

HIGH GRADE
URANIUM RESOURCES IN THE UNITED STATES:
AN OVERVIEW

by

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P R E F A C E

The results of a study on the potential United States uranium supply are presented in this paper. This study was conducted in the M.I.T. Energy Laboratory, as part of the continuing research on energy supply and demand (N.S.F. Grant # GI-39150). The results of this study will be utilized in conjunction with an electricity supply model under development.

A B S T R A C T

A time analysis of uranium exploration, production and known reserves in the United States is employed to reveal industry trends. The basis for this analysis is the data collected, processed and published by the A.E.C.'s Grand Junction Office. This analysis reveals that exploration, thus the quantity of known uranium, has been governed by demand. Factors affecting the prospects for future discoveries are discussed. The author concludes that the resource base may be substantially greater than is presently known, and calls for a national research effort to better quantify the extent of our uranium resources.

ACKNOWLEDGEMENTS

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The author wishes to thank the many employees of the U.S. Atomic Energy Commission whose assistance made this study possible. Thanks are due to Mr. Philip Keif, of the Office of Information Services, for producing copies of several A.E.C. documents and for referring the author to individuals at the A.E.C.'s Grand Junction Office. The contribution of these persons was invaluable. Special thanks go to Mr. Clifton Barnes, Director of the Office of Planning and Analysis; Mr. Ben Boyer, Director of the Resource Division; and Mr. Morris Hanson, of the Reserves Office. The author would also like to thank Mr. John Patterson, Chief of the Supply Evaluation Branch in Washington D. C. for assisting the author develop a better understanding of the uranium forward cost/market price relationship.

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INTRODUCTION

The subject of high grade (forward cost \leq \$ 30) uranium's availability is significant for the following reason. After the known high grade uranium is depleted, it has been assumed that the nation will have to turn to low grade deposits for its power needs. These deposits, such as the Chattanooga Shale and the Conway Granite, are known to contain more uranium than the nation is projected to need within the next fifty years. However, the cost of uranium from these deposits would be very high. For instance, production costs from the Shale have been estimated to reach as high as \$150 per pound U_3O_8 (uranium oxide), relative to current market prices below \$8 per pound.

Should the low cost resources prove to be insufficient to meet our power needs, utilization of the Liquid Metal Fast Breeder Reactor (LMFBR) would be an economical alternative to electricity generation with high cost uranium. The LMFBR would produce more nuclear fuel than it consumed. It would economize on high cost uranium by converting otherwise useless U^{238} , by far the most abundant isotope, into Plutonium 239. Plutonium, in turn, could be utilized in conventional-type nuclear reactors to produce electricity.

This report presents a time analysis of uranium exploration, production and known reserves in the United States. This type of analysis is often utilized in other mineral/fuel industries to elucidate trends. As such, it is useful in providing a qualitative indication of the potential undiscovered uranium reserves that now exist.

There are several indications that the nation's high grade uranium resources are greater than presently known. One, exploration of the regions currently producing uranium is incomplete. Historically, continued drilling in these areas has indicated the existence of additional

uranium resources. Two, all the exploration to date has been for the highest grade (\$8 forward cost) ore. If the industry begins to search for higher cost ores (forward costs between \$10 and \$30) more may be discovered. Three, the regions currently producing uranium comprise less than 10% of the land in the Western United States known to be favorable for uranium occurrences (the currently producing regions contain the bulk of the known and estimated high grade uranium reserves). And four, there is a potential for high grade uranium occurrences in regions other than the Western U. S.

However, knowledge on the extent of the high grade resources is limited. Thus, quantitative evaluations at this time must be classified in some sense as speculation. Knowledge is limited because no effort has yet been made to determine the size of the entire resource base.

The A.E.C. has formulated supply curve estimates for the potential uranium supply. For example, such supply curve estimates were utilized in the Cost-Benefit Analysis published as part of the LMFBR Environmental Impact Statement Draft (WASH-1535). This analysis includes uranium requirements projections through the year 2020. A number of cases are considered for different LMFBR introduction dates, and no LMFBR introduction during the period. On casual observation, their uranium supply estimates seem to span a reasonable range of uncertainty in the potential supply. However, even in their "optimistic" case, they assume that the nation eventually must utilize the low grade, high cost deposits during this period if the LMFBR is not introduced. In light of the uncertainty involved, and the sensitivity of the expected market price to the uranium supply assumptions, the author feels a more liberal "optimistic case" would be appropriate in performing such analyses; high grade resources could prove to be in excess of demand. The author has concluded that a quantitative evaluation of the high grade uranium resources should be part of the nation's energy research effort.

THE URANIUM INDUSTRY

Uranium resources are explored and developed by private industry. There are roughly eighty five firms engaged in this activity.

The term "resources", when used in regard to a mineral/fuel, refers to all the mineral contained in ores, regardless of their current commercial worth. "Resource" includes both known and undiscovered deposits. "Reserves" are the resources that comprise the industry's current working stock. This is the quantity of uranium, in known deposits, calculated to be producible at a given (usually market) price. The physical characteristics, quantity, and grade of these deposits have been established with reasonable certainty.

The deposit's characteristics are determined by detailed sampling, usually by exploratory and development drilling. Delineation of the deposit's characteristics must be completed before the decision is made to begin development.

The lead time for converting deposits to reserves, from the initiation of exploratory drilling to production, is about eight years. Physical limitations and economics preclude bringing the deposits into production in a shorter interval. Thus, reserve quantities adequate to meet cumulative projected demand eight years in advance are considered a minimum to assure adequate supplies. Historical data indicate that the industry maintained roughly a ten year advance supply from the middle 60's to the present.

A considerable expenditure is required to convert resources into reserves, i.e. to delineate prospective deposits so they can be developed. These costs have historically run almost 30% of the uranium market price^[1]. Thus, exploration and development efforts are largely restricted to the industry's current needs.

Before a firm will commit the investment to delineate a deposit, previous exploratory evidence must indicate the existence of a sufficiently large commercial grade ore body. Once it has been delineated, the exploration and property acquisition costs are irrevocably allocated. At this point, the company is committed to developing the deposit. The profitability of the uranium formation at a given market price is determined by its characteristics, i.e., the quantity and grade of material whose marginal production cost is below the market price. The marginal production cost only covers the cost mining the ore, transporting it to the mill, and mill processing the uranium material. When the firm exploits the deposit, it will withdraw all the material for which the marginal production cost is less than the market price^[19].

The market price itself is determined by supply/demand interactions. Utilities bid for the available uranium in both a current and a futures market. In the futures market, if the low cost supplies to be available were insufficient to meet the demand, the price would be bid upwards. Higher prices would increase available supplies in two ways. First, the higher market price would expand the amount of ore than could be commercially mined. Additional ore, at higher marginal production costs, could be economically withdrawn from producing deposits. Second, the higher prices would encourage the uranium companies to explore for uranium, as the higher prices would increase the industry's profitability. The same reasoning applies to an excess of uranium, depressing prices, available supplies and exploration.

URANIUM RESERVES

Estimates of domestic uranium reserves are formulated by the Grand Junction, Colorado Office of the A.E.C. These estimates are based on information supplied by the firms developing the uranium deposits. As this information is proprietary, no independent reserves estimates exist.

The A.E.C. collects data on deposit grade, thickness, depth, and other relevant information. On the basis of these characteristics, a cut-off, or minimum, grade, in per cent U_3O_8 , is determined which can be developed at the given "forward cost". The "forward cost" can be considered to be a marginal production cost, which just covers the cost of getting the ore out of the ground and to market. The cost calculations consider the mining, hauling and milling operations and the royalty payments only. Any material at a grade equal to or above the cut-off is considered a reserve at the particular forward cost. Other uranium production costs are not considered in the estimation of forward costs. These expenses include property acquisition costs, exploration costs, and profit^[2].

The A.E.C. has been estimating \$8, \$10, and \$15 and \$30 forward cost reserves since 1962, 1965, 1967 and 1973, respectively. Each year, the \$8 and \$10 reserve estimates are published in Statistical Data of the Uranium Industry (GJO-100). The higher cost reserve estimates are not released in an organized fashion.

