Key Issue:
1-Biological Diversity

Climate Zone:
Cf: Temperate Humid Climate

Subjects:
- Various Measures Concerning Ecosystem

Effects:
- Restoration of Ecosystem

Project Name: Okinawa Seawater Pumped Storage Power Plant
Country: Okinawa Pref., Japan (Asia) (N 26°40’, E 128°16’)

Implementing Party & Period
- Project: Electric Power Development Co. Ltd. (J-POWER)
1991 (Commencement of construction) -
- Good Practice: Electric Power Development Co. Ltd. (J-POWER)
1991 -

Key Words:
Biodiversity, Biotope, Seawater Pumped Storage

Abstract:
This project is located in the specific area in Japan, where many original species indigenous to the Okinawa Islands have been preserved until now. Right from the start of construction activity, several mitigation measures were undertaken to mitigate its impact. These included protection of habitat area, prevention of muddy water outflow, reduction of noise and vibration of heavy construction equipment, installation of slope-type side ditch, restoration and revegetation of the disposal area and creation of a biotope. These mitigation measures were decided on the basis of the study by a Special Committee formed from well-known local specialists and the local community.

1. Outline of the Project

The project is a demonstration plant for seawater pumped storage power generation located at the northern part of Okinawa Island. In practicalization of seawater pumped storage power generation, there was a necessity to find concrete solutions to technical problems arising from the use of seawater and problems of the environmental impacts. There is no case of seawater pumped storage power generation actually having been done anywhere in the world up to the present, and this pilot plant constitutes a first example.

The Electric Power Development Co. Ltd. (J-POWER) undertook implementation of the project on consignment from the Ministry of International Trade and Industry (MITI). Surveys and research regarding technical and environmental aspects of using seawater were carried out for six years from 1981. The feasibility of a seawater pumped storage power plant was studied and, having gained a favorable outlook, construction was performed from 1991 until 1999. Since 1999, a five-year program of demonstration tests has been going on with its aim the practicalization of seawater pumped storage power generation technology.

In Okinawa, where the project site is located, daily load fluctuations are being met with regulated operation of thermal and gas turbine and the need for pumped storage power generation is well recognized. Water resources are precious on Okinawa Island and construction of a conventional-type pumped storage power plant using river water would not be appropriate. As for the northern part of the island, it is mostly mountainous and there are many locations, which would be suitable for sitting of a seawater pumped storage power plant. With these in mind, sites meeting requirements were picked out from all over Okinawa Island and comparison studies were made of impacts on the natural and social environments, the result being selection of the present site.

Table 1 gives specifications, and Figs. 1 and 2 the general plan and profile, respectively, of the plant.

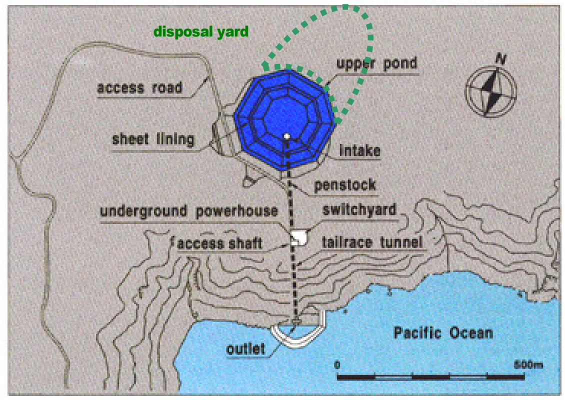

Fig.1 General plan

Table 1 Seawater pumped storage power plant specifications

Item		Specification
River system		—
Catchment area		—
Power Plant	Name	Okinawa Yanbaru Power Plant
	Max. output	30 MW
	Max. discharge	26 m^3/s
	Effective head	136 m
Upper regulating pond	Type	Excavated type, Rubber sheet-lined
	Max. embankment height	25 m
	Crest circumference	848 m
	Max. width	251.5 m
	Total storage capacity	$0.59\times10^6 m^3$
	Max. depth	22.8 m
Waterway	Penstock	Inside dia. 24 m Length 314 m
	Tailrace	Inside dia. 27 m Length 205 m

