Status of the Interoceanic Canal Study

Brigadier General R. H. Groves, USA
Corps of Engineers
Engineering Agent for the Atlantic-Pacific
Interoceanic Canal Study Commission

You have asked me to report on the current status of work being done by the Atlantic-Pacific Interoceanic Sea-Level Canal Study Commission, of which I am the Engineering Agent. Our studies are not as yet completed, although there is no reason at this time to doubt that the 1 December 1970 deadline for the Commission's final report will be met. Since it has not been published, I am unable to pass on to you any of its conclusions; they simply do not exist today. And it would be improper for me to reveal the substance of the Commission's deliberations to date or to speculate upon what their outcome may be. But many elements of the work being conducted under my supervision - The Engineering Feasibility Study - are already in the public domain. It is to them that my remarks here are addressed.

Of the six basic routes we have considered in our studies (FIGURE 1) for possible sea-level canal alinements, four could involve nuclear excavating techniques. The so-called nuclear alternatives are Route 8 along the Nicaragua-Costa Rica border, Route 17 across the Darien Isthmus of Panama, Route 23 crossing the Panama-Colombia border and Route 25 across the western tip of Colombia. The conventionally excavated routes are Route 10 west of the Panama Canal Zone and Route 14 along the alinement of the present canal. The engineering studies examine from a technical standpoint the feasibility of constructing these routes and estimate their costs. To accomplish this we have made conceptual designs for canals capable of transitting at least 40,000 vessels annually (and possibly several times that many) and of accommodating ships of up to 250,000 dwt in size. Thus, in terms of basic requirements, all alternatives - conventional and nuclear - have been made comparable.

Beginning with the northernmost route, let us now consider the four nuclear alternatives. Route 8 (FIGURE 2) is 137 miles in length. Its maximum elevations are slightly less than 800 feet in the Continental Divide and about 400 feet through the so-called Eastern Divide. The rock to be excavated is primarily volcanic tuff.

It is readily apparent that this route is not competitive with other nuclear alternatives because of its location in a relatively well developed, built-up region. Its construction would require the evacuation of more than one-quarter million people from the exclusion area for the duration of nuclear operations and for about a year thereafter. This would almost certainly be politically unacceptable. There would be an additional requirement on shot days for the temporary evacuation of an estimated 30,000 people from high rise buildings in Managua and San Jose to avoid casualties from possible structural collapse caused by ground shock. The magnitude of these problems can be expressed to some degree in terms of the estimated cost of their resolution. In this case, they constitute a major part - $1.7 billion - of the Route 8 construction costs which we estimate to be $3.5 billion.

