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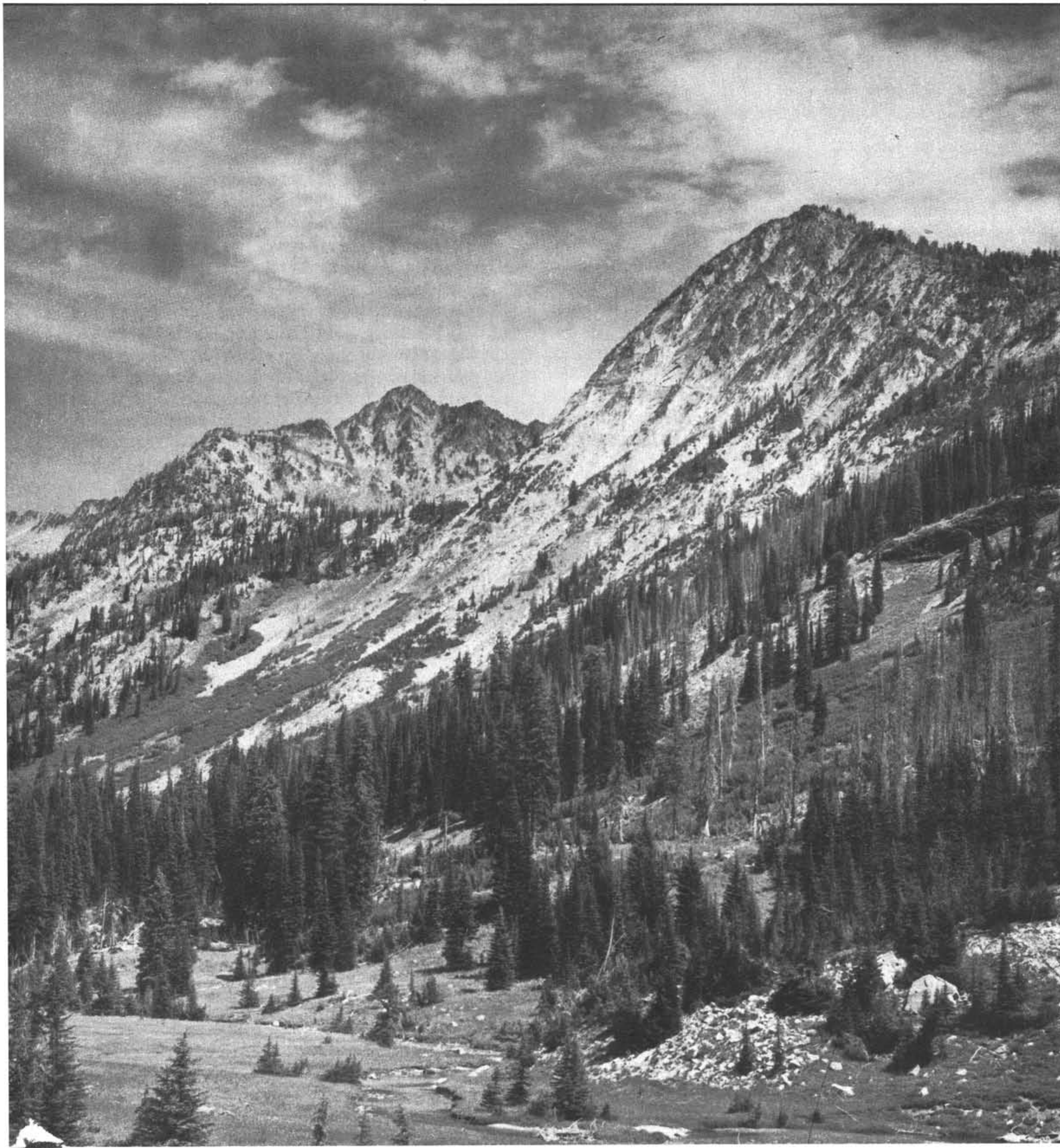

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COVER PHOTO

The Granite Mountains, located on the southern end of the Wallowa Mountains in northeastern Oregon. These mountains are part of the Upper Jurassic-Lower Cretaceous Wallowa Batholith. (Photo courtesy Oregon State Highway Department)

Mineral quadrangle map now available

The *Geologic Map of the Oregon part of the Mineral quadrangle*, by H.C. Brooks, was released by the Oregon Department of Geology and Mineral Industries last December. It is GMS-12, map no. 12 in DOGAMI's Geologic Map Series.

