8. ECONOMIC BENEFITS OF IMPROVED NAVIGATION

The preceding sections of the report explain in detail the expected future characteristics of waterborne transportation through the Upper Yangtze Region with and without Three Gorges. Section 3 describes the present day situation, and Section 4 describes how this might evolve in the absence of the Project both in terms of transportation costs and modal splits for future traffic. Sections 5, 6 and 7 describe the alternative future conditions assuming the Three Gorges dam is constructed as planned, and outline expected transportation costs and modal splits for various reservoir options.

The analysis described in this Section compares the "with" and "without Three Gorges" alternatives outlined in the previous sections, and provides a measure of the economic benefits of the Project which are associated with improved navigation conditions on the river.

8.1 Methodology

8.1.1 General

The general methodology for calculating the navigation—related economic impacts of Three Gorges Project consists of comparing the total economic costs of transportation through the Upper Yangtze corridor with and without the Three Gorges Project. "Total costs" are the long—run marginal costs of moving passengers and freight through the region, including capital and maintenance costs associated with right—of—way.

Economic costs rather than tariffs were used throughout the analysis both in calculating cost savings and in assigning traffic to alternative modes. Basing the traffic assignment on costs presumes that, in the longer term, the existing tariffs on both land—based and water—based modes will be restructured to more closely reflect their fully allocated costs. If this adjustment does not occur, however, some of the projected shift in traffic from rail to water may not arise, and hence at least a portion of the economic cost savings may not be captured.

8.1.2 Assumptions

A number of assumptions underlie the approach used in assessing the navigation impacts.
Three of these warrant separate mention.

1. **Continuity**

In evaluating the navigation impacts of the project, it has been assumed that navigation on the river will be maintained if Three Gorges is constructed. The analysis therefore does not examine the relative costs of terminating navigation in the upper reaches of the river and diverting all traffic to land–based modes.

2. **Alternatives**

In defining the "without Three Gorges" scenario, it is assumed that the next–best alternative to Three Gorges is to maintain the existing system. There were a number of reasons for adopting this approach. Chief among these is the difficulty in defining an alternative scenario which would yield a comparable level of navigation improvements. Three Gorges Project would have a dual impact on navigation. It would provide increased channel capacity by eliminating channel constraints. This in turn should lead to increased capacity and lower transportation costs by allowing the use of larger tows on a substantial segment of the Chongqing–Yichang Reach.

As noted in Section 4.1, the Ministry of Communications has identified a scheme of channel improvements which they anticipate would increase capacity in the Upper Channel to 30 x 10^6 t per year at a cost of 1.16 x 10^9 yuan. Full details of this proposal have not been provided to CYJV, but the main components are understood to include deepening some critical sections of the channel and widening the approaches to some of the one–way sections. The Ministry indicated, however, that this scheme would not permit a significant increase in tow size; nor would it substantially reduce operating costs in the Chongqing–Yichang section. Consequently, the savings in total transportation cost as compared with the existing system are likely to be small.

There are other alternatives to Three Gorges which would reduce costs and increase capacity on the river, including operating improvements such as modified equipment design, traffic control procedures, and increased mechanization of cargo handling. However, such operating changes could also be implemented in conjunction with Three Gorges Project, although they might yield lower additional savings in the latter case. Extensive analysis would be necessary to ensure that the operating improvements represented the "next–best" scheme and also that the levels of savings with and without Three Gorges Project were measured correctly. Accordingly it was judged, for the purpose of this study, that continuation of the existing system was a reasonable representation of the best alternative to Three Gorges in terms of navigation benefits.
Benefits to Induced and Diverted Traffic

In calculating the transportation cost savings associated with Three Gorges, it was assumed that the traffic moving through the Region would benefit from the full reduction in the weighted average costs of inter-regional transportation. This assumption is not strictly consistent with traditional economic theory, since it presumes that the total demand for inter-regional transportation is, and will continue to be unrelated to price. In addition, it presumes that traffic which shifts from rail to water does not suffer any non-tariff penalties which would offset the cost savings.

Neither of these presumptions is theoretically viable in a free market situation. Normal demand-price relationships suggest that when average inter-regional transportation costs decline, total traffic will increase as new traffic is "induced" to move. Since this new traffic would not have moved at the higher cost, it cannot be said to benefit to the full extent of the cost reduction. In calculating navigation-related benefits of Three Gorges, however, the same level of inter-regional transportation demand has been assumed "with" and "without" the Project (although for sensitivity purposes, three different levels of total inter-regional demand were considered). The analysis therefore does not take into account the possibility that total inter-regional traffic levels will be affected by the reduced average transportation cost, and hence makes no adjustment for lower benefit levels to "induced" traffic.

