SECTION II

MODIFICATIONS TO THE LNG EXPORT PROJECT DESIGN

CONTENT

FIGURES

1.0 INTRODUCTION

This Section describes the improvements and modifications that were introduced to the LNG Export Project Plant and explains the reasons for these changes. These improvements and modifications include changes in the equipment, relocation of equipment and structures as well as the introduction of new elements to the project.

The plant was originally described in Chapter II of the EIA prepared in 2002 and 2003 and approved in June 2004. All improvements and modifications proposed to the plant design are contained within the same area of influence as the original project, described in the EIA approved in June 2004. Current modifications to the project include generally changes to the plant access, liquefaction area, marine facilities, basic services and personnel accommodations area. **Figure 2.1**, shows the Original General Site Plan included in the approved EIA, and the main modifications introduced to the design marked in red circles. The following sections provide a description of these proposed modifications.

Along the Panamerican highway the construction of two acceleration and deceleration lanes and two underpasses are proposed; one for the main access to the plant on the south side and another on the north side for the quarry rock hauling. The crossing of two gas pipelines is also anticipated. The access road to the beach was relocated to the north side of the project to facilitate rock hauling that will be used for construction of the rock load-out jetty and the breakwater.

The capacity of the LNG tanks has been increased in the liquefaction plant. Also, the secondary containment sump for spills has been relocated farther from the cliff. Finally, the containment trench, the internal division berm, internal tank pumps and piping locations have been modified.

The number of flare tips has been increased thus obtaining a more efficient combustion system for reducing emissions. This will be obtained through the installation of a combustion system in a horizontal pit rather than vertical stacks. The BOG compressor and BOG flare of the load pipe return system was relocated to a higher position according to the new NFPA 59A thermal spacing requirements. The refrigerant storage equipment was relocated for greater protection of the liquid products inventory with this equipment now located further from critical equipment. These changes improve the safety and reliability of the plant.

With regard to the marine facilities, the construction of a rock load-out jetty is proposed. This jetty will be used for the breakwater construction with rocks hauled from a quarry located 20 Km east of the Panamerican highway. The trestle was reinforced and widened at the surface to allow rock haulage. Also, the trestle design has been modified so that angled piles are not used at every bend creating a smaller seafloor footprint than the original design. Additionally, equipment was relocated on the service dock, and the dredged navigational channel turning ratio has been increased to facilitate ship maneuvers.

Regarding basic services, the workers' permanent housing area was relocated further from the cliffs, power generators were changed to more efficient models, and the electrical substation was divided into two separate units. The waste management area was relocated with an incinerator, effluent treatment system and CPI oil separator included in the design. In the fuel storage area, a gasoline tank was added while the diesel tank and service station were relocated.

The modifications to the plant design are explained in the following sections and are classified in three main groups: 1) changes or modifications to equipment, 2) relocation of structures and equipment and 3) new components.

Figure 2. 1 Original Overall Plot Plan

2.0 CHANGES OF EQUIPMENT OR CAPACITY MODIFICATIONS

2.1 Modifications to LNG Tank Capacity and Tank Area

The capacity of each LNG storage tank has been increased to 130,000 m^3. Also, the secondary containment sump for spill management was relocated closer to the tanks to reduce trench vaporization. The storage capacity of each tank was originally defined as 110,000 m^3, as mentioned in Chapter II, Section 2.1.6 of the EIA. This increase in tank capacity will allow LNG ships to depart from the Peru LNG terminal with one load and distribute this load in a single trip to different re-gasification terminals and return to the LNG departure terminal without affecting the plant production. This increase in tank storage capacity does not involve any change in the designed LNG plant production capacity as described in Chapter II, Section 1.1.1 of the EIA.

The separation distance between the LNG storage tanks will be modified according to NFPA 59A regulations, which specifies the separation distance required to limit accidental thermal radiation for double and full containment tanks. Although the tanks designed for PLNG are single containment and would not need to comply with this proposed change, Peru LNG (PLNG) has chosen to follow this proposed change as the spacing basis for their tanks in the new design. This modification in the tank spacing also implied reviewing the calculation of the thermal radiation distance that separates the main containment sump from the LNG storage tanks.

With the reduction of the spacing between the tanks and the secondary containment sump based on thermal radiation modeling from in-tank or sump combustion as per NFPA 59A (for 130,000 m3 tank capacity), the actual design distance between the tanks and the sump shall be 105 m. This distance will allow installing this sump in a more stable area, further from the sea cliff.

The LNG containment pond was re-modeled to consider a fire event and the relocation and size change of the containment pond. This scenario assumes that the full contents of one LNG tank are drained into the pond and subsequently catches fire. The “front view” distance (distance from tanks to centerline of the pond) corresponding to 15 kw/m² and the heat flux is 216 m. This will be the new distance from the sump to the tanks, (see Sketch 1, Thermal Radiation Report, Appendix A). Also, this distance is reflected on the general plot plans and equipment spacing plans.

Another scenario assumes a roof collapse and subsequent fire inside the inner tank. The predicted distance for 15 kw/m² is 176 meters, the distance used as the new spacing between the tanks. Although not required by NFPA 59A, critical equipment was located at the outside of the 15 kw/m² circle. The equipment relocated includes the principal cryogenic heat exchanger (MCHE), the flare drums, Local Control Room 04 and electrical substation SS3400. The new locations for this equipment is shown on **Figure 2.2** and the equipment spacing is shown in **Figure 2.3** (see also Sketch 2, Appendix A).

In-tank pumps and piping were relocated to the east of the tanks for safer personnel access. The new design also details the spill containment trenches, located around the tanks, connected to the secondary containment sump and modified to reflect each tank capacity change.

