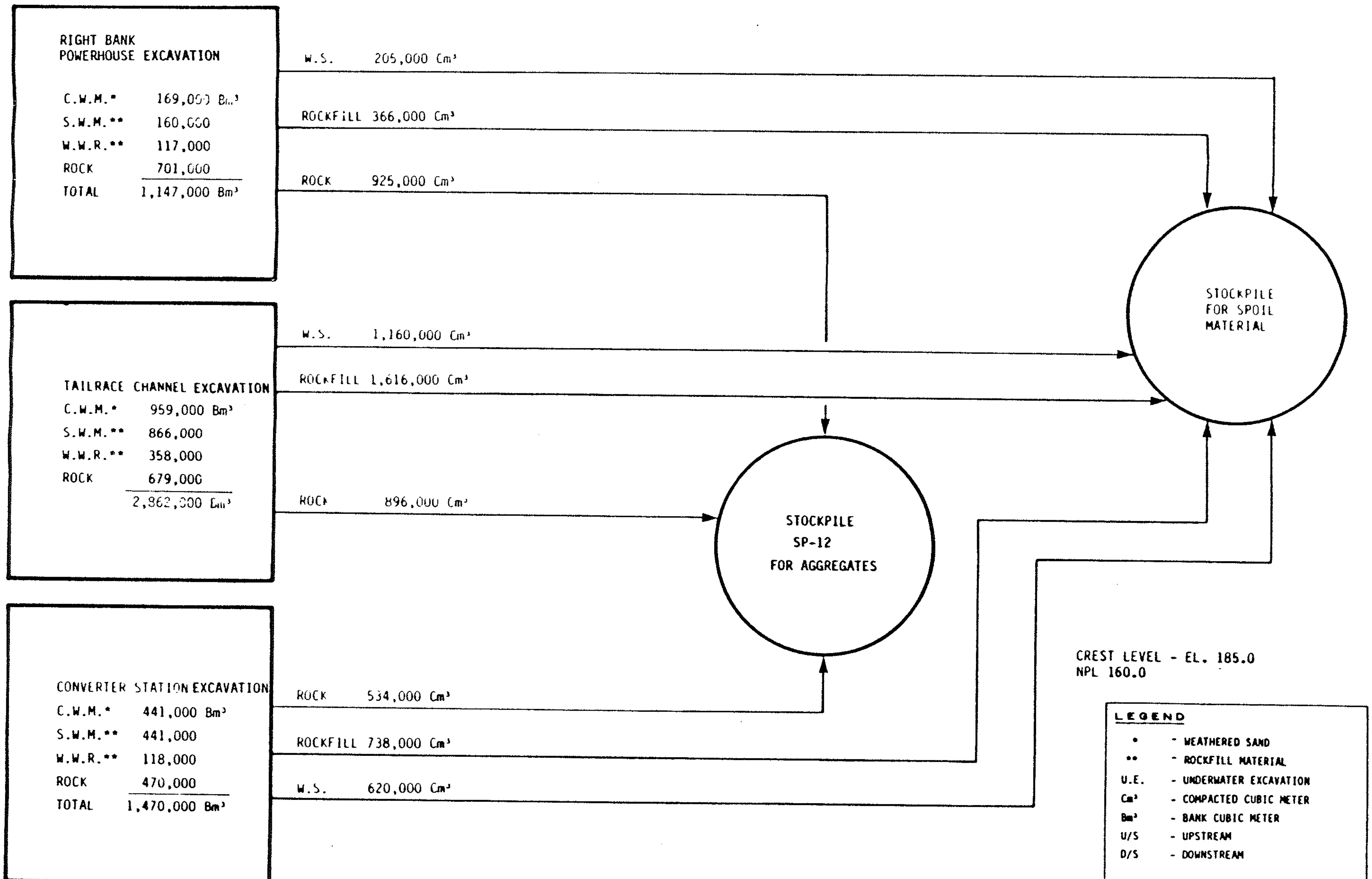


LEGEND

*	- WEATHERED SAND
**	- ROCKFILL MATERIAL
U.E.	- UNDERWATER EXCAVATION
Cm³	- COMPACTED CUBIC METER
Bm³	- BANK CUBIC METER
U/S	- UPSTREAM
D/S	- DOWNSTREAM
C.W.M.	- COMPLETELY WEATHERED MATERIAL
S.W.M.	- STRONGLY WEATHERED MATERIAL
W.W.M.	- WEAKLY WEATHERED MATERIAL
W.S.	- WEATHERED SAND
R.	- ROCK

THREE GORGES PROJECT FEASIBILITY REPORT
RIGHT BANK POWERHOUSE
AND CONVERTER STATION EXCAVATION

Volume 2
FIGURE 4.21

The right bank powerhouse construction is shown on schedule **Plate 2.31.** A starting date of August of Year 12 for the powerhouse civil work is considered reasonable by CYJV since there does not appear to be as much room for an early start on the inshore end of the right bank powerhouse as there was for the left bank powerhouse. The 47 month period from an August of Year 12 start gives an in–service date of July of Year 16 for the first unit of the right bank powerhouse. Water for testing the units is needed about 6 months after the projected dam completion date, October of Year 15.

While there is some potential for an earlier start of the powerhouse a detailed study would be needed to confirm that the early start would allow earlier commissioning of the powerhouse. An early start would also have to be coordinated with construction of the Stage III RCC cofferdam.

The 47 month period allowed from the start of concreting to the in–service date of first unit is a realistic schedule based on the analysis of the left bank powerhouse construction. There is however, potential reduction of time for some activities due to the experience gained on the previous powerhouse work in addition to the possibility of an early start of concrete work as mentioned above. On a project of such a long duration, an acceleration of the construction program for the last phase has a high probability. Many factors will contribute such as starting installation of units a few months earlier, time saved in the assembly and installation of units, shorter testing period, etc.

With a scheduled start of August of Year 12 and the same durations as in the left bank powerhouse the resultant work requirements per month are shown on **Figure 4.18** Schedule B. Comparison with the requirements for the left bank powerhouse (Schedule A) shows that there will be an increased intensity of work required in the right bank powerhouse. Four rotors are required to be assembled at the same time on the floor while other installation work is in progress.

4.4.5 RCC Cofferdam Removal

After the intake channel for the penstock intakes for the right bank powerhouse has been excavated to El 90, the top of the RCC cofferdam above El 90 estimated at approximately 313 000 m^3 of concrete will have to be removed.

The RCC cofferdam is approximately 70 m from the upstream face of the dam. Based on experience it is considered that controlled blasting to remove the cofferdam can be carried out successfully without damage to the intake dam or gates. Drilling of the blast holes should be carried out in the dry before the first blast is made and all holes should have casing installed. While it will be an advantage to have the casings extend to above the reservoir water level it is anticipated that these could be lost and some underwater work would be required after the first blast. A very preliminary estimate has indicated that blasting patterns of 1.5 m x 1.5 m to 2.25 m x 2.25 m with holes of about 65 mm to 75 mm diameter loaded with 0.5 to 0.9 kg per m^3 of an explosive such as CIL Inc.'s Hydromex M210 could be used successfully. Proper control of the size and delays would be necessary for individual blasts.

4.5 Navigation Facilities

The navigation structures for the Chinese base scheme having a normal pool level of El 150 were analyzed in detail to assess the feasibility of that scheme. The CYJV Recommended Project has a similar arrangement of navigation structures but requires five flights of locks for the higher normal pool level of El 160. The Recommended Project allows an additional year for construction of the permanent flightlocks and does not include the shiplift. The conclusions with regard to schedule and construction methods were arrived at by comparing the Recommended Project with the base scheme and prorating the results of the detailed study. The schedule of constructing the navigation facilities for the Recommended Project is shown on **Plate 2.6**.

4.5.1 Temporary Shiplock

CYJV proposed that the temporary shiplock be designed to operate for tailwater levels down to El 63 and headwater levels up to El 96, a lift of 33 m. The YVPO base scheme would operate only up to El 76 and rely on the shiplift for higher headwater levels.

