

# COASTAL GEOGRAPHICAL FEATURES OF LAGUNA GUERRERO NEGRO

ROBERT L. EBERHARDT

*Lockheed-California Company*

Lagoons on the lower western coast of Peninsula de Baja California, Mexico, between 24 to 30 degrees North are allied both geologically and biologically to those found further north in the States of Baja California, Mexico, and California, United States of America. The largest lagoon complex is the Bahia Magdalena series centered on 25 degrees North. Another large lagoon area is that one encompassing Laguna Ojo de Liebre (Scammon Lagoon) at 28 degrees latitude.

The Laguna Ojo de Liebre complex is on the depressed edge of an extremely flat alluvial plain lying between the Sierra de San Borjas of the Peninsular Range to the northeast and the Sierra Vizcaino de San Andreas, a range to the southwest that toes off into the Pacific Ocean at Punta Eugenio. Laguna Guerrero Negro lies near the center of this 200-odd square mile complex composed from north to south of three lagoons. They are Lagunna Manuela (6 square miles), Laguna Guerrero Negro (41 square miles), and Laguna Ojo de Liebre (156 square miles). Each of these opens to the sea by its own separate mouth and a bar is deposited across each entrance. Narrow land bridges separate the three lagoons, each of which is surrounded by extensive tidal flats.

The central axis of pear-shaped Laguna Guerrero Negro dips to the northwest (Figure 1). The north-south length is eight miles and the east-west width is approximately five miles. Wide-shelved and precipitously-walled meanders drain the lagoon. Typically, the deepest channels are immediately at the head of the entrance channel behind the lagoon barrier, which is a large sand island covered by scalloped barchans. There at the entrance depths are from 35 to 40 feet whereas the drainage laterals are 25 to 30 feet deep.

Barchans also lie on the northern and northwesterly shores of the lagoon. In places the lee slopes impinge directly on the channel, and at these points the channel sides slant as much as 40 degrees.

## SALT PROCESSING

The combination of these natural features is such that the lagoon is an excellent site for large-scale salt processing operations. Puerto Venustiano Carranza lies within Laguna Guerrero Negro at 28°02.1'N, 114°08.0' W and was established in 1957 as a company-operated port by Exportadora de Sal, S.A., to handle its salt trade.<sup>1</sup> Deep-draft freighters are accommodated at this port, which is located approximately 325 nautical miles southeast of San Diego, California, and 60 miles due east of Isla Cedros in Bahia Sebastian Vizcaino.

---

<sup>1</sup> U.S. Hydrographic Office, *Sailing Directions for the West Coast of Mexico*, 1951, 9th ed., pp. 8-11, 41-42.