Similarly economic theory recognizes that the choice between transportation modes is determined not only by tariffs but also by a number of non-tariff considerations. Hence when a shipper decides to shift from one mode to another, he may benefit from a reduction in tariffs but may suffer an offsetting cost in the form of increased transit time or reduced reliability. Thus, his actual benefit is somewhat less than the tariff reduction.

Unfortunately it is difficult to judge the extent to which non-tariff or capacity factors may play a part in the modal choice decision within the Upper Yangtze corridor. Current modal splits are based on a tariff structure which bears little relationship to the relative costs of rail and water, and consequently give only limited guidance regarding probable future modal splits when tariffs are assumed to be based on "economic costs". The projections of what these modal splits are likely to be with and without Three Gorges Project were largely judgmental and based primarily on costs. Further refinements to account for non-tariff considerations both in the modal splits and the benefits analysis did not appear warranted given the limited data. Consequently, it was decided to assume that traffic which was shifted from rail in the "without Three Gorges" case to water in the "with Three Gorges" scenarios would benefit to the full extent of the tariff savings. This is correct only insofar as there are no offsetting
non–tariff factors or the decision to use rail in the "without Three Gorges" cases was necessitated by lack of usable capacity on the water mode. Otherwise, benefits associated with the shift between modes are overstated.

While adopting the full cost saving as a measure of benefits may compromise the validity of the benefit calculations, it would have been difficult under the circumstances to develop a defensible set of demand/cost relationships applicable to inter–regional traffic in the Upper Yangtze Corridor. Both the overall traffic forecasts and the modal split assignments are based on tenuous data and assumptions, and any attempt to further qualify these numbers to account for different levels of benefits would only increase the risk of generating misleading benefit statements.

8.2 Navigation Benefits Model

8.2.1 Model Structure

Estimating the navigation–related impacts of Three Gorges Project was facilitated by a small computer model which calculated, for each year of the project life, the total inter–regional transportation costs, the discounted net present value of these costs, and the resultant total discounted costs over the assumed life of the project. The model calculated these costs both for the "without Three Gorges Project" scenario and for "with Three Gorges Project" scenarios at alternate reservoir levels. The difference in present value of total costs "with" and "without" Three Gorges Project represented the navigation–related benefit/disbenefit.

The key inputs to the model were the following:

- forecasts of transportation demand (passengers and freight) through the Upper Yangtze corridor;
- long–run marginal costs of river and land–based transport through the region both with and without Three Gorges Project;
- expected modal splits between river and land–based modes with and without the project;
- river capacity limits including capacity of the facilities at Three Gorges Project; and
- costs incurred to maintain right–of–way, especially on the river, with and without Three Gorges Project.

The values for most of these inputs for both the "with Three Gorges Project" and "without Three Gorges Project" scenarios have been defined in the previous sections. However, they are briefly reiterated here.
8.2.2 Traffic Forecasts

The navigation benefits were evaluated for three forecast levels of inter-regional traffic: Low (CYJV low forecast), Medium (CYJV high forecast) and High (YVPO/MOC forecast). In order to convert the High YVPO/MOC forecast of river traffic to a forecast of total inter-regional freight it was necessary to estimate the amount of overland traffic which would be associated with their projected 50 x 10⁶ t of downbound river traffic. Since the YVPO/MOC forecasts did not provide any information on this topic, it was assumed to be equal to the overland traffic in the CYJV high forecast for the "with Three Gorges Project" scenario — that is, approximately 16 x 10⁶ t of downbound/outbound freight and approximately 9 x 10⁶ t of upbound/inbound freight by the year 2030.

8.2.3 Long-Run Marginal Costs of Transportation

The marginal costs of river transportation were determined using the Vessel Costing Model described in Appendix D. Vessel operating scenarios with and without Three Gorges Project were described in Sections 4.2.2 (without Three Gorges Project) and 7.2 (with Three Gorges Project). In the "with Three Gorges" cases, separate vessel operating scenarios were defined for Low, Medium and High traffic forecasts and for alternative reservoir scenarios.

In the previous descriptions of vessel operating scenarios, it was pointed out that the proposed fleet mixes were not regarded as optimal either from the viewpoint of meeting demand or of minimizing cost and maximizing capacity benefits. They attempt only to represent one scenario for technological change in response to changing traffic and channel conditions.

Thus, while the modal costs projected under future reservoir conditions are a reasonable indication of the savings which might be achieved in the future, they are not necessarily the lowest costs which can be achieved.

