2 & 3

DECOMMISSIONING COSTS
SAN ONOFRE NUCLEAR GENERATING STATION
UNITS 2 & 3

FOR

Southern California Edison Company
Rosemead, California

NUS Report 3382
NUS Job 5215

By

NUS CORPORATION
Sherman Oaks, California

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1. INTRODUCTION

In late 1976 NUS completed a decommissioning study for Unit 1 at the San Onofre Nuclear Generating Station. At the request of SCE a proposal dated March 13, 1979 was submitted for a scope of work which included a similar study and estimate for Units 2 & 3, and an update of the earlier estimate for Unit 1.

The study for Units 2 & 3 was approached as a fresh effort, beginning with assignment of personnel to the plant site. This report presents the results of the decommissioning cost study.

II. SUMMARY AND CONCLUSIONS - UNITS 2 & 3

NUS has prepared and presents herewith an evaluation of the dispositions that can be applied to San Onofre Units 2 & 3 and which are associated with decommissioning them at the end of plant economic life.

The costs of decommissioning have been estimated and are also presented. The cost estimates are presented in 1979 dollars, and schedules indicating the timing of expenditures are included in this report. The estimates are based primarily on the cost of labor and services in the local area. SCE site and home office salary costs are averaged with respect to make up of the work force and include fringes and overheads, but do not include corporate administrative and general expense nor employee benefits. A contingency of 15% is provided.

Of the three basic decommissioning options generally considered technically viable in the industry (minimum decommissioning, entombment and removal) only minimum decommissioning and removal were considered. This is consistent with the approach taken earlier with Unit 1. Both the high cost of installing and ultimately removing entombment facilities and the uncertainty of future regulatory requirements preclude consideration of entombment as a viable alternative. Furthermore, the ongoing costs of site staff and property insurance, as well as the value of the site, override any cost savings attributable to decay of induced radioactivity.

The cost estimates presented herein were prepared on a site specific basis. NUS personnel were on site for an extended period of time, and the estimate reflects local labor costs, SCE's normal mode of contracting for services, the degrees of difficulty of removal of various portions of the plant and the availability of plant drawings and quantities at the plant site.

Other decommissioning related costs were also developed and included in the estimates. These include such items as radioactive waste disposal, indemnification, major remote tooling procurement, and subcontracts.

This evaluation considers the San Onofre plant on the basis of regulatory requirements and the equipment and facilities design in existence in early 1979. Future modifications must be treated separately.

The decommissioning option addressed herein contemplates plant shutdown, followed by decontamination, fuel shipping, removal of all radioactive material, razing and removal of remaining structures and facilities, and restoration of the site to essentially pre-construction condition, including extensive backfilling where necessary, allowing unrestricted use. Licenses would be terminated.

This option is considered achievable in the current and prospective future of nuclear plant decommissioning. The concepts of remote sectioning and removal of irradiated reactor components and full scale primary and secondary decontamination have been demonstrated, and will be further developed in the future.

The removal costs associated with decommissioning of both units are estimated to be $164,217,000 and the value of salvageable items and scrap are estimated at $24,308,000, yielding a net estimated decommissioning cost of $139,909,000.

The amount of this total allocated to Unit 2 is estimated to be $64,908,000. This is less than half the total because shared facilities such as the fuel handling building, control building and intake and discharge structure remain with Unit 3.

These costs are in 1979 dollars, and are exclusive of site security, operations, nuclear indemnification and property insurance. This is the same basis on which the earlier Unit 1 study was presented. These additional costs have been separately estimated and are also presented in this report.

The difference between our present estimate of $64,908,000 for Unit 2, and the June 8, 1979 preliminary estimate of $64,000,000 is that we tried to be careful in the preliminary approximation not to overestimate the cost.

III. DISCUSSION - UNITS 2 & 3

A. General

The decommissioning of nuclear reactors in the United States has substantial historical precedence. Over sixty small reactor facilities (excluding many very small research tools and military application reactors) have been shut down and decommissioned by the modes discussed herein. Further, it can be expected that a number of generating facilities of a size approaching San Onofre will be refurbished or decommissioned before San Onofre. Thus, the sophisticated technologies which are necessary and have been demonstrated in the past for this type of service will be further developed in the future.

It can be expected that three major factors will affect future power plant decommissioning.

1. The cost of decommissioning will be a significant factor in future decommissioning of facilities based on current experience and projections. Recovery of these expenditures over the operating lifetime of San Onofre would be a means of providing for decommissioning costs, along with the other costs associated with the cost of service.

2. Entombment of facilities will be difficult to justify, due to socio-political and technical factors. This is due to the fact that the entombed structures may not meet future regulatory requirements for long-term disposal. Also, the value of the property makes it uneconomical.