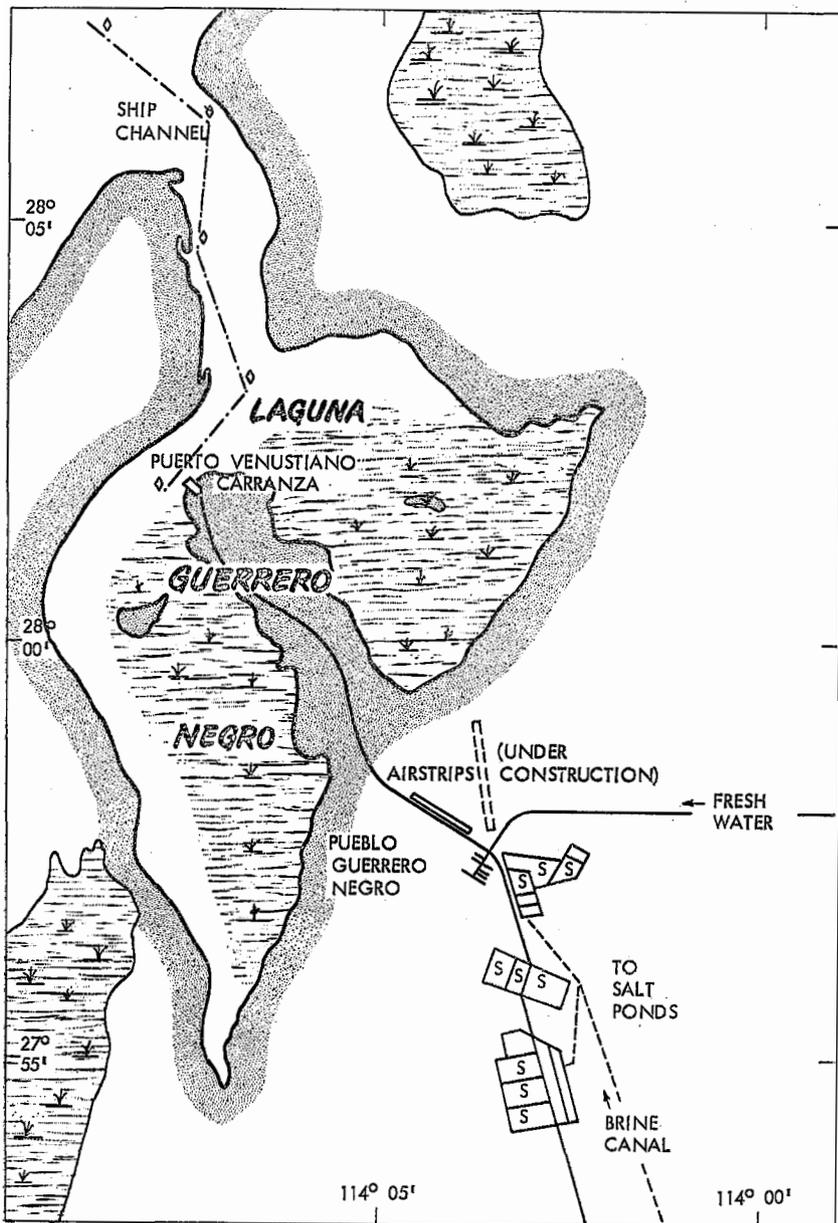


Figure 1. Geographical and cultural features of Laguna Guerrero Negro, Baja California del Sur, Mexico in 1962-64.

Although common salt is among the less spectacular marine products of commerce, there seems to be no end in the demand for this resource. Solar evaporation, the most common process used to obtain salt from the sea, is the basis for salt trade originating at this port. Salt operations were conducted in the immediate vicinity of Laguna Guerrero Negro for the last 80 years in a desultory fashion. However, in 1951, after a survey indicated promise, modern industrial techniques were introduced. By mid-1963 approximately 21 million dollars had been invested in evaporation, bulkloading, and administrative facilities at the port and Pueblo Guerrero Negro, a nearby settlement. This investment has been managed by National Bulk Carriers, New York City, of which Exportadora de Sal is a subsidiary.<sup>2</sup>

The port is reached via a seven-mile channel that is kept open by dredging. Because the channel walls are continually slumping, dredging is virtually a 24-hour task. Natural protection is given the port by the barrier island. Pilotage is required, and since Puerto Venustiano Carranza is a port-of-entry, customs and stores inspections are likewise mandatory. Port captain's duties are discharged informally by the salt company manager. No personnel of the Armada de Mexicana are stationed at the port, consequently the chief federal officer and authorized port captain is an Army officer commanding a garrison of 22 troops at Guerrero Negro.

Controlling depth of the entrance channel is 28 feet. The channel is buoyed for 6.3 miles of its length and is marked by ranges. Two square miles of anchorage lie within a three-mile arc of the headlands. In an emergency at least five times that area could be obtained for fair weather mooring.

To the casual eye at flood tide, all parts of the lagoon appear open to navigation. However, extensive shallow flats appear on the falling tide. Access to the upper reaches can only be obtained via lateral channels formed into a tortuous dendritic pattern. The lower laterals are 150 feet wide and remain well-defined for as much as eight miles from the barrier entrance before they grade into shallow water. However, the southern channel can be ascended only three miles with a vessel drawing six feet, while the northern channel is open for scarcely double that distance.

Configurations of the channels and the adjoining shelves are such that tides flood the lagoon complex with remarkable celerity. The tide rises across the tidal flats almost faster than a man can walk; consequently, vast areas become inundated within a few minutes. By reverse token, ebbs quickly expose the flats. Shallow pools appear in profusion across the flats after low water, but these are never more than a few yards in diameter and only a fraction of a foot deep. After a short time these pools disappear, probably by vertical drainage, and the bare tidal flats seem completely free of any life.

Notwithstanding the formidable appearance of the tidal race, currents are not greater than 2.3 knots. Phleger<sup>3</sup> made a similar observation in

---

<sup>2</sup> Cutting, P. J., Director General, Exportadora de Sal, S. A., personal communication, 1963.

<sup>3</sup> Phleger, Fred B., and Gifford C. Ewing, "Sedimentology and Oceanography of Coastal Lagoons in Baja California, Mexico," *Bulletin of the Geological Society of America*, Vol. 73, 1962, 145-182.

Laguna Ojo de Liebre. Afternoon ebbs carry away water that is perceptibly warmer than floods of an earlier hour. This follows, no doubt, from insolation of the sheets of water lying across the broad shelves of the flats. Horizontal underwater visibility varies during tidal stand from 8 to 11 feet during hours of bright sunshine.<sup>4</sup> When tides are flowing however, suspended debris turns the water murky. Tidal ranges are 3 to 5 feet.<sup>5</sup>

Waters of Laguna Guerrero Negro are known to be isohaline.<sup>6</sup> (There is no route by which salt brine from the industrial beds can drain into the lagoons.) Mid-summer salinities are 35.5 to 37.5 parts per thousand (0/00), while those of the winter are 34.7 to 35.6 (0/00). Presumably, this indicates the influences of increased evaporation and insolation during the summer months. Flood tide salinities, naturally, are more dilute than those of ebbs.