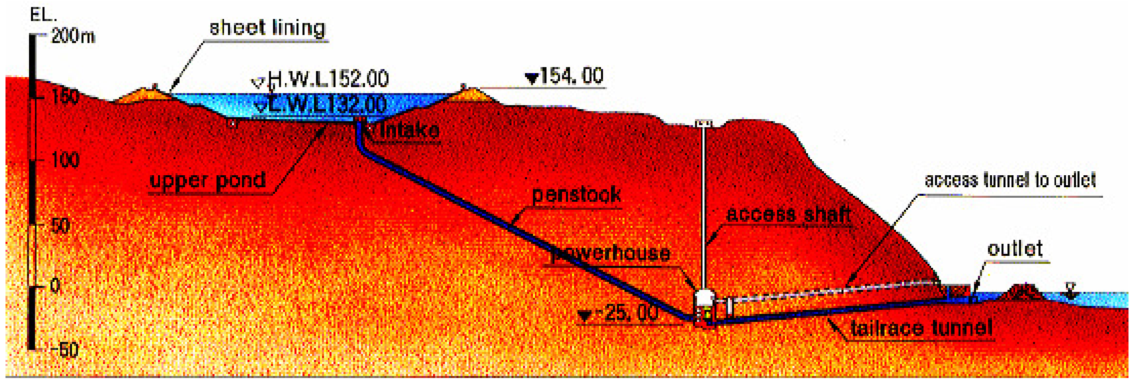

Fig.2 Profile of waterways

2. Features of the Project Area

It is said that the Ryukyu Island chain of which Okinawa is a part was connected by land to China on the Asian continent approximately 1.5 million years ago, but due to land upheavals and rising of sea level, a considerable area became submerged, the Ryukyu Islands remaining as a result. Consequently, fauna and flora which had existed in the area occupied by the islands have lived in an isolated state since then so that original species have been preserved, and there are many species and sub-species indigenous to the Ryukyus and not found anywhere else in the world.

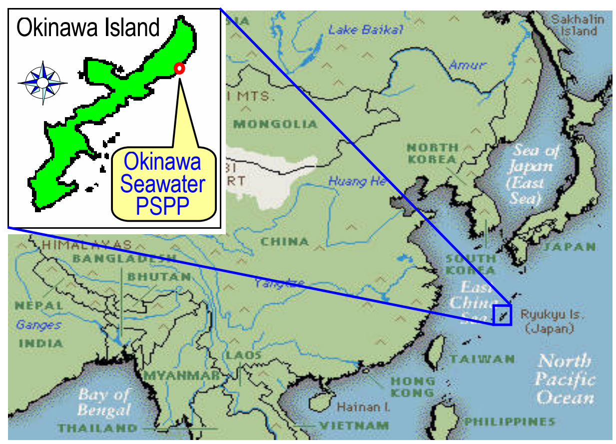

Fig.3 Site location

The climate is the closest to tropical in Japan and it is warm throughout the year with annual mean air temperature 23°C. Precipitation is approximately 2,400 mm, 40 percent rainier than the national average, short bursts of heavy squalls occurring frequently. Many typhoons strike the islands from July to September.

The regulating reservoir is located at the Pacific Ocean side of Kunigami Village, approximately 600 m from the shore and on a tableland roughly 150 m above sea level. This area comprises a gently sloped plateau of elevation 150 to 170 m, gradually declining toward the sea (east), and on nearing the sea, drops into it by a cliff of specific height from 130 to 140 m. Gullies 20 to 30 m deep and with gentle gradients are developed in dendritic form on this plateau. These gullies gradually join together as the sea is approached, and on reaching the cliff, feed into the sea as a continuous chain of waterfalls. The seashore immediately below the cliff consists of either large boulders or sandy beaches.

A red soil classified as Kunigami maaji, a special type of soil in geological terms, covers the greater part of Okinawa Island. Kunigami maaji is a soil from weathered sedimentary rocks, the parent rocks being of various kinds such as phyllite, andesite, and sandstone. Molecular binding is weak, while coefficient of permeability is low from 10^{-5} to 10^{-6} cm/s so that surface flows readily occur when it rains, and particles of this soil are washed out. Further features of Kunigami maaji are that it is highly weathered and kaolinite, a clay mineral, is contained, that specific gravity of Kunigami maaji is 2.6 to 2.8 and high, and when it is washed out to the sea, it tends to not go out to the open sea, and serious damage to coral reefs along the coast constituting a social problem for the local community.