Long-run marginal costs for land-based transportation were developed from information supplied by YVPO and by transport operators in China, supplemented where necessary by in-house experience of modal capital and operating costs. Since road transport is unlikely to be a major participant in inter-regional movements given the difficult terrain and the long distances involved, the focus of the analysis was the cost of rail transport. Fully-allocated long-run marginal costs were developed for the rail mode, including the capital cost of new rail construction and new rolling stock.

The capital cost of new rail lines was based on the particular characteristics of the rail route through the corridor. Construction costs per kilometre over easy, moderate and difficult terrain were provided by YVPO. Based on these unit costs and a topographic review of the expected route, the total capital cost of a rail line from Chongqing to
Wuhan was estimated at 6.5 x 10^9 yuan, including equipment. Capital costs per tkm were determined by discounting the flow of capital expenditures and dividing it by the discounted capacity of the line over its economic life. Railway operating costs, excluding capital, were based on national average figures per tkm. The combined capital and operating cost for rail movement through the region was estimated to be 3.8 fen per tkm.

It was noted in Section 7.2 that vessel operating costs in the Middle Reach of the river between Yichang and Wuhan were assumed to be equal under all NPL/FCL scenarios. Reservoir levels within the range considered in this analysis all allow minimum average daily discharge of 5 000 m³/s below Gezhouba — the flow rate defined by MOC as necessary to maintain navigation depths in the Middle Reach and allow the passage of standard 1 000 t barges. Consequently the higher discharge rates associated with higher live storage volumes were assumed to create no additional saving in vessel operating costs.

As further information becomes available regarding the project’s impact on the Middle Reach of the river, including the relationship between discharge rates and water depth at critical shallow sections, and the degradation effect of reduced sediment loads, it may be desirable to re-assess navigation costs through this reach (both vessel operating and channel maintenance costs) in order to determine whether higher reservoir levels might have a significant impact on navigation-related benefits.

8.2.4 Modal Splits

The assumed modal splits without and with Three Gorges were described in Sections 4.2.1 and 7.1.1 respectively. The rationale is discussed in detail in Appendix A and briefly described below.

The modal splits developed for freight traffic took into account two factors:

- the relative costs of the rail and water modes, and
- the characteristics of the commodities being moved, including physical properties, value, and origin/destination patterns.

These two factors provided an indication of the traffic which would, under unrestricted conditions, move on each of the modes. Once this was determined, a third factor, the capacity of the river channel and of the navigation facilities, was assessed to determine whether capacity constraints would force traffic away from the river and onto the rail mode.

A critical assumption relative to the modal split analysis is that the current transport tariff policies with regard to rail and water transportation will be changed. As noted in Section 3.3.3, current rail rates reflect a very small portion of the fully allocated costs of shipment.
through the Upper Yangtze Corridor. River rates, while still below fully allocated costs, are closer to full cost and significantly higher than the corresponding rail rates. Even the projected river costs after Three Gorges are equal to or marginally higher than the current rail rates.

If the current transport tariff policies are continued, many of the potential economic benefits associated with lower costs of river transport would not be realized as traffic would continue to move by rail. Accordingly it was assumed in this analysis that rail and river tariffs will be restructured to more fully reflect their relative costs. Without such restructuring, at least a portion of the cost savings associated with improved navigation may not be realized.

8.2.5 Channel Capacity Limitations

The capacity limitations in the Upper Reach of the river, including the channel and the facilities at Three Gorges, were outlined in Sections 4.3, 7.4 and 7.5. Calculations indicated that, with the fleet mixes postulated in the analysis, capacity would be limited by the permanent navigation facilities, at least for the YVPO/MOC forecast traffic.

These postulated fleet mixes were not, however, designed to make maximum use of the potential lock capacity, particularly in terms of depth. The maximum assumed draft of the barges was 2.4 metres while the design depth of the locks is 5 metres. Theoretically, as traffic approached the defined capacity limits of the locks, the limits could be extended by shifting to deeper-draft barges. At that point, the depth limitations in the river channel could become the constraining factor in defining system capacity.

In addition, the lock capacity calculations are based on average expected conditions and technology and represent a measure of practical throughput. However, if demand consistently exceeds capacity, these limits could be exceeded by operating closer to theoretical capacity in the short term and by instituting operating procedures to speed up lock cycle time in the long term.

