CHARGE-COUPLED-DEVICE (CCD) DIGITAL VIDEO STUDIES OF BEACH WIDTH, BLUFF EROSION, AND SHORELINE GEOMORPHOLOGY

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ABSTRACT
Charge-Coupled-Device (CCD) video digital imagery exhibits a potential for rapid and inexpensive beach-width and bluff-erosion monitoring as well as reconnaissance of geomorphology and seismic structures.

Examples from La Jolla to Oceanside, along the Southern California coastline, show that water and damp sand absorb the near-infrared wavelengths, causing these materials to appear darker than normal. This facilitates accurate (± 2 ft) mapping of the wetted bound, a frequently used reference line in detecting changes in beach width over time.

A digital mosaic developed from our CCD data of La Jolla Bay reveals previously unrecognized seismic structures exposed on the abrasion platform. These features are related to the active Rose Canyon fault zone and analogous to other shear zones cutting the sea cliffs north of La Jolla. The CCD images help to recognize landslide hazards within these shear zones.

Under certain circumstance, CCD video is more time and cost efficient than traditional aerial photo collection. The system is compact, adaptable, and can be flown on different aircraft and quickly configured for natural disaster assessment after storms, tsunamis, earthquakes, floods, and volcanic eruptions.

INTRODUCTION
Methods used to measure beach width, monitor coastal bluff erosion, and study shoreline geomorphology have included comparison of maps and photographs, traditional survey methods, and interpretation of recorded observations. In searching for a more effective approach, we collected data with a CCD integrated with a super VHS video camera and recorder mounted on a light airplane. This setup made it possible to collect data at rapid rates with low costs.

BACKGROUND
During 1996, the San Diego Association of Governments (SANDAG) showed interest in obtaining long-term data on the stability of the San Diego County coastline. The U.S. Army Corps of Engineers had surveyed the coastline and established beach profiling points (U.S. Army Corps of Engineers, Los Angeles District, 1991), and SANDAG had periodically commissioned traditional aerial surveys from the international border to
Camp Pendleton in Oceanside (Figure 1). Sometime had elapsed, however, since the last collection and assessment of data, and Coastal Consultants sought to demonstrate how new methods could be used to fill this data gap.

Figure 1. North San Diego County California Coastline
Coastal Consultants also sought to monitor rates of bluff erosion, landslide activity, and catastrophic meteorological events and recognize geomorphology and seismic structures associated with the active Rose Canyon fault zone (RCFZ). The RCFZ joins the Newport-Inglewood fault zone offshore from Oceanside and trends from SW Los Angeles through San Diego Bay and possibly into Mexico (Fischer and Mills, 1991), yet its seismic structures are not well documented or understood.

With the goal of developing a competitive method to replace traditional color/infrared (IR) aerial photography studies, we mounted a low-cost CCD video camera made by Xybian Electronic Systems Corporation with a SVHS recorder on a light aircraft modified to carry the camera. For data preparation and analysis, we selected Earth Resources Mapper (ER Mapper), an image-processing software.

The first flight during the early fall 1996 coincided with a period of maximum onshore accretion of sand and a maximum monthly low tide.

LOCATION AND GEOLOGIC OVERVIEW
Data collection covered the immediate coastline from La Jolla north to Oceanside. La Jolla Bay is cut by the RCFZ, estimated to be capable of a M 6 to M 7 earthquake (Lindvall, Rockwell, and Lindvall, 1990). Prominent right-lateral movement is responsible for the formation of La Jolla Bay and a left-hand restraining bend is compressing and uplifting nearby Mt. Soledad.

Southwest of the fault zone, rock outcrops are Cretaceous sandstones and conglomerates (Kennedy, 1975). Rocks northeast of the RCFZ and extending past Oceanside are Eocene mudstones, siltstones, and sandstones. These Eocene rocks were wave-eroded during eustatic sea-level stillstands and tectonically uplifted as a flight of marine terraces (Kern and Rockwell, 1992). Below the ocean, this morphology continues as a flight of submerged marine terraces separated by low-relief, paleo-sea cliffs (Emery, 1958).