The map is on a scale of 1:62,500 (about 1 inch = 1 mile) and covers the Oregon side of the Snake River Canyon between Powder River on the north and Hibbard Creek on the south. Printed on a topographic base, the black-and-white map identifies 12 different rock units, distinguishing some of them by patterns of differing texture.

Approximately half of the map area is underlain by metamorphosed late Paleozoic and Mesozoic marine sedimentary and volcanic rocks cut by small granodiorite plutons of late Jurassic age; the other half is underlain by continental volcanic and sedimentary rocks of Cenozoic age.

GMS-12 may be purchased from DOGAMI's Portland and Baker offices. Mailed orders should be addressed to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, OR 97201, or 2033 First Street, Baker, OR 97814. The price is $2.00 per map. Payment must accompany orders of less than $20.00. □

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NEXT MONTH

Geologic Field Trip Guide through the North-Central Klamath Mountains, by M.A. Kays and M.L. Ferns

Forecasting rock material demand: an overview of several techniques and detailed review of two

by Jerry J. Gray, Economic Geologist, Oregon Department of Geology and Mineral Industries

Managing rock resources can be reduced in its simplest form to: (1) a matching of supply with demand, and (2) a rational development of policies that conform to the constraints defined by supply and demand.

In Oregon, rock resource assessments are being developed by the Oregon Department of Geology and Mineral Industries on a regional basis to conform to market areas. These assessments provide needed information on supply. Demand is modeled in the Department's Special Paper 5, *Analysis and Forecasts of the Demand for Rock Materials in Oregon.*

The following article compares and contrasts various statistical methods for forecasting demand for rock resources. The applicability of each method is a function of available data, available funding, and desired resolution.

The article digresses slightly from the mainstream of geology but demonstrates very conclusively the practical application of geologic inventory data in addressing the needs of society.

—J.D.B.

INTRODUCTION

Society must provide for the future availability of needed resources. Through ORS 215.055 and LCDC Goal 5, Topic B, the State of Oregon formally directs counties and cities to take into consideration lands that are, can be, or should be utilized for material resources or for the processing of mineral aggregates in the adoption of any land use ordinance. LCDC Goal 9, Guideline A-2 states: "The economic development projections and the comprehensive plan which is drawn from the projections should take into account the availability of the necessary natural resources to support the expanded industrial development and associated populations. The plan should also take into account the social, environmental, energy, and economic impacts upon the resident population."

To do this, counties and other planning units need to know what their present mineral inventories are, what inventories they will need in the future, and where those inventories will be found. Such resource planning must take place before the mineral resource land base has been preempted by zoning for other uses.

The Oregon Department of Geology and Mineral Industries recently published Special Paper 5, *Analysis and Forecasts of the Demand for Rock Materials in Oregon*, by Friedman and others (1979). This report is the culmination of many years of Departmental study of rock material demand. Special Paper 5 is technically written for a limited audience; its application and the mineral production data contained within, however, concern a much broader audience. With the aim of making the report and data more readily usable in any given situation, the present paper reviews the forecast modeling spectrum from the very simple to beyond that presented in Special Paper 5, with emphasis on two particular types of modeling, so that anyone involved in forecasting can choose the type of modeling most appropriate for his needs. It also presents a cookbook approach to forecasting, relying mainly on Department studies by Schlicker and others (1978), Gray and others (1978), and Friedman and others (1979, the Special Paper mentioned above). Readers wishing to study the theory behind the forecasting techniques should consult the references listed at the end of this paper.

