats), and multiple sets of historical aerial photos spaced across history. The National Standard for Spatial Data Accuracy (NSSDA) 95% ranged from 5-19m in the historical aerial photos. According to the Minnesota Planning Land Management Information Center (MPLMIC
the 95% NSSDA statistic for horizontal error can be obtained by multiplying the horizontal RMSE by 1.7308. It is unclear, however, if this implies a systematic sampling technique to determine where error is measured, or whether they simply select opportunistic control points spaced as evenly as possible around their study area. In other words, I am not sure that this factor can be applied to the orthophotomosaic I generated from the 1943 photos.

Collins et al. (2003) also ground tested the accuracy of (originally) digital reference data to get CE90 statistic for 2000 data (a point on the map will fall within the CE90 distance of its actual location 90% of the time). The CE90 ranged from 2.5-4 m for the 2000 data. In this study, channel form & vegetation patches were digitized in ArcGIS, rather than spectrally classified. Digitized classes included the low flow channel, gravel bars, vegetation patches, forested islands, and the visible floodplain.

A good feature of this report is the table detailing the historical aerial photo sets used, scale, accuracy and comments. It will be worthwhile for me to organize my aerial photos similarly.

Further on the topic of error assessment, Congalton & Green (1999) describe sampling designs mainly designed to measure classification, rather than spatial error. They point out “A balance between what is statistically sound and what is practically attainable must be found. In our experience, a…good ‘rule of thumb’ seems to be collecting a minimum of 50 samples…this rule of thumb can be used as a general starting point”. I used their rule of thumb of 50 sample points when testing the horizontal error of the Miller Creek historical Aerial Photos. For my sampling design, I used their method of a “stratified, systematic, unaligned sample” (23). The purpose of this sampling design is to distribute sample points evenly throughout the study area to reduce the influence of spatial autocorrelation (see Tobler’s first law of Geography). The sample is “unaligned” to avoid bias in sampling linear or regularly spaced objects in the mapped landscape.

The USGS Standards for DEM Accuracy use a fixed grid for error sampling, and use only 28 points. The DEM case is not exactly comparable with ortho-imagery even though both are spatial raster data. DEM accuracy at the fixed grid positions is highly dependent on the measurement and identification of vertical relief. Nevertheless, LPS uses a DEM for a vertical reference for modeling the reprojected, ortho-corrected image. To some extent, the accuracy of the final product is dependent on the accuracy of the reference DEM.

Wang & Ellis (2005) describe a more sophisticated procedure for orthorectification and error assessment than the one I have used thus far. For a horizontal reference, they use IKONOS imagery. In contrast with the pre-packaged NAIP (2005) imagery I have used. For starters, they orthorectify the reference imagery with ground control points (GCPs) confirmed with in situ < 1m accuracy GPS location. RMSE for the reference IKONOS images was < 3m in all cases. Wang & Ellis use a spatially dispersed “optimum uniform distribution” (1902) sampling pattern (1898-9) for the reference GCPs. They also experimented with the influence of the influence on horizontal accuracy of 1) hilly terrain and 2) the number of GCPs per image. When measuring accuracy, accuracy is measured at independent checkpoints (ICPs). The sampling method for determining the location of ICPs was not detailed. Errors at GCPs are used as a proxy to measure systematic error in the orthorectification model, while errors at ICPs are used to measure the overall horizontal accuracy of the map.
The quality of the historical data used by Ellis & Wang (2005) is superior to the ones I had access to in several respects. More information was available about the individual photo series, the reproductions may have been of higher quality. They were also digitized at a higher spatial (1400 ppi) and spectral (14-bit greyscale) than my images. More precise parameters for flight altitude and camera focal length were known and could be fed into their orthorectification model. The location of control points for the historical aerial photos is more dependent on the ability to identify persistent features on the ground. Their historical orthoimagery had RMSEs at GCPs of .24 to 3.5 with CE90 of 0.34. At ICPs the horizontal accuracy decreases to RMSE 4.4 – 6.2 m with CE90s from 6.5 to 9.3 m. There is discussion of the merits of a “rational function model” (RF) versus a “bundle block adjustment” in the orthorectification process that I do not yet fully understand.

Missing
Gaps in this Research include literature discussing the following:
1. Miwok history, land-uses, shellmounds, what is un/known
2. Vegetation changes, succession and response to grazing of oak, grassland land cover
3. Relationship between soil and habitat type, historical hydrology and land cover.
4. Ignacio Pacheco Land grants & documentation for a small portion of the study area
6. JB Harley’s work on historical map interpretation
7. Munro-Fraser’s 1880 history of Marin
8. Marin County, Can the last place last? –a map of climate diversity (rainfall patterns) within the county (cited in Gerhart 2002)
10. Marin countywide plan 1971 – map of ranchos
11. C. Hart Merriam – ethnographer, mapper of Miwok villages including Nicasio
13. please add to this list, or give recommendations
Sources


Kerr, ??Rodgers and 1853. US Coast Survey Topographic map sheet (T-sheet) no. ??


USGS DEM Accuracy. National Mapping Program Technical Instructions

U.S. Geological Survey