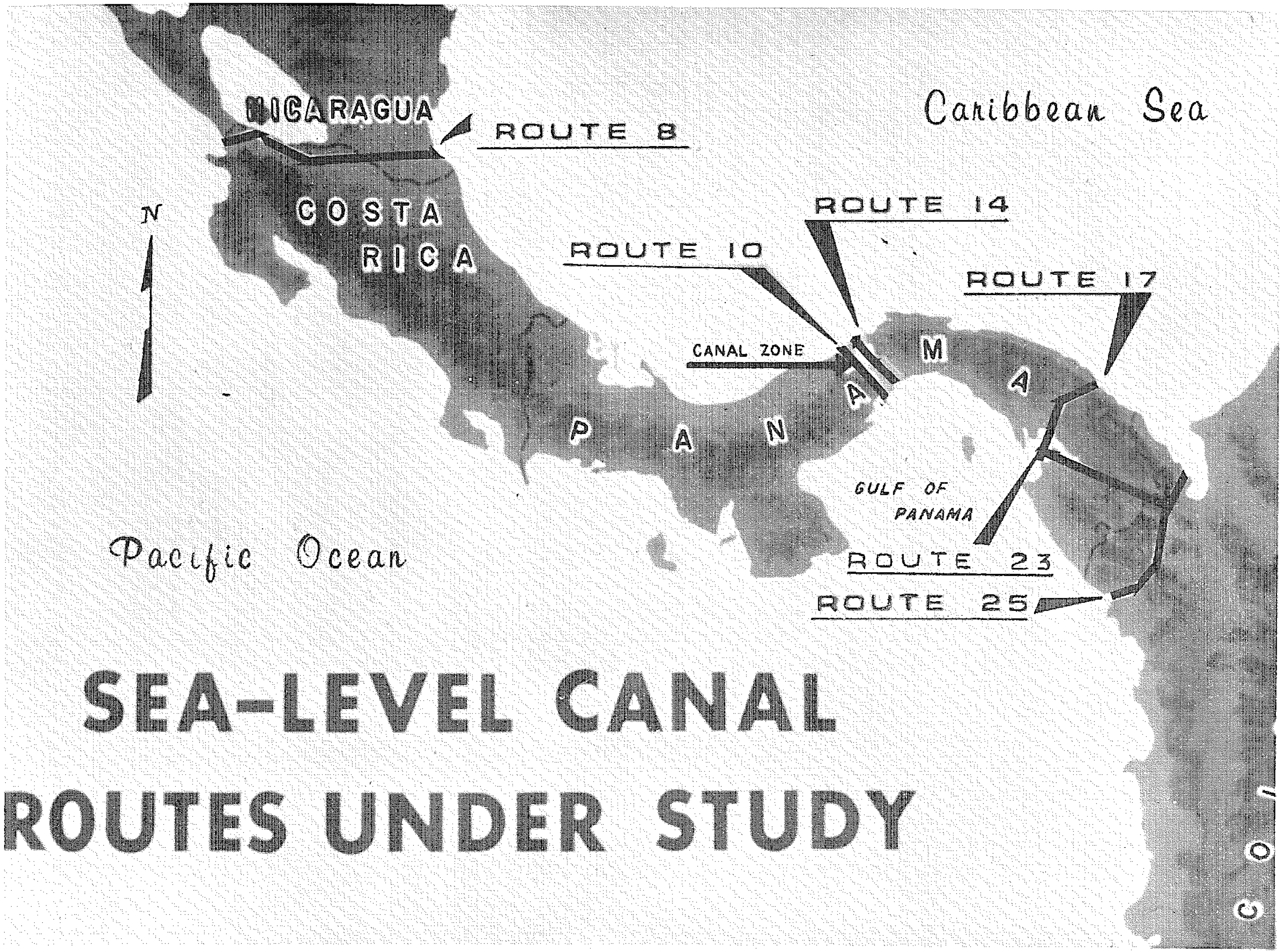
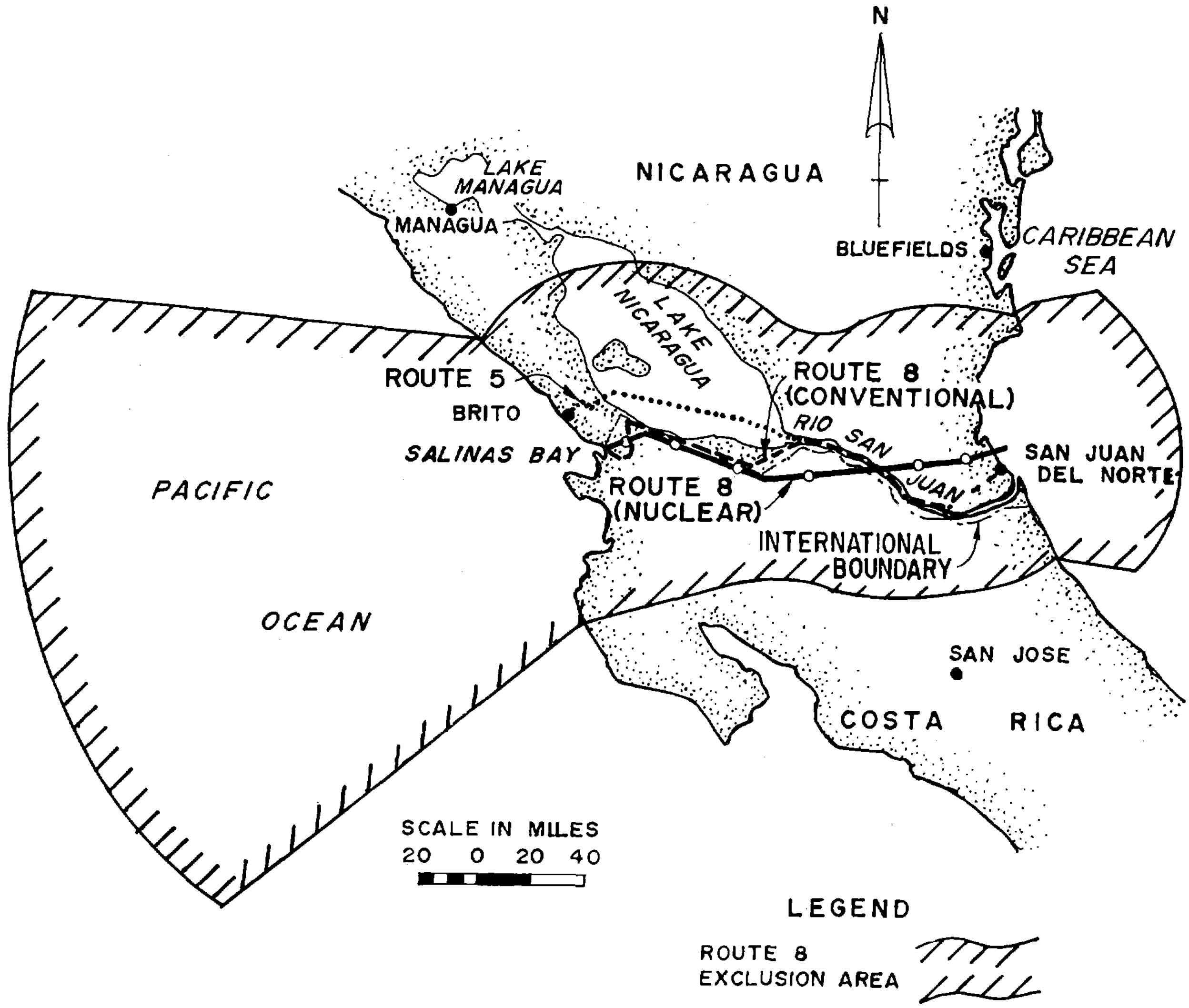


Figure 1. Routes selected for investigation by the Atlantic-Pacific Interoceanic Canal Study Commission. Route number system was established by an earlier study.



ROUTE 8

Figure 2. Alinement of Route 8, showing tentative nuclear exclusion area.

At the start of our studies in 1964, Route 17 (FIGURE 3) was thought to be the only alternative that could be built for less than one billion dollars. Since then our exploratory drilling in the Chucunaque Valley has identified an extensive formation of clay shales. Called Sabana Shale, this is a very poor construction material. From what we have learned about it, we would expect it to be unstable unless the bank slopes of any cuts we might make through it were extremely flat, possibly approaching slopes as flat as 1 on 14 in the higher elevations.