Bottom sediments of the lagoon basin are predominantly minute gray sand particles intermixed with organic silt. There are occasional outcrops of fine-grained fossiliferous sandstone strata. A coquina specimen taken from the southern part of the lagoon proved to be cemented detrital limestone. The cement was calcium carbonate, and detrital components were shell fragments plus pulverized foramens.<sup>7</sup> Occasional cobbles of limestone appear in dredge tailings.

Extensive salt beds surround the head of the lagoon, and in these the overburden is either pure salt or a mixture of salt and wind-blown sand. Levees separate the industrial sites from the natural tidal pans.

#### CLIMATE

Although the lagoon lies in the hot and dry BW climatic zone,<sup>8</sup> the wintertime climate is benign because of the offshore California current and upwelling in Bahia Sebastian Vizcaino.<sup>9</sup> Weather observations recorded in the port captain's log indicate that the mean monthly maximum temperature runs from 68 to 95 degrees F. and the minima from 30 to 48. Wintertime temperatures are in the mid-eighties, but are tempered by a daily afternoon breeze (12-16 knots). January is the usual period for freezing. In the late summer, temperatures regularly pass into the nineties but may go as low as 45 degrees at night.

After the spring equinox, the area is periodically dominated by 20- to 30-knot northwesterly winds in the afternoon.<sup>10</sup> This may last for 8 or 9 days and be followed by 3 to 5 days of gentle breezes. Occasionally warm winds sweep out from the desert. In the fall, pressure gradients over the mainland further curtail any wind, and, accordingly, temperatures remain high.

<sup>4</sup> Evans, William E., and Wheeler North, personal observations, 1963.

<sup>5</sup> U.S. Coast and Geodetic Survey, *Tide Tables, High and Low Water Predictions, 1964, West Coast North and South America Including the Hawaiian Islands*, 1962, pp. 70-73.

<sup>6</sup> Phleger, and Ewing, *loc. cit.*

<sup>7</sup> Inderbitzen, Anton, personal communication, 1963.

<sup>8</sup> Espenshade, Edward B., ed., *Goode's World Atlas*, 11th ed., Chicago, Rand McNally & Company, 1960, pp. 8-9.

<sup>9</sup> U.S. Hydrographic Office, *loc. cit.*

<sup>10</sup> *Ibid.* and Phleger and Ewing, *loc. cit.*

Rainfall is slight. In 1938 and again in 1951 there were two storms that swept the area. From 1961 to 1963 the total rainfall was scarcely above two inches, and this small amount fell between January and March.

Fog is not uncommon along the entrance channel and near the bar in the winter. However, at the same time ten miles inland the sky is open and visibility unlimited.

#### FLORA AND FAUNA

Vegetation of the dryland fringes of the lagoon is dominated by salt bush (*Suaeda californica*) and pickleweed (*Salicornia virginica*). Marsh grass (*Spartina foliosa*) is the principal species of the exposed tidal flats. Eel grass (*Zostera marina*) grows at the extreme edge of the tide lines and will be found along the margins of the lateral channels down to a depth of twenty feet. *Salicornia* blends into heavy stands of marsh grass (*Batis*) in the direction of the salt marshes, but toward dry land it phases into *Suaeda*. Samples of foramenifera taken from the beach sands contained abundant concentrations of *Elphidium gunteri* and *Quinqueloculina laevigata*. All of these samples contained small amounts of *Rotorbinella versi*, *Q. lamarckiana*, *Q. limbata*, and *Q. costata*.

The most abundant copepod in the winter appears to be *Acartina tonsa*. Also present with incidental frequency are *A. lilljeborgii*, *Paracalanus*, and *Pseudodiaptomus* spp. The indicator species of the marshes are the fiddler crab (*Uca crenulata*) and the horn snail (*Cerithiidae californica*). On the flats one will often find bubble shells (*Bulla gouldians*), starfish, and, if one digs, an abundance of clams and sweet potatoes (*Molpadia arenicola*). Common fishes of the channels are guitarfish (*Rhinobatos productus*), mullet (*Mugil*), and species of bass (*Paralabrax* spp). Ducks and shorebirds, especially whimbrels (*Numenius phaeopus*) and curlews (*N. americanus*), are present in the winter by the tens of thousands. Bottlenose dolphin (*Tursiops gilli*) and calving gray whales (*Eschrichtius gibbosus*) occasionally enter the lagoon.