These reserve estimates are made on the basis of current dollars. Until recently, inflation has been offset by industry productivity increases. The high inflation rates we are currently experiencing, however, are not being equaled by higher productivity. This will be a factor in reserve estimates for 1974, diminishing the quantity of uranium available at each forward cost^[3].

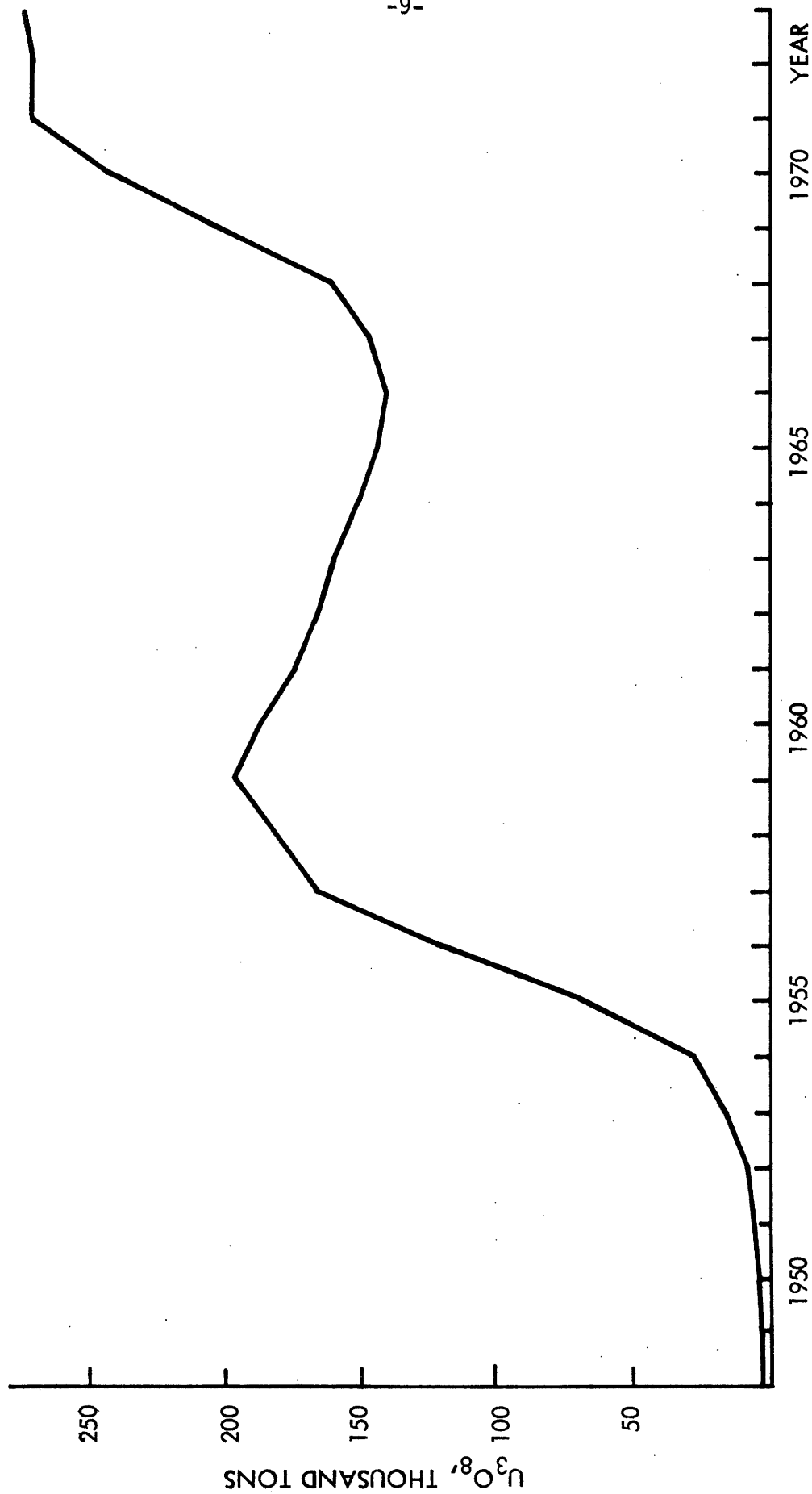


Figure 1: Uranium Reserves \$8 Forward Cost *

* Prior to 1962, reserve estimates were based on criteria other than forward cost cutoff

source: reference 4

In recent years, uranium production has been derived from \$8 reserves. The A.E.C. estimates of these reserve quantities are displayed in Figure 1 by year. Before 1962, reserves were estimated on a basis other than \$8 forward cost. However, the estimates do approximate the industry's working stock.

Note there are two periods during which reserve quantities were rapidly increasing: 1954 through 1959 and 1966 through 1971. Beginning in 1948, the A.E.C. instituted a program to stimulate domestic uranium production. Purchases were guaranteed at fixed prices, bonuses were offered for initial production from new mines, and air and ground surveys were conducted to locate new deposits [5]. Thus, exploration and reserves were on the increase. This program was brought to a close when the A.E.C. announced in November, 1958, that it would no longer purchase uranium ore. Thereafter, reserve quantities declined because yearly production exceeded additions to reserves. During the mid-sixties, demand for uranium began to increase as a result of the growing civilian power industry. Thus, exploration intensified, and reserve quantities increased. Exploration began to wane after 1969, however, as licensing and construction delays reduced the short term demand.

These trends are again illustrated in Figures 2 and 3. Figure 2 displays the sum of reserves and cumulative production, thus "known uranium" by year. The yearly drilling level and additions to reserves are presented in Figure 3. Note the upsurge in drilling that occurred in the late 50's and late 60's. These high drilling levels resulted in large additions to reserves, thus, rapid increases in the quantity of "known uranium".

In viewing Figure 3, the reader probably noted that the reserve additions during the 1967 through 1971 period required significantly more drilling than during the 1955 through 1959 period. Thus, the uranium was discovered at a lower "finding rate", expressed in pounds U_3O_8 (uranium oxide) per foot of drilling.