Consequently, limiting the system capacity to the capacity of the locks under the assumed set of fleet and operating conditions may misrepresent the potential benefit levels. It also means that differences among scenarios in terms of conditions in the backwater reach are not fully reflected in the cost comparisons. These differences could be significant if the backwater reach ultimately becomes the constraining part of the system, especially if barges have to be lightened due to depth restrictions under some reservoir scenarios.

Navigation benefits were therefore calculated under two assumptions regarding limiting capacity. For the base case, capacity was limited by the permanent lock capacity under the postulated fleet mixes. As a sensitivity analysis, the capacity was limited by the river channel. Channel
capacity through constraining sections in the NPL season was based on an average tow size of 6,000 t. During the FCL season, capacity through constraining sections was based on an average tow size of 3,000 t.

8.2.6 Maintenance of the Navigation Channel

The costs of operating and maintaining the navigation channel with and without Three Gorges are described in Sections 3.4 and 7.3. In calculating the future costs of channel maintenance without the Project, it was assumed that, unless a major improvement program was undertaken, the annual costs would remain fairly constant. A large proportion of the cost of operating winching stations and traffic control stations is fixed while maintenance of navigation aids is related primarily to river conditions. Consequently, increased traffic volumes would not likely lead to significant increases in channel maintenance costs.

8.3 Benefits Related to Improved Navigation

The total costs of transportation through the Upper Yangtze Corridor were calculated for seven scenarios under each of the three levels of forecast traffic. The scenarios were:

- No Three Gorges – continue existing conditions
- Three Gorges Project – 150/135/130 (NPL/FCL/PDL)
- Three Gorges Project – 160/135/145 (NPL/FCL/PDL)
- Three Gorges Project – 160/140/140 (NPL/FCL/PDL)
- Three Gorges Project – 170/140/150 (NPL/FCL/PDL)
- Three Gorges Project – 170/145/150 (NPL/FCL/PDL)
- Three Gorges Project – 180/150/165 (NPL/FCL/PDL)

All cost streams were based on a reservoir with a 130 m pool level effective mid-2000, year 12 after the start of construction, with final NPL reached in mid-2004, year 16. Cost streams were computed through to the year 2050 in order to be consistent with other aspects of the economic evaluation. However, after the year 2020, the system was assumed to stabilize and traffic growth represented the only source of further savings.

Table 8.1 shows a sample of the cost streams developed, first for the "without Three Gorges" case and then for the 150/135 reservoir scenario. Both cost streams are based on the medium traffic forecast. Although the Table shows calculations at 5-year intervals, the model calculated these costs for each year of the project life.
### Three Gorges Project Feasibility Report

#### Table 8.1

**Example of Total Transportation Cost With & Without Three Gorges**

*(150/135 Reservoir - Medium Traffic Forecast)*

<table>
<thead>
<tr>
<th>Year</th>
<th>Without Three Gorges</th>
<th>With Three Gorges</th>
<th>Total Cost Without</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rail</td>
<td>Water</td>
<td>Rail</td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>Tonnes</td>
<td>Y</td>
<td>Tonnes</td>
<td>Y</td>
</tr>
<tr>
<td>1990</td>
<td>9.0</td>
<td>412</td>
<td>6.0</td>
<td>199</td>
</tr>
<tr>
<td>1995</td>
<td>11.3</td>
<td>513</td>
<td>7.6</td>
<td>233</td>
</tr>
<tr>
<td>2000</td>
<td>14.0</td>
<td>641</td>
<td>9.6</td>
<td>272</td>
</tr>
<tr>
<td>2005</td>
<td>16.8</td>
<td>767</td>
<td>10.2</td>
<td>284</td>
</tr>
<tr>
<td>2010</td>
<td>20.0</td>
<td>912</td>
<td>11.1</td>
<td>302</td>
</tr>
<tr>
<td>2015</td>
<td>23.7</td>
<td>1081</td>
<td>12.2</td>
<td>328</td>
</tr>
<tr>
<td>2020</td>
<td>28.0</td>
<td>1279</td>
<td>13.6</td>
<td>359</td>
</tr>
<tr>
<td>2025</td>
<td>33.1</td>
<td>1511</td>
<td>15.2</td>
<td>403</td>
</tr>
<tr>
<td>2030</td>
<td>39.1</td>
<td>1786</td>
<td>17.2</td>
<td>453</td>
</tr>
<tr>
<td>2035</td>
<td>44.2</td>
<td>2015</td>
<td>19.3</td>
<td>510</td>
</tr>
<tr>
<td>2040</td>
<td>50.0</td>
<td>2281</td>
<td>20.9</td>
<td>554</td>
</tr>
<tr>
<td>2045</td>
<td>58.3</td>
<td>2659</td>
<td>21.0</td>
<td>555</td>
</tr>
<tr>
<td>2050</td>
<td>67.6</td>
<td>3084</td>
<td>21.0</td>
<td>555</td>
</tr>
</tbody>
</table>

* All figures are x 10

** Pax = passengers
The cost streams under each scenario were discounted to mid-1987 levels at a 10% discount rate. Separate calculations were made for "transportation cost" (i.e. the costs of moving freight and passengers through the corridor) and costs of channel maintenance.