DATA BASE

Data for mineral economic marketing or forecasting studies are collected by the U.S. Bureau of Mines in its annual canvass of mineral producers and made available in various Bureau of Mines publications. In Special Paper 5, the Oregon Department of Geology and Mineral Industries published 15 tables (Tables 31 to 46) of Bureau of Mines statistics for Oregon's 13 marketing units, the State as a whole, and that production that could not be assigned to a single county (mainly U.S. Forest Service stone output). The statistics include tonnage and value statistics by year from 1940 through 1976 for sand and gravel and stone (including any cinder used for road metal) and for the two commodities combined. These 15 tables provide a starting point for demand analysis and forecasting for any area in the State. Other economic statistics can be obtained from the Oregon Employment Division, Research and Statistics Section; the Oregon Department of Transportation, Policy and Program Development Section; the Center for Population Research and Census, Portland State University; the U.S. Department of the Interior, Bonneville Power Administration; and the Oregon Department of Revenue.

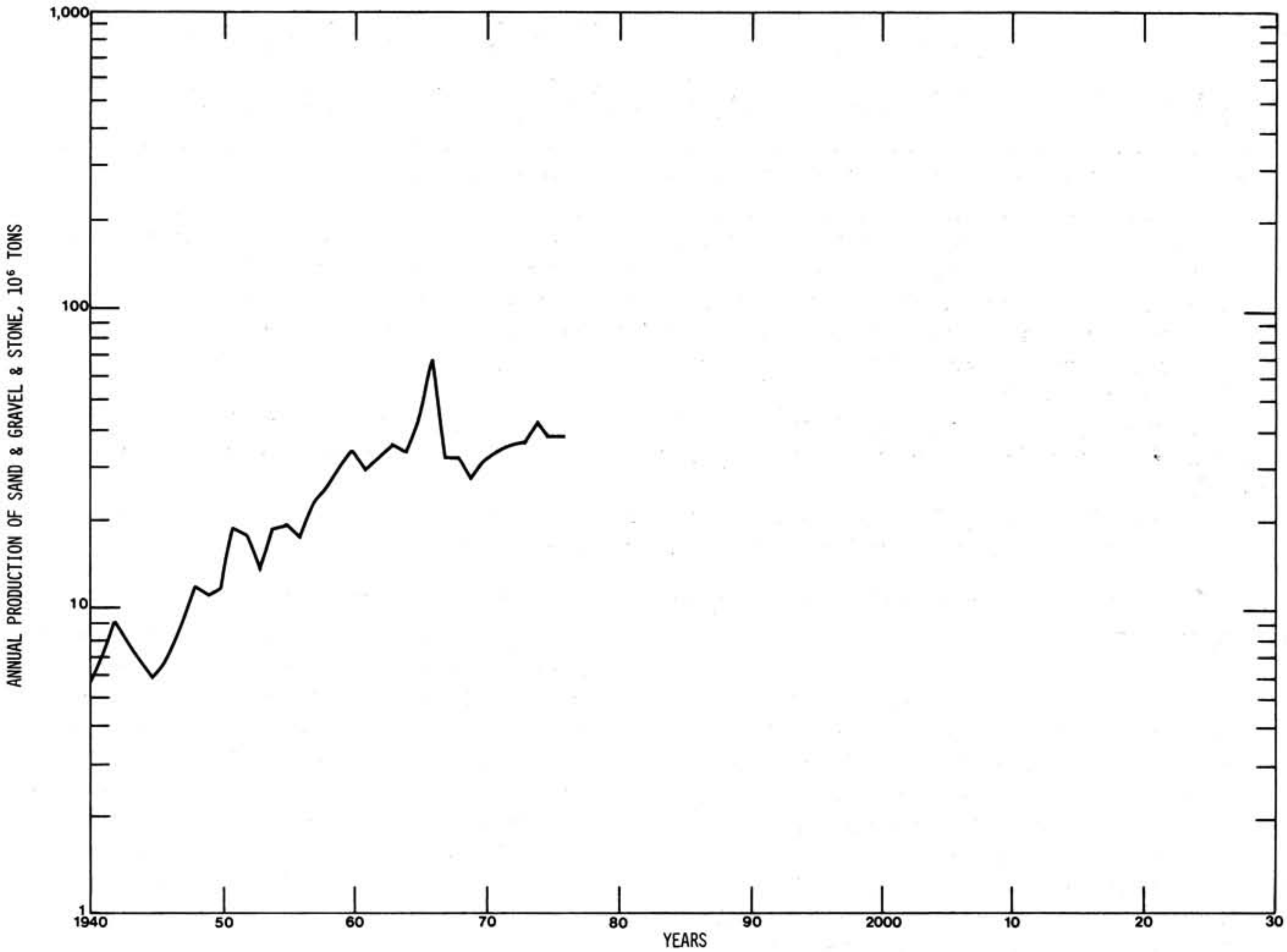

Figure 1. Oregon's annual production tonnages of sand and gravel and stone vs. time.