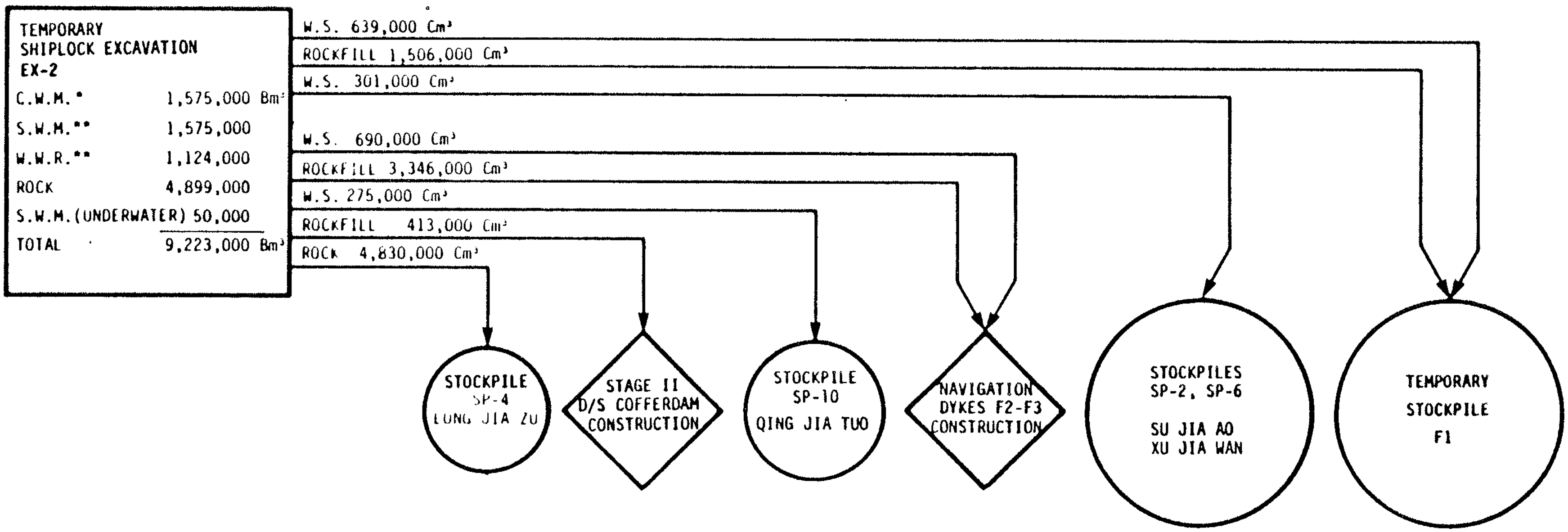
The temporary shiplock requires an estimated $9.2 \times 10^6 m^3$ of open cut excavation. The work is scheduled to start at the beginning of Year 3 and be completed at end of Year 6. The quantities and proposed use of the material is shown on flow diagram **Figure 4.22.**

The method of excavation of the different types and layers of material will be as described in Section 3.3. It is planned to use 77 and 45 t trucks and $9.5 m^3$ hydraulic excavators, 10.5 and 5.4 m^3 loaders for the loading and hauling of the material. A peak production rate of about 2.8×10^6 m^3 is planned for Year 3 and decreases in the next three years.

The temporary shiplock concrete works has been estimated at 603 000 m^3 including the inlet structure plug. The main concrete work is carried out in Years 5 and 6, and the plug is completed in 12. The lock is scheduled to be in service on 1 May of Year 7 prior to the flood season. The temporary lock provides supplementary navigation capacity to the right bank diversion channel through 1 May of Year 12.

The commencement of impoundment in May of Year 12 requires that the upstream stoplogs be placed and the lock taken out of service. The inlet structure plug is then concreted to El 185.

The construction scheme for the schedule was based on the layout and schedule shown on YVPO **Dwg. 8–45.**



LEGEND

*	- WEATHERED SAND	C.W.M.	- COMPLETELY WEATHERED MATERIAL
**	- ROCKFILL MATERIAL	S.W.M.	- STRONGLY WEATHERED MATERIAL
U.E.	- UNDERWATER EXCAVATION	W.W.M.	- WEAKLY WEATHERED MATERIAL
Cm³	- COMPACTED CUBIC METER	W.S.	- WEATHERED SAND
Bm³	- BANK CUBIC METER	R.	- ROCK
U/S	- UPSTREAM	F2	- LEFT BANK ISOLATING DYKE
D/S	- DOWNSTREAM	F3	- MAIN NAVIGATION DYKE AND CLOSING COFFERDAM

CREST LEVEL - EL. 185.0
NPL 160.0

THREE GORGES PROJECT FEASIBILITY REPORT

TEMPORARY SHIPLOCK EXCAVATION

Volume 2
FIGURE 4.22

The construction equipment layout included concrete delivered by rubber tired vehicles along a road to the right of the facilities and across a trestle located just upstream of the headworks, all at El 115. Concrete placement was by 3–20 t whirley cranes, one on the right shoulder, one on the upstream trestle and one on bolsters on the centerline of the shiplock headworks.

Any required foundation support and treatment was assumed to be completed concurrent with the excavation. The installation of the trestle and cranes was scheduled to start upon completion of excavation and commencement of the headworks concrete on 1 October Year 3.

In general 2 m lifts were assumed. The individual lifts were reviewed and judgement was applied as to time durations. This included allowances for galleries, water passages, primary embedments, soffits, form changes, etc.

For the shiplock passage through the headworks it was assumed that a good deal of preparatory work will be carried out prior to the installation of preassembled soffit packages. This may involve the preinstallation on scaffolding or embedment of "seats" in previous lift concrete to support the soffit form packages.

The excavation of the channel plugs is scheduled from December of Year 6 through March of Year 7, with the upstream plug at elevation 85 m and the channel invert at elevation 60 m. It was assumed the plug would be breached about 1 February of Year 7. The upstream stoplogs must be completed prior to this date.

By May 1 of Year 12 the Phase III RCC cofferdam will be advanced sufficiently for impoundment of the reservoir to begin. The reservoir level is expected to reach El 130 by about July 1 of that year.

The temporary shiplock becomes inoperable when the reservoir level reaches elevation 96 m. At that time the upstream stoplogs are placed in the opening, the lock chamber is dewatered and the construction of the concrete plug to permanently block the temporary lock begins.

Placement rate of this plug concrete will be constrained by temperature controls. This would require that the lift height be 1.5 m and that the concrete is precooled to 7 C and postcooled to 8 C prior to the contact grouting of the top surface only.

It is recognized that this opening may be utilized for additional auxiliary spillway capacity or for additional generating plant, but this has not been included in the construction analysis.

Analysis of the schedule indicates that it is feasible to construct the concrete structures in the time provided. The critical path for the facility passes through the excavation, construction of the headworks, installation of stoplogs and removal of the upstream channel rock plug.

4.5.2 Permanent Shiplocks

The largest excavations on the Recommended Project are for the permanent shiplocks, with an estimated quantity of 24.5×10^6 m^3 of material. The breakdown is as follows:

Upstream Channel	–	$2.2 \times 10^6 m^3$
Downstream Channel	–	$2.5 \times 10^6 m^3$
Tunnel Excavation	–	$1.3 \times 10^6 m^3$
Lock Chambers 1 and 2	–	$8.2 \times 10^6 m^3$
Lock Chambers 3, 4 and 5	–	$10.3 \times 10^6 m^3$
Total		$24.5 \times 10^6 m^3$

The type of material and the proposed use is shown on flow diagram **Figure 4.23.**

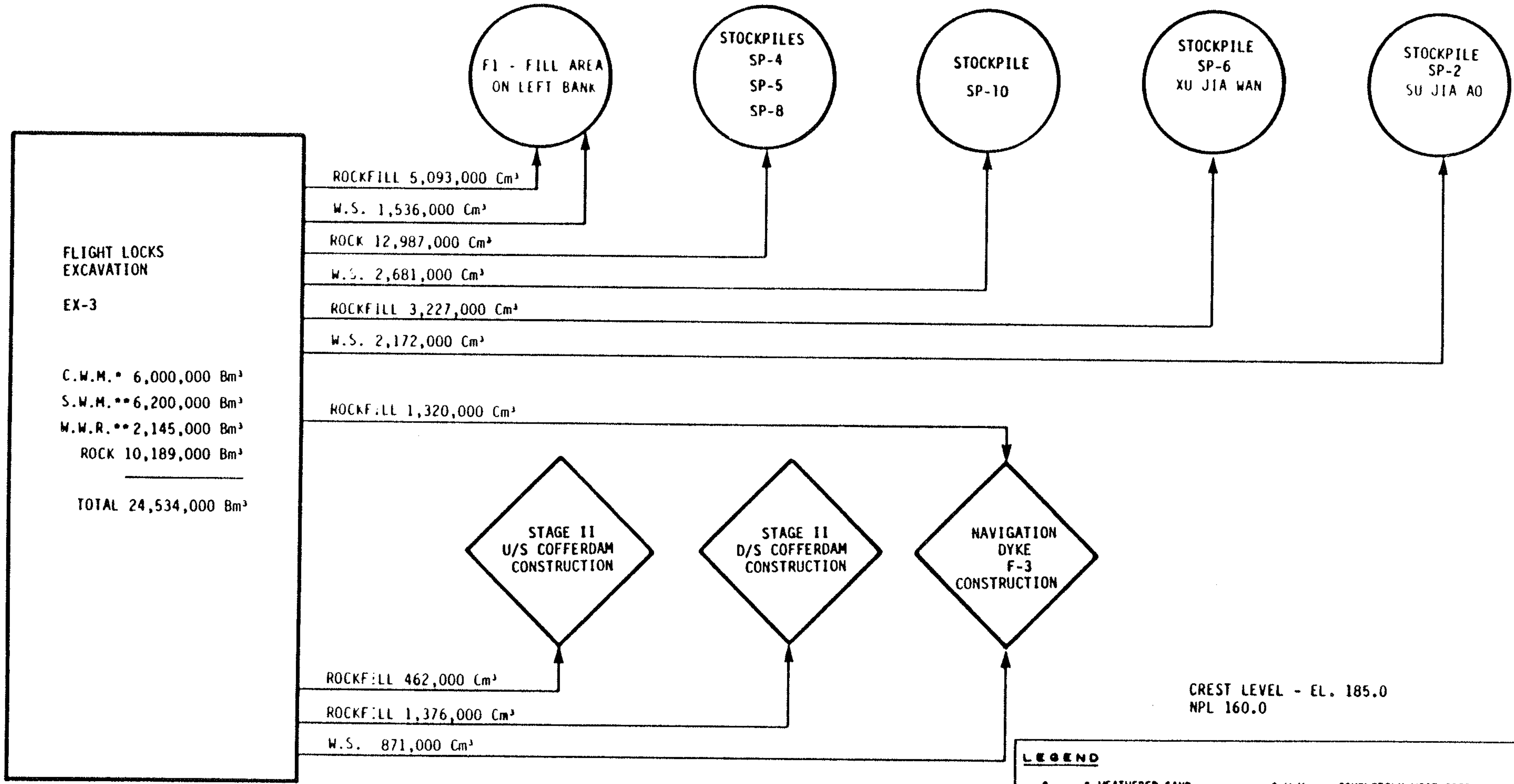
Referring to the Master Project Schedule **Plate 2.6,** it is planned to start underground excavation for the water filling system at the beginning of Year 3, the open cut excavation for the lock chambers at the beginning of Year 4, the concreting in mid Year 6 and conclude with completion of the lock chambers mechanical works at the end of June of Year 12. The permanent facilities are put into service on 1 July Year 12, as intermediate impounding of the reservoir reaches El 130.