Our present conceptual design of this 49 mile-long canal calls for nuclear excavation through the Pacific Hills and through the Continental Divide on the Atlantic side. The reach through the Pacific Hills is about ten miles long, averaging about 250 feet in elevation, and cuts through a maximum elevation of nearly 800 feet. The Divide cut is nearly 20 miles long, averaging 400 feet in elevation, reaching a maximum of 980 feet. Rock in the Divide is mainly pyroclastic and volcanic basalts, while the Pacific Hills are formed mostly of sedimentary rock of volcanic, pyroclastic or tuffaceous origin.

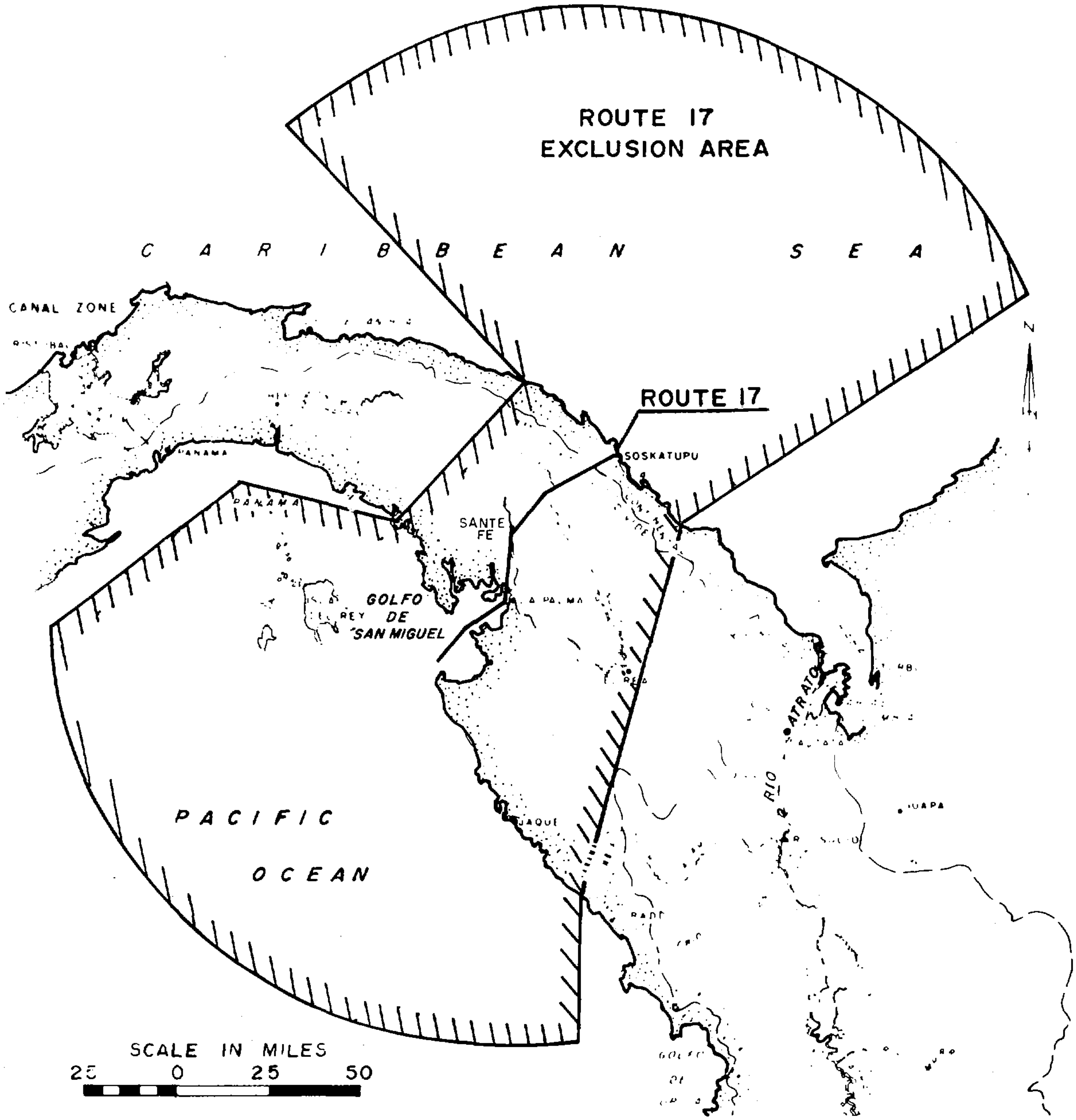
On the assumption that nuclear excavation is found to be engineeringly feasible, the nuclear design calls for 250 devices in 27 separate detonations of from one to eleven megatons. The largest single charge would be three megatons. Some 40,000 people now live in the exclusion area. Although relatively speaking, the economic burden imposed by moving them is not large - about $140 million - the social and political consequences of this project for Panama might make it unacceptable.

In the final analysis, however, the economic feasibility of Route 17 hinges on the method employed to cut through the Chucunaque Valley. We have investigated many ways to use nuclear explosives for this, including overexcavation, slope flattening by hydraulicking and subsidence cratering. The most promising results have been obtained from arrays of explosives; however, we have not yet achieved the stable bank slope conditions that we must have. At the present time, we believe that the flattest slopes we could produce by nuclear means would be on the order of 1 on 8, and even that capability has not yet been demonstrated. Consequently, our estimates currently show the Chucunaque reaches to be constructed by conventional means at a cost of $1.8 billion of the total $2.9 billion estimated for this alternative.

Recently the Colombian Government requested informally that we evaluate Route 23 (FIGURE 4) which might offer certain political advantages over other routes. Unfortunately, by then we had withdrawn our personnel and equipment from the field; consequently, we have had to base our estimates for that route upon the limited data which have been accumulated by others.