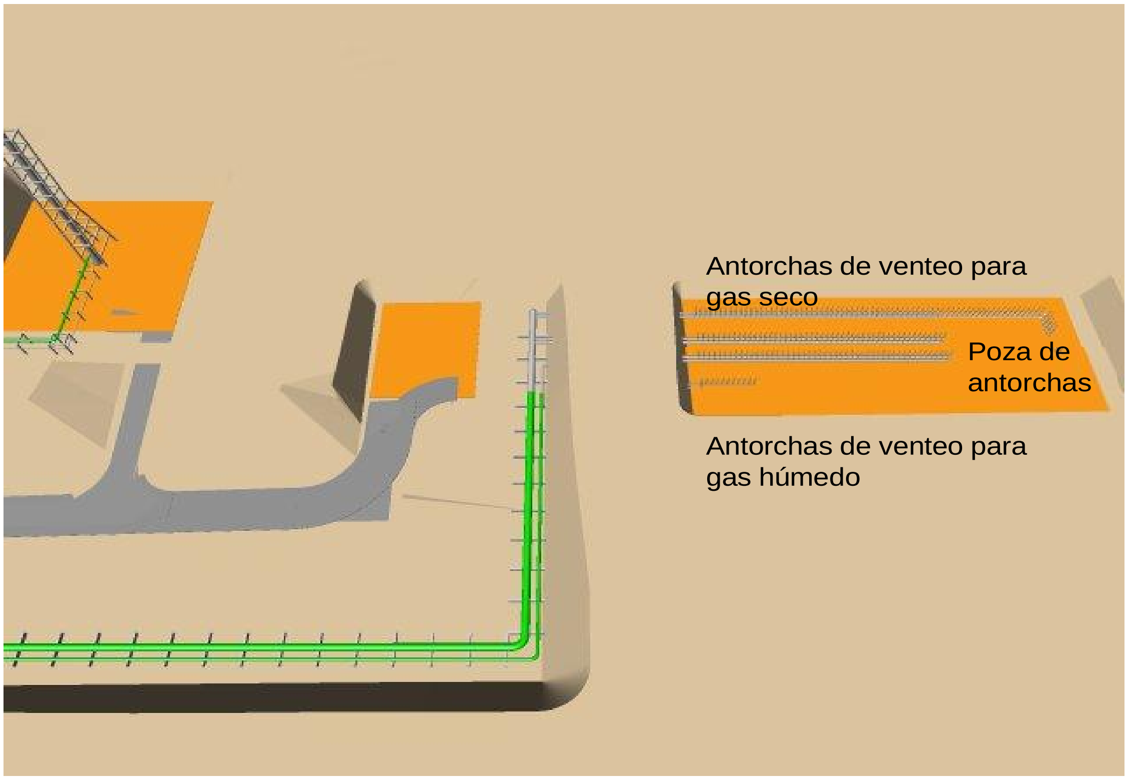
Figure 2. 2 Updated Overall Plot Plan

Figure 2. 3 Overall Plan of Equipment Spacing

2.2 Changes in the wet and dry gas flare system

The original wet and dry gas flare system designed for the plant consisted of a two-stage vertical ground flare. The new design now has a horizontal system parallel to the ground surface and contained in a flare pit, producing less emission and lower thermal radiation. The previous design consisted of two wet and dry gas flares installed on a common tower (see Chapter II, Section 2.3.8 of the EIA). The current design proposes the installation of a series of small flare tips in a pit to reduce the effect of thermal radiation (see **Figure 2.4**). At the same time, the combustion using small flare tips is more efficient than using a single large flare, generating less atmospheric emissions.

Figure 2. 4 Wet and Dry Gas Flares



Description of the INDAIR Flare Tips

The Multi-Point INDAIR flare tip design consists of small diameter flare tips mounted on a common flare stack. Each flare tip on the main system (4” to 12” tulip diameter) is fabricated as solid castings. The entire tulip assembly is a thick, solid stainless steel casting. This is in contrast to other large tulip assemblies that require welding of a rolled plate tulip cone to the forged tulip bowl assembly.

The INDAIR flare was developed to provide a safe and reliable high efficiency flare tip which produces smokeless, low radiation flare without the assistance of external media such as forced air or pressured steam. This is a pressure-assisted flare design which utilizes the internal energy within high-pressure gas streams to produce a highly aerated, turbulent flame.

As described in Appendix B ‘Description of the Gas Flares’, the flares utilize the “Coanda Effect”, to entrain and mix air into the hydrocarbon gas stream. The pre-mix air/gas mixture creates very efficient, 100% smokeless combustion of the flare gases. The flame produced by this efficient combustion is a very low radiation, low luminance flame. The flame length is less than half that produced by a conventional flare. The flame is also a thin, stiff, pencil shape that is not easily distorted by crosswinds.

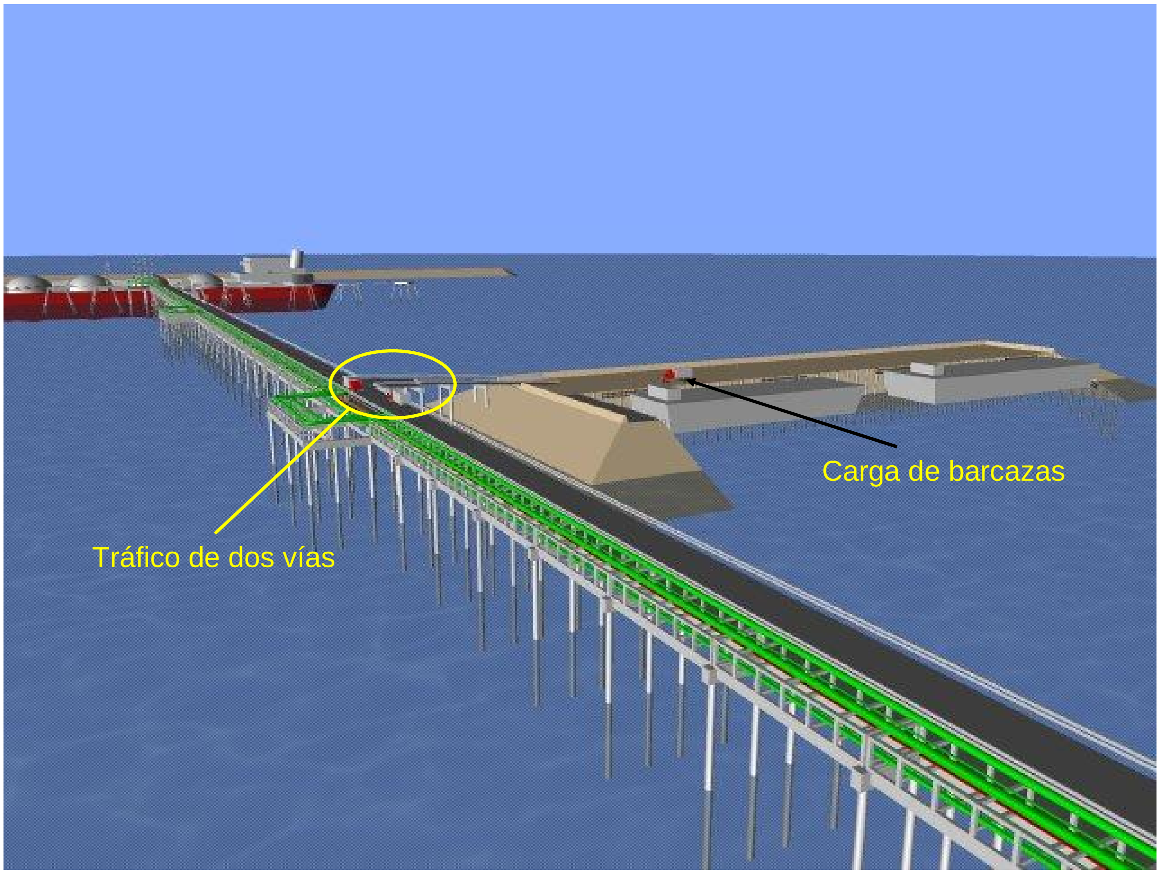
Flame initiation always takes place near the maximum diameter of the tulip, ensuring reliable ignition of the gas by external pilots, even on sudden venting and under high wind conditions. Smokeless, low radiation combustion is achieved without the need for ancillaries such as steam, compressed air or fuel gas.