It is planned to use 77 and 45 t trucks for hauling of material and 9.5 m^3 hydraulic excavators and 10.5 and 5.4 m^3 loaders for loading of material. The yearly peak excavation is estimated at $9.0 \times 10^6 m^3$ in Year 6 (see **Figure 3.2**).

The foundation support, rock bolting and drainage work will be carried out concurrently with the excavation and the methods are described in detail in Volume 4, Section 3.4.4. The shiplock concrete quantity is estimated at $4.08 \times 10^6 m^3$ **(Plate 2.37)**.

The concrete for the underground water filling system for the locks, including tunnels, shafts and chambers was not reviewed in detail since it was considered non critical. The constraint that the underground excavation is completed prior to the adjacent open cut excavations results in subsequent float available for placement of concrete linings. In addition, various options exist for the opening of additional faces for construction of the linings. Therefore, the concrete quantity and schedule estimate was averaged over the year and added to the surface structures to complete the schedule analysis.

The surface structures were broken down into head works, lockheads, outlet works, chamber walls, slabs and downstream training walls. These were further subdivided by block and isometrics of the blocks were prepared. The volume was calculated and the quantities tabulated. The blocks were then subdivided by lift and the quantities were calculated by



NOTE: QUANTITIES ON THE LEFT ARE EXPRESSED IN BENCH m³ AND QUANTITIES ON THE RIGHT ARE IN COMPACTED m³

LEGEND

*	- WEATHERED SAND	C.W.M.	- COMPLETELY WEATHERED MATERIAL
**	- ROCKFILL MATERIAL	S.W.M.	- STRONGLY WEATHERED MATERIAL
U.E.	- UNDERWATER EXCAVATION	W.W.M.	- WEAKLY WEATHERED MATERIAL
Cm³	- COMPACTED CUBIC METER	W.S.	- WEATHERED SAND
Bm³	- BANK CUBIC METER	R.	- ROCK
U/S	- UPSTREAM		
D/S	- DOWNSTREAM		

THREE GORGES PROJECT FEASIBILITY REPORT

PERMANENT SHIPLOCKS EXCAVATION

Volume 2
FIGURE 4.23

lift and accumulated by structure. Based on the **YVPO Drawing 84–6–31**, average lifts of 2.5 m were used for quantity and scheduling purposes.

The second phase of the review was the preparation of the concrete placement schedule.

The concrete placement schedule was based on the construction scheme shown on YVPO **Drawings 8–46** and **8–47** which call for sequential completion of concrete in the chambers and completion of structures prior to placement of slabs.

The major equipment includes 20 t whirley cranes on bolsters, one for each lock located at the head and outlet works. The intermediate lockheads and the chamber walls and slabs are constructed by 10 t tower cranes located on a trestle erected along the centre line of each lock chamber.

The concrete is delivered by rubber tired bucket haulers from production centre F located near the locks at El 110 as shown on **Plate 2.3.** The bucket haulers deliver the concrete to the cranes approximately 50 m above the invert of the chambers and the concrete is generally lowered to placement. The peak placement requirement is estimated at about $1.0 \times 10^6 m^3$ in Year 8.

The schedule for placement of the chamber slabs is based on the assumption that the slabs are placed progressively as the tower crane trestle is removed. The last sections of slab in each chamber are then placed by mobile crane before the removal of the tower crane and last section of trestle. This requires the selection of the appropriate section to be completed last and the design of the trestle to meet this condition.

In general, 2 m lifts were used, with the exception of some off rock lifts which varied in height, and some slab lifts which were reduced to 1 m depending on invert and soffits of galleries and water passages and for the last slab lift.

The outlet mitre gates are scheduled to be completed in 10 months by 31 March Year 12. This is followed by the breaching and excavation of the downstream plug in April and May. The scheduled in–service date of the facility is 1 July Year 12.

Since the schedule review indicates the construction is feasible in the time required, further optimization has not been carried out. Various options exist which may reduce the duration of the work and provide some slack time. These options include:

– rearrangement of work precedence between headwork blocks;

– concurrent work on lockhead and outlet;

- priority for blocks containing mitre gate recesses to expedite installation of mitre gates;

- more concurrent work between lock chambers 1 and 2 slabs and chamber 3 and 4 structures; and

- the demand on the 10 t tower cranes when placing concrete in chamber walls is low (as long as significant overbreak is not experienced) and high during placement of slabs.

If the walls were constructed in thirds e.g. middle third first, the trestle can be progressively removed and the walls and slabs constructed concurrently. Therefore, while the schedule review indicates that the chamber walls can be constructed with one 10 t tower crane (2 shift/ workday), it may be beneficial to use 2 – 10 t tower cranes as indicated by YVPO and construct walls and slabs concurrently.

The schedule analysis indicates that the construction of the facility within the time provided is feasible. The critical path for the facility passes through the excavation for chambers, concreting for chambers and installation of the mitre gates. A concurrent critical path exists through the completion of the chamber slabs.

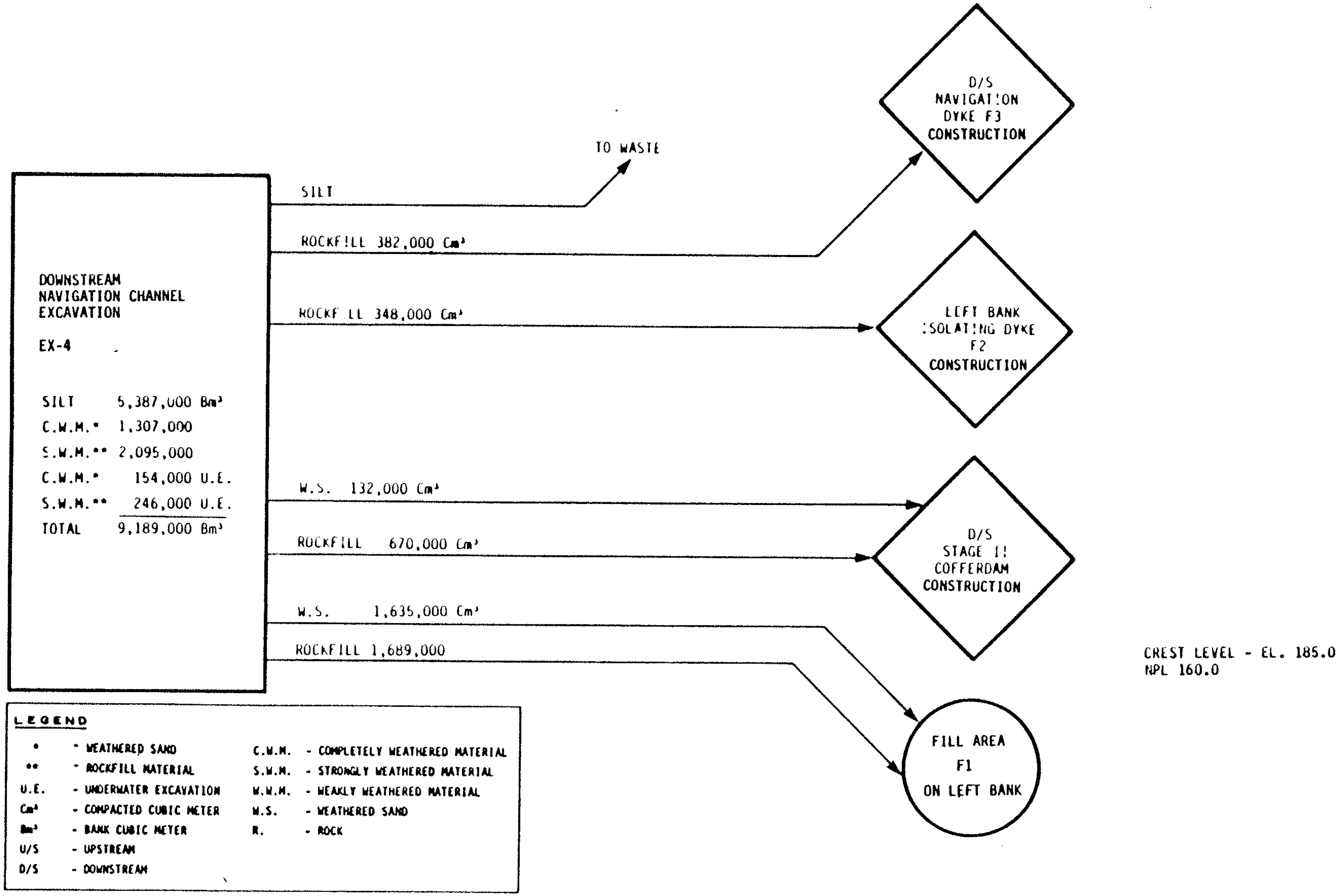
4.5.3 Downstream Navigation Channel Excavation

The total excavation in the downstream navigation channel is estimated at $9.2 \times 10^6 m^3$ comprising $5.4 \times 10^6 m^3$ of silt and $3.8 \times 10^6 m^3$ of weathered sand and rock.