At 470 feet, its Divide elevation is among the lowest of the routes under consideration. Much of its 140-mile length is scarcely above sea level and could be excavated by hydraulic dredges, but the Divide cut would pass through elevations greater than 100 feet for about 25 miles and should be considered for nuclear excavation. Our very superficial knowledge of its geology indicates that the Divide consists largely of tuffs, limestones and interbedded sands and shales. Assuming that they are competent and that we could employ nuclear techniques, we would estimate the construction costs of this route to be approximately $3.0 billion. We should note, however, the possibility that the Sabana Shale formation found on Route 17 extends into this area, making nuclear excavation of this entire reach unlikely.

The Divide cut of Route 25 (FIGURE 5) at the Pacific end of this alternative, would pass through 20 miles of uplifted volcanic rock and overlying sediments, with an average elevation of 500 feet and a 930 foot maximum. Almost all of the remaining 80 miles of this alinement lie in the Atrato River's estuary and,



ROUTE 17

Figure 3. Alinement of Route 17, showing tentative nuclear exclusion area.

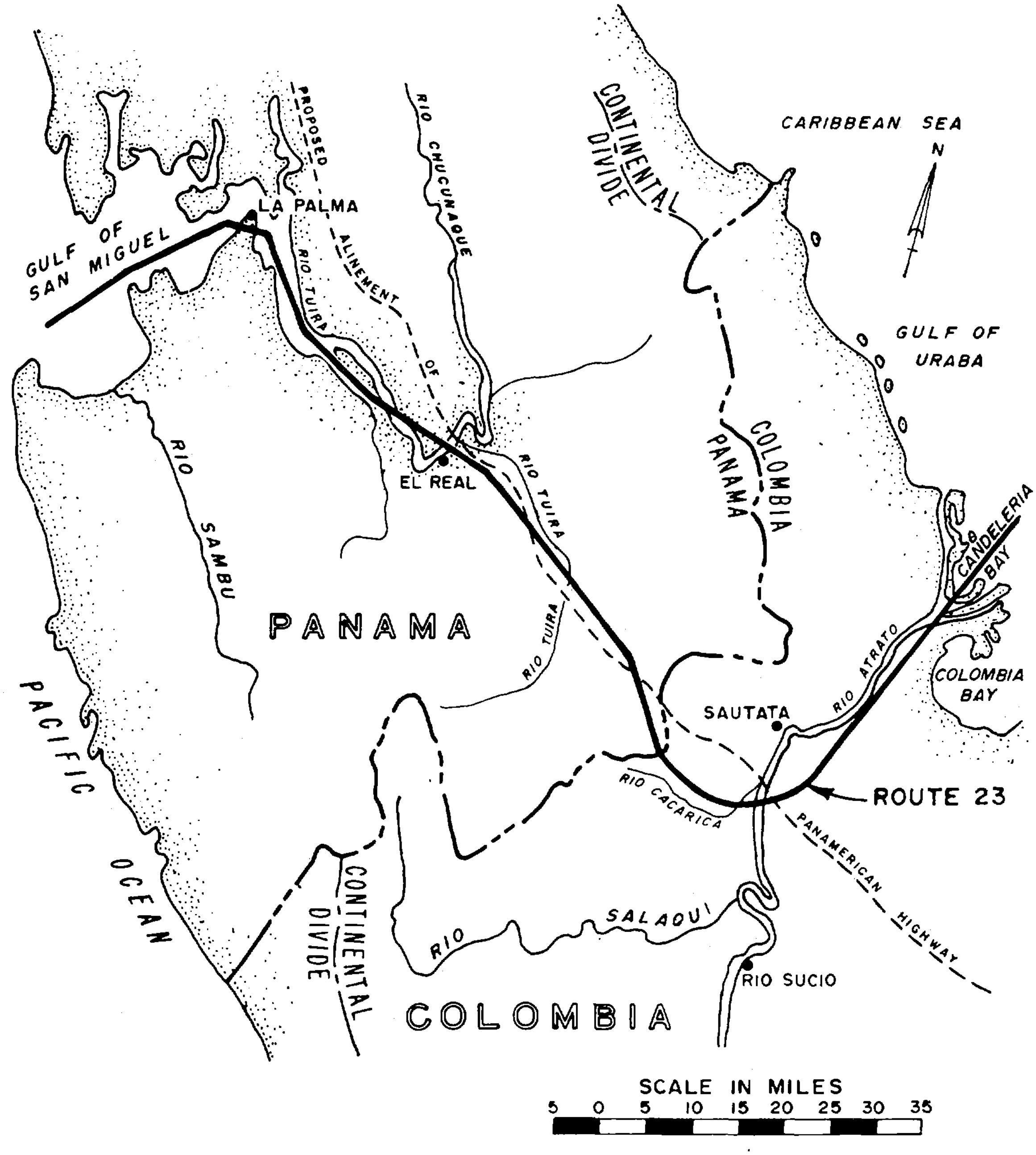
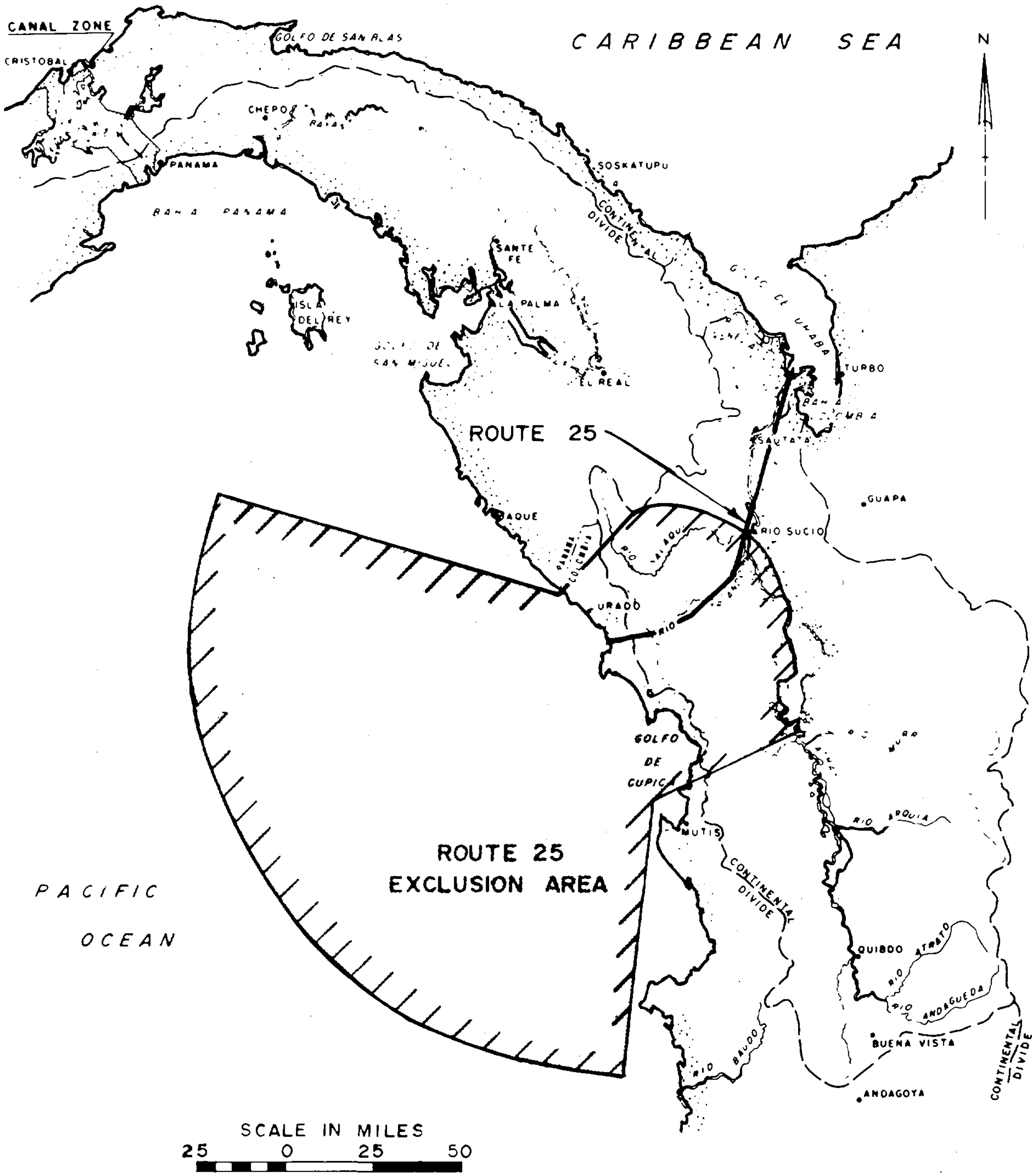