The vicinity of the construction site is surrounded by state-owned forestland, and the area had been designated a U.S. Marine Corps training grounds under the Japan-U.S. Status-of-Forces Agreement, but a portion was released as demonstration tests were to be conducted while a separate portion is now leased and is being jointly used. The project site is not in an area designated as a natural park, while there are no cultural assets or recreational facilities.

3. Major Impacts

J-POWER under consignment from MITI to carry out Environmental Impact Surveys and Studies of Seawater Pumped Storage Power Generation, began field surveys in 1982, and compiled environmental impact assessment report in 1989. In Table2, EIA items are shown.

Table 2 Environmental impact assessment items

<table>
<tr><th colspan="3">Environmental impact assessment items</th></tr>
<tr><td colspan="3">Meteorology, Weather, Air quality, Water quality, Noise, Vibration, Offensive odor, Soil contamination, Ground settlement, Topography, Geology, Sea current, Marine phenomenon</td></tr>
<tr><td colspan="3">Salt spray, Seawater seepage</td></tr>
<tr><td>Plant</td><td colspan="2">Vegetation, Rare plant, Soil profile, etc.</td></tr>
<tr><td rowspan="3">Animal</td><td>Terrestrial animal</td><td>Mammals, Birds, Reptiles, Amphibians, Insects, Soil fauna</td></tr>
<tr><td>Aquatic organism</td><td>Gully animals</td></tr>
<tr><td>Marine organism</td><td>Coral, Fishes, Benthic organisms, Plankton, Eggs and fry,
Tideland organisms, Seaweed, grasses</td></tr>
</table>

The environmental problem of greatest concern was the effects there might be of salt spray on the surrounding environment due to pump-up of seawater. Wind tunnel water tank tests and simulations using numerical models were carried out regarding this matter and it was ascertained that there would be little difference from salt spray flying directly from the sea.

With regard to animal life, it was confirmed there were l6 species of rare animals inhabiting the area of which five were listed as endangered and seven as threatened in the Red Data Book. As for plant life, there were many indigenous species (Okinawa Island-indigenous: 3 species, Okinawa Island northern limits-indigenous: 5 species, Ryukyu Islands-indigenous: 9 species), while in the sea area there were found reef-building coral.

Under these circumstances, a Study Committee for the Protection of Invaluable Assets was organized mainly of local specialists in 1989. Using findings of the study committee as references, Fundamental Principles of Environmental Conservation were set up as follows:

1) Organisms inhabiting the project area are the natives and, as such, are to the given consideration with a modest attitude.
2) The development area is to be held to a minimum in order that the ecosystem will be disrupted as little as possible.
3) The scope of implementation of measures for natural environment protection is not to be limited to the construction area, and is to be applied to the surroundings as well.

4) Any damaged environment is to be restored without delay taking advantage of natural self-healing powers.

Based on these fundamental principles, the environmental impact factors below were extracted:

1) Outflow of muddy water (red water) produced from the construction area into gullies and sea area near the river mouth
2) Reduction of habitat area due to changes made in land
3) Noise and vibration from heavy equipment
4) Damage to small animals from construction vehicles and accidents due to falls down to structures

4. Mitigation Measures

The environmental conservation measures in Table 3 were considered and implemented for each environmental impact factor. Meetings were held with the local community to explain these measures and consent was obtained.

Table 3 Countermeasure by environmental impact factor

Environmental impact factor		Countermeasure
a) Outflow of muddy water produced from the construction area into gullies and sea area near the river mouth	Construction water	- Chemical treatment by turbid water plant
	Turbid water from red soil	- Chemical treatment by turbid water plant - Reduction of turbid water by separation into red water and clear water - Reduction of red water by spraying asphalt emulsion or seeds on bare ground - Install gabion weir at downstream area of gully
b) Reduction in habitat area due to changes in land	Reduction of area changed	- Layout of powerhouse and waterways underground - Omit access road and work adit to outlet and powerhouse - Reduce construction area by balancing cuts and embankments as much as possible
	Protection, restoration of vegetation	- Sculpt and green construction site without delay - Protect existing forest by planting low-height trees
c) Noise, vibration from heavy equipment		- Prohibit nighttime work in surface construction - Use low-noise type machinery - Travel at low speed inside construction area
d) Harm to small animals from construction vehicles and accidents due to falls down to structures		- Capture and remove animals and plants in construction area - Install facilities (intrusion prevention nets) to prevent entry of rare animals - PR activities using posters, lecture meetings, pamphlets, etc. - Prevent accidents from falls of small animals through installation of sloping side wall gutters

Items thought especially to be of unique nature (underlined portions in above table) are discussed in detail below.