The type of material, quantities and proposed use are shown on **Figure 4.24.**

It is planned to excavate the silt underwater with suction or bucket wheel dredge and use the material as backfill for the area inside the isolating dyke F2 shown on **Plate 2.3.**

A large quantity of the weathered material $3.4 \times 10^6 m^3$, will be excavated in the dry within the confinement of the downstream navigation dyke F3, the left bank isolating dyke F2 and a temporary cofferdam at the downstream end of the navigation dyke. The material under the temporary cofferdam and in the outlet of the channel will be excavated underwater. The quantity is $400\,000 m^3$.



THREE GORGES PROJECT FEASIBILITY REPORT

DOWNSTREAM NAVIGATION CHANNEL EXCAVATION

Volume 2
FIGURE 4.24

5. SCHEDULES

All schedules begin in January of Year 1 with the Preparatory Phase, which is the start of Construction Support Facilities. For the purposes of this study, this is assumed to be January 1989. Project approval would be required a minimum of 6 months earlier which would be by July 1988.

The work has been planned on the basis of optimal coordination under the aegis of a single management group, with constraints imposed only by technical limitations of design, physical space limitations of the site and production limitations of the proposed construction equipment. No constraints were imposed on coordination of the work because of contractual priorities which may be established during contract packaging.

5.1 River Diversion Sequence

As the project construction schedule is governed by the river diversion sequence, this section provides an outline of the diversion method.

The presence of Zhong Bao Island at the damsite divides the river into a main channel on the left and a subsidiary or flood channel on the right. These geographical features make an ideal situation for creating a temporary diversion channel in the right bank subsidiary channel and hence the facility to divert the river from one side to the other. All work in the river has to be coordinated with the river stages and because of the required scale of the controlling structures this imposes particularly difficult construction problems for the Stage II and III cofferdams. The scheduling difficulties for constructing the permanent works behind the cofferdams results from having to build at the fastest rate possible to obtain maximum project benefits and to coordinate the work with cofferdam construction and removal.

5.1.1 Selected Diversion Scheme

The proposed river diversion phases are shown on **Plate 2.4** and on the Project Master Schedule, **Plates 2.5** and **2.6**.

<u>The phases are as follows:</u>

- Phase I in which the Stage I cofferdams are constructed, permitting excavation of the diversion channel in the dry, construction of the concrete longitudinal wall and finally, removal of the Stage I cofferdams allowing water to flow through the channel.

- Phase II in which the Stage II cofferdams are constructed, rerouting the Yangtze River through the diversion channel and permitting foundation excavation and concreting for the spillway dam, the left bank intake dam, and the left bank powerhouse. Phase II also includes the removal of the Stage II cofferdams allowing water to flow through both the temporary diversion ports in the spillway and the permanent spillway openings.

- Phase III in which the Stage III cofferdams are closed to block the diversion channel so that the river flows through the openings in the spillway dam. This permits construction of the RCC cofferdam in the diversion channel. After completion of the RCC cofferdam, the diversion outlets in the spillway will be closed and the reservoir filled to El 130, allowing the start of generation in the left bank powerhouse. Behind the RCC cofferdam, the right bank intake dam and the right bank powerhouse are then constructed. Phase III continues till the last generating unit in the right powerhouse has been installed and the top portion of the RCC cofferdam has been removed.

5.1.2 Alternative Diversion Scheme

The CYJV feasibility study has received and adopted the YVPO diversion scheme described in the previous section. Two alternative schemes have also been studied by YVPO and are described in the YVPO Design Report, 1985, Volume 8. Briefly they are as follows:

Alternative 1:

During Phase I, excavate a diversion channel and construct the right bank intake dam section in it to El 73 with 20 low level diversion outlets at El 48.

In Phase II, the 2nd stage cofferdams are constructed and the river flow is diverted in December of year 6 through the right diversion channel and through the low level outlets with the temporary spillway formed by the intake dam at 73 m available for passing high flows. Throughout Phase II construction, the right bank diversion channel and diversion outlets would be used for river diversion only and only the temporary lock would be available for navigation. The temporary navigation facilities may be inadequate for traffic in which case additional facilities would be required. After the flood season of year 10, when left bank dam and spillway have reached El 110, the 2nd stage cofferdams are removed and the right bank dam is raised to El 95 with provision of a temporary weir at that elevation. This work is completed before the year 11 flood season. Then in low water season year 10–11 the right bank dam is raised to 135 m, with temporary weir incorporated at that elevation.

In April of year 12, the low level outlets in the right intake dam are closed and reservoir is impounded to El 130 for initial power generation. Excess flows would then be discharged through the submerged spillway bays.

Alternative 2:

In this alternative, the spillway would be located in the right bank diversion channel and the whole powerhouse in the left bank main channel.

In phase I work, the spillway dam is constructed to El 73 to form a temporary weir and diversion outlets are provided at El 50 and 66. The upstream water level would reach 92.5 m at a flood discharge of 79 000 m^3/s. In phase II work, the 2nd stage cofferdams are constructed and main river channel closed in December of year 6. The partially constructed spillway will serve as the river diversion structure and navigation will be routed through the temporary shiplock. The shiplock may be inadequate for traffic and additional installations may be required.

CYJV have recognized these possibilities but have not studied them in view of the joint decision by MWREP and MOC that the right bank diversion channel should be used for navigation during Phase II construction.

In addition to the above alternatives, it may be of interest to consider starting Stage III RCC cofferdam one year earlier which means that it would be used as a temporary overflow weir with crest at 80 m for one flood season. This alternative would permit the use of the channel for navigation during 4 years while providing one additional year for construction of the RCC cofferdam.

A detailed study of these alternatives is recommended during the detailed design stage.

5.2 Master Project Schedule

The project schedule is divided into five groups of activities. These are Preparatory Works, Stage I Works, Stage II Works, Stage III Works and Navigation Facilities. In each of the three numbered stages the first major activity is the construction of the cofferdams designated by the same number. Thus the first major activity in Stage I is construction of the Stage I cofferdams.

The master project schedule for the Recommended Project is presented in two parts on **Plates 2.5** and **2.6**.

The total project duration, from the start of construction support facilities, assumed as 1 January of Year 1, to the in–service date of the last generating unit is 18 years. First power will be generated 11 years and 8 months from the start of construction support facilities or 9 years and 11 months after the start of construction of the Stage I cofferdams which is assumed to be 1 October of Year 2.

It is significant that construction of the project is virtually completed in mid–year 16 with installation of the last six generating units the only activity thereafter.

The master project schedule is based on the construction analysis and methods, rates, equipment and construction sequences determined in Sections 2, 3 and 4 of this report.

5.2.1 Major Project Milestones

The key construction and in–service milestones which result from the CYJV study and assuming 1989 as the first year of the project are:

Date	Schedule Year	Milestone
Preparatory Phase		
July 1988	0	Project Approval
January 1989	1	Start of Construction Support Facilities
January 1990	2	Approval of Stage I Construction
Phase I		
October 1990	2	Start of Stage I cofferdam construction
July 1991	3	Finish Stage I Cofferdam. Initial Loop
February 1994	6	Flood the Diversion Channel
July 1994	6	Diversion Channel available for Navigation
Phase II		
December 1994	6	Close Main River Channel
May 1995	7	Finish Temporary Shiplock
July 1995	7	Finish Stage II Cofferdams
June 1999	11	Breach Stage II Cofferdams
Phase III		
December 1999	11	Close Diversion Channel
February 2000	12	Start Stage III RCC Cofferdam
May 2000	12	Close Diversion Outlet Gates
June 2000	12	Finish Stage III RCC Cofferdam

July 2000	12	Impound Reservoir to El 130
July 2000	12	Finish Permanent Shiplocks
September 2000	12	First Unit in Left Bank Powerhouse In Service
October 2002	14	Final Unit in Left Bank Powerhouse In–Service
May 2003	15	Raise Overflow Spillways to El 146
January 2004	16	Breach Stage III Downstream Cofferdam
May 2004	16	Finish Removal Stage III RCC Cofferdam
May 2004	16	Finish Overflow Spillways to El 158
July 2004	16	First Unit in Right Bank Powerhouse In Service
September 2004	16	Impound Reservoir to Normal Operating Level
December 2006	18	Final Unit in Right Bank Powerhouse In Service

5.2.2 Critical Path

The project critical path or the chain of activities which determines the duration of the construction, is 11 years 8 months to first power and 18 years to in–service date of last generating unit.