Total discounted costs under each of the "with Three Gorges" scenarios were compared with the costs without the project to determine the net benefit of navigation improvements arising from Three Gorges Project.

As a base case, the capacity of the river system without Three Gorges was taken as 15 x 10^6 t per year downbound and 6 x 10^6 t upbound. The capacity of the system with Three Gorges was the capacity of the twin flight locks under the postulated (unoptimised) fleet mixes, with 12 passenger transits per day. One-way system capacity therefore was taken as 34 x 10^6 t for the High traffic case and 29 x 10^6 t for the Medium and Low traffic forecasts.

The resultant savings associated with Three Gorges are shown in Tables 8.2 and 8.3 below. Table 8.2 deals with savings in transportation cost while Table 8.3 deals with savings in channel operating and maintenance costs. The findings in Table 8.2 are shown graphically in Figure 8.1.

THREE GORGES PROJECT FEASIBILITY REPORT

TABLE 8.2 — TRANSPORTATION COST SAVINGS
(Net Present Value — Yuan x 10^6)

<table>
<thead>
<tr>
<th>Reservoir Scheme</th>
<th>Low Traffic</th>
<th>Medium Traffic</th>
<th>High Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPL/FCL/PDL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150/135/130</td>
<td>435</td>
<td>732</td>
<td>1 398</td>
</tr>
<tr>
<td>160/135/145</td>
<td>449</td>
<td>757</td>
<td>1 442</td>
</tr>
<tr>
<td>160/140/140</td>
<td>454</td>
<td>767</td>
<td>1 456</td>
</tr>
<tr>
<td>170/140/150</td>
<td>466</td>
<td>788</td>
<td>1 495</td>
</tr>
<tr>
<td>170/145/150</td>
<td>475</td>
<td>803</td>
<td>1 522</td>
</tr>
<tr>
<td>180/150/165</td>
<td>479</td>
<td>810</td>
<td>1 533</td>
</tr>
</tbody>
</table>

THREE GORGES PROJECT FEASIBILITY REPORT

TABLE 8.3 — SAVINGS IN CHANNEL MAINTENANCE AND OPERATING COSTS
(Net Present Value — Yuan x 10^6)

<table>
<thead>
<tr>
<th>Reservoir Scheme</th>
<th>Total Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>14.3</td>
</tr>
</tbody>
</table>
THREE GORGES PROJECT FEASIBILITY STUDY

PRESENT WORTH NET BENEFITS (million Yuan, 1987 at 10%)

LOW TRAFFIC
MEDIUM TRAFFIC
HIGH TRAFFIC

TRANSPORTATION COST SAVINGS

NPL/FCL

150/135  160/135  160/140  170/140  170/145  180/150
Table 8.2 indicates that there is some improvement in transportation cost savings associated with higher reservoir levels. The savings associated with the NPL 180 scheme are approximately 10% higher than those associated with the NPL 150 scheme for all three traffic cases. The total increase in benefits ranges from $44 \times 10^6$ yuan for the Low traffic case to $135 \times 10^6$ yuan for the High traffic case. However, differences between alternate reservoir scenarios are less significant than the differences in savings between alternate traffic levels.

There are three factors contributing to the lack of a major difference in savings under alternate reservoir levels. First, the differences between scenarios in terms of the length of the reservoir is small relative to the total distance travelled. Consequently, the additional reductions in vessel costs associated with the longer reservoirs at higher NPLs are minor.

Secondly, much of the transportation cost saving per tkm comes from the ability to use larger tows. All NPL scenarios would permit the use of $9 \times 1000$ t tows up to Chongqing during a large part of the dry season. The lower NPLs might require one-way operations through critical sections or reconfiguration of large tows during low flows with associated delays and capacity limitations. However, a substantial portion of the voyage would be accomplished in large tows under all scenarios. All FCL scenarios require that large tows be reconfigured into smaller units below the Tongluoxia Gorge. As a result, there is little difference between scenarios in transportation costs during flood season.