Among the latent resources of the lagoon complex are those that are based on the harvest or observation of wildlife. One can see multitudes of sea ducks and other edible waterfowl, since these lagoons lie within the Pacific flyway. Fishing, certainly a likely source of recreation, may also serve as a base for a limited commercial fishery. Green turtles were seen infrequently. These are used elsewhere on that coast for food, and fishermen from Isla Cedros enter the lagoon to take them for market.

For the moment, however, salt processing is the sole industry. The belt conveyor structure on the salt wharf and a gleaming white hill of salt nearby dominate the flat landscape from miles around. A stream of 70-ton tractor-trailer units continually replenishes the 45-foot high stockpile. A two-hundred foot long concrete and sheet piling-faced dock lies under an adjustable bulk loader, which can be elevated from 30 to 50 feet above the wharf.

In 1962, the total export was slightly over 2 million tons of industrial grade sodium chloride. During that year 97 vessels flying the flags of Japan, Greece, Canada, and the United States called and carried away

2,202,346 tons of salt. Japanese markets took 700,000 tons, the Pacific American 400,000 and various European ports the remainder of the total.

Salt is obtained by progressive solar evaporation of impounded waters drawn from Laguna Ojo de Liebre. As the salinity of these waters increases, the bittern is transferred by pumps to settling beds. From there the bittern is drawn off at a rather low density for final processing. As a result, nearly pure sodium chloride is obtained. Laboratory samples of recently harvested salt were noted to be above 99.8% purity. Salt so processed is trucked directly to dockside loading facilities.

Included in the harbor facilities are a heavy-duty harbor tug used for docking, a small harbor tug, and two survey boats. Two crawler cranes service the wharf. There are limited fuel and water supplies.

### COMMUNITIES

Pueblo Guerrero Negro is located approximately five miles inland from Puerto Venustiano Carranza. It is a "company town" with 125 houses laid out on a grid pattern. There are one dozen concrete-block houses occupied by supervisory employees. There are also 60 double-unit frame dwellings and 30 Quonset buildings likewise divided in half. In addition to these types, another two dozen structures in varying grades of excellence serve town folk who are not directly employed by the salt company. The population of this settlement is approximately 500 people.

Fresh food supplies are available in local grocery stores and from itinerant farmers. Water is drawn from wells five miles to the eastward and piped to homes after chlorination. Electricity is supplied by three 110 volt 100 kilowatt generators. Communications within a 25-mile radius are furnished over a short-wave radio band used by all company units.

There is a church, a hospital, a library that adjoins a large social hall, two military buildings, and a school. The small central business district includes a department store, restaurant, barber shop, and two groceries identified by garish signs and advertisements. Goods offered include beverages and toiletries as well as canned goods under familiar American brand names but from Mexican manufacturers. At least one-quarter of the town area is taken up by a vehicle maintenance yard and fenced storage compound. Adjoining this area is the company office and administration building. The streets are unpaved but are graded and kept in repair.

A 6,000-foot airstrip with a 40 x 40-ft. hangar is next to the town. Company-operated aircraft, one a two-engined transport and the other a light monoplane, use this field regularly. Bi-weekly non-scheduled commercial flight connections with the rest of the peninsula can be made in advance. A secondary 3,000-foot dirt-surfaced airstrip nearby is no longer in regular use.

The nearest settlement is a village of seven frame buildings approximately three miles away at the northeast corner of the lagoon. One of the principal occupations of those who live there is fishing. This hamlet is not under control of the salt company.

A 50-mile road net surrounding the salt ponds culminates at the salt loading area. The roadway is kept in excellent condition for the use of rapidly shuttling truck and trailer rigs. A full stock of graders, bulldozers, and utility trucks used in loading and hauling is in the best of operating condition. A few private automobiles were seen.

Exportadora de Sal spends large sums each year to maintain an efficient, large-scale salt processing facility. The enterprise is well-run and shows an air of flourishing progress. A company-sponsored program of civic development and public building is enhancing the well-being of Pueblo Guerrero Negro's population. However, one natural condition overshadows whatever commercial development may transpire. Here the reference is to the recurrent silting of the ship channel. Heavy discharge of sand with each ebb tide as well as continual slumping of the channel walls combine to make dredging a formidable but essential task. When the last of these field observations was made (early in 1964) two schemes were being considered to alleviate this confrontation with nature. One was to re-orient the overland truck route northwestward to an anchorage in Laguna Manuel that would not be exposed to tidal discharge. The other was to build an entirely new port within the barrier island directly to the westward of the present port. This new port, likewise, would not be subjected to tidal silting.

As it stands today, Laguna Guerrero Negro has become the site of the largest salt producing facility along the eastern Pacific coast. Processors at San Francisco and San Diego have responded to this challenge by increasing their production. The future of Puerto Venustiano Carranza is now limited by coastal oceanographic factors which cannot be controlled economically through current engineering techniques. Consequently, it appears that the configurations of the present port and lagoon will be changed to allow further industrial development.