The beach and near-shore sands rest on the Holocene terrace, the present-day abrasion platform. In many instances, sand loss to the deeper submerged terraces has exposed the abrasion platform or left it covered with cobbles. Water and wave erosion, fault-controlled erosion, landsliding, and tectonic movement have deformed the cliffs, bluffs, and terraces above the abrasion platform, which are intermittently separated by small estuarine river mouths.

METHODS

Image Collection
Xybian’s rapid gating, monochromatic CCD video camera, mounted on a light airplane, recorded imagery in wavelengths from 400 to 900 nanometers. The camera collects 30 images per second with digital RS-170 output captured on SVHS tape. The small footprint obtained is a result of lens focal length, altitude, and an effort to maximize resolution. The camera was mounted on the airplane wheel strut and experienced a lot of vibration; therefore, higher resolutions than shown in the examples are expected if the camera is mounted inside the plane.

Image collection was monitored in real time, and this showed that the gusting offshore winds were pushing the aircraft off course. This real-time information made it possible to re-fly immediately those portions of the shoreline not covered and thus avoid
the necessity of making later compensatory flights. Real-time annotation of video images with time and GPS (satellite) position data is also possible. Since the San Diego coast line already has plenty of ground control points, GPS was not used.

**Image Processing and Analysis**

Super VHS playback screened the data, allowing for identification of portions of the coastline of interest to be placed on a PC via a video capture board. Grablt. Grablt has the capability to present 6 images at once and allows the user to capture the frames of interest at resolutions of 1440 x 960 lines. Captured images were stored in computer TGA files and then imported into ER Mapper. Image processing was used to enhance wet/dry contrast and structural features affecting bluff erosion. A number of photo-mosaics were also developed by stitching multiple frames together to cover selected areas of interest.

Although we chose not to do so at the time, measurements could be made by scaling the imagery from shoreline and backshore landmarks; scaling from known distances from survey points and maps; and by rubber sheeting the images to base maps. Beach width comparisons can be accomplished by picking common locations on imagery collected during different time frames; rubber sheeting these images will permit direct overlay for change comparison.

**RESULTS AND DISCUSSION**

**North Del Mar Beach**

The North Del Mar beach imagery reflects the wetted bound, a reference line frequently used in detecting changes in beach width (Figure 2). Water and damp sand absorb near

![Figure 2: CCD ST Video Image of North Del Mar Beach. US Army Corps of Engineers Beach Profile Range Number DM-0880 Image Acquired 10/21/96, 2:20 PM High Tide at 7:48 AM, Low Tide at 2:02 PM](image-url)
infrared wavelengths, causing these materials to appear darker than normal. For ground-truthing, a beach profile from one of the U.S. Army Corp benchmarks was developed through traditional, non-imagery methods (Figure 3).

Beach Profile - DM0580
Summer - Winter Shoreline Comparison

Figure 3 Example of Del Mar Fall and Spring Beach Profiles. Wetted Bound for 9/24/96 is Inland of the Average Wetted Bound, Which Is Represented by the Top of the Berm

The distinctive wavy dark band running along the beach face correlates with the crest of the berm and, in this instance, with the seasonal average wetted bound. Afternoon sunlight, reflected off the steep, seaward berm face causes it to appear as a whitish band running parallel to the average wetted bound. In addition, the berm face is comprised of coarser, lighter-colored, more quartz-rich sands relative to sands deposited seaward of the berm face and along the berm crest.

The most recent wetted bound (deposited during the morning hours prior to the survey) is inland of the average wetted bound. The accuracy with which these features may be recorded is estimated at better than ±2 ft. The CCD imagery shows that both the seasonal and the recent wetted bound can be mapped easily and accurately using near-infrared monochromatic video.

La Jolla Bay and the Rose Canyon Fault Zone
A digital mosaic, made from CCD video imagery of La Jolla Bay, was computer enhanced to show the shallow ocean floor and geologic structures with criss-crossing lineations
(Figure 4). Lineations paralleling the NW trend of the RCFZ represent the intersection of the abrasion platform with SW-dipping Cretaceous sedimentary beds. Other lineations, trending in a NE direction, represent previously unrecognized shear zones cutting the sedimentary beds.