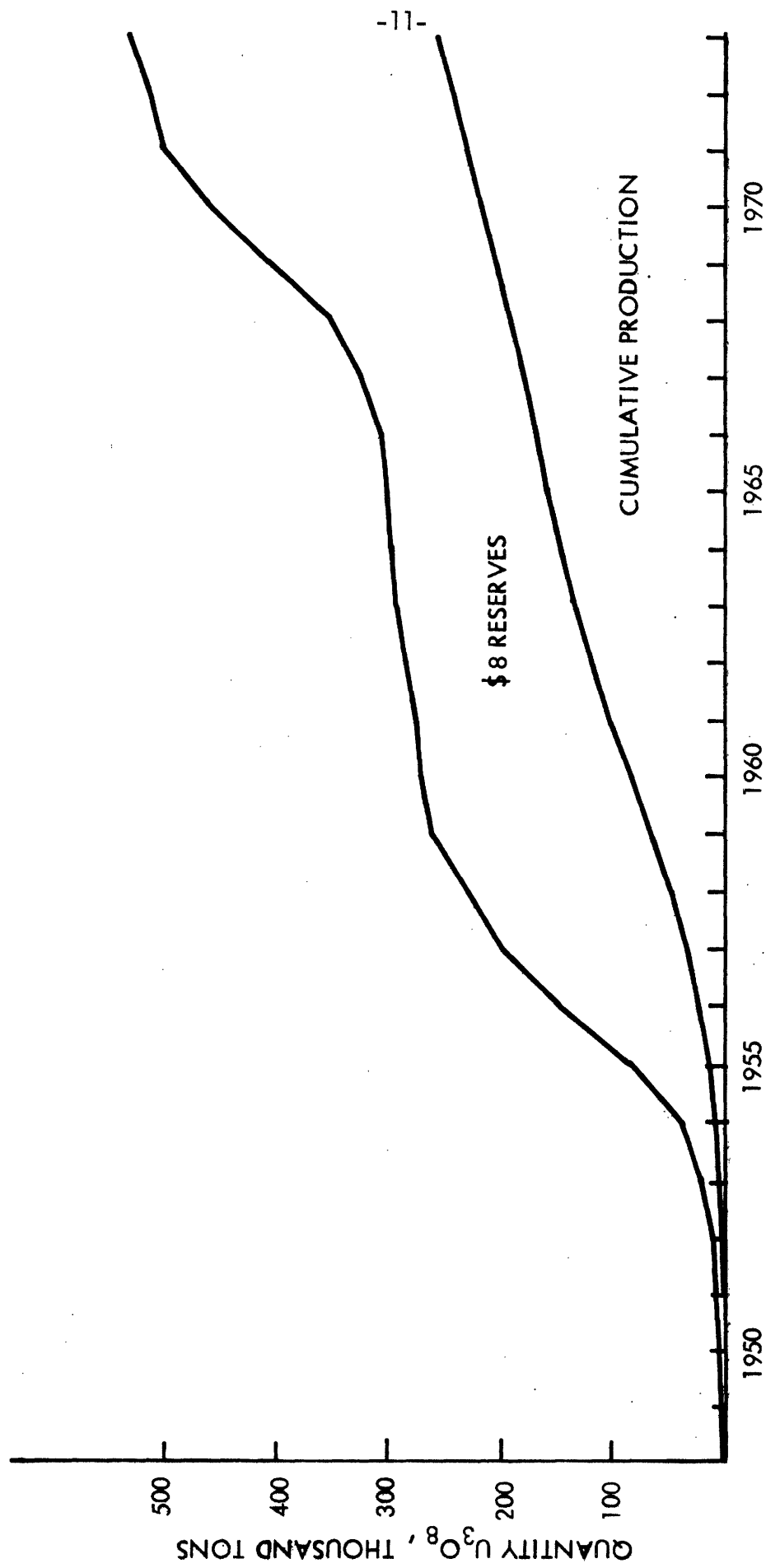


Figure 2: Uranium Reserves and Cumulative Production

source: reference 4

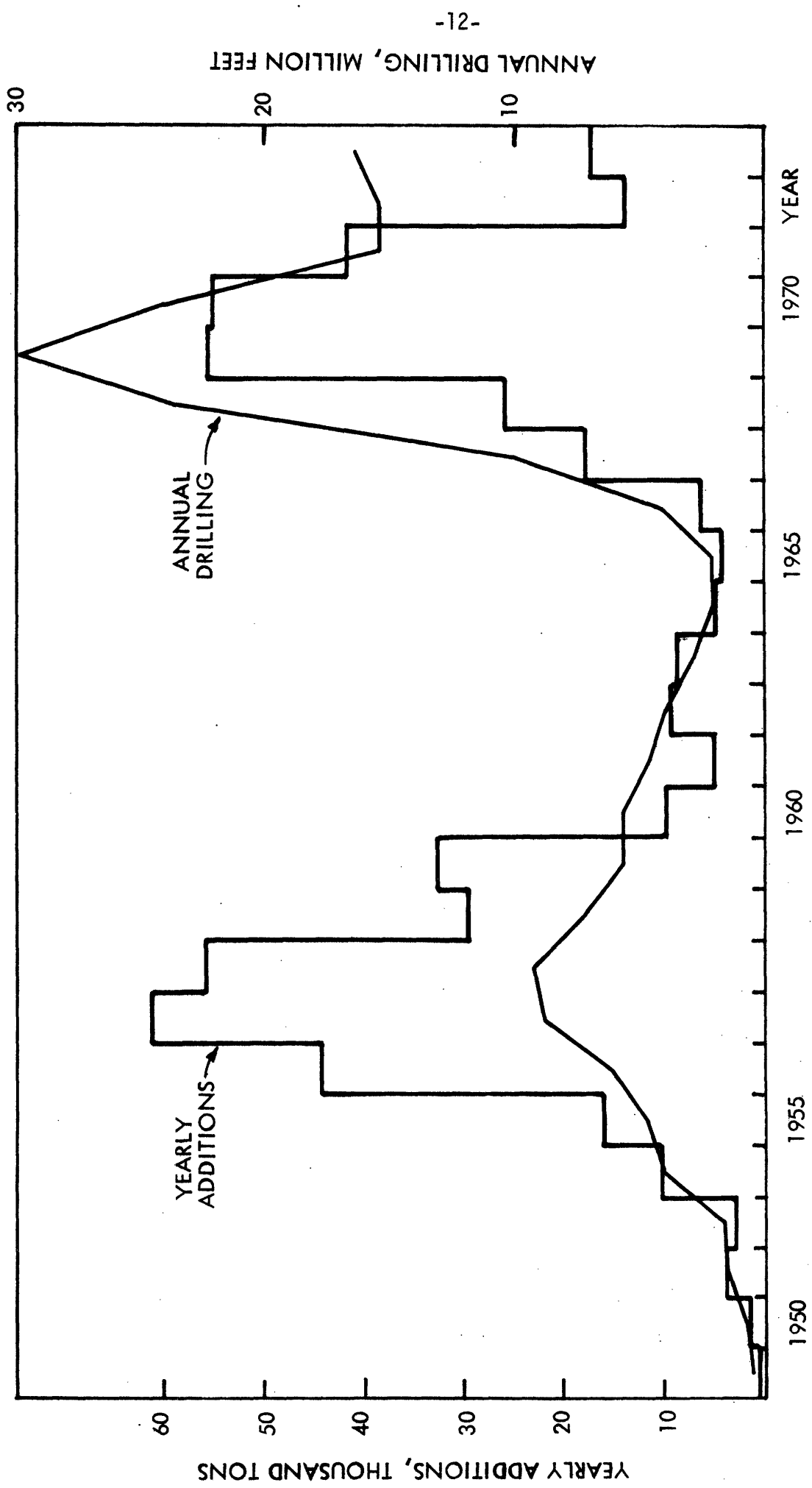


Figure 3: Yearly Additions to Reserves U_3O_8 * and Annual Drilling Footage

* \$ 8 forward cost

source reference 6

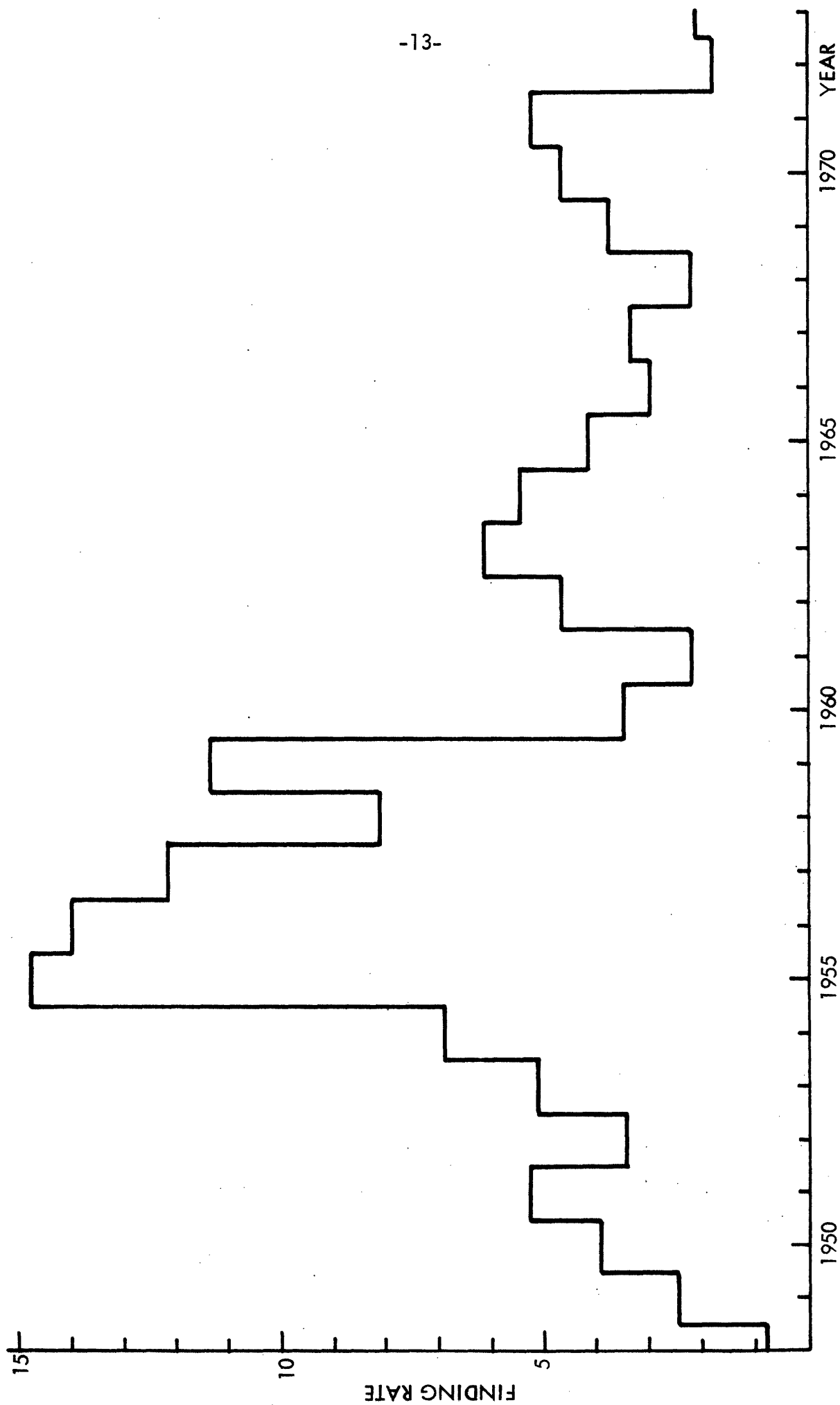


Figure 4: Uranium Finding Rate, pounds U_3O_8 per foot of drilling

source: reference 6

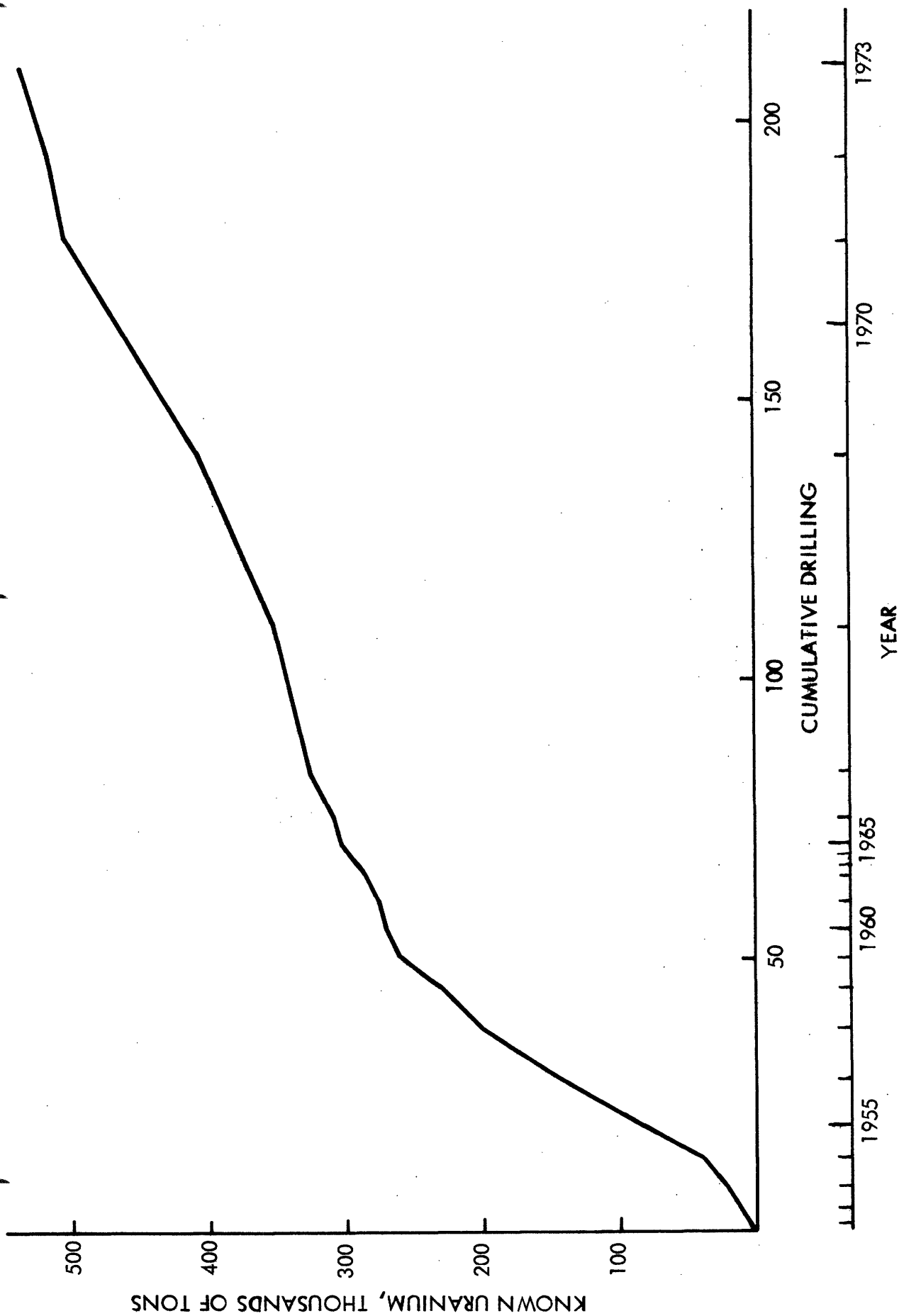


Figure 5: Known Uranium and Cumulative Drilling *

* \$8 reserves plus cumulative production.

source: reference 7

The finding rate for each year's drilling is displayed on Figure 4. In mineral/fuel industries, yearly finding rates of this sort are normally erratic. However, there is a definite peak in the curve in the last half of the 50's. Thereafter, it appears as if the finding rate has more or less stabilized below 4 lbs/ft.

These finding rate curves by year can be somewhat misleading in that no indication is given of the relative importance of a year's drilling. To give a truer indication of the finding trends, the finding rate should be weighted by the year's total drilling footage. Thus, the integral of the finding rate and the drilling level, i.e., known uranium, is often plotted against cumulative drilling. The slope of the resulting curve is the finding rate.

Known uranium (\$8 reserves plus cumulative production) is displayed against cumulative drilling in Figure 5. As was indicated in Figure 4, finding rates were high during the middle and late 50's, averaging 10.4 pounds per foot. Thereafter, the finding rate has averaged roughly 3.4 lbs./ft.

The very high finding rates in the 50's probably resulted from the exploration of deposits closer to the surface than those presently being developed. Such deposits were probably located during the course of the A.E.C.'s ground and air radiation surveys previously conducted. Although data on the average depth per well extends back only to 1958, the trend exhibited by the available data supports this hypothesis. Average depth has been increasing, from 150 feet in 1958 to 480 feet in 1973. This increase, roughly a factor of three, accounts for most of the decrease in the finding rate.