Figure 4. Tentative alinement of Route 23.



ROUTE 25

Figure 5. Alinement of Route 25, showing tentative nuclear exclusion area.

while they would be excavated conventionally, almost all of this work could be done by relatively cheap hydraulic dredging. Consequently, in terms of excavation costs only, Route 25 appears to be the least expensive alternative, nuclear or conventional, by a considerable margin, at our current estimate of $1.9 billion provided, again, that nuclear excavation is found engineeringly feasible.

This sum is based on a design calling for 150 nuclear explosives ranging in yield between 0.1 and 3.0 megatons. They would be fired in 21 separate detonations ranging from 0.9 to 13 megatons. The total yield would be 120 megatons.

Again, we run into fallout problems. The estimated long term land exclusion area covers more than 3,000 square miles and is presently inhabited by as many as 20,000 people. Serious seismic effects are not likely to be felt outside of this area.

Time does not permit me to discuss the wholly conventional routes. Suffice it to say that our investigations have convinced us that both are engineeringly feasible. We estimate their construction costs to be $2.7 billion for Route 10 and $2.8 billion for Route 14. From this (FIGURE 6) we might conclude that the Route 25 nuclear solution is by far the most economical; it has nearly a billion-dollar advantage over the cheapest conventional solution. But I cannot at this point in time recommend nuclear construction to the Commission. I am unable to do so because we do not yet know enough about nuclear excavation.

A stated purpose of the Commission's study has been to determine "the best means of constructing a sea-level canal connecting the Atlantic and Pacific Oceans, whether by conventional or nuclear excavation, and the estimated cost thereof." Implicit in this purpose, and prerequisite to its accomplishment, are the development and verification of necessary nuclear excavation technology.

By now it should be apparent to you that the Plowshare testing program designed to support the Commission's study will not be completed before our investigations are terminated. Our inability to conduct the tests needed to prove out nuclear excavation theory leaves large gaps in our knowledge, making it impossible for us to state unequivocally that nuclear excavating techniques are feasible. Nor do we have any valid basis for comparing construction costs of routes relying in whole or in part upon these nuclear techniques with other routes in which only proven conventional construction methods would be employed.