OVERVIEW OF FORECASTING TECHNIQUES

Introduction

All forecasting starts with an examination of the past. One relatively informal way is to consult an experienced rock material industry expert. On a more sophisticated level, one can study past production figures, statistical trends, economic cycles, or demographic changes. The past may be shown on a graph in which past production is related to time (Figure 1) or some other economic factor such as population (Figure 2). For forecasting, the scale used to record the past is extended into the future, and the trend line or correlations are extended over the scale. The scale can be either arithmetic, logarithmic, or exponential.

Forecasting costs time and money. As the sophistication increases, so does the cost. Thus, for example, the input-output method of modeling discussed later in this paper is so costly that its use in forecasting rock material demand is not feasible. All current methods of modeling, however, are described below, proceeding from the simplest to the more sophisticated.

Opinion polling

Opinion polling consists simply of asking several rock material industry experts what the future holds for rock material demand. The results are then averaged. Averaging good forecasts with bad forecasts, however, has a few shortcomings. Care should be taken in selecting experts, because if the experts consulted are producers, their estimates might be high. Individual producers tend to believe that their firms will grow at rates faster than that of the market as a whole.

For a small market area with only two or three producers, however, their estimates on the amount of land that will be needed to insure a good future supply of rock material may provide all the demand analysis that is needed by the local planner.

Freehand time trending

The next type of modeling consists of plotting rock material production against time, drawing a smooth curve through the data points, and extending the curve into the future. Figure 3 shows Oregon's sand and gravel