4.1 Measures during Construction

1) Capture and Transfer of Fauna and Flora in Construction Area

Since the construction area during the construction period would become an uninhabitable environment for rare animals due to changes made in land and traffic of large heavy equipment, small animals of limited travelling capabilities such as frogs, turtles, and newts were captured and moved to favorable environments outside the construction area. Prior to carrying out capture and removal, tests to see whether the animals would survive resettling were conducted and it was confirmed that resettling would be possible. (Resettling survival tests consisted of capturing several individuals of a rare animal species and marking them before release in an optimum environment outside the construction area and confirming several weeks later that they were active and that no dead bodies were to be found, by which it was deemed possible for resettling to be carried out.)

2) Installation of Intrusion Prevention Nets

In order to prevent small animals such as turtles from entering the construction area from outside and being harmed by construction vehicles, polyethylene nets approximately 30 cm high were installed along 8 km of the outer perimeter of the construction area.

Fig. 4 Intrusion prevention net

3) PR Activities Aimed at Construction Personnel Concerned

In order for as many construction personnel concerned as possible to be interested in rare animals, pocket booklets and pamphlets containing photographs of rare animals, precautions in executing work for the environmental conservation, and what to do when encountering a rare animal were distributed, posters calling attention to protection of rare animals were put up, and lecture meetings concerning rare animals were held. The photographs of the rare animal species contained in the pocket booklets were 16 in color of birds, amphibians, and reptiles. A protected animal monitor was appointed, who, carrying out patrols, checked whether the rare animal protection measures were functioning effectively and whether handling of rare animals was appropriate. At the end of the pamphlet was included a rare animal sighting report form for mandatory reporting in case of encountering a rare animal.

4.2 Permanent Measures

1) Installation of Slope-type Side Ditch

Ordinarily, road ditches are U-shaped and if a small animal were to fall in it would have trouble climbing out, and in the hot sun of Okinawa, the animal would be fried to death with heat absorbed by concrete. There have been a number of cases in the prefecture of chicks falling into U-shaped ditches and being killed by the heat. Therefore, ditches with sloping sidewalls enabling animals to climb out by themselves were installed. The ditches have sloping walls on their mountain sides and vertical walls on their road sides so that animals will be guided toward natural ground, the ditches thus playing a role in promoting traffic safety.

Fig. 5 Slope-type side ditch

2) Restoration and Revegetation of the Disposal Yard, and Biotope Creation

Regarding the construction site, it was considered necessary to regain as quickly as possible a natural environment in which rare animals could live through restoration of the site to its original state. Particularly, regarding the disposal yard provided adjacent to the regulating pond where 210,000 m^3 had been accommodated at the beginning, it was thought to abandon the conventional concept of a disposal yard, positioning it as a place (biotope) for creating an environment in which wildlife (birds, insects, plants, etc.) can coexist.

Fig.6 Central pond in disposal yard

In order to recreate vegetation similar to the Itajii (the village tree of Kunigami Village, Lithocarpus edulis) forest in the surroundings, about 20 varieties beginning with priority-status trees such as Itajii and Adeku (Syzygium buxifolium), fruit-bearing trees such as Shimaguwa (Morus australis) and Sharinbai (Umbellata), and pioneer trees such as Akamegashiwa (Mollotus japonicus) and sendan which grow rapidly to form windbreaks for Itajii and others and aid in their growth, were selected and around 30,000 trees were planted intermixed in the disposal yard of approximately 45,000 m^3. Saplings of the trees planted are almost nonexistent commercially, and seeds collected from actual stands were sown in pots and grown for two to three years and then transplanted. If left as bare ground after planting, there would have been outflow of red soil whenever it rained so that the surface of red soil was covered with bark and wood chips at flat areas and coconut fiber mats at slopes, and at the same time, it was endeavored to hold down evaporation and improve the environment for growth of trees.