But we do have good reasons for believing that nuclear excavation might offer the best method for constructing a canal under certain conditions. In the course of our work on this study the potential advantages of nuclear excavation have become increasingly clear - as have its limitations. The advantages which it promises are probably most easily described in economic terms, as shown in these current best estimates of the costs of excavating large volumes of hard rock by three different means - conventional dry excavation, nuclear explosives and chemical explosives (FIGURE 7).

Our understanding of these methods is not equally well developed; hence, our cost estimates are not uniformly accurate, but they are certainly good enough to arouse our interest in nuclear excavation for large volumes. Note the economies of scale which appear to be available from nuclear excavating techniques. Note, too, where we hope to arrive with chemical explosives in the very near future. We would expect to employ whichever of these methods is least costly for the volume to be excavated (FIGURE 8), all other considerations being equal. On this basis, it would seem likely that nuclear excavating techniques will be widely used in the future if only we can equalize all of these other considerations. This makes it imperative that the work undertaken to support the canal studies be pushed through to completion.

NUCLEAR EXCAVATED SEA-LEVEL CANAL CONSTRUCTION COSTS

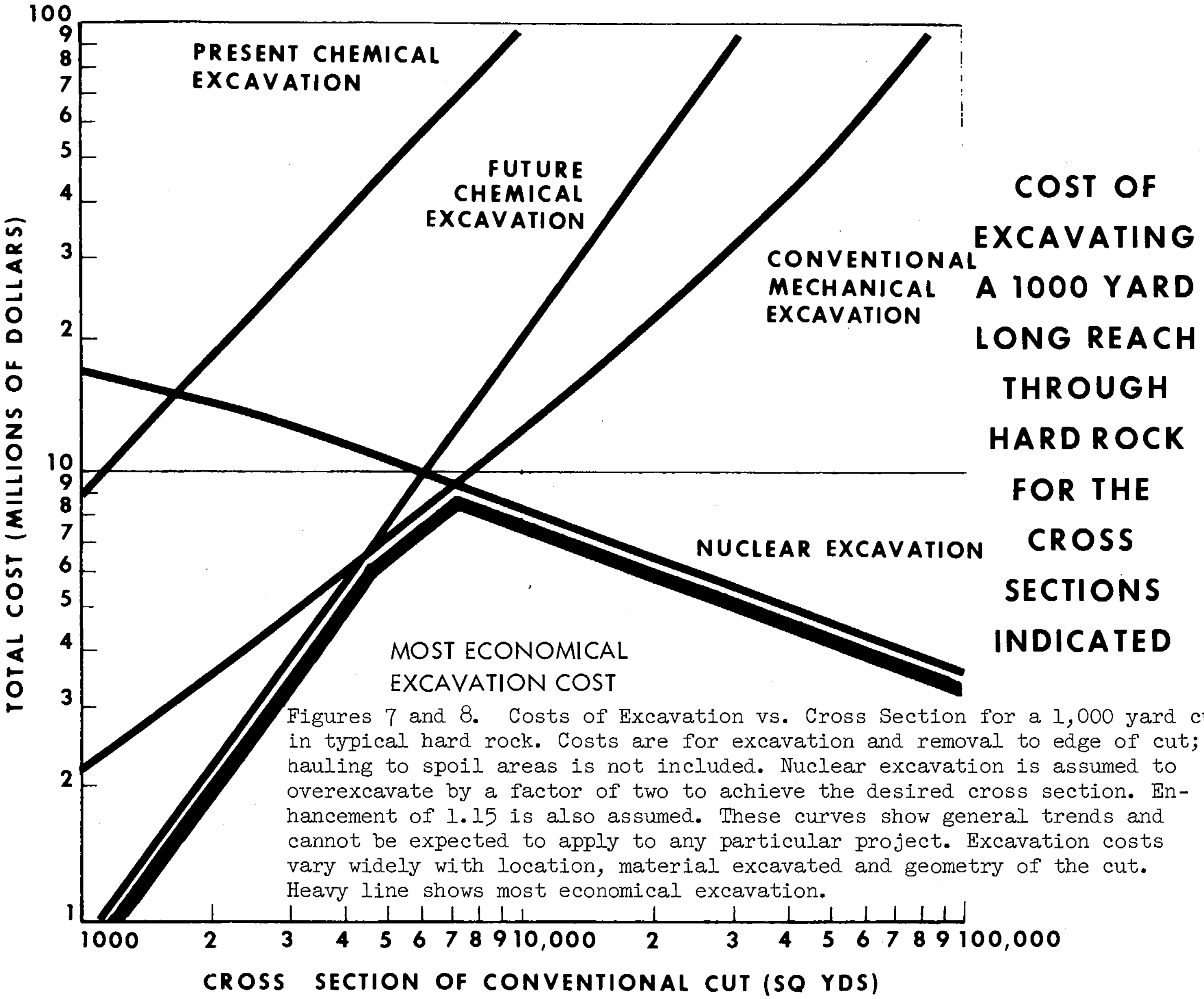
(millions of dollars)

ROUTE	CONVENTIONAL EXCAVATION	NUCLEAR EXCAVATION	ASSOCIATED NUCLEAR COSTS	SUPPORTING CONSTRUCTION	TOTAL CONSTRUCTION
8	100	900	1,700	800	3,500
17	1,800	300	200	600	2,900
23					3,000*
25	800	300	100	700	1,900
Comparative Costs - Conventional Canal Construction					
10	2,200	—	—	500	2,700
14	2,300	—	—	500	2,800

Based on a capability to handle at least 40,000 transits annually of ships up to 250,000 dwt. These costs are based on present construction cost estimates.