To review more detail on these flares, see Appendix B ‘Description of the Gas Flares’.

2.3 Modifications to the Trestle

A shared marine trestle has been designed for simultaneous use in rock hauling and pile support (see **Figure 2.5**). The original design considered the construction of a narrower trestle supporting less weight (See Sections 2.2.1 and 3.1.4., Chapter II of the EIA). The new design considers the additional weight associated with rock haulage for the breakwater construction.

Figure 2. 5 Modifications to the Trestle



The trestle has been reinforced from the shore to its end point 800 m from the coastline and its width has been increased by 2.50 m to allow 30-ton haul trucks to travel in both directions simultaneously with access to the rock load-out jetty.

Although the number of piles supporting the trestle has not changed, the new design considers 3 vertical piles (compared to 2 vertical plus 1 battered pile in the former design). The trestle surface in the new design is concrete rather than steel providing a longer service life and requiring less long-term maintenance against corrosion. In the current design the contractor has the option of installing walkways and handrails made of fiberglass instead of steel for the same reason.

Also, in the current design a trolley system has been added to the lower part of the trestle to facilitate maintenance and inspections. The LNG Loading Head is now designed to be mounted on a pedestal to allow for pipe installation.

The seawater intake structure has been located further from the surf zone allowing for cleaner seawater intake and a safer operation farther from the surf zone (See references in Section 2.3.10.1, Chapter II of the EIA).

The abutment elevation of the trestle has been raised to +20 m, from the original design level of +7 m. The level at the Loading dock area of +8 m has not been changed (this allows more flexibility of the trestle system during a tsunami or earthquake using a "constant" pile length). Geotextile mesh will be used to protect the abutment against erosion and undercutting and rock bulkhead will be placed on the sides of the abutment for protection against Tsunami currents.

The access road to the trestle has been moved to the trestle's north side to intersect with the beach access road which now also enters from the north. The piping and expansion joints have been moved to the south.

2.4 Utility Dock

The utility dock and the tug service area have been moved to the north side of the trestle. The control room, substation and transformers are now located on the utility dock.

The surge tank has been removed. Pipes and fittings have been upgraded with a system that allows for containment of surge conditions eliminating the need for this tank. Also, the level located "below the deck" has been removed.

The size of the loading dock deck has been reduced and the equipment is now located on the service dock. Concrete has been added to the jacketed sections from -2m to +3m to provide protection against freezing in the event of a LNG spill.

2.5 Changes in the Power Generation

More fuel efficient GE LM2500+ gas turbines will be used to generate electric power which will replace the former GE MS5001 gas turbines (see Section 2.3.1.1, Chapter II of the EIA).

The new generators provide 3.6 Megawatts more electric power per turbine and therefore, use less fuel. The maximum exhaust flow of the GE LN2500+ is 192 lb/sec at 960oF (see Table 3.5, Section III of this document), which is less than the gas exhaust from the MS5001 turbine which is 273.7

lb/sec at 909 oF. The GE LM2500+ was designed as a more powerful version of its predecessor with lower life-cycle costs. GE Engineers increased the airflow of the turbine compressors by 23% with a minimum increase of the combustion chamber firing temperature (35 degrees °C, approximately). This increased the turbine power while maintaining reliability and availability.

GE LM2500+ speed is 3,600 revolutions which provides 39,000 brake horsepower with a single-cycle thermal efficiency of 39 percent.

2.6 Dredged Navigational Channel

The dredged navigation channel configuration has been adjusted based on ship maneuvering simulations. A single approach line with one turn to the berth has been designed rather than a continuous curve to improve the berth reliability and safety.

The dredged navigational channel was described in Section 2.2.3, Chapter II of the EIA. The modified channel introduces a larger turning radius to facilitate ships maneuvers during their approach and exit behind the breakwater (see **Figure 2.6**). An additional sediment volume of 200,000 m^3 will be dredged which, added to the initial volume of 3 millions m^3, creates a total of 3.2 million m3, representing an increase of 7% in the volume of material to be dredged. The additional dredging material will be placed in the same disposal site considered in Appendix 6 of Volume II of the EIA and in responses 104, 142 and 172 to the EIA Observations. This additional dredging material will be disposed within the boundaries of the disposal site considered in the EIA.