3. Maintaining low personnel exposure during decommissioning is a prime consideration in the decommissioning effort. Removal of the components of a primary system dictates that radiation fields of more than several millirem/hour must be avoided. In order to achieve this goal, a full scale equipment decontamination is planned. As a practical consideration, this must be performed at the end of life while the operating crew and service systems are intact and the in-plant facilities to support such an activity exist. Any future updates of decommissioning costs will reflect the impact of developments in such technologies.

B. License Requirements

The steps a licensee will go through to achieve the complete release from all USNRC Part 50 and Part 30 license requirements are as follows:

Prior to shutting the plant down for the last time, the licensee can obtain a Part 50 possession only license which permits him to possess but not operate the reactor past the time it is finally shut down. At the outset of the time this license amendment is in force, the license requirements concerning manning, qualifications, surveillance, etc., will be the same as the operating license. As work progresses (defueling, fuel shipping, removal of sources and reduction of the radiation control areas), the requirements decrease. This is usually accommodated through a set of revised Technical Specifications which automatically permit certain changes at the completion of certain milestones and USNRC inspections.

Ultimately, for a minimum decommissioning, the licensee could qualify for and change the license to a Part 30 possession only license, which would either be administered by the USNRC or the state if the plant was located in an agreement state. As a practical fact, the continuity in licensing, the size of the facility and the scope suggest that there is a significant advantage in staying in Part 50 status under the authority of the USNRC.

All decommissioning activities necessary to place the facility in its final status (be it minimum decommissioning or complete removal) are described in a document prepared by the utility called the "decommissioning plan." This document discusses the objectives of the decommissioning, plans and schedules and other salient safety considerations. The USNRC, in approving the plan, will establish "hold points" and at the time the plan is accepted and a decommissioning authorization is issued, the plan becomes the working document. Typically, compliance inspections continue during decommissioning. A schedule showing major milestones is included as Figure 1.

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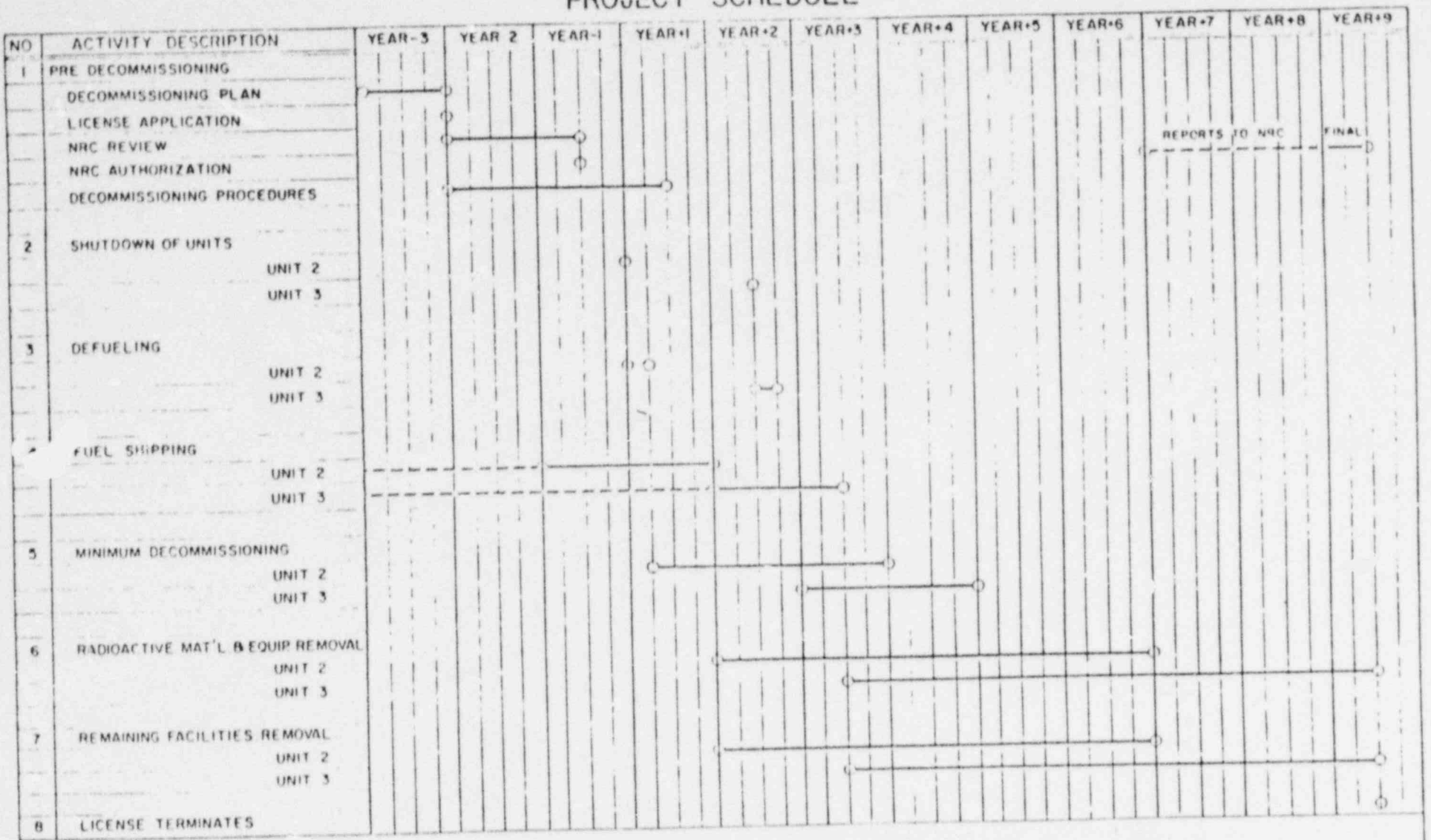
PLANT SAN ONOFRE UNITS 2 & 3
PROJECT DECOMMISSIONING