The critical path to first power, is as follows:

–	The preparatory phase of the construction support facilities	21.0 months
–	Stage I cofferdam construction and dewatering	11.0 months
–	Excavation of diversion channel	29.0 months
–	Removal of Stage I cofferdam	8.0 months
–	Construction of Stage II cofferdam and dewatering	11.0 months
–	Excavation and concreting of spillway and intake dam structures	45.0 months

– Removal of Stage II cofferdam		6.0 months
– Construction of Stage III rockfill cofferdams		2.5 months
– Stage III RCC cofferdam		4.0 months
– Testing of unit # 1		2.5 months
	TOTAL	140.0 months or 11 years 8 months

The critical path to the in–service date of last unit is similar to the previous one from year 1 to completion of Stage III RCC cofferdam on 15 June year 12. From thereon, the events are as follows:

– Start of project to completion of RCC cofferdam		137.5 months
– Excavation and concreting of right bank powerhouse		23.5 months
– Installation and testing of turbine generators (11 units)		55.0 months
	TOTAL	216.0 months or 18 years

5.2.3 Critical Path Analysis

The construction analysis and scheduling described in this report were carried out on the basis of North American and international construction practices and experience at similar large scale projects. The successful completion of the Three Gorges Project within the proposed schedule is conditional upon adopting North American and international methods and particularly upon the creation of a strong project management team to deal with project implementation.

An analysis of critical activities of the project was made to evaluate the risk of delays in the in–service date of the first unit and in the completion date of the overall project and to determine the slack time available in the various phases of the schedule. The analysis does not include any allowance for risk of late delivery of materials and services.

The schedule of construction of the Three Gorges Project is, to a significant degree, influenced by the seasonal floods of the river. Failure to start or complete an activity on schedule has the potential to result in a delay of one year. The activities that are most vulnerable to floods are the Stage I, Stage II and Stage III cofferdam construction.

The discussion below on the project critical path described in article 5.2.2 is based on the detailed studies of the construction activities and schedule. The purpose was to identify the slack time, the critical activities and the alternatives that may ease scheduling risks.

Preparatory Phase

Twenty–one months have been allowed for preparatory activities before starting the construction of Stage I cofferdam scheduled to begin in October of year 2. Important activities before the start of Stage I cofferdam include the construction of camps, roads and docks as well as the development of a rock quarry on the right bank. The critical path for the work in this phase could be less. However, the schedule was not shortened because the overall quantity of work and number of different activities is so great. A delay of a few months in the start of the preparatory work will not necessarily delay the start of Stage I cofferdam. Similarly an earlier start of the preparatory period (say 3 months) will not improve the starting date of Stage I cofferdam because the start is controlled by the flood season. Twenty–one months is judged a sufficient period to complete all installations required to start the cofferdam work.

Phase I

Phase I starts with Stage I cofferdam and ends when main river channel is closed in December of year 6 as shown on **Plate 2.5**. The critical path runs through Stage I cofferdam construction; the diversion channel excavation; the Stage I cofferdam removal; and the rockfill closure for the Stage II cofferdam. The total available time is 50 months with about 10% slack time. The peak placement rate of 800 000 m^3 per month of fill in Stage I cofferdam (see **Plate 2.9**) and peak excavation rate of 900 000 m^3 per month (see **Plate 2.11**) in the diversion channel are within the calculated production capability.

Phase II

Phase II is scheduled over 60 months from December year 6 to December year 11 and the critical path runs through the completion of Stage II cofferdams construction; the concreting of the spillway; the removal of Stage II cofferdams and the rockfill closure for the Stage III cofferdam.

The construction of Stage II cofferdams is scheduled to be completed on 1 July year 7 before the flood season. To meet the schedule, average peak placement rates of 2000 m^3 per hour (see Section 4.3.1) are required on each cofferdam. The rates are within the placement capability using large and efficient equipment. The high rates of placement of fill and the time for cutoff wall construction make Stage II cofferdam construction a critical item. The schedule provides about 5% slack time and additional studies of alternatives are recommended to reduce the criticality.

In Phase II, the construction of the spillway is also critical. It is scheduled to start in year 7 after dewatering between Stage II cofferdams and to be completed by 1 June year 11 before intake and tailrace flooding. The construction period is 45 months including foundation excavation with a slack time of about 5%.

The last activity on the critical path of Phase II work is the removal of Stage II cofferdams and the diversion of the river flow through the low level outlets in the spillway. There are 8 months available for this work from April year 11 to December year 11 with about a 20% slack time.

Phase II work can be carried out within the scheduled duration although Stage II cofferdam schedule is tight and will need a high degree of planning and organization. A reevaluation of the construction methods and equipment size would be appropriate for all of the Phase II work in order to insure that no unexpected difficulties arise.

Phase III

The work in Phase III begins with the closure of the diversion channel in December year 11 and continues to end of December year 18 when the project is completed. It has a duration of 85 months. The most critical activity of this phase and, indeed, of the entire construction schedule is the closing of the diversion channel and the construction of Stage III RCC cofferdam in the first half of year 12 to permit the reservoir to be filled to El 130 for commissioning of the first generating units in the left bank powerhouse. The schedule for the Stage III RCC cofferdam construction is critical because the available time is only 3 1/2 months to construct the 950 000 m^3 RCC structure. The average placement rate required to meet the schedule is 600 m^3 per hour with peak rates in excess of 800 m^3 per hour (see Appendix B). These rates are well above the rates obtained on RCC structures to date. There is no slack time in the schedule and the risk of a delay is considered to be high. Additional studies should be carried out to see how more time can be provided for this activity or of other diversion or cofferdam schemes to avoid this critical schedule.

Failure to close the diversion gates as scheduled, in order to raise the water level for bringing the first generating units into service, would not delay the completion of the project. It would delay only the in–service dates for the first four generating units.

The other activities to completion of the last generating unit of the project including construction of the right bank intake dam and powerhouse are not critical. Slack time is available over the 78–month period as the commissioning of last units can normally be accelerated as a result of experience gained from commissioning of the other units.

5.2.4 Risk of Failure to Meet the Construction Schedule

The probability of completing any phase of construction on time has been computed by the method recommended for PERT applications (PERT, 1965). The method involves the comparison of the estimated slack time in a schedule with the estimated standard deviation in time of completion.

Slack time is defined as the difference between the available time, and the expected time to completion:

$$S = T_l - T_E, \text{ where}$$

T_l = longest time available within the schedule

T_E = expected time of completion as defined by:

$$T_E = \frac{T_a + 4\,T_m + T_b}{6} \quad \text{where}$$

T_a = the optimistic estimate of time required for completion of the major activities of each phase of the work;

T_b = the pessimistic estimate for completion of the major activities of each phase; and

T_m = the estimate of the most probable time for completion of the major activities of each phase.

The probability of completing on time is estimated from normal distribution of probabilities as a function of the slack time S, and the standard deviation of the time of completion for any sequence under study.

Using the above method, estimates were made of the probability of completing various phases of the project as scheduled. The results are shown in the following tabulation:

Work	Probability of Construction Within Schedule (no cofferdam overtopping)	Probability of Cofferdam Not being Overtopped by Floods	Combined Probability of Construction Within the Schedule
Preparatory Phase	.98	1.00	.98
Phase I	.97	.92	.89
Phase II	.95	.97	.92
Phase III to Project Completion	.96	.98	.95
Cumulative Probability	.87	.88	.76

The time available for construction of the Stage III RCC cofferdam is short. Consideration was given in this estimate to the possibility of starting the Stage III work earlier and also of closing the gates later than scheduled, depending on the magnitude of river flows. The cofferdam must be constructed to a level such that when the gates are closed the water level can be controlled by the spillway discharge to remain below the top of the RCC cofferdam. Based on completing closure by about the 20th of May, with flows of about 20 000 m^3/s, the cofferdam should be built to El 112 before closure is started. If closure of the gates were planned for June, when the river flows are higher, the cofferdam would have to be completed to a higher level and the gates would have to be designed to close under a greater head than the planned 45 m.

Analyses of the schedule, construction methods and probable river flows indicate that there is about a 50% chance that the diversion gates, as presently designed, could be closed prior to the summer floods. If an extra month can be gained by use of faster equipment, more efficient techniques or new developments in the next 10 years, this probability increases to .90. However, if the diversion gate closure had to be delayed to about mid–October when the river flow drops to about 20 000 m^3/s, it would result in a 5–month delay in the in–service dates of units 1 and 2, a 3 or 4 month delay in unit 3 and a 1 or 2 month delay in unit 4. The late closure would not affect the in–service dates of other units. But it would increase the probability of success for the RCC cofferdam to .99.

With the recommended schedule it appears the risk of delay would be evenly divided between the possibility of cofferdam overtopping and slow construction progress. However, no account was taken of the possibility of protecting the cofferdams for flood levels greater than the design levels by sand bagging or adding fill during a severe flood. These actions would reduce the risk of delay due to floods.

The most critical construction item is the RCC cofferdam which based on current technology has about a 50% chance of being completed in time to allow the diversion gates in the dam to be closed before the summer flood. Failure to close the diversion gates would delay first power from the first few units as discussed above. However this delay would not be cumulative as the subsequent units could be installed as originally scheduled.

In summary the main conclusions are:

1. There is a high probability of completing the construction of the project in 18 years as scheduled.

2. There is a low probability of completing the RCC cofferdam as scheduled. Further studies of alternative construction methods, cofferdam design or diversion schemes need to be carried out.

5.2.5 Project Management

A modern project management organization is required to deal effectively with project implementation. Such an organization will establish a reporting system for progress and costs that is designed to quickly identify any problems and will facilitate timely decisions on any required corrective measures. The prime responsibility of the Project Manager would be the construction of the Three Gorges Project on schedule and within budget. Consequently he would have authority consistent with this responsibility.