The finding rates have been relatively low recently (2.0 pounds/foot in 1973), however, and officials at the A.E.C. have indicated the "dry spell" has continued through 1974. Whether or not the industry will

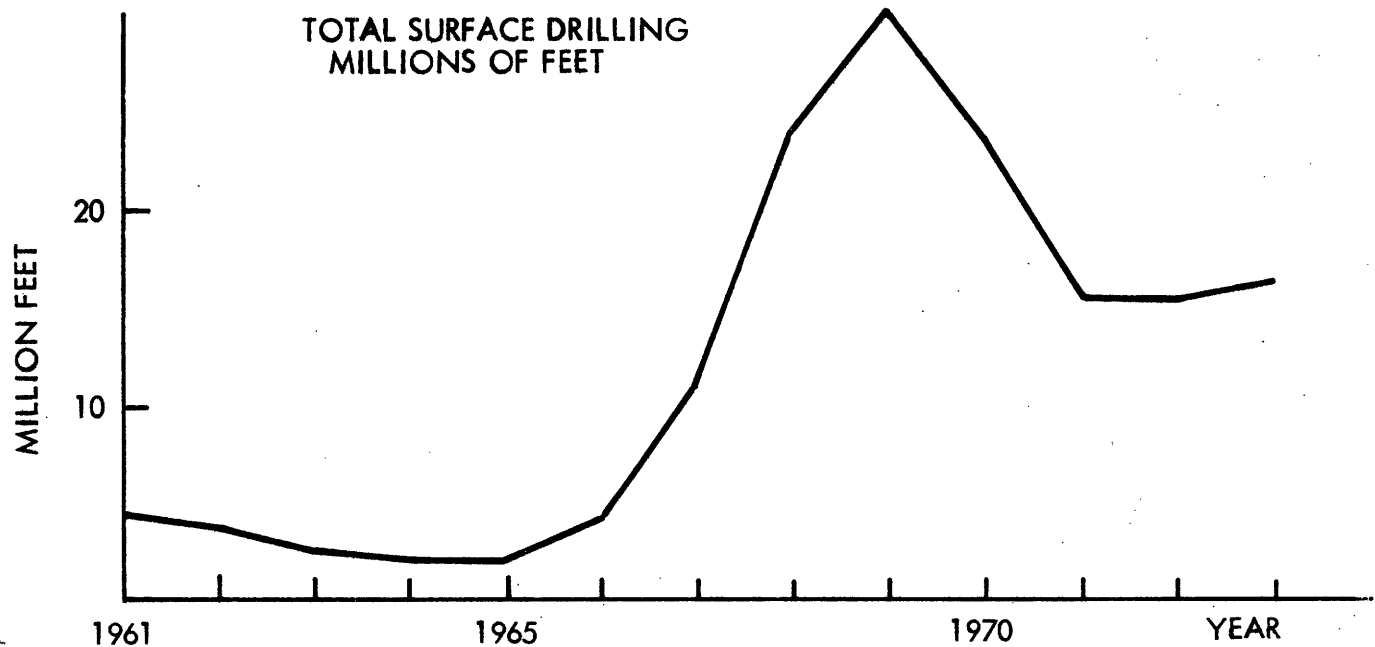
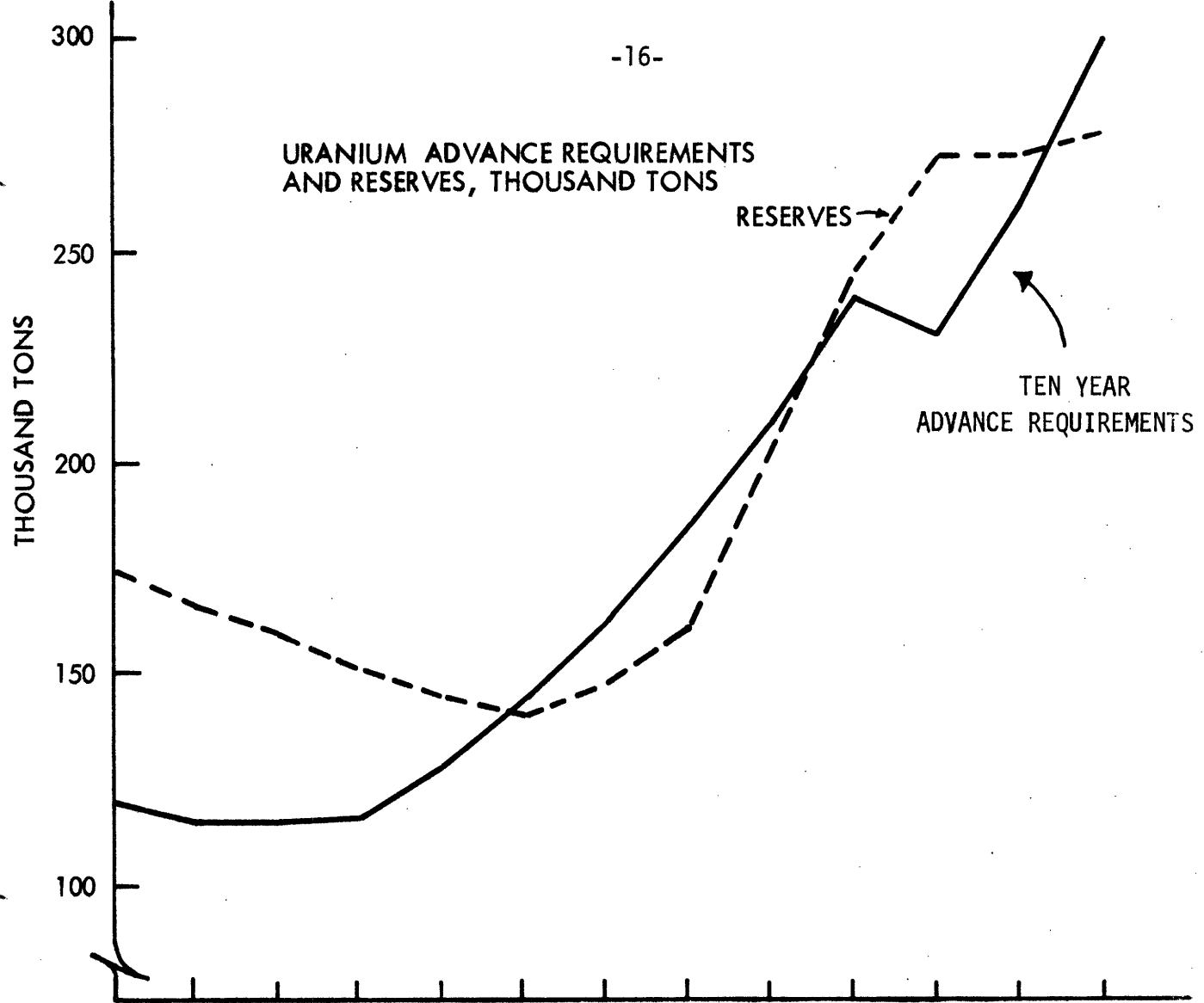


Figure 6

source: reference 9

continue to encounter this relative difficulty in finding uranium is not known. However, this relative lack of success has not decreased reserve estimates.

A trend of lower finding rates around 2 pounds/foot would probably increase the long term uranium market price by about \$3 per pound, *ceteris paribus*^[8]. This is a large increase, relative to \$8 per pound uranium. However, this increase to the cost of all high grade uranium (\leq \$30/lb.), relative to the projected costs for production from low grade ores, is not a significant factor.

The conditions that motivated the upsurge in drilling between 1965 and 1971 are revealed in Figure 6. Reserves are plotted by year against 10 year advance requirements. Also plotted is the annual drilling level. Observe that reserves are declining between 1961 and 1965, when reserve quantities were greater than 10 year advance requirements. Exploratory drilling was at a low level, hence additions to reserves were small and yearly production drew down reserves.

From 1966 to 1968, the 10 year forward requirements exceeded reserves. Drilling levels, hence additions to reserves, were on the increase. Drilling peaked in 1969. Thereafter, the licensing and construction delays resulted in a downward revision of uranium requirements projections. Drilling and additions to reserves thus declined.

For 1973, advance requirements are again in excess of reserves. One would thus expect that drilling will increase in 1974. However, industry does not plan a large enough drilling increase to meet advance requirements. This fact has received considerable publicity recently, at least within the uranium industry.

The explanation for this follows. The expertise and equipment required for uranium exploration is similar to that for coal, shale and oil exploration. The uranium industry is having to compete for these services.