Figure 2. 6 Navigational Channel

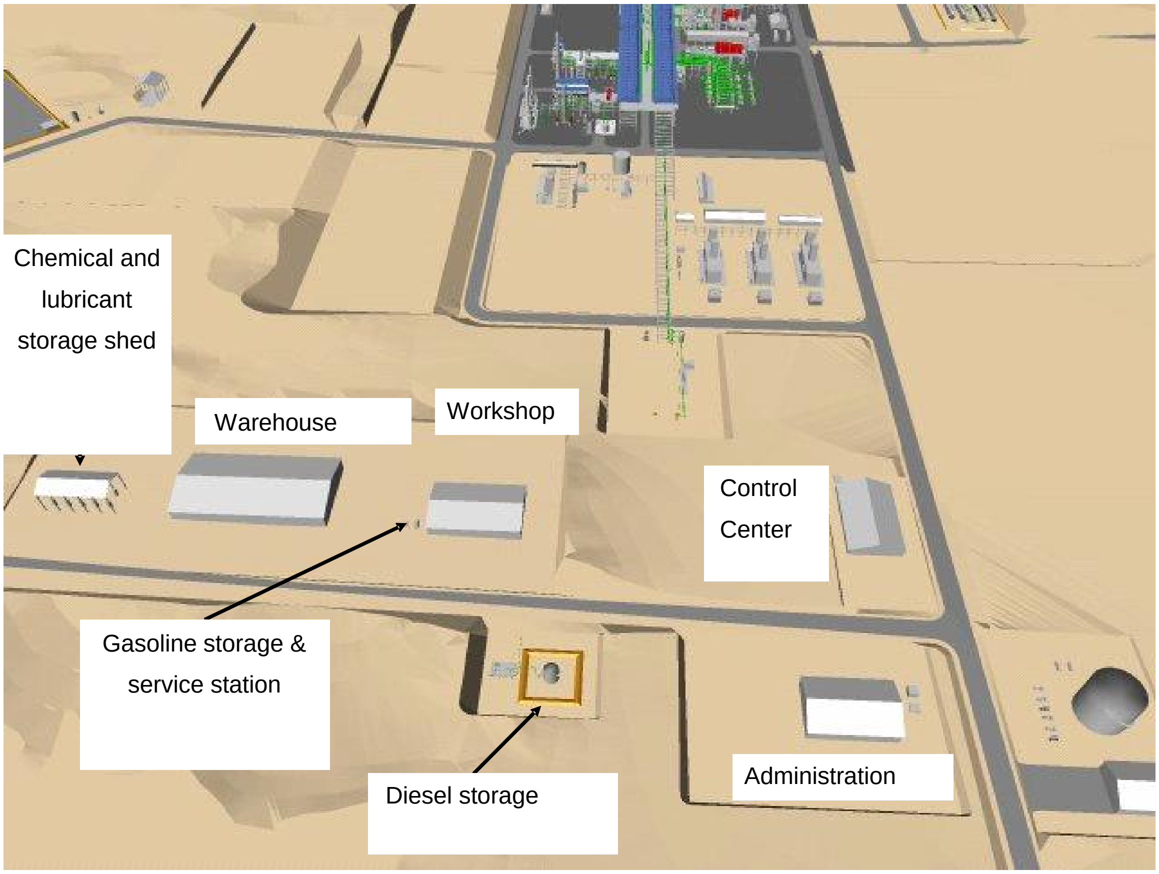
3.0 RELOCATION OF STRUCTURES AND EQUIPMENT

3.1 Diesel and Gasoline Storage and Fueling

The diesel fueling area was moved from the plant area (see Section 2.3.4 Chapter II) to the administration building for safety reasons (see **Figure 2.7**). This new location will allow safer diesel fueling operations to tank trucks located outside the plant area. The size of the diesel storage tank has not been changed.

The vehicle and plant services station will be located near the Maintenance Shop. PLNG will provide a gasoline and diesel reception, storage and fueling service for motor vehicles.

Figure 2. 7 Diesel and Gasoline Storage



The on-site gasoline fueling system for light vehicles and trucks will have a horizontal storage tank with 8m^3 or 2,100 US gallons capacity located above ground in a containment dike.

The gasoline storage tank will be a horizontal atmospheric drum mounted on supports and placed within a containment area with a holding capacity of 110% the tank volume. The drum inlet will be through a vertical pipe with end perforations and there will be a level gage and transmitter to prevent overfilling. The tank will have a vent pipe for gasoline vapors exhaust to the atmosphere at a safe location and will have a pressure control device.

Gasoline will be transported to the plant by tanker trucks where it will be transferred to the storage tank using the tanker truck pump. The fueling to vehicles will be performed through a compact metering pump composed of a hose and a self-closing manual nozzle.

3.2 Waste Management Area

The sewage treatment system, incinerator, effluent treatment process, CPI separator and solid waste storage area have all been designed according to the requirements of the EIA (see Section 2.3.11.1 and Section 3.6.2, Chapter II of the EIA).

The Waste Management Area is located in a central location for more efficient waste management control. (see Figure 2.2, General Plant Plan).

3.3 Process Fluid Storage

The activated Methyldiethanolamine (aMDEA) storage tank has been located adjacent to the Oil (Therminol 55) Storage Tank at the periphery of the process area so that supply trucks do not need to enter this area. Section 2.3.3.5, Chapter II of the EIA describes these process fluids. In the former design the aMDEA tank was located on the south side of the process area.

3.4 Relocation of Hot Section Equipment

In the current design the separation distance between the equipment is greater to reduce the insulating piping requirements used for gas regeneration and for hot oil systems. A description of this equipment is provided in Section 2.3.3.6, Chapter II of the EIA.

Equipment spacing was determined by considering the greatest distance established by NFPA 59A standards and the Peruvian design standards.

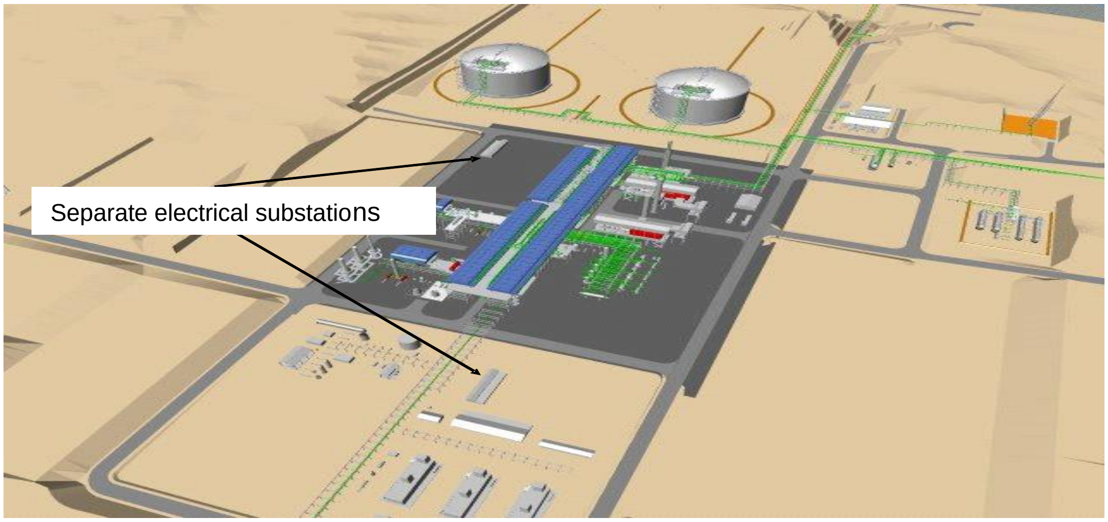
3.5 Refrigerant Storage

Containers of liquid refrigerant such as scrubbers, vaporizers and propane accumulators were relocated on the opposite side of the refrigerant compressors. They will be pedestal mounted between the main cryogenic heat exchanger and the LNG storage tanks for greater protection. A description of this equipment is provided in Section 2.1.5, Chapter 2 of the EIA.