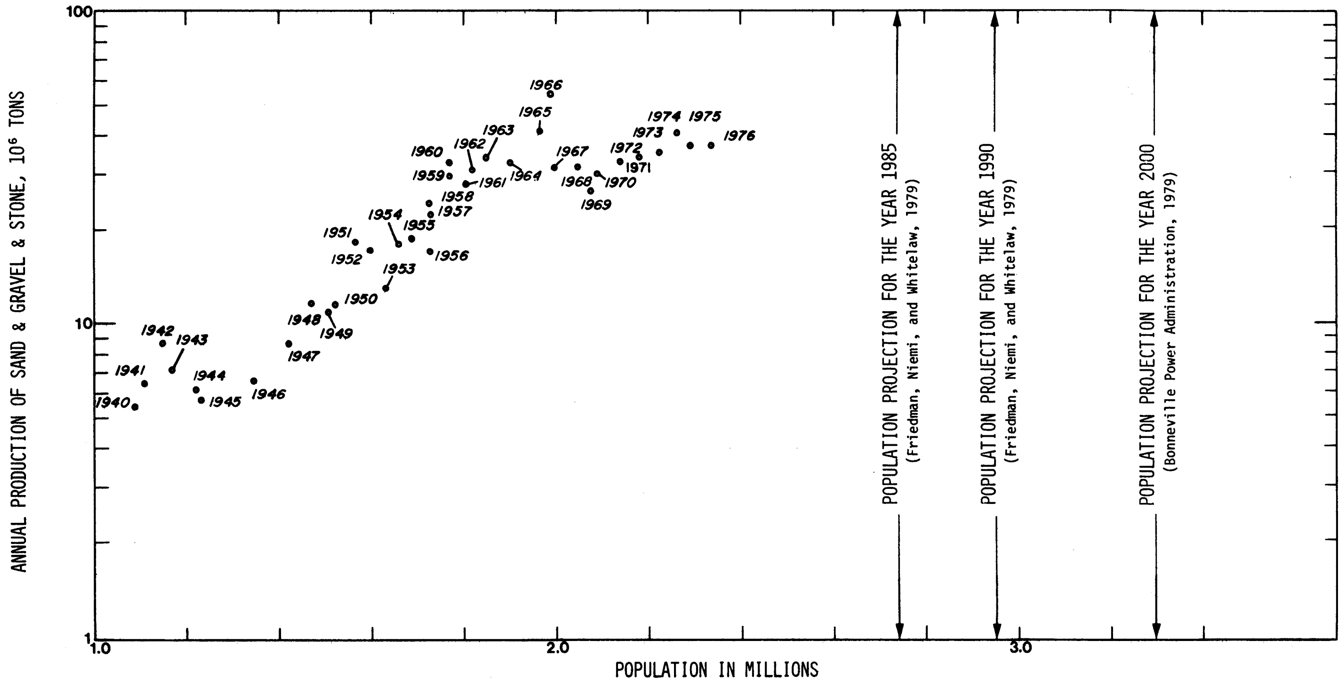

Figure 2. Oregon's annual production tonnages of sand and gravel and stone vs. population.