![Figure 4. CCD Video Mosaic of La Jolla Bay: Image Shows Tilted Bedding and Seismic Structures Crisscrossing the Abrasion Platform](image)

Following the 1996 CCD video survey, La Jolla Bay was surveyed a second time using hand-held, 35 mm cameras. These higher resolution images, in addition to ground evidence, are being used to alert the public about seismic and slope stability hazards. Ground studies at the point where these NE-lineations intersect with the bluffs along the beach suggest both lateral and thrust shearing (Figure 5). The resulting complicated...

![Figure 5. Photomosaic Along Trend of Previously Unrecognized NE-Steering Shear Zone Showing Evidence of Lateral Movement and Compression For Location, See Figure 4](image)
shear systems are often involved in modern ground instability. For example, Coastal Consultants has become aware of a private residence experiencing repeated landsliding problems at the intersection of the sea cliff with a NE-trending shear zone.

Research approximately one mile north of the RCFZ, at the cliff base beneath the Southwest National Marine Fisheries Science Center (SWMF), has revealed a set of strike-slip conjugate thrust faults trending in a NE to E-W direction (Rindell, 1993 and 1994). A second shear zone of prominent NE-striking, possibly left-lateral shears is also reported along the base of the SWMF. The CCD imagery depicts strong NE lineations crossing the upper cliff face. In its ongoing geologic investigation for the National Oceanographic and Atmospheric Administration, Coastal Consultants has come to recognize that the lineations in the upper cliff are also NE-lateral shears. Their presence in the upper cliff helps determine the rate and morphology of landsliding at the SWMF.

The CCD imagery highlights several other NE-trending shear zones similar to those of La Jolla Bay and the SWMF. These cut the seacliffs at numerous locations between La Jolla and Ocean Diese. The most prominent zones cut through the North Torrey Pines sea cliffs and the mouth of Carmel Valley (Rindell, 1994) and the town of Carlsbad (Schlemann and Kuhn, 1997; Kuhn, 1997).

Recent published fieldwork suggests a probability of co-seismic activity along some of these shear zones if the RCFZ were to rupture. The trends of these lineations are analogous to features predicted by a right-lateral strain ellipse oriented N50W, the strike of the Rose Canyon fault as it enters La Jolla Bay (Figure 6). (For a discussion of the strain ellipse, see Christie-Blick and Biddle, 1985, or Davis and Reynolds, 1996.) The strain ellipse suggests that these NE-trending lineations are zones of left-lateral conjugate

![Diagram](image)

**Figure 6.** Strain Ellipse Rotated To N50W, the Average Strike of the Rose Canyon Fault Zone as It Bends Around Mount Soledad.
Reidel shears, part of a complex system of shears associated with the RCFZ. The California Division of Mines and Geology, however, has mapped these features as normal faults (Bulletin 200). The suggestion that these are lateral shears and not normal faults is a new concept.

While the possibility of seismic hazard poised by the NE shears is being debated, the adverse effects these features have on sea cliff stability and landslide hazard is becoming painfully real to numerous coastal landholders. The CCD imagery of Torrey Pines, La Jolla Bay, and other studies indicate that bluff erosion and landsliding occur more rapidly where the shoreline bluffs have been weakened by faulting and associated fractures.

The recognition of the previously unknown La Jolla Bay seismic structures and other NE-trending features shows that CCD video imagery can be used for quick and inexpensive preliminary geomorphologic surveys over long stretches of shoreline.

SUMMARY AND CONCLUSIONS
CCD video digital imagery exhibits a potential for rapid and inexpensive beach-width and bluff erosion monitoring as well as reconnaissance of geomorphic and seismic structures. Although film generally has higher resolution, video provides more images (30 images/second) and has lower initial acquisition costs than aerial photography. By eliminating film development, prints, and digitization, video is more time and cost efficient.

The resulting low-cost imagery is available for immediate interpretation. Coupled with hand-held photography and ground truthing, it can provide significant flexibility while remaining within the client’s budget. The final product can be tailored for use with vector data and stored as files compatible with most government and private-agency GIS systems.

The video collection system is compact, adaptable, and can be flown on different aircraft and quickly configured for natural-disaster assessment after major storms, tsunamis, earthquakes, floods, and volcanic eruptions.

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REFERENCES