Thirdly, a key argument in favour of higher reservoir scenarios is the added channel capacity associated with higher reservoir levels. Under this base case scenario, however, system capacity is constrained by the capacity of the navigation facilities at the dam. Since this is not affected by reservoir levels, there is no additional benefit to through traffic associated with higher channel capacities upstream of the Project. The effect of constraining the system capacity to the capacity of the upper channel rather than the navigation facilities is examined, however, in the sensitivity analysis.

8.4 Sensitivity Analysis

8.4.1 Capacity of the River System

The findings presented in Section 8.3 presume that the system with Three Gorges is limited by the capacity of the permanent navigation locks under the assumed fleet mixes. As noted earlier, however, neither fleet mixes nor lock design and operations were optimised. Hence the assumed capacity constraint may be unduly limiting. With a more optimal system, it may be possible to significantly increase the throughput of the navigation locks.

To evaluate the impact of relaxing this constraint on system capacity, transportation cost savings were calculated using the capacity of the upstream channel as the upper limit of throughput under each reservoir
scenario. System capacity was assumed to be $45 \times 10^6$ t for the NPL 150 scenario, $50 \times 10^6$ t at NPL 160, and $52 \times 10^6$ t at NPL 170 and 180. Capacity of the system without Three Gorges was held at $15 \times 10^6$ t downbound. The resultant savings are shown in Table 8.4 below.

### THREE GORGES PROJECT FEASIBILITY REPORT

#### TABLE 8.4 — SENSITIVITY TO SYSTEM CAPACITY TRANSPORTATION COST SAVINGS

(Net Present Value — Y \( \times 10^6 \))

<table>
<thead>
<tr>
<th>Reservoir Scheme (NPL/FCL/PDL)</th>
<th>Low Traffic</th>
<th>Medium Traffic</th>
<th>High Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>150/135/130</td>
<td>435</td>
<td>734</td>
<td>1,528</td>
</tr>
<tr>
<td>160/135/145</td>
<td>449</td>
<td>759</td>
<td>1,606</td>
</tr>
<tr>
<td>160/140/140</td>
<td>454</td>
<td>769</td>
<td>1,621</td>
</tr>
<tr>
<td>170/140/150</td>
<td>466</td>
<td>790</td>
<td>1,672</td>
</tr>
<tr>
<td>170/145/150</td>
<td>475</td>
<td>805</td>
<td>1,702</td>
</tr>
<tr>
<td>180/150/165</td>
<td>479</td>
<td>812</td>
<td>1,713</td>
</tr>
</tbody>
</table>

The above results indicate that, under the Low and Medium traffic forecasts, there is virtually no change in transportation cost savings associated with a higher assumed capacity of the river system. Under the High traffic assumption, savings increase by approximately 9% for the NPL 150 scheme, and by 11–12% for the higher reservoir scenarios. Also under the High traffic assumption, the benefits at NPL 180 are 11% higher than those at NPL 150.

The lack of sensitivity to system capacity at the Low and Medium traffic levels is due to the fact that demand is not constrained by the capacity of the flight locks until well into the Project's life. Consequently the benefits of added capacity, in terms of the ability to carry more traffic on the lower-cost water mode, are not realized for many years. Under the High traffic assumption, however, demand reaches the flight locks capacity at an earlier date. Hence the impact of a higher capacity assumption is realized sooner and the present value of benefits increases.

#### 8.4.2 Capacity of the Existing Channel

The findings presented in Section 8.3 presume that the existing river channel could, in the future, handle a maximum of $15 \times 10^6$ t per year downbound and $6 \times 10^6$ t per year upbound. This assumption creates a capacity benefit from Three Gorges in that, without Three Gorges Project, traffic in excess of these amounts must be moved on the more costly rail mode.
In order to evaluate this capacity benefit, transportation cost savings were calculated assuming a 50% increase in the capacity of the existing channel, i.e. $22.5 \times 10^6$ t downbound and $9 \times 10^6$ t upbound. System capacity with Three Gorges was assumed to be limited by the capacity of the upper channel, as in the sensitivity analysis shown above. The resultant savings are shown in Table 8.5 below.