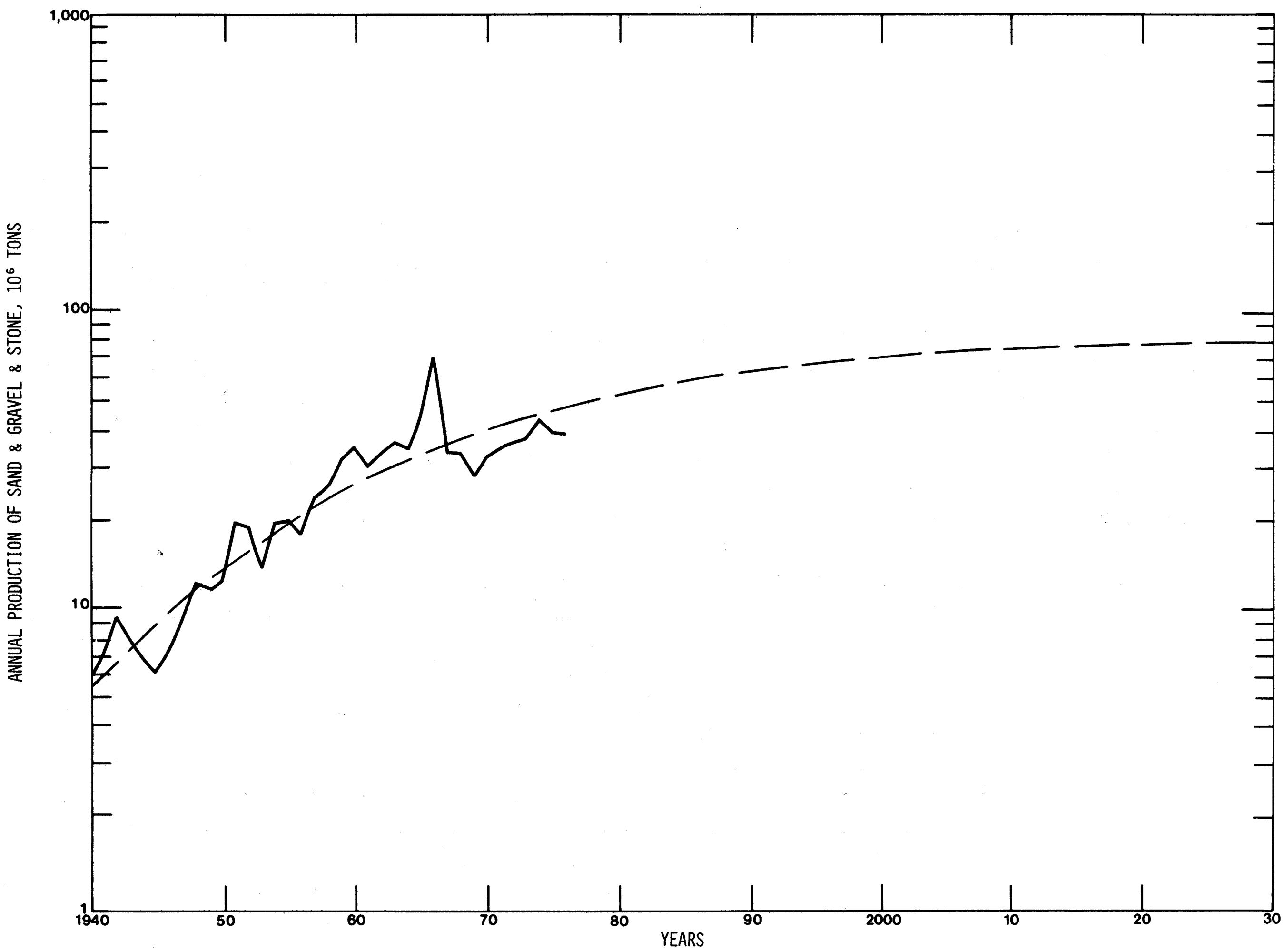

Figure 3. Oregon's annual production tonnages of sand and gravel and stone vs. time, with freehand-drawn curve.