* Preliminary estimate

Figure 6. Current estimated costs for routes proposed for nuclear excavation. All except Route 8 would have a significant portion excavated by conventional means.



Figures 7 and 8. Costs of Excavation vs. Cross Section for a 1,000 yard cut in typical hard rock. Costs are for excavation and removal to edge of cut; hauling to spoil areas is not included. Nuclear excavation is assumed to overexcavate by a factor of two to achieve the desired cross section. Enhancement of 1.15 is also assumed. These curves show general trends and cannot be expected to apply to any particular project. Excavation costs vary widely with location, material excavated and geometry of the cut. Heavy line shows most economical excavation.

I would hope that those who move on toward our goal of a proven, useful nuclear excavation technology, will take full advantage of the knowledge and experience we have gained while studying these isthmian canals. Much of what we have done could be instructive to those who must carry on our work. To that end let me attempt a brief critique of our efforts to date as I view them. In so doing I do not intend to imply criticism of any individual or agency participating in this study. Speaking with benefit of hindsight, I have nothing but admiration and respect for those who have contributed to the present state of our knowledge of this very difficult subject. But, also with the benefit of hindsight, I believe we can discern where we must apply greater efforts in the future if we are ever to see civil engineering projects constructed by nuclear means.

My critique will be in three parts - our accomplishments, our unresolved problems, and what we might do differently in the future. Taking them in that order, by way of accomplishment we can point with pride to:

-- Having developed a much clearer and more accurate picture of the probable cost and effort required to construct a sea-level canal with nuclear explosives;

-- To having stimulated the theoretical determination and experimental verification of nuclear cratering effects of yields up to 35 kilotons, and for crater predictions into the megaton range for single and row charges in varying media and terrain;

-- To having shown by large scale chemical explosive tests, the feasibility of connecting row craters to form a continuous channel; and

-- To having prepared detailed nuclear operations plans which could serve as a guide for any future nuclear excavation project.

In these and in many other facets of our work we have made real contributions to man's knowledge. We must not permit them to be forgotten; we must continue to build upon them and to expend our knowledge.

Those items which might be listed among the group headed "Unresolved Problems" all stem from the lag in the testing program associated with Plowshare. Tests have not yet been conducted in the megaton yields and hence we do not have assurance that our present cratering scaling relationships will apply in that range. The practicability of nuclear excavation in rock of high water content has not been demonstrated. We have not yet developed and demonstrated our ability to design and execute row charge excavations at high yields and in varying terrain, to connect row craters smoothly, and to perform nuclear excavation in relatively weak materials, producing structurally stable craters. The tests that were planned in order to achieve these goals must be made. Although they will involve additional effort and expenditures, the savings that could ensue are far greater by comparison. I, for one, am convinced that our country cannot afford to overlook the overwhelming advantages promised by the use of nuclear energy for the execution of large civil works projects.

Finally, let us turn to the matter of what we might do in the future in addition to presently planned programs.

Until now we have made an intensive effort to maximize efficiency and economy by increasing explosive yields. There are strong inducements to do this, as we have seen in the way that the direct nuclear excavation costs fall off dramatically with increasing yields. But as we go to higher yields, we reap consequences which work against the ultimate employment of nuclear explosives, especially in close proximity to inhabited areas.

Consider this in light of the Corps of Engineers current assessment of what lies ahead of us in the field of water resources development. Although we anticipate some major projects, such as interbasin water supply transfers, it is becoming increasingly clear to us that most of our work in the future will be to provide services to an urbanized society. We expect that demands for water related public works will grow, but as we meet them we will place our principal emphasis on the use and management of resources for human ends and services rendered, rather than on the number or size of projects built. This is the policy we are pursuing in the Corps today. I believe its basic principles are equally applicable to our work in developing nuclear excavation technology.