THREE GORGES PROJECT FEASIBILITY REPORT

TABLE 8.5 — SENSITIVITY TO EXISTING CHANNEL CAPACITY TRANSPORTATION COST SAVINGS

(Net Present Value — Yuan x $10^6$)

<table>
<thead>
<tr>
<th>Reservoir Scheme (NPL/FCL/PDL)</th>
<th>Low Traffic</th>
<th>Medium Traffic</th>
<th>High Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>150/135/130</td>
<td>435</td>
<td>732</td>
<td>1300</td>
</tr>
<tr>
<td>160/135/145</td>
<td>449</td>
<td>757</td>
<td>1378</td>
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<tr>
<td>160/140/140</td>
<td>453</td>
<td>766</td>
<td>1393</td>
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<tr>
<td>170/145/150</td>
<td>475</td>
<td>803</td>
<td>1474</td>
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<tr>
<td>180/150/165</td>
<td>479</td>
<td>810</td>
<td>1485</td>
</tr>
</tbody>
</table>

Comparing the above Table with the figures in Tables 8.2 and 8.4 indicates that, under the Low and Medium traffic forecasts, the transportation cost savings associated with Three Gorges Project are almost unchanged as the potential capacity of the existing and future river system is increased. Under the High traffic forecasts, however, transportation cost savings decline to levels below those in the base case.

8.4.3 Higher-Capacity Barges

The base-case analysis of navigation savings assumes that the largest tow size after Three Gorges will consist of 9 x 1 000 t barges with a maximum draft of 2.4 metres. Development of the Three Gorges Project reservoir, however, could permit the use of larger barges with deeper drafts or larger dimensions or both, at least for part of the year. Larger barges could provide additional savings in vessel operating costs and could lead to increased capacity of the river system.

To evaluate the potential benefits associated with the use of larger barges, transportation cost savings were calculated assuming, as an example, that 75% of the CSC cargo would be carried in tows of 6 x 2 000 t barges. Dimensions of the 2 000 t barges were 85 m x 10.5 m x 3.1 m draft. Allowing for 0.5 metres of water under the hull, associated channel depth would have to be of 3.6 metres or more.
The sensitivity analysis was carried out for the Medium and High traffic forecasts only. The traffic volumes associated with the Low forecast would probably not justify extensive use of the larger barges. Under the Medium forecast, the remaining 25% of CSC’s cargo was carried in tows of 6 x 1,000 t barges, while under the High forecast the remainder was carried in 9 x 1,000 t units. In both cases, the system capacity with Three Gorges was limited by the capacity of the upper channel, as in Section 8.4.1 above. Table 8.6 below shows the resultant transportation cost savings associated with Three Gorges Project.

THREE GORGES PROJECT FEASIBILITY REPORT

TABLE 8.6 — SENSITIVITY ANALYSIS — HIGH CAPACITY BARGES TRANSPORTATION COST SAVINGS

(Net Present Value — Yuan x 10^6)

<table>
<thead>
<tr>
<th>Reservoir Scheme (NPL/FCL/PDL)</th>
<th>Medium Traffic</th>
<th>High Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>150/135/130</td>
<td>783</td>
<td>1,624</td>
</tr>
<tr>
<td>160/135/145</td>
<td>801</td>
<td>1,688</td>
</tr>
<tr>
<td>160/140/140</td>
<td>807</td>
<td>1,697</td>
</tr>
<tr>
<td>170/140/150</td>
<td>827</td>
<td>1,748</td>
</tr>
<tr>
<td>170/145/150</td>
<td>838</td>
<td>1,767</td>
</tr>
<tr>
<td>180/150/165</td>
<td>843</td>
<td>1,775</td>
</tr>
</tbody>
</table>

Comparing the figures with those in Table 8.4 indicates that the transportation cost savings associated with Three Gorges Project would increase somewhat if larger, deeper-draft barges were used. The net present value of the added savings over the life of the project is in the range of 62 to 96 x 10^6 yuan for the High traffic forecast and 31 to 49 x 10^6 yuan for the Medium traffic scenario. This represents an increase in savings of between 4 and 6.5% as compared with the use of shallow-draft 1,000 t barges.

While the above would suggest some advantage in being able to move higher-capacity barges in the upper reaches of the river, it should be noted that the assessment has not taken into account the possibility that new berths and handling equipment may be required in order to handle larger barges or that additional dredging in harbour areas may be required to accommodate deeper drafts. These factors would have to be evaluated in order to determine whether the larger barges were economical in the context of the total river system.
9. CONCLUSIONS

The previous sections have described the expected inter—relationships between navigation on the Yangtze River and the proposed Three Gorges Project, and have presented the findings of the navigation studies with respect to the adequacy of proposed facilities and the economic benefits associated with improved navigation conditions.

On the basis of these studies, a number of conclusions have been drawn regarding the effects of Three Gorges Project on navigation in the Upper Reach of the Yangtze. The most significant of these are:

— The facilities proposed by YVPO to handle navigation both during the construction of the project and after it is in operation are adequate to meet the capacity and operating requirements of the navigation sector.