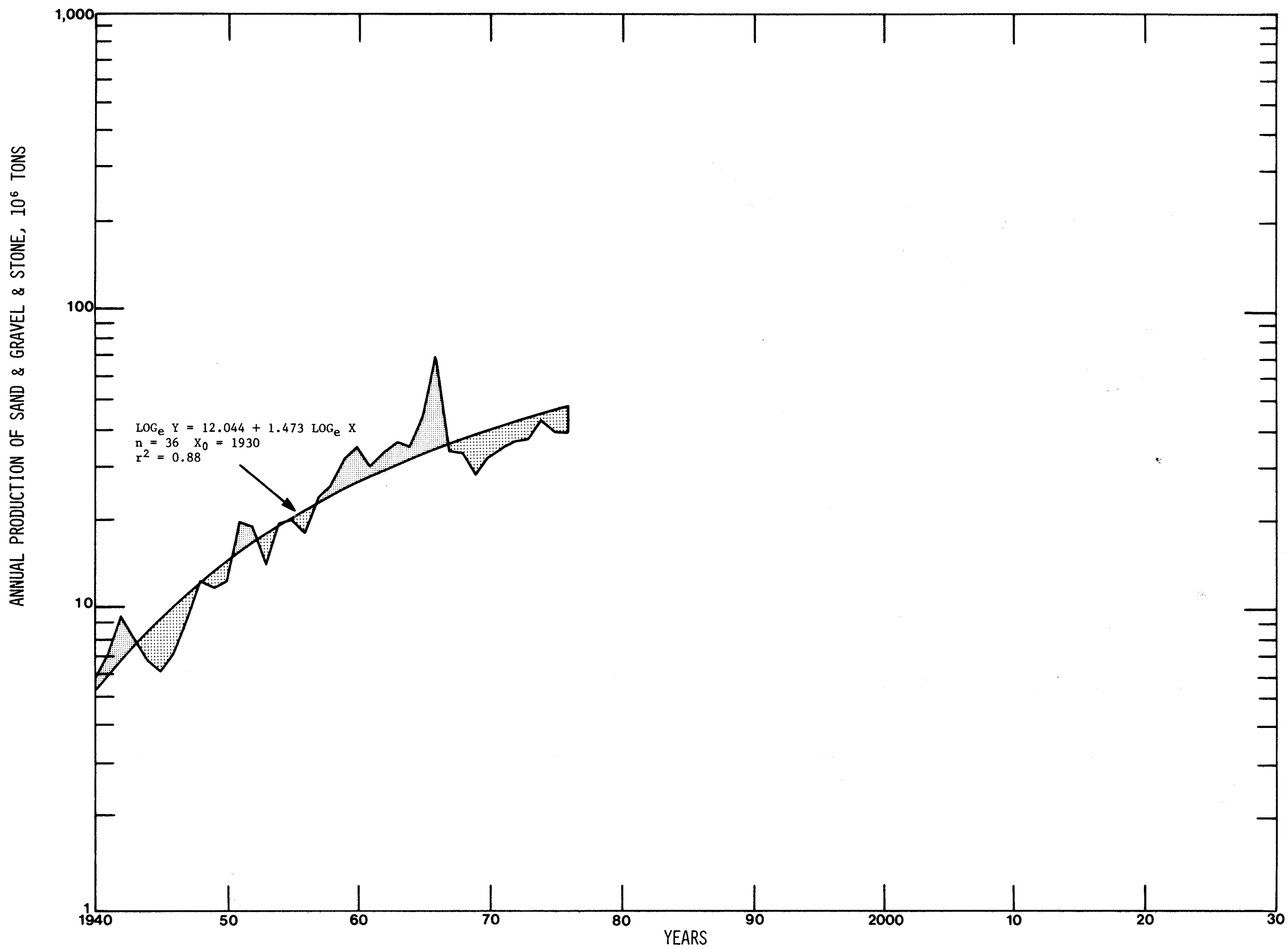

Figure 4. Oregon's annual production tonnages of sand and gravel and stone vs. time, with least-squares curve. Shaded area above curve nearly equals the shaded area below curve. Sum of the two areas is at a minimum.

and stone annual tonnages plotted against time, with a freehand curve drawn through the data points so that half of the points are above the curve and half are below. The advantage of this type of modeling is that it is fast. The disadvantages are that there is no way to judge how well the curve fits the data points and there is no measure of how the rise and fall of output tonnages over time may affect the forecast. For small market areas, production can swing up and down wildly, and the selection of linear trends is somewhat arbitrary.

Least-squares time trending

The least-squares technique is a statistical way of passing a curve (or a straight line) through a set of data points in such a way that square units of area over the curve will equal those under the curve and the sum of those areas will be the smallest possible amount. The degree to which the curve fits its data points is given a statistical number from 0 to 1 and is indicated by the symbol r^2. In general terms, the r^2 represents the total size of square area over and under the curve. An r^2 of 1 is a perfect fit, meaning there are no data points above or below the curve (Figure 4). An r^2 of 0 means that the data points vary so much that there is no linear trend within the data. The least-squares technique is discussed in greater detail later in this paper.

Other time trend techniques

When the economic base is small, another way to forecast is to compare the local market area to the surrounding larger market area or to a market area that has already passed through the economic stages the smaller area is experiencing (e.g., state vs. county, as in Figure 5).

This approach is good if data are available for a county but not for a city: demand can be estimated for the county, and city-to-county ratios, based on such economic factors as population, miles of streets and roads, or value of building permits, can be used to split out the city's portion of the total county rock material demand.