FIGURE 1
PROJECT SCHEDULE



C. Insurance

The indemnification requirements for decommissioning sites can be greatly reduced. Typically in the past, for an independent single unit generating facility placed in Part 50 possession only status, at the time minimum decommissioning is completed the total pool liability indemnification carried is about $10,000,000. This assumes no fuel is stored on site. For a minimum decommissioning mode, the licensee would keep a relatively large insurance policy in force for a long period of time (until the containment vessel was completely decommissioned, and all fuel was off site, for example). If fuel is stored on site, the full nuclear indemnification pool insurance would be maintained as required by law. Property insurance, while it is an expense item, is included as a separate item in the report.

D. Non-Manual Labor

The labor commitment projections shown in Figure 2 are based on the following mix of non-manual resources in each of the categories:

1) SCE site staff. This effort peaks at 110 field non-manual personnel and is made up as follows:

Security Force - day shift	10
- night shifts	8
Health Physics - day shift	3
- night shifts	2
Supervision of craft labor	50
Warehousing, tool room, etc.	10
Clerical and support	10
Documents and records	7
Inspection and Q.A.	10
	110

2) SCE home office staff. This effort begins with two professionals during the pre-decommissioning phase, preparing the decommissioning plans, schedules

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FIGURE 2
PROJECT SCHEDULE

CLIENT SCE
PLANT SAN ONOFRE UNITS 2 & 3
PROJECT DECOMMISSIONING

NO	ACTIVITY DESCRIPTION		YEAR-3	YEAR-2	YEAR-1	YEAR+1	YEAR+2	YEAR+3	YEAR+4	YEAR+5	YEAR+6	YEAR+7	YEAR+8	YEAR+9
	UNIT SHUTDOWNS													
		UNIT 2				○								
		UNIT 3					○							
	SCE SITE STAFF													
		MEN	5	10	30	55	110	110	69	69	69	55	41	41
		MANHOURS	10,000	20,000	60,000	110,000	220,000	220,000	138,000	138,000	138,000	110,000	82,000	82,000
	SCE HOME OFFICE STAFF													
		MEN	2	2	2	5	5	5	5	5	5	5	5	5
		MANHOURS	4,000	4,000	4,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
	CONSULTANT STAFF													
		MEN	2	5	5	2	2	2	2	2	2	2	2	2
		MANHOURS	4,000	10,000	10,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000

and other licensing related documents with assistance from the consultant. It then peaks at five professionals during decommissioning, engaged primarily in licensing related activities such as reports to NRC, and tracking of plans and schedules, with a lower level of consultant assistance.

3) Consultant Staff. This effort peaks at five professionals during pre-decommissioning, furnishing fairly heavy licensing, planning and procedure preparation assistance to SCE, and then drops to two professionals during decommissioning, when a lower level of assistance is estimated to be required.

E. Estimate Qualifications

The cost estimates prepared as part of this work are NUS' best cost estimates and include 15% contingency. All costs are in 1979 dollars. A summary second-level breakdown of the estimate, showing expenditures by year, is given in Table 1. As shown in Figure 1, shutdown of the first unit occurs at the beginning of year 1. Average costs for SCE site non-manual and home office engineering personnel were furnished by SCE, as were unit costs for contractor labor. Consultant non-manual costs were estimated by NUS.

Contractor labor costs were estimated on the basis of using a single craft (laborers) for the removal work. This is reasonable for demolition work at the current time. Should this change in the future, or should the size of the job result in new labor negotiations for use of other crafts, this would increase the cost of the labor content of the estimate considerably. Quantities used as a basis for the estimate were obtained from the Summary Quantity Comparison - Forecast 9, and from the Station Manual - Equipment Data, Vol. 3 and 4.

We have also considered the probable salvage value of plant components with high capital costs and which would be maintained up to the end of plant economic life. It was concluded that even in the extreme cases (reactor coolant pump drive motors, as an example), the equipment would have a very limited salvage value based on the potential market, and compared to the cost of removal. The same holds true for the turbine generator and condensers.