Before development, there were gullies at this construction site and a riverine environment existed. In order to restore this environment, ponds and waterways of various sizes were arranged in a well-balanced manner to create habitats for small animals (aquatic organisms, insects, etc.) thereby aiming for biodiversity. The ponds and waterways were lined, giving consideration so that small animals could inhabit gaps between stones. The stones for lining were of different sizes, large and small, for variation. Coconut fiber mats were used to cover the surfaces of small ponds and waterways to prevent outflow of red soil.

Fig.7 Cover by Coconut fiber mats

5. Results of the Mitigation Measures

Environmental impact surveys have been made continuously since 1990 to assess the impacts of construction work on the surrounding environment. The outline of environmental monitoring in 1999 is given in Table 4.

The condition of growth of the principal varieties of trees at the disposal yard, a part of the results, is shown in Fig. 8. The numerical values used were obtained from trees growing in areas of 10 m x 10 m at l0 locations around the regulating pond. (Regarding data for 1997, they were greatly affected by a slowly moving typhoon resulting in very long hours of strong wind and rain, and therefore, were considered unsuitable for comparisons and omitted.)

Table 4 Outline of environmental monitoring

Environmental monitoring item			Monitoring frequency
Terrestrial monitoring			
Vegetation (before, after typhoon)		10 points around plant	Twice/year
Animals	Mammals, Birds, Reptiles, Amphibians, Insects, Soil fauna, Aquatic organisms	Line census, fixed point survey	
Noise, vibration		4 points around plant	
Regulating pond water quality	Water quality, Electrical conductivity	1 point in regulating pond	Continuous
	Transparency, pH, DO, COD, SS, n-hexane extract		Once/year
Marine monitoring			
Water quality	Water temperature, Salt content, Transparency, pH, DO, COD, SS, n-hexane extract, Coliform group number, T-n, T-P	4 points in frontal sea area	Twice/year
Bottom sediment	COD, total sulfides, particle-size distribution, loss on ignition	5 points in frontal sea area	
Organisms	Tideland organisms, Eggs-fry, Zoo / phytoplankton	2-3 points in frontal sea area	
	Marine algae and grasses	3 traverse lines in frontal sea area	
	Coral	3 traverse lines, 5 points in frontal sea area	
	Fishes and other nekton	1 traverse line in frontal sea area	

At the disposal yard biotope, saplings have grown satisfactorily as shown in Fig. 8, while tadpoles and newts can be seen swimming, and dragonflies fitting about in and around water. Because fruit of trees and insects that could be fed on by animals had increased, rare birds and boars began to appear (Ref. No.3). As an unexpected secondary effect, aquatic animals were found to be laying eggs on the coconut fiber mats which had been spread out so that the mats were fulfilling the roles of aquatic plants.

Regarding measures for preventing red soil from running out, there were no outflows even when typhoons had approached, and it was confirmed that muddy water had not been produced (Ref. No.4).

Because rare species have been discovered at the site and this was shown on television, many people from the general public began coming to visit the site. The fact that rare animals and plants can be seen in a short period of time without needing to go deep into the surrounding mountains and forests has won attention (Ref. No.9). Studies are being made at the Kunigami Village Office to see whether this feature can be taken advantage of and the site used as a place for education of children and for general environmental education.

Figure 9 is a photograph showing the condition at the central part of the disposal yard.

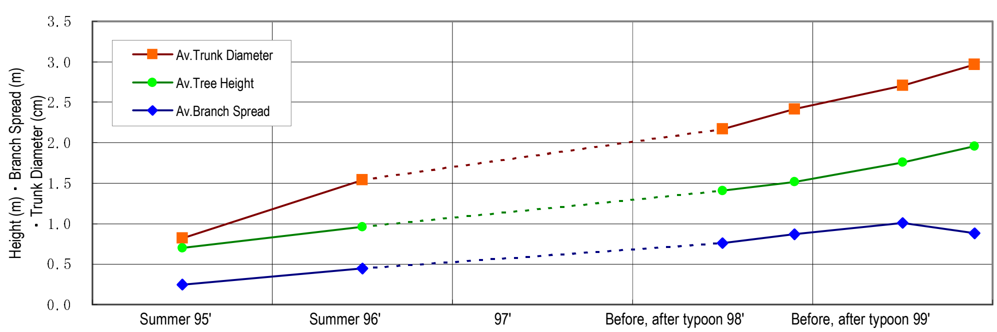

Fig. 8 Environmental impact assessment results (source: Ref. No.12)