3.6 Division of the Electric Substation

The Plant electrical substation was divided in two to reduce the electric wiring requirements and to use underground wiring for greater protection and safety (see **Figure 2.8**). Both substations are located far away from the equipment containing hydrocarbons.

Figure 2. 8 Division of the Electric Substation



3.7 Relocation of Boil-Off Gas Flare and Compressors

The BOG Compressor was relocated closer to the LNG tanks but at a higher elevation to reduce back pressure and provide greater safety.

The BOG Gas Flare was relocated to a higher elevation with the stack height increased from 20 to 30 meters to prevent an accidental fire resulting from an LNG release.

3.8 Permanent Housing

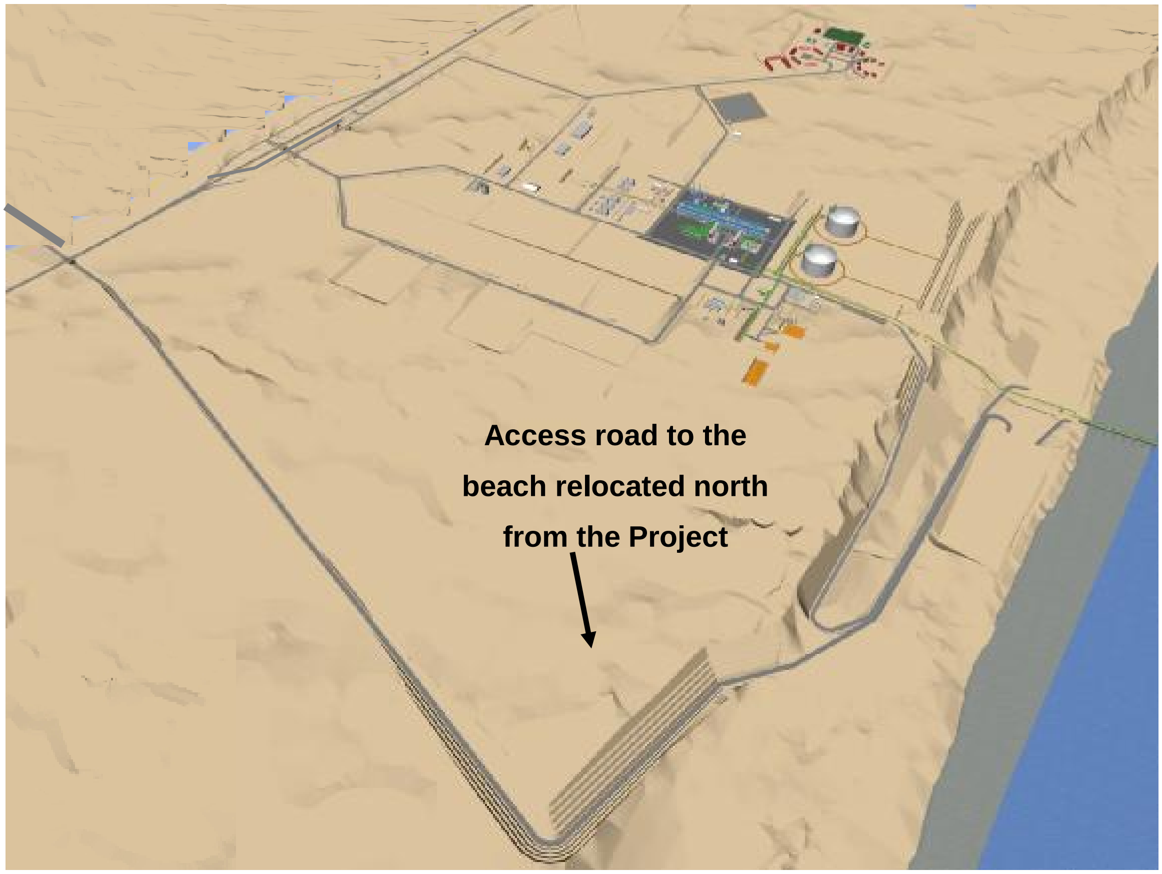
The permanent housing area for plant workers was relocated further from the cliffs to provide better protection and safety to personnel. The houses are now located further east, away from the cliffs, on more stable ground to prevent damage to personnel and property from landslides or during a seismic or any other event. A description of this area is provided in Section 2.4, Chapter 2 of the EIA.

An additional area was included for lodging temporary maintenance workers during operations.

3.9 Access Road to the Beach

The access road to the beach was relocated along the northern property boundary and descends along the cliff to provide access to the work areas during plant construction and operations. (See **Figure 2.9**)

Figure 2. 9 Access Road to the Beach



4.0 NEW COMPONENTS

4.1 Acceleration and Deceleration Lanes and Underpasses

The proposed Plant access road includes the construction of two underpasses with parallel acceleration and deceleration lanes (see **Figures 2.10** and **2.11**). The underpasses will be used for: 1) allowing the entrance of vehicles from the Panamerican South Highway to the PLNG facilities, and 2) to facilitate the crossing of trucks hauling rock to be used during the plant's construction. The original access to the plant was through a direct detour road from the Panamerican highway. The use of underpasses will allow safe crossing without stopping traffic flow or reducing visibility.