Nonetheless, some value will be recoverable from these and other components, and Table 2 summarizes these estimated values. Table 3 summarizes the decommissioning and salvage estimates by FERC accounts.

F. Decommissioning Activities

Pre-decommissioning, defueling and fuel shipping are common to all options. See Figure 1. SCE site and home office costs, and consultant costs have been included for these items. The contract costs for fuel shipping have not been included, on the basis that they are a normal plant operating expense. A milestone schedule relating the significant project tasks, is shown in Figure 3.

During the pre-decommissioning period no significant decommissioning activities except some area decontamination and waste processing will be undertaken. Shipping of cool spent fuel will be going on on a routine basis, and virtually all shared plant systems will remain in service.

Immediate minimum decommissioning is also common to all options. The activities taking place at this time are summarized as follows for either unit:

A. Primary System
   1. Defuel and replace vessel head
   2. Process refueling and primary water
   3. Prepare for decontamination
   4. Decontaminate primary system
   5. Process and dispose of decontamination solutions

B. Containment
   1. Remove salvagable equipment
   2. Removal all sources which can be disconnected
   3. Drain fluid systems
   4. Remove oils and lubricants
   5. Prepare sumps, monitors and air locks
   6. Install security gates
   7. Conduct radiation survey and fire survey
   8. Install access control

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FIGURE 3
PROJECT SCHEDULE

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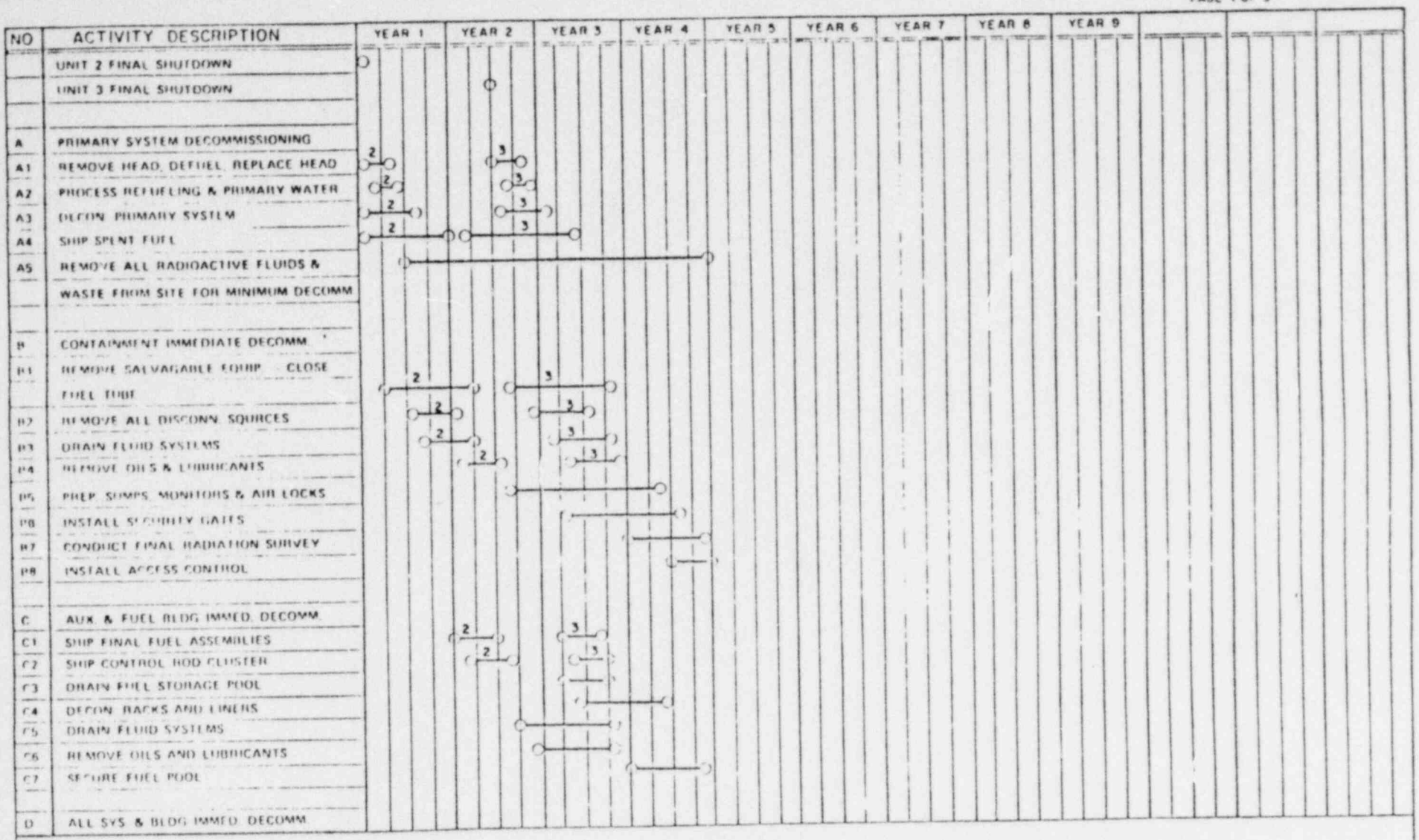
PLANT SAN ONOFRE UNITS 2 & 3
PROJECT DECOMMISSIONING