Fig. 9 Central part of disposal yard (source: Ref. No.4)

6. Reasons for Success

The Study Committee for the Protection of Invaluable Assets was formed by local specialists before start of construction, studies were made of environmental conservation measures and their effects, and construction was performed taking these into consideration, and this is thought to be the primary reason environmental protection measures succeeded.

In particular, it is thought effects of creation of a biotope at the disposal yard from the point of view of recovery of nature can be given high marks. Especially, the soil at the disposal yard was inorganic while there were conditions for severe wind and salt damage, so that studies regarding planting had been made from an early stage of planning. Based on such studies, surveys of salt damage and survey of tree types favorable to nesting of birds were carried out. These were useful in deciding tree types to be planted and the method of planting. As an example, the outline of testing for a method of planting is given below.

- **Period of Testing** : From 1994 to 1996
- **Place of Testing** : Vicinity of upper regulating pond
- **Problems Studied** :

  Trees in the area not being for gardening, whether or not they will root

  Planting density and layout method suited to sound growth and taking into consideration economics

  Selection of optimum soil conditioner

  Ascertainment of salt damage inhibition effect due to installation of windbreak net

  Influence of bare ground cover materials on growth of saplings

- **Content of test** :

Contents of test	Material selected
1. Adaptability of tree	Planted tree species: Itajii (Lithocarpus edulis), Adeku (Syzygium buxifolium), Tabunoki (Persea thunbergii), Isunoki (Distylium racemosum), Nezumimochi (Ligustrum japonicum), Oobagi
2. Planting layout method selection	Planting layout method: Row planting (0.5 m x 2.0 m pitch), Close planting (5-10 tree/m^2), Point planting (1.0 m x 1.0 m – 1.2 m x 1.2 m pitch)
3. Soil conditioner selection	Soil conditioner: Cattle manure, Coal ash, Driftwood compost
4. Windbreak net necessity	Windbreak nets used, not used
5. Mulching material selection	Mulching material: Unwoven coconut fiber mat, Bark, Straw bed, Sprayed seeds

- **Results of Survey** :

As an example, the results with the tree species Itajii indicated in terms of ratios of growth in tree heights one year later, are as given below.

2. Planting layout method selection		3. Soil conditioner selection		4. Windbreak net necessity		5. Mulching material selection	
Row planting	2.28	Cattle manure	2.28	Net used	1.69	Unwoven coconut fiber mat	2.07
Close planting	1.7	None	1.08	Net not used	Died	Straw bed	1.27
Point planting	1.23	Driftwood compost	1.07			Bark	1.23
		Coal ash	0.2			Seed spraying	0.33

- **Output from Results** :

With the results of tests in hand, potted saplings which had grown to heights of about 50 cm were transplanted in rows. Windbreak nets were installed where winds were strong. Regarding mulching materials and soil conditioning, bark compost was used at places of gentle gradient giving consideration to water flow during rainfall, and unwoven coconut fiber mats at places of steep gradients. The thicknesses of mulching materials and compost were selected as suited depending on the location.

It is believed that having paid meticulous attention to thorough prior surveys and studies was the reason for the healthy growth of plants at this site where the environmental conditions are severe. Furthermore, it is thought that having taken the viewpoint that "humans are there for assisting self-healing of nature" when carrying out studies and having kept in mind revegetation with the necessary and minimum amount of aid had also been effective.

7. Outside comments

<Asahi Shimbun (14.6.1999)>

"The young plants are growing well into their 4th year while newts and tadpoles are seen swimming in the man-made water pool. About ¥300 million out of the total construction cost, just over ¥30 billion, is used for environmental measures. Yanbaru-Waterrails were also recently observed around the upper pond.
It is to be kept a close watch on whether the Hydropower plant will succeed in establishing a symbiotic relationship with the surrounding ecosystem. "

8. Further Information

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