Figure 2. 10 Underpasses and Access Road

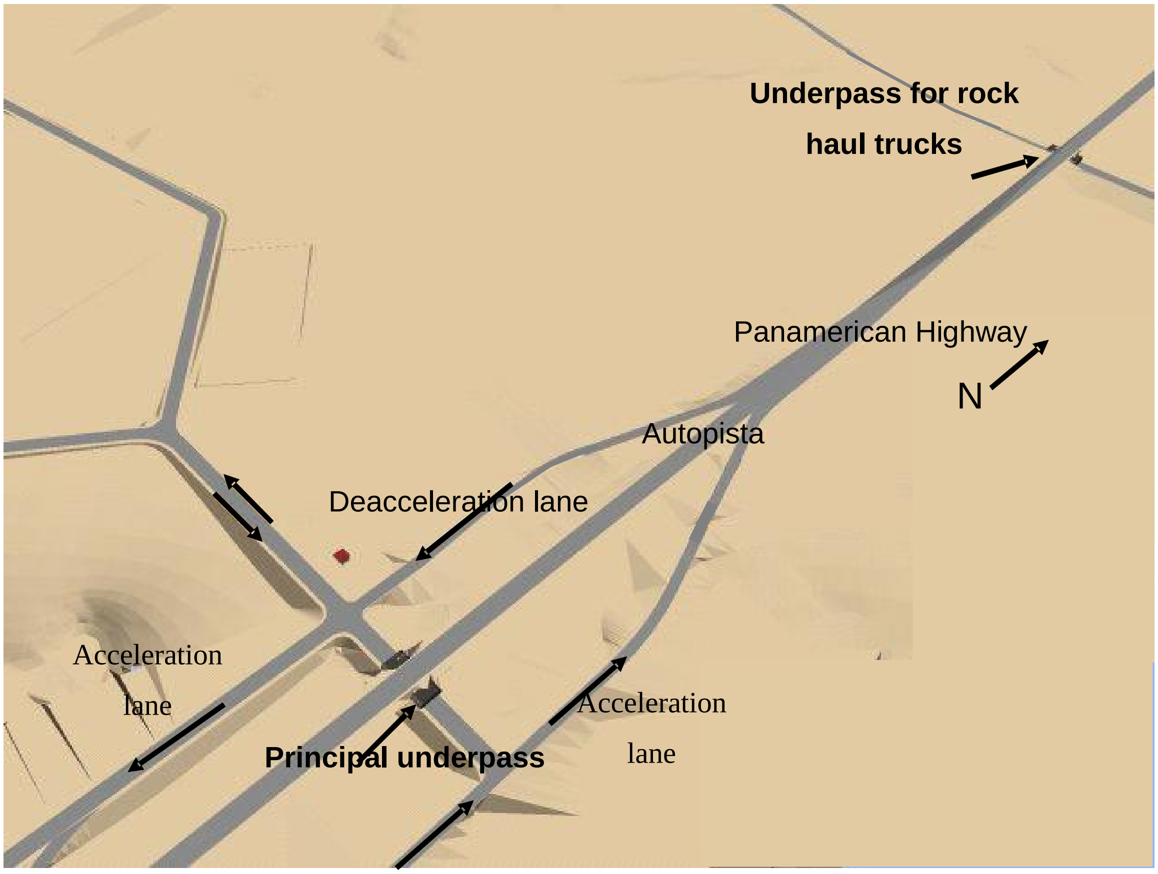


Figure 2. 11 Plant Plot Plan and Cross Section View of the Underpasses

Acceleration and Deceleration Lanes

The new lanes will provide proper distance for safe vehicle acceleration and deceleration both in regular or unusual highway traffic. The sections for acceleration and deceleration will be 300 m and 120 long, respectively. The width of the lanes will be 11.50 m and the distance between axes to the Panamerican highway will be 35 m.

Underpasses

Both intersections cross below the Panamerican highway as previously described and will be constructed with high profile arc-type steel structures.

The clear span for vehicular traffic according to Peruvian standards DG-2001, indicate that the minimum dimension recommended is 5,50 m for rural and urban main roads and 5,00 m for other roads.

The underpass geometric section was designed according to the same design parameters considered in the engineering and environmental study prepared for the underpass located in Cerro Azul at Km 28+000-37+160 of the Cerro Azul - Ica highway (Geometric Design Standards DG-2001) belonging to Red Vial Nº 6. The project speed (Vp) considered in that study is 120 km / hr.

The steel super-span structure to be used will be a high profile arc of 10,78 m x 4,96 m height on the base. This structure is composed of iron curved plates with bolted joints that provide high resistance and rigidity.

Traffic for Rock Haulage Underpass

The typical vehicles using the rock haulage underpass will be 22-tons dump trucks, 45-tons semi-trailers with flatbeds, 9000-gal tanker trucks and CAT 12-H graders.

A total of 20 to 40 trucks will be used daily for rock haulage with a frequency of 2 to 6 daily cycles (depending on the material to be transported), for which 40 to 240 trips per day will be required.

Installation of Fuel Gas Pipeline and Main Gas Pipeline

Two gas pipelines, or their casings, will be installed across the Panamerican highway: one main gas pipeline and the other a temporary line to be used during construction of the plant. The approximate crossing point on the Panamerican highway is at coordinates 360243.70 east and 8536194.68 north, as shown in Figure 2.11.

The two pipelines or their casings will be installed across the Panamerican highway using the open cut method during construction of the two underpasses so as not to cause any additional inconvenience to vehicular traffic on the highway. It is anticipated that the main gas pipeline will have a diameter of 32” to 34” at the crossing point however this is subject to the final hydraulic calculations. The temporary fuel gas pipeline will be 8” to 10”, depending on the final fuel requirements for the plant construction phase. Should the pipelines not be installed during construction of the underpasses, their respective casings with the proper diameter will be installed.

The final decision regarding installation of the pipelines or their casings will depend on final determination of the pipeline diameters. As a minimum, the corresponding casings will be installed with the proper diameters to accommodate final pipeline installation without affecting vehicle flow along the highway.

A separate EIA which includes the pipeline installation is being prepared and will be submitted to the authorities on the proper time.