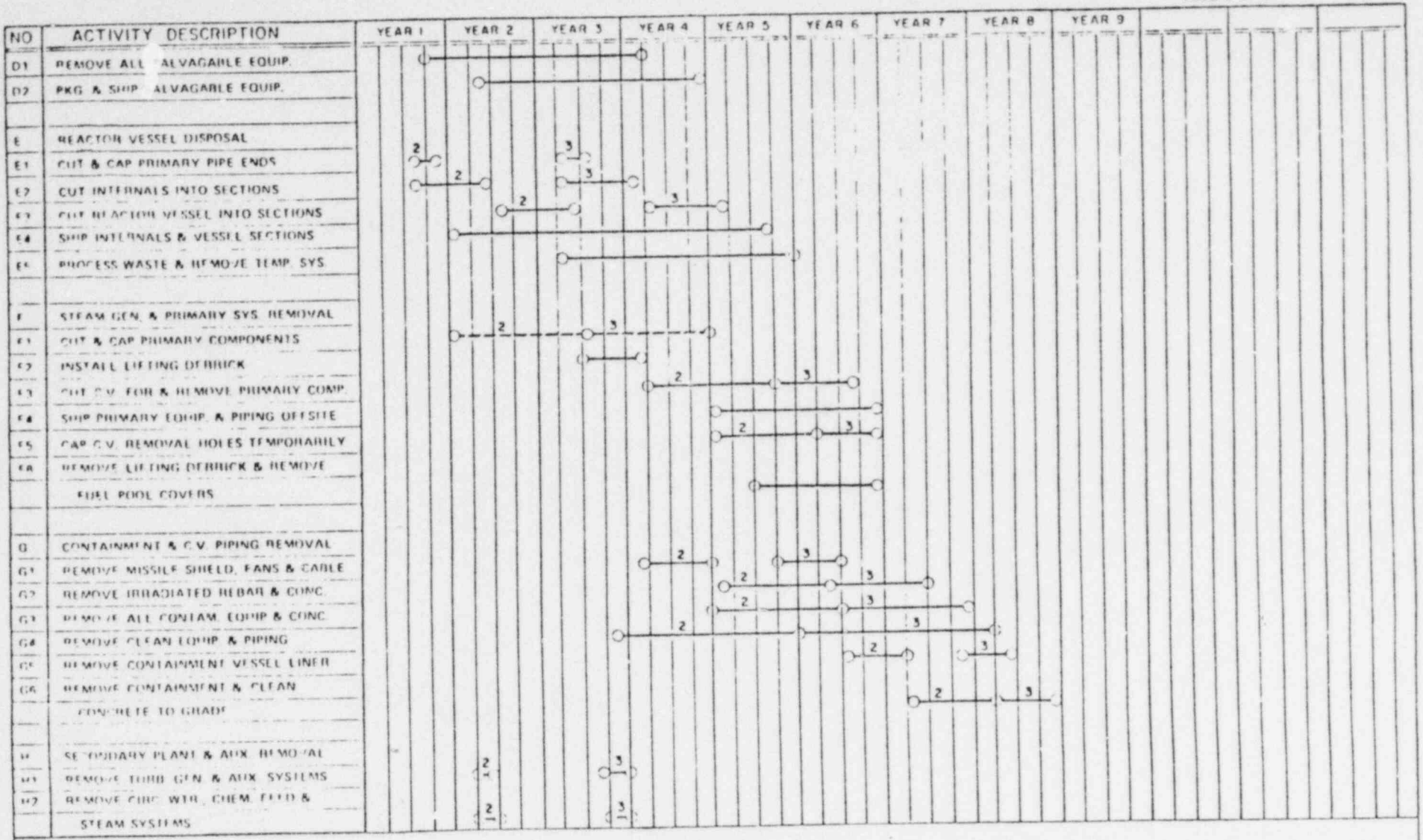


NOTES

ACTIVITIES PERTAINING TO A SPECIFIC UNIT HAVE THE UNIT NUMBER SHOWN ABOVE ACTIVITY LINE

FIGURE 3
PROJECT SCHEDULE

CLIENT SCE
PLANT SAN ONOFRE UNITS 2 & 3
PLANT DECOMMISSIONING



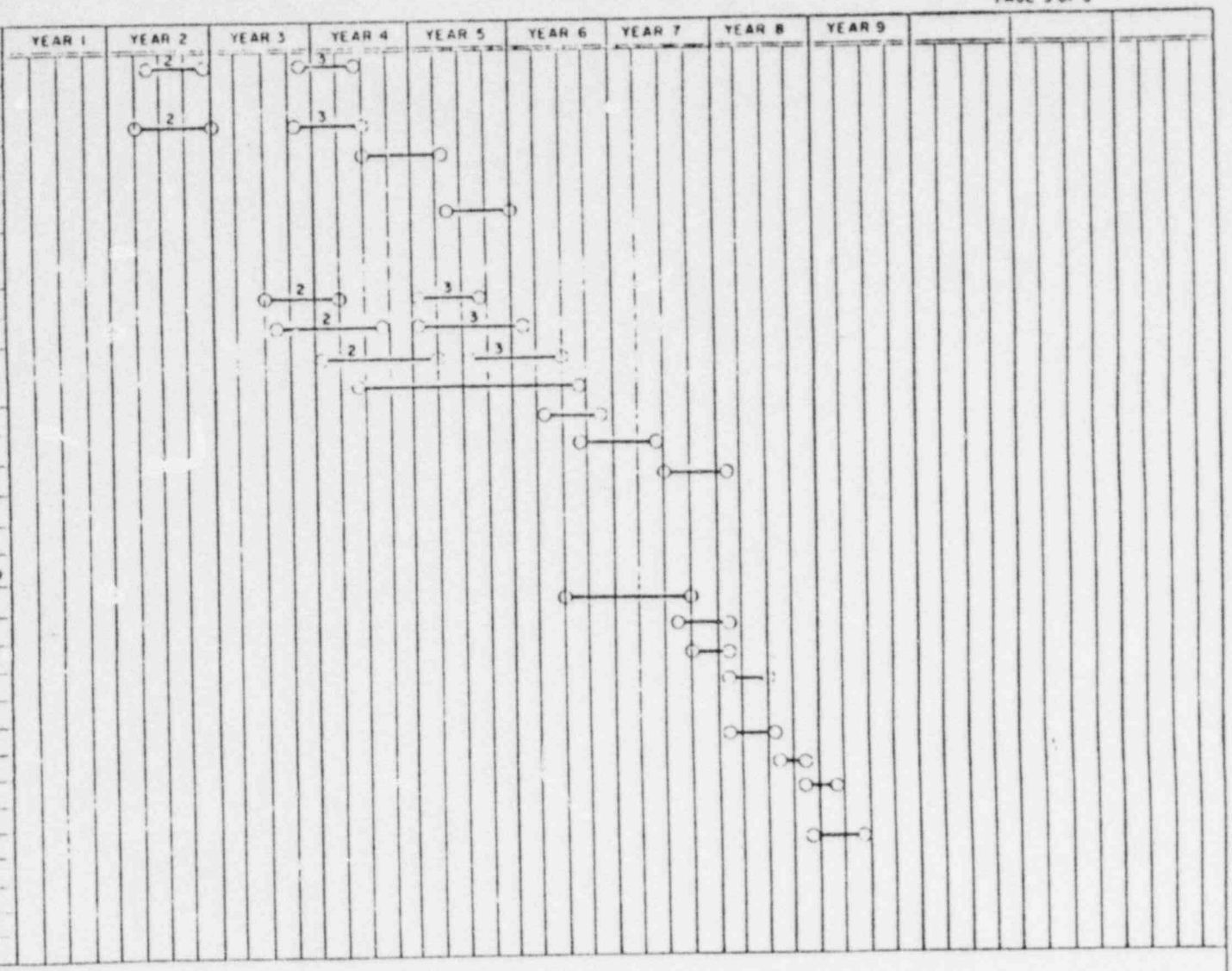
NOTE

ACTIVITIES PERTAINING TO A SPECIFIC UNIT HAVE THE UNIT NUMBER SHOWN ABOVE ACTIVITY LINE

PROJECT SCHEDULE

CLIENT SCE
PLANT SAN ONOFRE UNITS 2 & 3
PROJECT DECOMMISSIONING

NO	ACTIVITY DESCRIPTION
H3	REMOVE MAIN CONDENSERS
H4	REMOVE GAS, COMP. AIR & MISC
	WATER SYSTEMS
H5	LEVEL UNCONTAM. STRUCTURES
H6	EXCAVATE CONC. UNDER TURB. &
	CIRC. WATER SYSTEMS
I	AUX & FUEL HANDLING FAC. REMOVAL
I 1	REMOVE RACKS & FUEL POOL LINER
I 2	REMOVE CONTAM. EQUIP & PIPING
I 3	REMOVE CONTAMINATED CONCRETE
I 4	REMOVE ALL CONTAM. MATERIALS
I 5	REMOVE FUEL TRANSFER TUBE & SYS
I 6	TEAR DOWN ABOVE GRADE STRUCTURE
I 7	EXCAVATE CONC. BENEATH POOL
J	CIVIL/STRUCT & SITE REFURBISHMENT
J1	REMOVE ALL REMAINING ABOVE GROUND
	STRUCTURES
J2	REMOVE INTAKE/DISCH. STRUCTURE
J3	COLLAPSE CONDUIT TO TURB. BLDG.
J4	COLLAPSE ALL SUBTERRANEAN VOIDS
J5	EXCAVATE AND REMOVE BELOW GRADE
	STRUCTURES
J6	BACKFILL AND GRADE
J7	PLANTING AND ROCK PLACEMENT
J8	REMOVE FINAL FENCE AND GUARD
	HOUSE