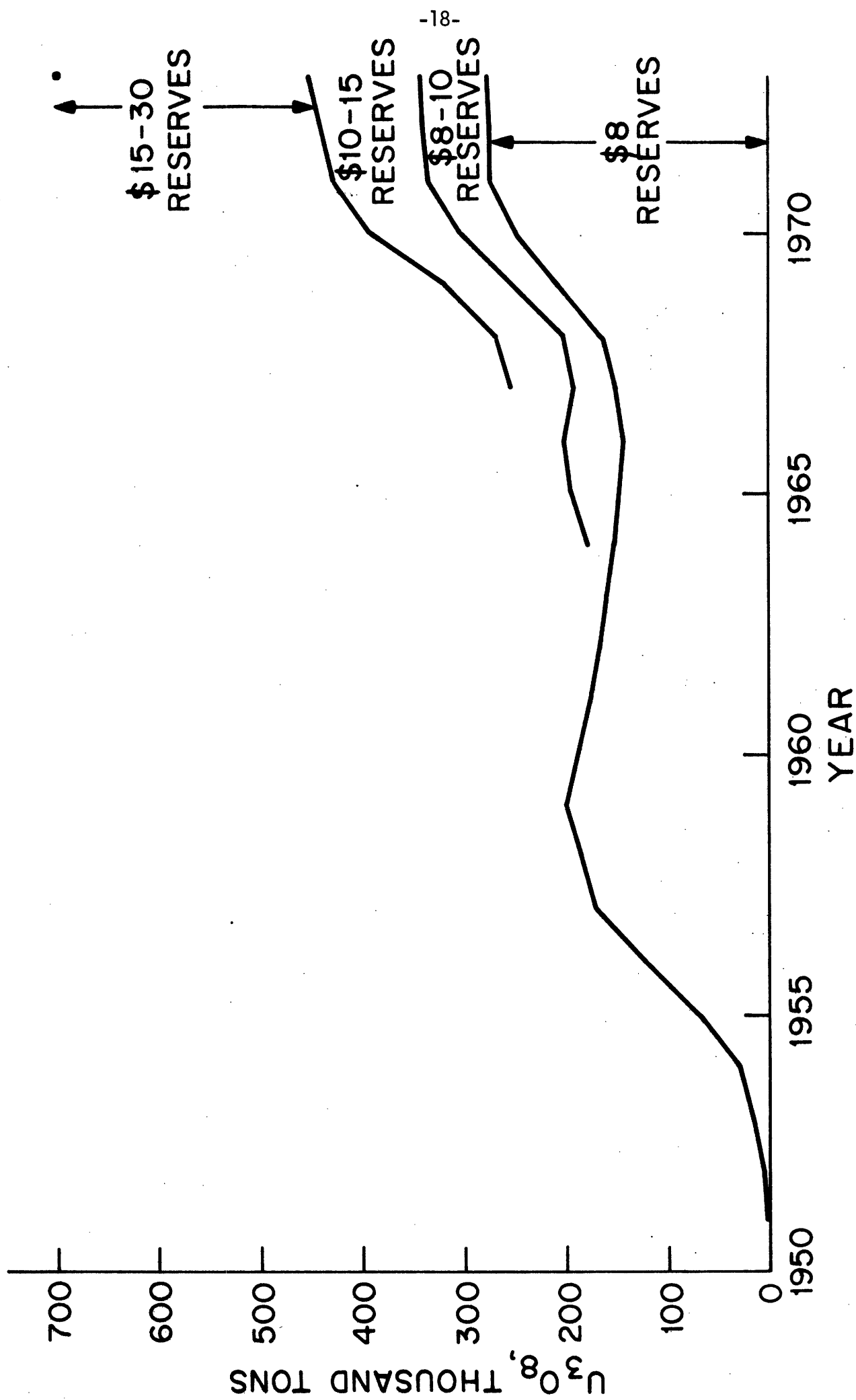


Figure 7: Uranium Reserves \$8, \$10, \$15, and \$30 Forward Cost

source: Reference [11]

High returns and relatively short lead times are available in the fossil fuel sectors. The uranium industry, on the other hand, faces longer lead times. In addition, the returns are not as certain, as the electricity consumption growth rate and utility commitment to nuclear power have been put in question recently. Thus, some of the industry's capacity for exploration has been shifted to fossil fuels. In addition, the industries that produce exploration equipment are operating at the limit of their capacity. They are beset with steel and other materials shortages. Waiting times for new drilling rigs are about two years^[10].

Although the industry is currently unable to maintain uranium resources at desirable levels, there is no danger of depleting uranium reserves, at least for the time being. Higher cost reserves are known to be available. The A.E.C. estimates of higher cost reserves are plotted by year in Figure 7. Note the increases in the reserves estimates between 1967 and 1971.

The ore that comprises these reserves is of a nature similar to the \$8 reserves, i.e. it is contained in sandstone deposits. All of this material is in formations associated with the \$8 reserves. It is, however, at a lower concentration, or in formations that are more expensive to mine than the \$8 reserves. This uranium was discovered in the course of exploring for and developing the \$8 ore. As a result, A.E.C. uranium experts concur that it is likely additional quantities of the higher cost resources remain to be discovered. If the exploration efforts were directed specifically toward that end, as opposed to being directed toward the discovery of \$8 ore only, more might be found.

These higher cost ore estimates need some qualification, however. In the process of mining the higher grade material, some of the lower grade ore can be "lost", i.e., rendered available only at a significantly higher cost. For instance, if a quantity of \$8 ore is mined and depleted, and the hole is filled, the associated lower grade uranium left in the ground will be more expensive to produce than was originally estimated.

When uranium prices were near \$8 per pound and no trouble was encountered in the discovery of additional high grade uranium, some \$10 and \$15 material was lost. The reserve levels for \$10 and \$15 ore were maintained over the years despite these losses.

The extent to which lower grade ore will be "lost" in the future depends on the market conditions. If contract prices for delivery in 1980 remain close to \$20, where they are currently, losses of \$10 and \$15 reserves will probably be negligible. If significant discoveries of \$8 ore are made, however, and the uranium price drops, the losses would be greater. Thus, the degree to which current higher cost reserves are lost is dependent on the extent of future uranium discoveries and demand.

The fact that uranium prices for delivery in 1980 are almost \$20 is not necessarily an indication that \$8 reserves are nearing depletion. An unprecedented expansion of the industry, in terms of reserves to meet advance requirements, and mine and mill (for ore processing) capacity, must begin to meet demand in 1980 and beyond. This, plus the rapid escalation of all energy prices over the last year has resulted in a significant escalation of uranium contract prices for delivery around 1980. The high prices are simply a signal for the industry to begin this expansion.

* * *

To summarize, the level of exploration and the level of known uranium have been governed by demand. Advance requirements have provided a limited motivation for uranium exploration. Assuming the industry will, from this point, discover no more high grade resources is clearly arbitrary. However, the industry is currently experiencing difficulties at maintaining forward requirements, but these are not problems of insufficient uranium resources. Rather, they are the result of the peculiar conditions the uranium industry and the entire economy now face.

POTENTIAL RESOURCES

In addition to the reserves estimates, the A.E.C. has formulated yearly "potential resource" estimates. As in the estimation of reserves, the A.E.C. estimation of potential reserves is made on the basis of "forward costs". The A.E.C. has published estimates since 1968, 1966, and 1974 for \$8, \$10, and \$30 forward costs, respectively. Estimates of \$15 forward cost potential reserves have not been released in an organized fashion for years prior to 1974.

These estimates are not attempts to assess the total resource base. This estimation is restricted to uranium in conventional sandstone deposits and consists primarily of uranium surmised to occur in unexplored extensions of known deposits and postulated deposits within known uranium areas^[13, 14]. Thus, these estimations are based on extrapolations of known deposits in areas adjacent to those well explored. There is, of course, some uncertainty in them. However, as the industry has encountered little difficulty in maintaining reserves at an appropriate level, there has been little incentive to verify the estimates.

The potential reserve estimates are intended to approximate the quantity of uranium contained within the producing areas. Thus, one could expect that more intensive exploration, within these regions, would result in increasing the known reserves at the expense of the potential reserves. However, precisely the opposite has been the case. Figure 8 displays the A.E.C. estimates of proven and potential reserves by year of estimation. Observe that known and potential uranium, in both the \$8 and \$10 cut off categories, nearly doubled between 1968 and 1970. Perhaps this is an indication of the thoroughness (or lack thereof) with which these regions have been explored.