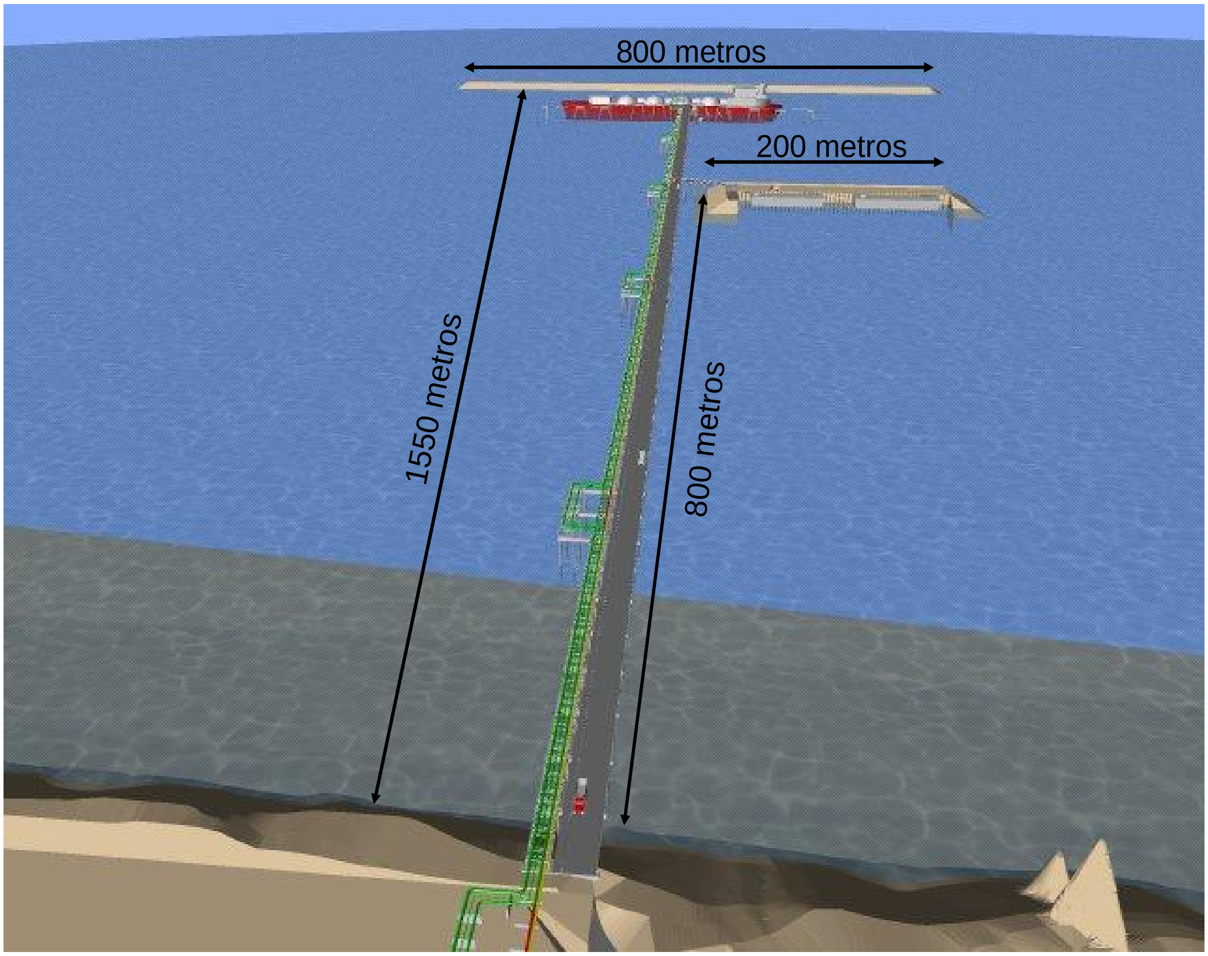
4.2 Rock Load-out Jetty

The new design of the marine facilities includes the construction of a rock load-out jetty. This jetty will be used by trucks as a platform for unloading rocks to be transported by barge to the site of the breakwater construction located 1,550 m from the coastline (see Section 2.2.2, Chapter 2 of the EIA). This jetty will also be used as a service area and berth for small vessels and ships.

The rock load-out jetty will be located immediately north of the trestle and 800 m from the coastline. This jetty will be sheltered by the breakwater and will be less exposed to waves and marine currents. The rock hauling trucks will have access to the jetty through a trestle that will be used as a connection between both structures.

The rock load-out jetty will be 200 meters long and 8.00 meters above sea level (See **Figure 2.12**), and will be placed along the 10m depth contour of the seafloor with a similar structure to that of the breakwater.

Figure 2. 12 Location of the Rock Load-out Jetty



Approximately 600,000 m3 of rock will be required for constructing the jetty, which in conjunction with the 2.6 millions m3 considered in the EIA for construction of the breakwater, implies an increment in the rock volume of 23% compared to that identified in the original design**. Figure 2.13** shows the plot view, and **Figure 2.14** shows the cross sectional view of the jetty.

Figure 2. 13 Plant Plot of the Rock-Load out Jetty

Figure 2. 14 Cross Section View of the Rock Load-out Jetty

Analysis of Alternatives for the Rock-Load out Jetty

PLNG has analyzed the alternatives to determine the best option from environmental, social and engineering perspectives for hauling rocks to the site where the breakwater will be constructed.

At first, different quarry options were considered, along with the option of transporting rocks to the site by sea from Port San Martín (see EIA 2002-2003 Chapter IV, Section 4.3.1). However, these options would require rock hauling along the Panamerican South highway increasing safety risks. In addition, there were environmental and social concerns associated with crossing the Paracas National Reserve by truck to get to the port. Under these alternatives, rock would be transported from Port San Martín to the project site by ships that would possibly cross maritime traffic lanes and run close to sensitive natural habitats. These were strong reasons for looking at other alternatives for the quarry site and rock haulage methods. Finally, after technical, environmental and social assessments the rock quarry (GNL) located 20 Km east from the project was chosen.

It was initially planned to construct a rock load-out jetty in different locations south of the project area, where trucks arriving from the quarry would have access to the rock loading zone. These two alternatives were analyzed according to the conceptual engineering design as is shown below:

1. *<u>Perpendicular Solid Jetty Connected to the Beach</u>*

This construction was considered as a temporary structure. The company Sandwell conducted a modeling exercise to assess the effect of the structure on marine sediment transport considering the currents and the wave energy by applying the GENESIS model used by the US Corps of Engineers

The modeling exercise showed erosion effects on the north side of the beach and sand accumulation on the north side of the breakwater due to the wave action to the north. Also, this model predicts that the accumulation of fine sands sheltered by the breakwater will be in a sheltered area parallel to the beach, where big waves will not reach.

Figures 2.15 and **2.16** show the prediction of the beach morphology: one year and three years after construction of the breakwater.