NOTES

ACTIVITIES PERTAINING TO A SPECIFIC UNIT HAVE THE UNIT NUMBER SHOWN ABOVE THE ACTIVITY LINE

C. Auxiliary and Fuel Handling Building

1. Ship final fuel assemblies
2. Ship control rod clusters
3. Drain fuel storage pool
4. Decontaminate racks and liners
5. Drain fluid systems
6. Remove oils and lubricants
7. Secure pool

D. All Systems and Buildings

1. Remove all salagable equipment
2. Package and ship all salvagable equipment

A thorough primary system decontamination is planned in order to reduce the steam generator and primary loop contact dose rates to less than approximately ten millirem/hr. Full scale decontamination is cost effective because a small well trained group can be used, rather than a large work force if larger dose rates have to be tolerated. The plant staff, which will still be available at the completion of defueling would provide the logical support for this activity, and the primary system will still be serviceable.

Removal of radioactive material and equipment will proceed from the most highly radioactive sources in descending order of activity through the less radioctive components and structures. The most highly radioactive components and structures, as a result of neutron activation during operation, will be in the core area. Other major sources will then be removed and disposed of.

This is different from simply reversing the installation procedure because these components, such as the reactor pressure vessel and steam generators, will be too radioactive to handle without adding extensive shields that would increase the weight excessively. (It is estimated that a steam generator shielded for legal shipment would weigh between 1500 and 2000 tons). All of the major components, therefore, have to be decontaminated and shipped by barge, or remotely sectioned and loaded into shielded shipping containers for transport to licensed disposal facilities.

The costs for disposal of these materials were estimated on the basis that the burial site would be on the existing Hanford reservation at Richland, Washington. The estimated costs include packaging, shipping, burial and surcharge costs where applicable.

Following the removal of the major equipment (typically the NSSS and reactor internals), the concrete shielding in the area of the reactor core will be manually removed.

The remaining "low-level" material will be surface contamination. This can be removed by washing, leaching, or, in the case of sumps and lower floors, chipping away several inches of surface concrete. It is important to note, however, that all surfaces must be accessible to smear testing for contamination. This means that pipes and ducts that cannot be entered must be removed.

After completion of the above activities and comprehensive surveys, the containment would be declared "clean", and would be released as a controlled-access area. As in the case for all of the facilities, the normal hazards (falling into openings or being hit be a falling object) would remain. Should the plant remain in this status for a long period, sand or other fill might be brought in to prevent such accidents.

The facilities in the auxiliary and fuel-handling buildings (as well as contaminated piping connecting the two buildings and containments) would be removed in much the same manner, keeping the essential equipment in service.

After the removal of all radioactive materials and contamination from surfaces, these facilities would also be released. As for the containment, ordinary industrial hazards would be eliminated by demolition, removal, or filling with sand. The site would then be comprehensively surveyed for residual contamination by SCE and the NRC, and finally released for unrestricted use. If any further "nuclear" use were made of the site, it would be under a new license.

All remaining plant structures including power lines, towers, fences, macadam roadways, and parking facilities would be removed and buried in a landfill. For the purposes of this option, it is assumed that the landfill would have to be licensed by

the State, and that it would be in the Japanese Mesa area. Removal would proceed on the basis of the following outline:

1. Removing of all aboveground structures to at least 6 feet below grade.

2. Removing of the intake discharge structure and collapsing the conduits to the turbine building.

3. Collapsing of all subterranean voids more than 6 feet below grade.

4. Removing of buried pipe down to 20 feet below grade.

After removal of all structures in accordance with the above list, the site would be restored by filling all remaining holes; essential grading, planting, and replacement of rock, as required to prevent erosion and to protect the coastline, would complete the effort.