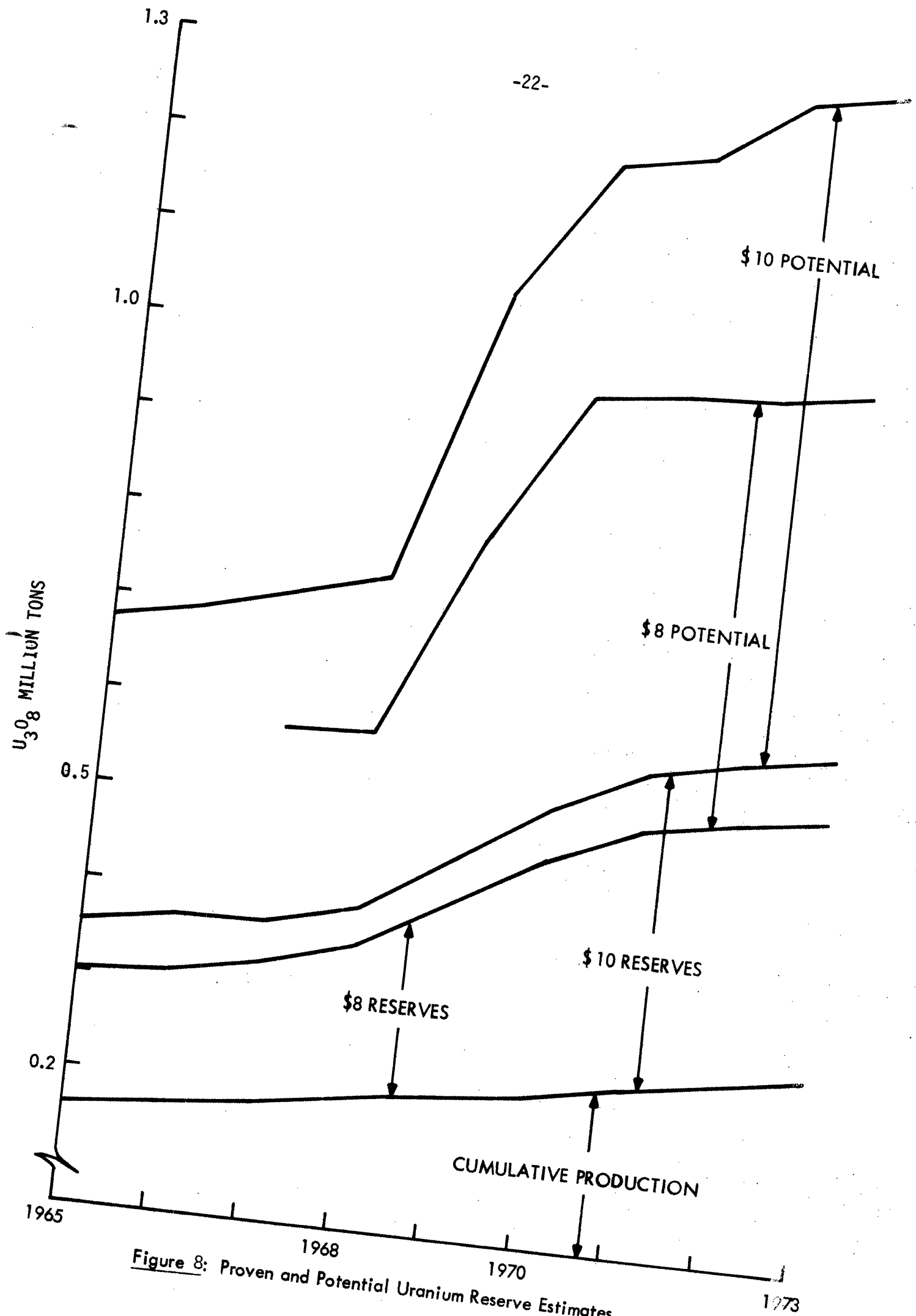


Figure 8: Proven and Potential Uranium Reserve Estimates

source: reference 15

These increases were based on the new data made available by the high drilling levels during those years. The additional potential resources are estimated to be in the three principal uranium producing regions: the Colorado Plateau, the Wyoming Basins, and the Texas Gulf Coast Plains^[16]. These areas are displayed on Figure 9. 95% of proven reserves and approximately 85% of potential reserves are located in these producing regions, (darkly shaded)^[14]. To date, the extent of the exploration of these areas is termed incomplete^[17]. Yet, the presently producing areas comprise less than 10 percent of the total area of the Western United States in which uranium occurrences have been found (lightly shaded in Figure 10). Because there are still ample opportunities for exploration in the producing areas, there has been little incentive to explore in the other regions.

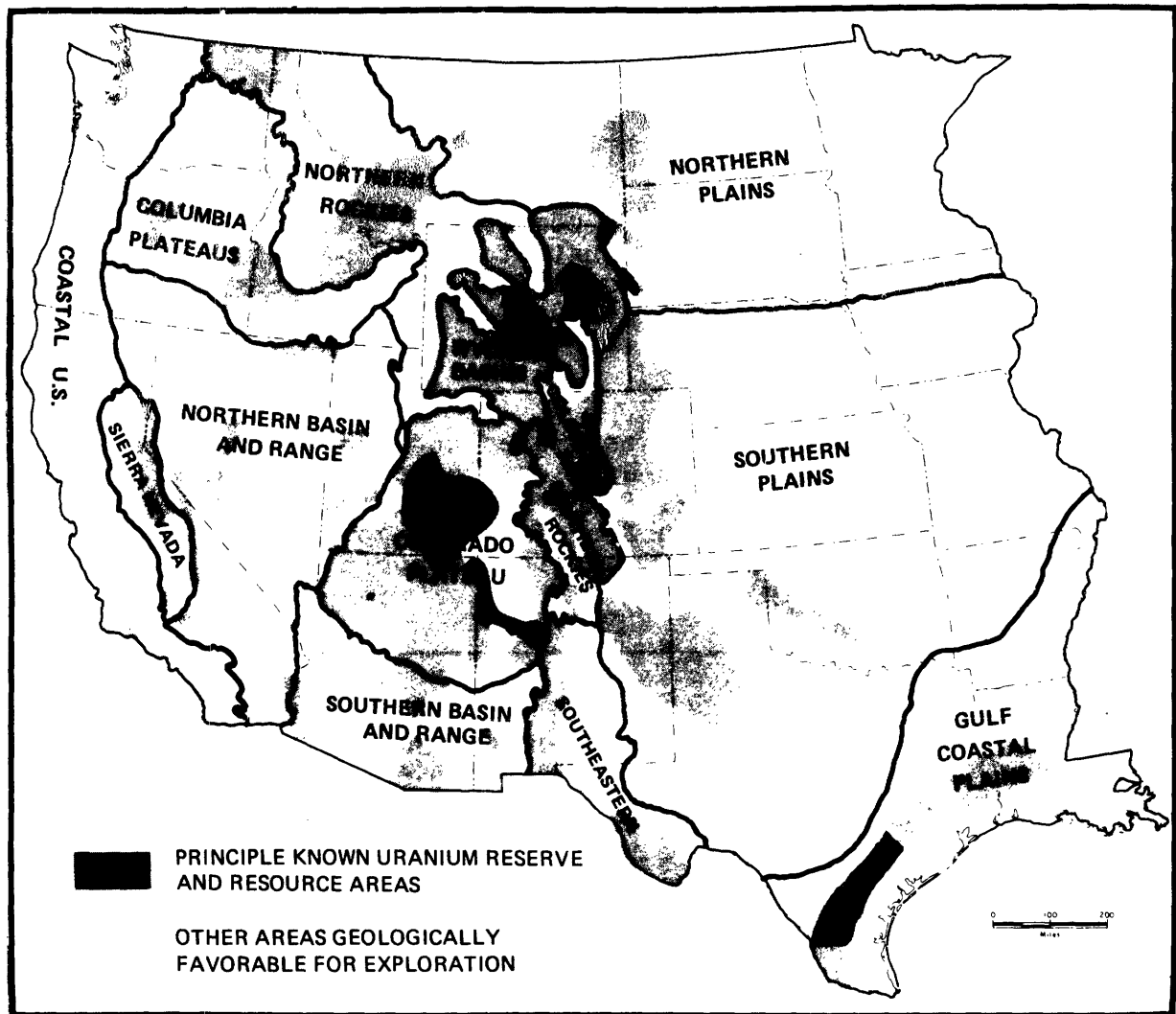


Figure 9: KNOWN URANIUM REGIONS IN THE WESTERN UNITED STATES

[Source: Reference 16]

NATIONAL URANIUM RESOURCE EVALUATION

A National Uranium Resource Evaluation (NURE) study is now underway to better determine the nature and extent of the nation's uranium resources. The study is being performed at the Grand Junction, Colorado, Office of the Atomic Energy Commission. Preliminary results will be available in 1975. Final results will not be available for several years.