The organization should be established before construction starts. It could be initiated by the creation of a project management task force whose membership would include international experts. The Task Force could deal with urgent project matters as well as the management organization.

The Three Gorges Water Control Project will be the largest in the world, will involve a large number of contractors and will require about 18 years to construct. The quantity of work on this project surpasses world experience. Many structures require rates of construction never before achieved. Consequently, the construction logistics require detailed long–term planning, extensive coordination and follow–up.

The schedule indicates that there will be several major contracts in progress at the same time. This will require very close coordination which requires an efficient project management organization with an effective system to monitor and control all activities for construction of the project.

To facilitate an efficient start of construction, a project management organization must be established and be in operation before the start of construction. This organization must carry out early detailed planning for all critical steps and decisions so that appropriate and timely action will be taken. Policy decisions must be made early with regard to international bidding and contract packages as well as procurement of construction equipment and permanent equipment.

Project Management will develop, implement and control all procedures, directives and policies for:

- engineering
- specifications
- procurement
- contracts
- planning and scheduling
- construction
- project budget and cost
- transportation
- personnel
- administration
- finance

The main features of an effective project management organization are that it will:

- be established, organized and in operation during the detailed planning stage before the start of construction;
- have strong government representation in the senior level of the management structure to expedite required government reviews and approvals during project construction;
- have strong senior level management leadership to efficiently direct the management team and to ensure coordination between the various disciplines;
- establish and implement directives and procedures that will expedite decision–making;

- have a clear line of authority and well defined level of delegation;
- have an efficient management reporting system to anticipate and identify upcoming problems, expedite decision–making and implement appropriate solutions; and
- have an Advisory Board comprised of a panel of international experts on design and construction.

6. CONTRACT PACKAGES AND PROCUREMENT SCHEDULE

On large projects it is normal international practice to subdivide the construction work into a number of contract packages. This reduces the risk and financing problems for contractors and increases competition because smaller contracts enable more construction firms to bid. It thereby, also reduces the risk to the owner, provided his management organization can control and coordinate the separate contract packages.

The work is divided into two main groups: Work which could be carried out by local companies and work which would be more suitable for bidding on the international market.

The division into contract packages takes into account the nature and complexity of the work and criticality of the construction schedule. The size, monetary value and the interfacing between each package is also considered.

A numbering system in three parts has been assigned for the contracts. It consists of: The letters LC and IC to differentiate local and international contracts; the major account numbers as detailed in Appendix C; and, a number to differentiate each contract of the major account.

For example:

Local contract		Major Account		Contract
LC	–	NA50	–	2

which represents local supply of mechanical equipment for the permanent shiplocks.

The major account numbers are:

Major Account Number	**Description**
RE 10	Land, relocation and resettlement of inhabitants.
DI 20	River diversion facilities.
IN 30	Intake Dams, Spillway and Right and Left Bank Dams.
PH 40	Powerhouse and generating facilities.
NA 50	Navigation facilities
PE 60	Permanent support facilities
TE 70	Temporary Works
EN 80	Engineering, & Management
OW 85	Owner's costs
CO 90	Contingencies

ES 92	Escalation
IC 95	Interest during construction

6.1 Local Contracts

The proposed contracts restricted to local construction firms are:

LC–DI 20–1	– Stage I cofferdam initial loop.
LC–IN 30–1	– Supply and installation of spillway operating gates and service gates.
LC–IN 30–2	– Supply and installation of spillway bottom outlet tainter gates and emergency gates.
LC–IN 30–3	– Supply and installation of diversion outlet gates.
LC–IN 30–4	– Fabricate and install left bank steel penstocks.
LC–IN 30–5	– Fabricate and install right bank steel penstocks.
LC–PH 40–1	– Left bank intake, powerhouse and spillway electrical/mechanical installation.
LC–PH 40–2	– Right bank intake and powerhouse electrical/mechanical installation.
LC–PH 40–3	– Supply of 11 turbine generator units for the right bank powerhouse.
LC–PH 40–4	– Supply and installation of the left bank powerhouse cranes.
LC–PH 40–5	– Supply and installation of the right bank powerhouse cranes.
LC–PH 40–6	– Installation of the left bank power house turbine generator units (11).
LC–PH 40–7	– Installation of the right bank powerhouse turbine generators units (11).
LC–PH 40–8	– Supply and installation of left bank intake gates, trashracks and draft tube gates.
LC–PH 40–9	– Supply and installation of the right bank intake gates, trashracks and draft tube gates.
LC–PE 60–1	– Construction of the Xiling permanent bridge.
LC–PE 60–2	– Construction of the permanent access road from Yichang to Three Gorges site.
LC–PE 60–3	– Construction of the permanent housing, office building and services for permanent operation.
LC–TE 70–1	– Installation of batch plants and supply and installation of ice plant, manufacture of concrete on the right bank.

LC–TE 70–2	–	Installation of batch plants and supply and installation of ice plant, manufacture of concrete on the left bank.
LC–TE 70–3	–	Installation of plant and manufacture of aggregates on the left bank.
LC–TE 70–4	–	Installation of plant and manufacture of aggregates on the right bank.
LC–TE 70–5	–	Construction of on–site roads and bridges on the left bank.
LC–TE 70–6	–	Construction of on–site roads and bridges on the right bank.
LC–TE 70–7	–	Construction of wharf facilities on both left and right banks of the river.
LC–TE 70–8	–	Campsite construction on left bank.
LC–TE 70–9	–	Campsite construction on right bank.
LC–TE 70–10	–	Transportation of sand and gravel from downstream of Gezhouba
LC–TE 70–11	–	Construction of access road, preparation and operation of rock quarry on left bank and processing of sand for concrete.
LC–TE 70–12	–	Installation and operation of the natural sand processing plant on the left bank.
LC–TE 70–13	–	Supply and transportation of cement #425
LC–TE 70–14	–	Supply and transportation of cement #525
LC–TE 70–15	–	Supply and transportation of flyash
LC–TE–70–16	–	Supply and transportation of reinforcing steel
LC–NA 50–1	–	The supply of mechanical equipment for the temporary shiplock.
LC–NA 50–2	–	The supply of mechanical equipment for the permanent shiplocks.
LC–NA 50–3	–	The temporary lock mechanical/electrical installation.
LC–NA 50–4	–	The permanent shiplocks mechanical/electrical installation.

6.2 International Contracts

The proposed contracts which could involve International contractors or joint ventures of Chinese and International contractors, are as follows.

IC–DI 20–1	–	Diversion channel excavation longitudinal cofferdam construction and Stage II cofferdam construction.
IC–DI 20–2	–	River diversion stage III.
IC–IN 30–1	–	Spillway, left intake dam and powerhouse civil.
IC–IN 30–2	–	Right bank intake dam and powerhouse civil.
IC–IN 30–3	–	Supply of steel plates for penstocks.
IC–IN 30–4	–	Supply of 800 000m² of plywood for work.
IC–IN 30–5	–	Supply of 70 000m³ of processed lumber.
IC–PH 40–1	–	Supply of 11 turbine/generators for left bank powerhouse.
IC–PH 40–2	–	Supply of 11 power transformer three phase banks for left powerhouse.
IC–PH 40–3	–	Supply of 11 power transformers for right bank powerhouse.
IC–PH 40–4	–	Supply of 1100m of isophase bus for left bank powerhouse.
IC–PH 40–5	–	Supply of 1100m of isophase bus for right bank powerhouse.
IC–PH 40–6	–	Supply of 4300m of SF6 enclosed bus for left bank powerhouse.
IC–PH 40–7	–	Supply of 4300m of SF6 enclosed bus for right bank powerhouse.
IC–PH 40–8	–	Supply of 30 SF6 500 kV breakers for left bank powerhouse.
IC–PH 40–9	–	Supply of 30 SF6 500 kV breakers for right bank powerhouse.
IC–PH 40–10	–	Supply of 13 tower cranes 20t.
IC–NA 50–1	–	Temporary shiplock civil work.
IC–NA 50–2	–	Permanent shiplocks civil work.
IC–TE 70–1	–	Supply of batch plants (4–3 m³ mixer plant and 1–6 m³ mixer plant)
IC–TE 70–2	–	Supply of batch plants (6–3 m³ mixers plant)
IC–TE–70–3	–	Supply of large construction equipment not available in China.

6.3 Procurement Schedule

The procurement program for the Recommended Project has been prepared based on the master project schedule presented on **Plate 2.5** and **2.6** and on the proposed contract packaging listed in Section 6.1 and 6.2. The procurement program comprises two schedules; the construction equipment schedule **Plate 2.32** and the permanent equipment schedule **Plates 2.33** and **2.34**.

The schedules include only the major equipment contracts and the estimated required quantities. They also indicate whether foreign or locally supplied.

The activities that have been scheduled for each procurement contract include the preparation of the technical specification; the tender and contract analysis period; the design, model testing and fabrication period to delivery ex–factory of the different components.

The allocated time for each of these activities is as follows:

1. Preparation of the technical specifications.

   - 3 to 6 months for "off the shelf" construction equipment.

   - 6 to 12 months for custom built equipment such as batch plant, aggregate plant etc.

   - 12 months for permanent equipment.