Figure 2. 15 Result of the dock modeling one year after construction

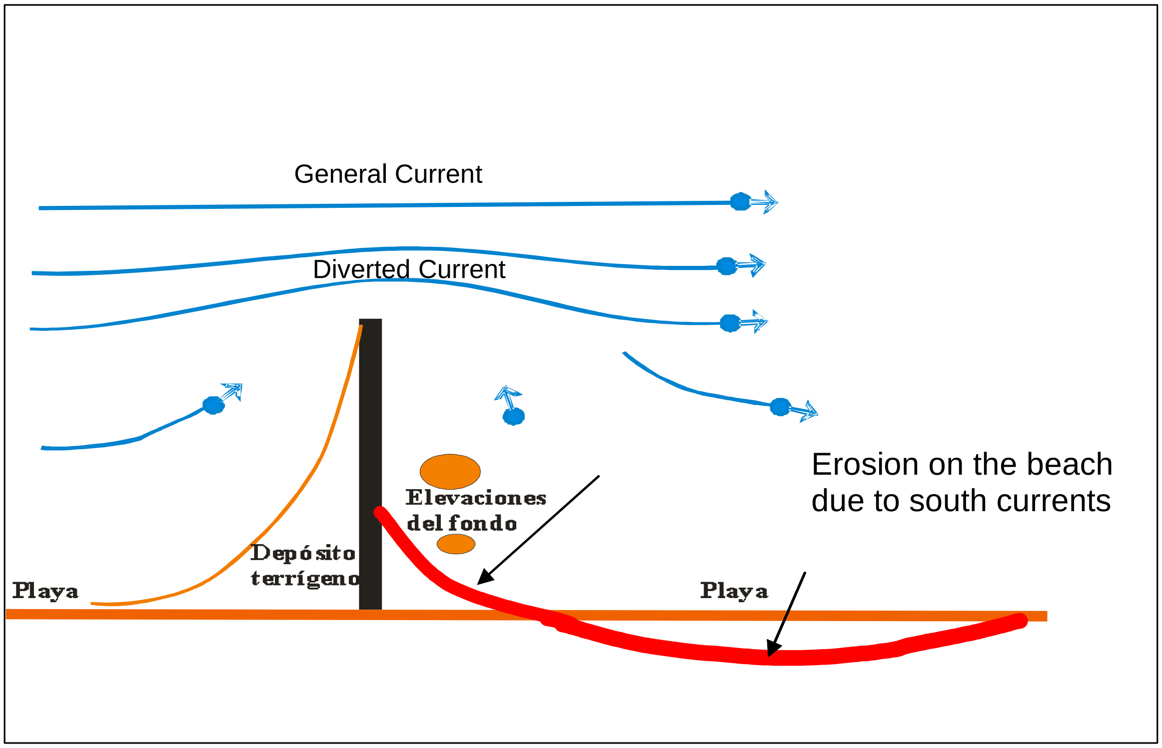
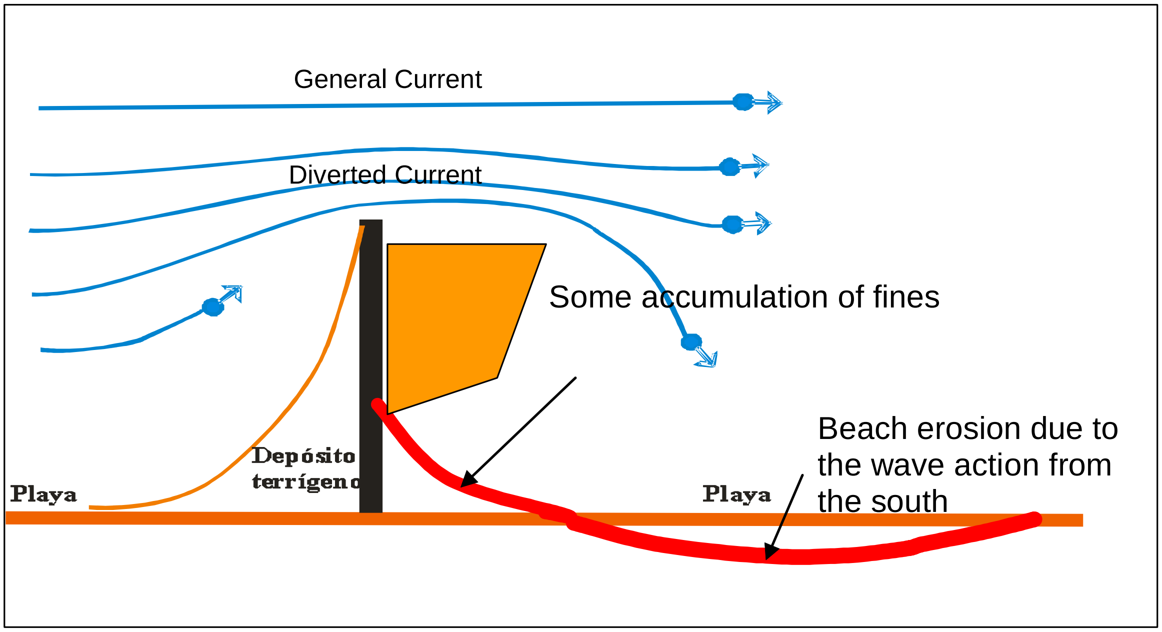


Figure 2. 16 Result of the dock modeling 3 years after construction.



The maximum values found in the modeling of the coastline changes were:

- Maximum change in the wet part of the coastline in one year : 75 m
- Maximum change in the dry part of the coastline in one year: 45 m
- Maximum change in the wet part of the coast line in 3 years: 105 m
- Maximum change in the dry part of the coastline in 3 years: 85 m

This rock dock connected to the beach would not be feasible from the environmental point of view, and was not accepted due to the potential for change of the beach morphology.

2. Reinforcement of the projected trestle and construction of the rock load-out jetty.

After discarding the former alternative, the decision to reinforce the trestle was selected as the best option from the environmental point of view with this solution included in the present EIA Modification.

4.3 Rock Quarry

The Quarry referred to as "GNL-2" is located 20 km east of the Project site and was chosen to supply material for construction of the breakwater. On April 7, 2005 PLNG submitted the EIAS for the quarry, but had to re-submit the document again on July 5, 2005, after DGAAE approved a new Exploration Quarry Program on July 1, 2005.

The area covered by the quarry EIAS, although approval is still pending, comprises the road section from the quarry to the Panamerican highway. For this reason this Modification to the LNG Export Project EIA considers only the road section between the Panamerican highway and the beach. Initiation of work to develop the quarry is planned for the end of 2006.