— Notwithstanding the above, some modifications to the proposed design would appear to be cost—effective. In particular, eliminating the shiplift from both the temporary and permanent designs would lead to significant net cost savings.

— A system of twin five-stage flight locks is recommended for the permanent navigation facilities. Twin separate locks with intervening channels would be more costly to construct and could interfere with construction of the dam and powerhouse facilities.

— The separate lock system would be less costly if it were built in two stages, and if demand growth was low enough to allow the second stage to be deferred sufficiently to compensate for the additional capital costs (at least 6 years at a 10% discount rate). However, it is not possible, given the existing traffic data base, to predict with any degree of confidence whether or not staged construction may be cost—effective. Consequently, until such time as additional data becomes available, the twin flight—locks scheme is recommended on the basis of its potentially lower capital cost.

— The Project will create a deep reservoir over most of the reach between Yichang and Chongqing, lowering stream velocities during both dry and flood season. Most navigation constraints on this part of the river will be eliminated.

— With the Project, costs of transportation on the river will decline and capacities will increase, leading to overall reductions in the costs of moving freight and passengers through the Upper Yangtze Corridor.

— The longer reservoir associated with higher pool levels for the Project will generate greater transportation cost savings. However, since most of the reach to Chongqing is improved under all of the
scenarios which were assessed, percentage differences are fairly small. Total transportation cost savings increase by approximately 10% when the pool levels are raised from 150/135 to 180/150.

- Costs of operating and maintaining the river channel will decline as a result of the Project, although the savings in winching, one-way sections and maintenance of navigation aids will be partially offset by the dredging required to remove gravel deposits in the fluctuating backwater section.

- The value of benefits related to improved navigation is highly sensitive to the future demand for transportation through the corridor. With the Medium traffic forecasts, transportation cost savings range from 732 x 10^6 yuan at NPL 150 to 810 x 10^6 yuan at NPL 180. With the Low traffic forecasts, savings range from 435 to 479 x 10^6 yuan, while with the High forecasts proposed by YVPO/MOC, they range from 1 398 to 1 533 x 10^6 yuan.

- The level of benefits is relatively insensitive to the potential range of river system transportation capacities. Even under the High traffic forecast, a 50% increase in the capacity of the system with Three Gorges generates a 10% increase in transportation cost savings. If increased system capacity is combined with a shift towards larger or higher capacity barges, an additional 4 to 6.5% saving is achieved.

The above conclusions are contingent upon a number of assumptions which have been defined in the various sections of the Report. Among the most critical of these from the viewpoint of achieving transportation benefits, is the assumption that future transport tariffs will be proportional to the fully allocated costs of alternate modes, and that shippers will be free to choose between modes on the basis of these relative costs. If tariffs are not adjusted, it is not possible to ensure an economic allocation of traffic between modes, and a part of the economic benefit associated with improved navigation conditions may not be realized.

The inter—relationships between the Three Gorges Project and the navigation sector on the Upper Yangtze river are extensive and complex. The project will materially affect the future navigation conditions on the river, generally to the benefit of the users.

While the benefits as measured in this study increase with higher NPL/FCL levels, the increases are small in relation to total navigation benefits. However, the analysis did not attempt to optimize navigation to each water level and traffic scenario. If fleets and operations were optimised to the different reservoir levels and forecast demands, differences between scenarios might be greater.

While the economic analysis indicates that navigation will benefit as a result of the creation of the Three Gorges reservoir, the predicted benefits
are based on the presumption that reservoir operating procedures will reflect the requirements of the navigation sector. The operating rules adopted with regard to the timing of transitions between NPL and FCL (including the rate of change and the flow conditions in the river) and the rules established with regard to timing and duration of controlled flows through the power plant can all affect, on a temporary basis, navigation on the river. In establishing the day-to-day operating rules for the reservoir, it will therefore be necessary for the project operators to be sensitive to these potential impacts if Three Gorges is to successfully fill its role as a multi-purpose project.
PHASE I

PHASE II

PHASE III

CALENDAR YEAR FROM START OF CONSTRUCTION *

LIFT, LOCK AND CHANNEL

* Based on the construction schedule for the Recommended Project

Canadian International Development Agency
People's Republic of China
Ministry of Water Resources and Electric Power

THREE GORGES WATER CONTROL PROJECT
FEASIBILITY STUDY

TEMPORARY NAVIGATION FACILITIES
CAPACITY ESTIMATES

CIPM Yangtze Joint Venture
MARCH 1988
PLATE 5.5
NOTE: Distances are kilometres above Yichang