   These durations include time for preliminary design, preparation of the specifications and required drawings and comments and approval of the specifications. Prequalification of suppliers would be done during this period.

2. Tender and contract period.

   - 6 to 9 months for construction equipment.

   - 12 months for permanent equipment.

   These time periods will include the preparation of the tender document, the call for tender, the tender period, the analysis of the tender, the recommendation and award of the contract.

3. Design, model testing and fabrication.

   The duration is dependant on the extent of the design, modelling and testing, fabrication and material procurement. The delivery time from factory to the site is not shown on the schedule but the delivery date indicated is 6 months before the required date at site.

6.3.1 Construction Equipment Schedule

The procurement schedule as shown on **Plate 2.32** is critical for the construction equipment which is required soon after the start of construction support facilities in January of year 1. Specifications for some items will have to be prepared during a pre–construction period between the project approval date and start date.

Some major construction equipment is required in large numbers by the middle of Year 2 for the preparatory works (road construction, preparation of rock quarries and borrow pits, etc.) and for the start of Stage I cofferdam construction in October of Year 2. It includes 77 t and 45 t trucks, 10.5 and 5.4 m^3 loaders, shovels, compressors and track drills, etc. to be purchased and supplied within a period of 2 years. This is a potential source of delay to the project and a detailed schedule and plan should be prepared as early as possible to identify the exact requirements, the available equipment and the required lead time for new equipment.

6.3.2 Permanent Equipment Schedule

The permanent equipment schedule **Plates 2.33** and **2.34** indicates that the temporary shiplock gates are the earliest major items to be required at the site. The preparation of the technical specifications is scheduled to start 6 months after start of construction support facilities (January of Year 1) thus requiring the lock arrangement to be finalized by July of Year 1.

Other equipment such as turbine generators, powerhouse gates, permanent shiplock gates, etc. require specification documents to start in mid–year 3.

The fabrication and supply of gates and associated equipment is the most critical permanent equipment for the left bank structures. The intake gates and trashracks, the diversion outlet gates, the spillway low level gates, the spillway overflow gates and the tailrace gates are to be delivered in years 9, 10 and 11. The total quantity of steel for gates and trashracks is approximately 50 000 t. The fabrication capacity of China's existing plants must be investigated to determine whether the proposed delivery program can be met or whether fabrication should be advanced or some items awarded to foreign fabricators.

7. PROJECT CONSTRUCTION COST ESTIMATES

7.1 General

The total project cost is made up of four main categories:

- Project construction costs which are mainly related to the dam and ancillary facilities,
- Transmission construction costs which cover the cost of the additional transmission system to deliver power to load centres. These are given in Volume 10, Part 2, Sections 6, 10 and 11. The dividing point between the project construction cost estimate and the transmission construction cost estimate is the point of take–off of the outgoing 500 kV transmission lines from the high voltage switching station at the Three Gorges.
- Resettlement costs for people who will be displaced by reservoir flooding. These are given in detail in Volume 9, Section 9 and include the cost of resettlement of all of the people who will be displaced by construction at the damsite.
- Environmental mitigation costs. This is given in Volume 8, Section 8.

This section of the report deals with the first category, project construction costs.

The project construction cost estimate for the Recommended Project with a dam crest of 185 m, NPL 160 and FCL 140, as described in the Preface, is 16.11×10^9 Yuan. This estimate is based on prices and conditions in effect as of January 1987 and includes both direct and indirect costs associated with the project. Interest during construction and escalation beyond January 1987 are not included.

The cost estimate summary by major account number is presented in **Table 7.1.** The cost estimate by account number is presented in **Table 7.2,** sheets 1 to 4.

7.2 Organization of the Detailed Estimate

The estimate is based on the master project schedule as outlined in Section 5 and shown on **Plates 2.5** and **2.6**. The quantities were derived from the YVPO 1984 cost estimate and then checked and adjusted for the Recommended Project. Quantities for alternative arrangements and designs were calculated. Construction equipment types were selected. Equipment fleets and rates of production were determined and construction methods outlined to establish individual unit prices. Cost of permanent equipment, construction equipment and material were obtained from YVPO, Canadian and international sources. Upon completion of the

THREE GORGES FEASIBILITY STUDY

CYJV COST ESTIMATE SUMMARY

RECOMMENDED PROJECT CREST 185,NPL 160 (22 UNITS)

MAJOR ACCOUNT DESCRIPTION	MAJOR ACCOUNT NUMBER	LOCAL PORTION JAN 1987 YUAN	FOREIGN PORTION JAN 1987 YUAN EQ.	TOTAL COST JAN 1987 YUAN
RIVER DIVERSION FACILITIES	DI 20			
INTAKE DAMS,SPILLWAY & RIGHT&LEFT BANK DAMS (CIVIL WORKS)	IN 30-C			
INTAKE DAMS,SPILLWAY & RIGHT&LEFT BANK DAMS (MECH./ELECT. WORKS)	IN 30-EM			
POWERHOUSE & GENERATING FACILITIES (CIVIL WORKS)	PH 40-C			
POWERHOUSE & GENERATING FACILITIES (MECH./ELECT. WORKS)	PH 40-EM			
NAVIGATION FACILITIES (CIVIL WORKS)	NA 50-C			
NAVIGATION FACILITIES (MECH./ELECT. WORKS)	NA 50-EM			
PERMANENT SUPPORT FACILITIES	PE 60			
TEMPORARY CONSTRUCTION SERVICES&FACILITIES (CIVIL WORKS)	TE 70-C			
TEMPORARY CONSTRUCTION SERVICES&FACILITIES (MECH./ELECT. WORKS)	TE 70-EM			
SUB-TOTAL				
ENGINEERING & MANAGEMENT	EN 80			
OWNER'S CORPORATE OVERHEADS	OW 85			
SUB-TOTAL				
CONTINGENCIES				
GRAND - TOTAL				16 112 702 462

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CYJV COST ESTIMATE BY ACCOUNT NUMBER
RECOMMENDED PROJECT CREST 185,NPL 160 (22 UNITS)

ACCOUNT NO.	DESCRIPTION	LOCAL PORTION JAN 1987 YUAN	FOREIGN PORTION JAN 1987 YUAN EQ.	TOTAL COST JAN 1987 YUAN
DI 20	RIVER DIVERSION FACILITIES			
DI 20100	RIVER DIVERSION- STAGE 1			
DI 20200	RIVER DIVERSION- STAGE 2			
DI 20300	RIVER DIVERSION- STAGE 3			
		--------------	----------------	----------------
	TOTAL-RIVER DIVERSION			
IN 30	INTAKE, DAMS, SPILLWAY			
	A) CIVIL WORKS			
IN 30100	LEFT BANK DAM			
IN 30210	LEFT BANK INTAKE & DAM			
IN 30310	LEFT BANK TRANSIT. & TR. WALL			
IN 30410	SPILLWAY			
IN 30500	RIGHT BANK TRANSIT. & TR. WALL			
IN 30610	RIGHT BANK INTAKE & DAM			
IN 30700	RIGHT BANK DAM			
		--------------	----------------	----------------
	SUB-TOTAL IN 30-CIVIL WORKS			
	B) MECH./ELECT. WORKS			
IN 30220	LEFT BANK INTAKE DAM(PENSTOCKS)			
IN 30230	LEFT BANK INTAKE DAM - GATES			
IN 30240	L/B INT.DAM -GATES (SED. OUTLETS)			
IN 30270	L/B INT.DAM - GENERAL EQUIPMENT			
IN 30320	L/B TRANSITION-GATES (SED.OUTLETS)			
IN 30420	OVERFLOW SPILLWAY - GATES			
IN 30430	SPILLWAY OUTLETS - GATES			
IN 30440	SPILLWAY DIV. OUTLETS - GATES			
IN 30450	SPILLWAY TRASH SLUICES - GATES			
IN 30460	OVERFLOW SPILLWAY -ELECTR. EQUIP.			
IN 30490	SPILLWAY - GENERAL EQUIPMENT			
IN 30620	RIGHT BANK INTAKE DAM(PENSTOCKS)			
IN 30630	RIGHT BANK INTAKE DAM - GATES			
IN 30640	R/B INT.DAM -GATES (SED. OUTLETS)			
IN 30670	R/B INT.DAM - GENERAL EQUIPMENT			
		--------------	----------------	----------------
	SUB-TOTAL IN 30 - M/E WORKS			
		--------------	----------------	----------------
	TOTAL-INTAKE DAMS & SPILLWAY			

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CYJV COST ESTIMATE BY ACCOUNT NUMBER

RECOMMENDED PROJECT CREST 185,NPL 160 (22 UNITS)