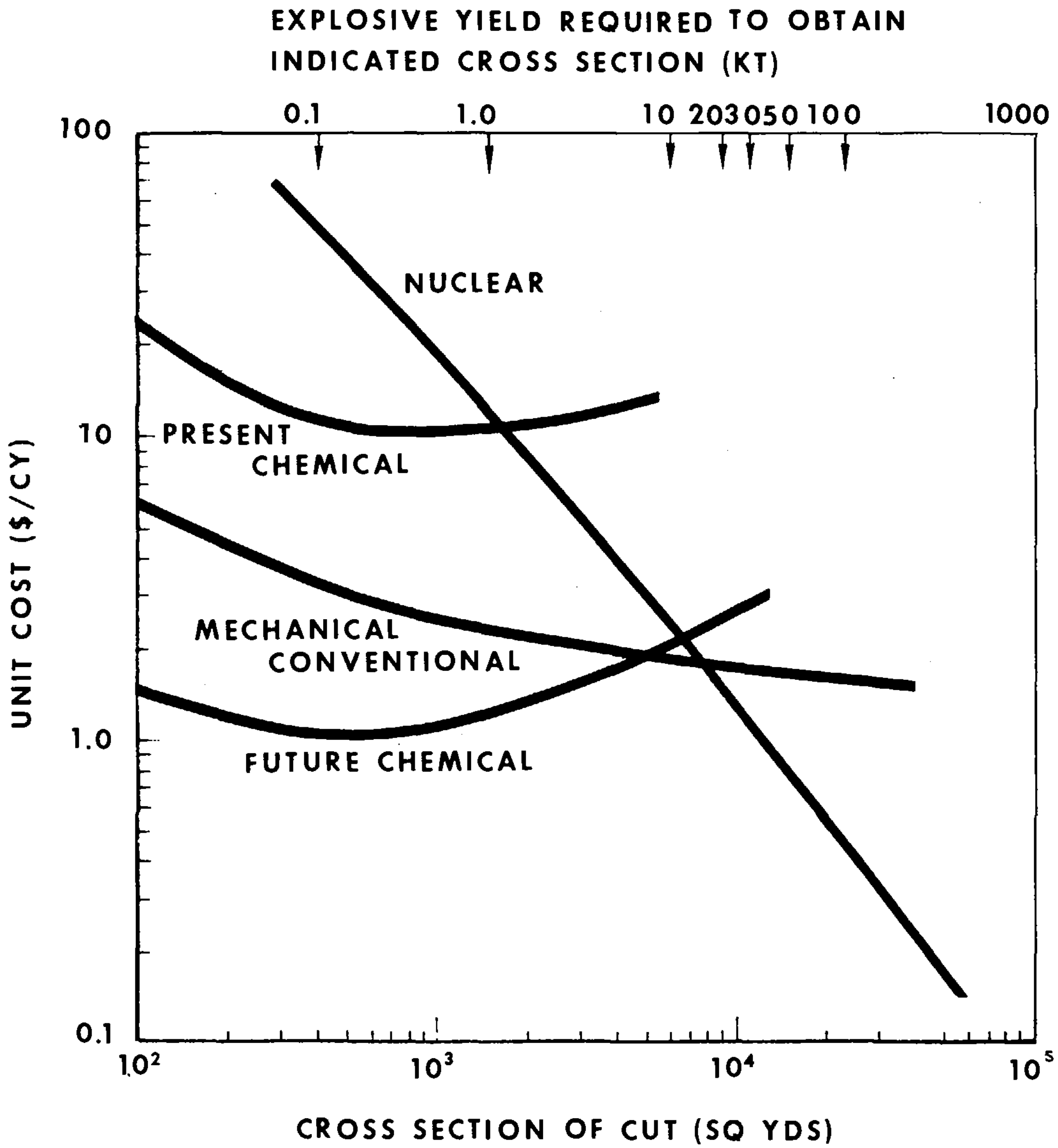
I believe the time has come when we must intensify our efforts on the low yield explosives. Already, the Corps has underway a program to develop, test and employ chemical explosives in the sub-kiloton and low kiloton ranges for excavation. As we look ahead to the projects which the Corps or other agencies like us might build in the future, we cannot visualize many where explosives could be employed with yields greater than 50 kilotons; on the other hand, there are very many, indeed, where small yields could be employed, if available. So, where does that leave us today? Consider the unit cost curves for yields in the 20 to 50 kiloton range (FIGURE 9) and you will find that they are very close to the margin. If we throw into the equation such intangibles as preserving the ecological status quo, we probably do not have at this time a competitive alternative to conventional excavating techniques. The lesson here is clear; we must work harder to develop better small yield nuclear explosives.

And, they must be clean explosives. As we use smaller yields to make deep cuts, we will have to work in stages. If such work is to be economically feasible, we must be able to re-enter the site quickly and get back to work. At the present time this is not possible. The fact that the total radioactivity produced and released per unit of energy decreases as yield increases may lead us to make explosives radiologically cleaner by making them larger, reinforcing our tendency to rely on larger yields. But it is also a fact that the total amount of radioactive materials produced and released increases as yields increase. As we move up the scale to larger yields, we soon come up against more stringent restrictions, such as the Limited Test Ban Treaty of 1963, which prohibits us from carrying out any nuclear explosion which causes radioactive debris to be present outside our territorial limits, and which, as President Kennedy said, "speaks for itself, there are no hidden meanings." And finally, do not forget that on every side voices are being raised to preserve and protect our environment. We should have no illusions about this movement; either we are going to have to revise some of our present beliefs about efficiency and economy to accommodate it, or we will become completely bogged down in fruitless argument. So, again the lesson to be learned from the canal studies is clear - we must reorient our future efforts so as to develop smaller, even cleaner nuclear excavating explosives which are efficient, economical and capable of being used in proximity to people.

How, then, shall we assess our work in the Engineering Feasibility Study?

Summing up our present situation, I would say that we have not yet attained the objectives of our study, as they pertain to nuclear excavation, nor are we likely to do so in the time remaining to us. We have not yet established the feasibility of constructing by nuclear means a sea-level interoceanic canal; we are unable to state unequivocally that were this technique feasible, it would be the best.

We know now that a conventionally constructed canal is technically feasible and we know its approximate cost. We are confident from a purely engineering



HARD ROCK EXCAVATION COSTS

Figure 9. Unit cost of excavation in hard rock. Assumptions are as for Figure 7.

standpoint that it could be built, if desired.

But we recognize that the question of its technical feasibility, even though answered favorably, will not in itself govern the decision on a new canal. Many other factors - diplomatic, military, political, sociological, economic and ecological, to name but a few - must also be considered and any one of them can influence the course of action which is finally adopted.

While a conventionally-constructed canal is feasible today, we cannot be sure that it would be the best solution to the canal problem until such time as we know more about nuclear excavation technology than we now know. I would expect that the necessary knowledge can be acquired before construction of a new canal begins, if only the Plowshare investigations now planned are executed.

Yet, no matter when the final decision is reached concerning the sea-level canal or what it may be, I am convinced that the case for developing nuclear excavation technology is fully capable of standing on its own merits. In its techniques are such vast potentials for applications to public works that its technology must be fully developed, regardless of how the canal question is settled. And if, by developing it, the well-being of our fellow Americans is enhanced, all the time and effort that have gone into the Engineering Feasibility Study will have been worthwhile.