Table 1

San Onofre Nuclear Generating Station, Unit No. 2 & 3
Minimum Decommissioning, Immediate Removal
FPC Account Classification Summary, 1979 Dollars (thousands)

	Account	-3	-2	-1	1	2	3	4	5	6	7	8	9	Total
SCE Site Decommissioning Labor	321	33	59	166	331	596	629	398	397	365	298	265	252	3,789
	322	80	144	402	804	1,447	1,526	965	965	884	723	643	610	9,193
	323	5	9	24	47	85	90	57	57	52	43	38	36	543
	324	4	7	18	37	65	68	43	43	40	33	29	28	415
	325	2	5	12	25	46	48	29	29	28	23	20	19	286
	Misc.	1	1	3	6	11	14	8	9	6	5	5	5	74
Subtotal:		125	225	625	1,250	2,250	2,375	1,500	1,500	1,375	1,125	1,000	950	14,300
SCE Staff Labor & Consultants	321	28	55	55	40	40	40	40	40	40	40	40	40	498
	322	249	502	502	352	352	352	352	352	352	352	352	352	4,421
	323	4	6	6	4	4	4	4	4	4	4	4	4	52
	324	7	16	16	12	12	12	12	12	12	12	12	12	147
	325	6	11	11	8	8	8	8	8	8	8	8	8	100
	Misc.	-	4	4	2	2	2	2	2	2	2	2	2	26
Subtotal:		294	594	594	418	418	418	418	418	418	418	418	418	5,244
Craft Labor	321	-	-	-	825	825	2,888	5,362	9,075	9,900	9,900	9,075	3,261	51,111
	322	-	-	-	143	143	501	930	1,573	1,716	1,716	1,573	572	8,867
	323	-	-	-	3	3	10	20	33	36	36	33	12	186
	324	-	-	-	19	19	66	123	209	228	228	209	76	1,177
	325	-	-	-	10	10	35	65	110	120	120	110	40	620
	Misc.	-	-	-	-	-	-	-	-	-	-	-	39	39
Subtotal:		-	-	-	1,000	1,000	3,500	6,500	11,000	12,000	12,000	11,000	4,000	62,000
Subcontracts:														
Manipulator	322	-	-	-	-	-	-	2,500	-	-	-	-	-	2,500
Decontamination	322	-	-	-	2,695	-	2,695	-	-	-	-	-	-	5,390
Waste Disposal	321	-	-	-	-	300	168	439	1,007	1,007	840	140	140	4,041
	322	-	-	-	646	3,830	1,292	4,141	-	957	-	-	-	10,866
Removal Costs	321	-	-	-	447	1,341	1,564	1,564	670	-	-	-	-	5,586
For Salvage	322	-	-	-	112	336	392	392	168	-	-	-	-	1,400
	323	-	-	-	402	1,206	1,407	1,407	603	-	-	-	-	5,025
	324	-	-	-	39	117	137	137	59	-	-	-	-	489
Material & Equipment	All	-	-	-	7,725	12,154	6,077	-	-	-	-	-	-	25,956
Subtotal:		-	-	-	12,066	19,284	13,732	10,580	2,507	1,964	840	140	140	61,253
Contingency - 15%														21,420
Total Decommissioning Cost		419	819	1,219	14,734	22,952	20,025	18,998	15,425	15,757	14,383	12,558	5,508	164,217
SCE Site Labor - (O & M and Security)		125	225	625	1,250	2,250	2,375	1,500	1,500	1,375	1,125	1,000	945	14,295
Nuclear Indemnification		-	-	-	100	100	100	10	10	10	10	10	10	360
Property Insurance		-	-	-	300	300	300	300	300	300	300	300	300	2,700
TOTAL COST:		544	1,044	1,844	16,384	25,602	22,800	20,808	17,235	17,442	15,818	13,868	6,763	181,572

TABLE 2

SCRAP AND SALVAGE VALUE

	Item and FERC Account Number		$ 1979[1]
1.	Turbine Generators and Associated Equipment		
	Account	323 (turbine generator)	1,700,500
		324 (electrical)	819,000
2.	Main Condenser		
	Account	323 (turbine generator)	915,000
3.	Major Pump Drive Motors		
	Account	324 (electrical)	2,660,000
4.	Transformers, Switchgear		
	Account	324 (electrical)	685,000
	Account	325 (miscellaneous)	520,000
5.	Miscellaneous Tanks, Structural Steel and Scrap Steel[2]		
	Account	322 (reactor)	2,474,500
	Account	323 (turbine generator)	2,380,000
	Total:		$12,154,000

(1) Values are per unit.

(2) Based on 7 cents/lb., FOB site, in movable sizes.

TABLE 3

DECOMMISSIONING COST SUMMARY

Account	Removal Cost Units 2 & 3 $1,000	%	Removal Cost Unit 2 $1,000	%
321	66,673	47	29,796	45
322	47,586	33	23,750	35
323	15,797	11	7,898	12
324	10,~~566~~ 556	7	4,684	7
325	2,046	2	812	1
Misc.	139	-	70	-
	$142,797	100	$67,010	100
Contingency -15%	$ 21,420		$10,052	

Account	Salvage per unit Unit 2 or 3 $1,000	%
321	-	-
322	2,475	21
323	4,995	41
324	4,164	34
325	520	4
Misc.	-	-
	$12,154	100