ACCOUNT NO.	DESCRIPTION	LOCAL PORTION JAN 1987 YUAN	FOREIGN PORTION JAN 1987 YUAN EQ.	TOTAL COST JAN 1987 YUAN
PH 40	POWERHOUSE			
	A) CIVIL WORKS			
PH 40110	LEFT BANK POWERHOUSE			
PH 40210	RIGHT BANK POWERHOUSE			
PH 40300	CONVERTER STATION			
		--------------	----------------	----------------
	SUB-TOTAL PH 40-CIVIL WORKS			
	B) MECH./ELECT. WORKS			
PH 40121 @ 40124	L/BANK TURBO-GENERATORS(#1 TO 4)			
PH 40125 @ 40133	L/BANK TURBO-GENERATORS(#5 TO 11)			
PH 40221 @ 40227	R/BANK TURBO-GENERATORS(#12 - 22)			
		--------------	----------------	----------------
	SUB-TOTAL TURBO-GENERATORS			
PH 40140	LEFT BANK P/H MECH.EQUIPMENT			
PH 40240	RIGHT BANK P/H MECH.EQUIPMENT			
		--------------	----------------	----------------
	SUB-TOTAL MECH. EQUIPMENT			
PH 40150	LEFT BANK P/H ELEC.EQUIPMENT			
PH 40250	RIGHT BANK P/H EL.EQUIPMENT			
		--------------	----------------	----------------
	SUB-TOTAL ELECT. EQUIPMENT			
PH 40160	LEFT BANK TRANSF. & H.V. EQUIP.			
PH 40260	RIGHT BANK TRANSF. & H.V. EQUIP.			
		--------------	----------------	----------------
	SUB-TOTAL MAIN TRANSF.& H.V.			
PH 40270	RIGHT BANK P/H EQUIP. GENERAL			
	SUB-TOTAL PH 40-M/E WORKS			
		--------------	----------------	----------------
	TOTAL - POWERHOUSE			

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CYJV COST ESTIMATE BY ACCOUNT NUMBER
RECOMMENDED PROJECT CREST 185,NPL 160 (22 UNITS)

ACCOUNT NO.	DESCRIPTION	LOCAL PORTION JAN 1987 YUAN	FOREIGN PORTION JAN 1987 YUAN EQ.	TOTAL COST JAN 1987 YUAN
NA 50	NAVIGATION FACILITIES			
NA 50100	TEMPORARY SHIPLOCK			
NA 50110	CIVIL WORKS			
	MECH./ELECT. EQUIPMENT			
NA 50120	TEMP. SHIPLOCK - GATES			
NA 50130	TEMP.SHIPLOCK- OP.&CONTROL EQUIP.			
	SUB-TOTAL TEMPORARY SHIPLOCK M/E			
	SUB-TOTAL TEMPORARY SHIPLOCK			
NA 50300	FLIGHT LOCKS			
NA 50310	CIVIL WORKS			
	MECH./ELECT. EQUIPMENT			
NA 50320	FLIGHT LOCKS-GATES			
NA 50330	FLIGHT LOCKS-OPER.&CONTROL EQUIP.			
NA 50340	FLIGHT LOCKS- GENERAL EQUIPMENT			
	SUB-TOTAL FLIGHT LOCKS M/E			
	SUB-TOTAL FLIGHT LOCKS			
NA 50400	D/S NAVIG. CHANNELS & DYKES			
	CIVIL WORKS			
	SUB-TOTAL CHANNELS & DYKES			
	SUB-TOTAL NAVIG.FACIL.-CIVIL			
	SUB-TOTAL NAVIG.FACIL.-M/E			
	TOTAL NAVIGATION FACILITIES			

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CYJV COST ESTIMATE BY ACCOUNT NUMBER
RECOMMENDED PROJECT CREST 185,NPL 160 (22 UNITS)

ACCOUNT NO.	DESCRIPTION	LOCAL PORTION JAN 1987 YUAN	FOREIGN PORTION JAN 1987 YUAN EQ.	TOTAL COST JAN 1987 YUAN
PE 60	PERMANENT SUPPORT FACILITIES			
TE 70	TEMPORARY WORKS			
TE 70100	LEFT & RIGHT BANK CONSTR. ROADS			
TE 70200	BRIDGES & WHARVES			
TE 70300	PREPARATORY WORKS			
TE 70400	TEMP. SHIPLOCK OPERATION			
TE 70500	SERVICES (CIVIL WORKS)			
TE 70500	SERVICES (MECH./ELECT. WORKS)			
TE 70600	ELECTRICAL POWER SUPPLY			
TE 70700	COMMUNICATION			
TE 70800	CONSTRUCTION CAMPSITE			
TE 70900	AUXILIARY MISC. CIVIL WORKS			
	TOTAL TEMPORARY WORKS			
	TOTAL PROJECT CONSTRUCTION COST			
EN 80 OW 85	ENGINEERING, MGT & OWNER'S COST			
	TOTAL PROJECT COST (NOT INCL.RESETTLEMENT COST)			
	CONTINGENCIES			
	GRAND TOTAL PROJECT COST (NOT INCL.RESETTLEMENT COST)			16 112 702 462

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direct cost estimates for each facility and contract, contractors indirect cost, profit and contingency were determined and pro–rated to individual items to arrive at the final construction cost.

Careful consideration has been given to the provision of contingencies in the estimate. The level of uncertainty in quantities and other factors has been assessed separately for each major account and given a factor of contingency. A total contingency of was included in the estimated cost.

A more comprehensive description of the estimating procedures, methods, and assumptions as well as the results are included in the following subsections.

7.3 Estimate Breakdown

The project was divided into major accounts and sub–accounts. All elements of the estimate were coded in accordance with the numbering shown in Appendix 2C.

The major accounts are:

RE 10	– resettlement;
DI 20	– river diversion facilities;
IN 30	– intake dams and spillway;
PH 40	– powerhouse and generating facilities;
NA 50	– navigation facilities;
PE 60	– permanent support facilities;
TE 70	– temporary works;
EN 80	– engineering and management;
OW 85	– owner's costs;
CO 90	– contingencies;
ES 92	– escalation; and
IC 95	– interest during construction.

The items which comprise each major account and account are listed in Appendix 2C. The general methods and procedures used in estimating each of these accounts are described below:

<u>RE 10 Resettlement</u>

Land relocation and resettlement costs were evaluated by the resettlement study group and the amounts do not appear in the attached summaries. However, the cost of slope stabilization in the reservoir area has been included in the contingency factor and evaluated at 0.5% of the total project cost.

DI 20 River Diversion Facilities

The river diversion facilities include Mao Ping diversion works, stage I cofferdams, diversion channel excavation, longitudinal concrete cofferdam, stage II upstream and downstream cofferdams and stage III upstream, downstream and roller compacted concrete cofferdams.

The estimate has been based on quantities obtained from YVPO and from a quantity take–off from sketches of the Recommended Project.

The unit prices for most of the civil work were calculated in detail as per the method described in Section 7.4. The items costed include rock, weathered sand and clay fill for cofferdams, weathered sand, weathered rock and hard rock excavation; standard concrete and roller compacted concrete; cofferdam cutoff wall; dewatering.

The indirect cost or bid factor for the diversion work has been calculated See **Table 7.3.**

An allowance of 5% has been added to the estimate to cover miscellaneous work. An overall contingency factor of has been estimated for diversion works (see **Table 7.4**).

IN 30 Dams, Intake Dams and Spillway Work

This account includes all the work related to the construction of the left and right bank dams and intake dams and spillway including civil, electrical and mechanical works, direct and indirect costs.

The estimate has been based on quantities derived from YVPO and adjusted to the Recommended Project.

The unit prices of concrete and excavation work have been calculated in detail by the method described in Section 7.4. The estimate includes five types of concrete; 15mPa, 20mPa, 30mPa, 40mPa and roller compacted concrete as listed on **Table 3.5.** The unit prices of concrete for each structure vary as a function of formwork ratio, concrete batching cost, placement method, etc.

The material prices used in determining the cost of concrete (cement, flyash, equipment, etc.) are those listed in **Table 3.8, 3.11** and **3.12** and discussed in Section 7.4.

The unit cost for excavation was determined for several types of material (weathered sand, weathered rock, hard rock, etc.) and adjusted for each structure for differences in hauling distances, type of equipment used, etc.

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TABLE 7.3 - INDIRECT COST OR BID FACTORS

ACCOUNT NUMBER	ITEM	INDIRECT COST	BID FACTOR
DI 20	River diversion		
IN 30-C	Intake dam,spillway & dam civil works		
IN 30-EM	Intake dam, spillway & dam electrical-mechanical		
PH 40-C	Powerhouse civil works		
PH 40-EM	Powerhouse electrical-mechanical and turbine-generators		
NA 50 C	Navigation facilities civil works		
NA 50 EM	Navigation facilities electrical-mechanical		
PE 60	Permanent support		
TE 70	Temporary construction and services-civil		
TE 70 EM	Temporary construction and services-electrical-mechanical		

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TABLE 7.4 - OVERALL CONTINGENCY FACTOR CALCULATION

ACCOUNT NO.	DESCRIPTION	% CONTINGENCY
DI 20	River Diversion Facilities Average	
DI 20100	River Diversion - Stage 1	
D1 20200	River Diversion - Stage 2	
D1 20300	River Diversion - Stage 3	
IN 30	Intake, Dams, Spillway Average	
	A) Civil Works Average	
	B) Mechanical/Electrical Works	
PH 40	Powerhouse Average	
	A) Civil Works Average	
	B) Mech./Elect. Works Average	
	Turbo-Generators	
	Mechanical Equipment	
	Electrical Equipment	
	Main Transformer & H.V.	
	P/H Equipment General	
NA 50	Navigation Facilities Average	
	Temporary Shiplock Average	
	Flight Locks Average	
	D/S Navig. Channels & Dykes	
PE 60	Permanent Support Fac. Average	
TE 70	Temporary Works Average	
EN 80		
OW 85	Eng., Mgt, & Owner's Cost Average	
RE 10	Contingency for slope stabilization in reservoir area	
	Overall contingency excluding resettlement cost	