The sole purpose of the study is to identify geographic regions within the U.S. that possess a potential for commercial uranium resources. By disseminating this information, the A.E.C. thus hopes to encourage private industry to explore the areas they identify. Neither the A.E.C. nor any other government agency plan to explore for uranium.

Based on their present knowledge, the officials conducting the study are "hopeful and optimistic" that significant quantities of high grade (forward cost \leq \$30) uranium remain to be discovered. The A.E.C. experts consider the possibility of substantial additional ore discoveries in the \$15 to \$30 range particularly promising. They expect that these resources may be discovered both in conventional sandstone deposits and in other geological strata. Potential for such discoveries exists in the Western United States, as well as in areas in the Eastern United States. Furthermore, geographic regions of Alaska are known to be highly similar to those regions currently producing in the Rocky Mountain areas^[12].

C O N C L U S I O N S

The outlook for discoveries of at least some uranium beyond that presently known is practically a certainty. The prospect for the discovery of substantial additional quantities is bright. At this time, however, there is simply no factual basis for a quantitative appraisal of the undiscovered high grade resources.

As of January 1, 1974, the A.E.C. estimated that 2.4 million tons of U_3O_8 (reserves and potential) are available at a forward cost less than or equal to \$30 per pound^[18]. In the draft of the LMFBR Environmental Impact Statement (WASH-1535), cumulative uranium usage, without the breeder, is projected to reach 6.3 million tons by 2020. The most optimistic supply estimate used in that study is based on the assumption that known high grade (forward cost \leq \$30) uranium will be roughly double current estimates (2.4 million tons) of reserves and potential. The supply estimates are, by the A.E.C.'s own admission, judgemental^[19].

In light of the potential for additional discoveries, the fact that reserves and potential increased by over 80% between 1968 and 1970 alone (see Figure 8, page 22) and the sensitivity of the expected uranium prices to the supply assumptions, the author feels that the A.E.C. estimates may be conservative. High grade uranium resources could prove to be in excess of cumulative demand.

The reason no quantitative estimates of the entire resource base are available is that no effort has been made, up to this point, to make such an appraisal. In addition, no significant effort is being made at this time. The NURE will simply serve to define areas of potential deposits. It will take several years to complete, and, most importantly,

it will provide no more quantitative information on the nation's uranium resource base than is consistent with the industry's current needs. Private industry will explore for only as much uranium as the market will demand ten years hence. As a result, if an assessment of the entire resource base is desired in the near future, the government will have to take the initiative.

As the nation plans to utilize uranium-fueled nuclear reactors to satisfy a significant portion of its future power needs, the author feels a quantitative appraisal of our uranium resources base is necessary for long range planning. The author specifically proposes that the effort to achieve the goals of the NURE study be intensified. The author further advocates that intensive exploratory drilling be conducted in those regions identified as holding a potential for high grade resources. Thus, the appraisal of the region would be either confirmed or refuted, and a quantitative "potential resource" estimate could be made.

NOTES AND REFERENCES

- [1] The exploration cost given in reference 2, on page 25, is \$0.72 per pound \$8 reserves. This is an average cost for the period 1966 to 1973. This expenditure is required roughly ten years in advance of the uranium production, which ultimately must finance the exploration costs. At a 12% discount rate, the exploration cost would be about \$2.24 at the time of production, almost 30% of an \$8 per pound market price.
- [2] Grand Junction U.S.A.E.C. Office, Statistical Data of the Uranium Industry, GJO-100 (74), January, 1974, p.13.
- [3] Personal Communication with Mr. Morris Hanson, Ore Reserves Office, Grand Junction U.S.A.E.C. Office, August, 1974.
- [4] Statistical Data of the Uranium Industry, op.cit., p. 14.
- [5] Arthur D. Little, Inc., "An Assessment of the Economic Effects of Radiation Exposure Standards for Uranium Miners", Report to the Federal Radiation Council (September, 1970), p. 74.
- [6] The yearly drilling data is taken from Statistical Data of the Uranium Industry, op. cit., p. 41. The yearly additions data is derived from information given in the same source, on pages 14 and 18. For the years 1949 through 1972, inclusive, yearly reserve additions were calculated by adding the increase in reserves from the previous year and year's ore shipments. For 1973, ore production, p. 18, was used in lieu of ore shipments.
- [7] Cumulative Drilling is given in Statistical Data of the Uranium Industry, op. cit., p. 41. Known Uranium is given in the same source on page 14, under "Sum of Cumulative Production and Reserves".
- [8] This estimate was based on information given in U.S. Energy Outlook, Nuclear Energy Availability, National Petroleum Council, Nuclear Task Group, 1973, page 52. A figure is presented depicting the relationship between exploration costs and finding rates. The difference in cost between 3.4 and 2.0 pounds/foot was estimated to be \$0.85 per pound (1970 dollars). For uranium produced ten years hence, at a 12% discount rate, the opportunity cost would be \$2.64 per pound.

- [9] Reserve and Drilling Levels were taken from reference [2], pages 14 and 41. Ten year advance requirements, for years prior to 1971, were taken from Forecast of Growth of Nuclear Power, WASH-1084, December, 1967. Thereafter, they were taken from Nuclear Power 1973-2000, WASH-1139 (72), December, 1972, at 0.25% tail assay.
- [10] Personal Communication with Mr. Clifton Barnes, Director, Office of Planning and Analysis, Grand Junction Office, U.S.A.E.C., August, 1974.
- [11] \$8 forward cost reserve estimates were taken from reference [4]. \$10 reserve estimates were taken from the same source, page 19. \$15 estimates were obtained from Mr. Morris Hanson, Ore Reserves Section, Grand Junction Office of the A.E.C. \$30 reserve estimates were obtained from Outlook for Uranium, by John A. Patterson, Chief, Supply Evaluation Branch, Division of Production and Materials Management, A.E.C. Paper presented at 17th Minerals Symposium, American Institute of Mining, Metallurgical, and Petroleum Engineers, Casper, Wyoming, May 11, 1974.
- [12] Personal Communication with Mr. Ben Boyer, Director, Resource Division, Grand Junction Office, U.S.A.E.C., August, 1974.
- [13] Statistical Data of the Uranium Industry, op. cit., page 25.
- [14] U.S.A.E.C., Grand Junction Office, Potential Uranium Resources of the Western United States, GJO-104 (73), 1973, p. 3
- [15] All information is from Statistical Data of the Uranium Industry, op. cit. Cumulative production and \$8 reserves are given on page 14. \$10 reserves are listed on page 19. The estimates of potential reserves are given on page 26.
- [16] U.S.A.E.C., Grand Junction Office, Nuclear Fuel Resource Evaluation: Its concepts, Uses and Limitations, GJO-105, 1973, p. 17
- [17] National Petroleum Council, U.S. Energy Outlook, Nuclear Energy Availability, 1973, p. 36
- [18] Outlook for Uranium, cited in [11].
- [19] Personal communication with Mr. John A. Patterson, Chief, Supply Evaluation Branch, Division of Production and Materials Management, U.S.A.E.C., October 1974.