This technique can also be used as a check for

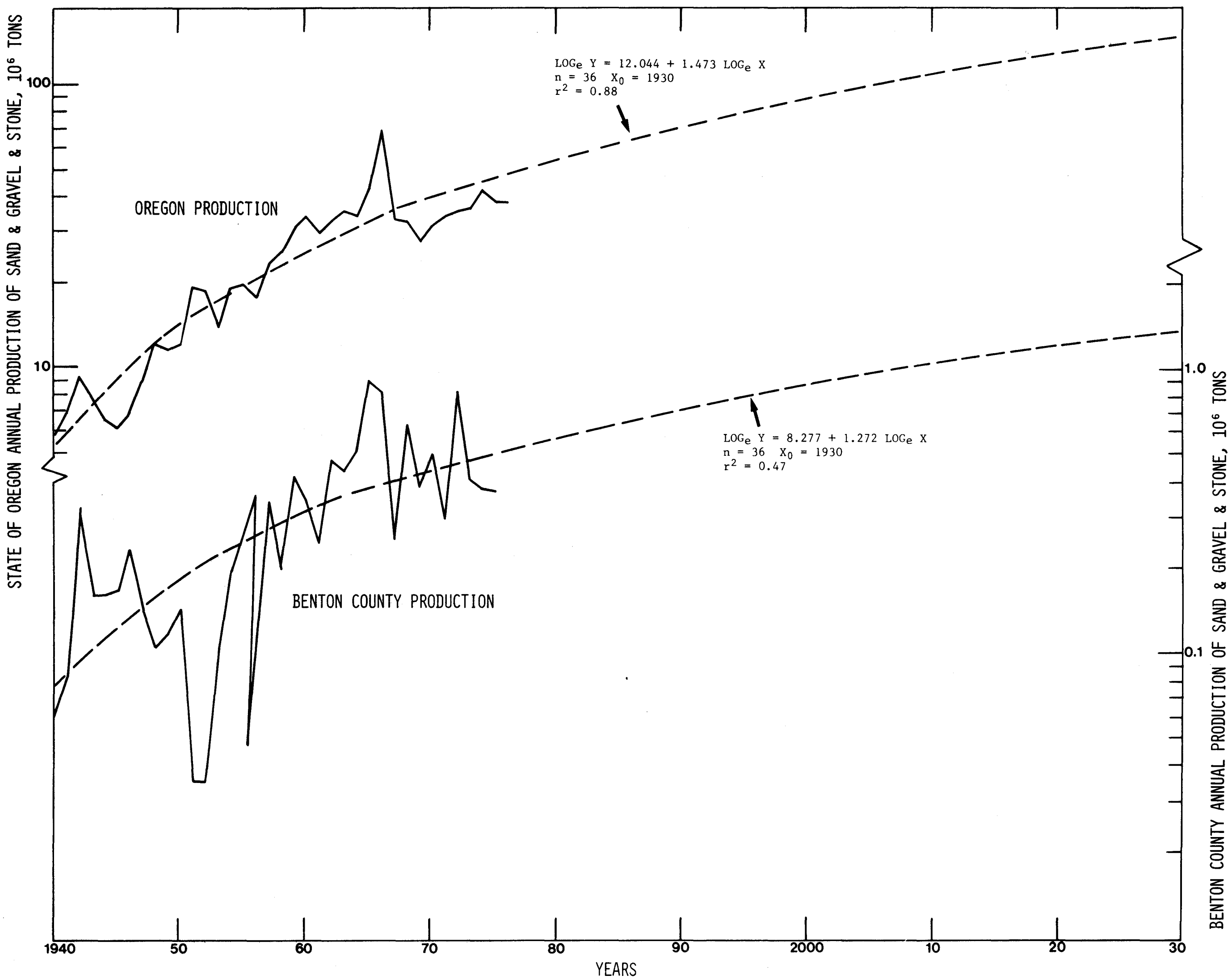

Figure 5. Oregon's and Benton County's annual production tonnages of sand and gravel and stone vs. time, with least-squares curve.

Table 1. *Present and predicted production of sand and gravel and stone**

Area	1976 Production (tons)	1976 Per capita consumption (tons)	2000 Estimated production (tons)	2000 Per capita consumption (tons)
State of Oregon	37,903,905	16	88,852,000	26
Willamette Valley	18,991,621	12	46,907,000	22
Benton County	538,142	8	1,468,339	16

* Source: Gray and others, 1978.

reasonableness of a forecast. After the forecast has been obtained, the tonnages are checked against an as yet unused economic factor. If this is population, for example, the local per capita figure is compared to the larger marketing area's per capita figure. If the two differ greatly, a second look at the economic base of the smaller marketing area may be needed.

Table 1, for example, shows the relationship between the present (1976) output of two larger marketing areas and a smaller marketing area and the predicted production for the year 2000 for the three market areas. To check the reasonableness of the smaller area (Benton County) forecast, per capita consumption is also shown. The Benton County per capita figure of 16 is reasonable when compared to the State per capita figure of 26, if the characteristics of the two markets are also compared. The State's economy is well diversified, but that of Benton County is not.

Econometrics/multiple regression analysis

Econometrics/multiple regression analysis compares rock material output (a dependent variable) to several economic factors (independent variables). This technique uses the demand from each of the independent variables to build a model of total demand. The independent variables relate only to that portion of rock material output which is controlled by the market place. They do not relate to demand caused by external influences, such as a Federal dam building program. The econometrics/multiple regression analysis technique and the result of its use in Special Paper 5 are discussed in the second half of the present paper.

Input-output table

The basis for the input-output system of economic analysis and forecasting is that all of the economy is interrelated. The output from one segment of the economy becomes part of the input to several other segments. A change in one segment affects all the other segments of the economy.

If enough data can be gathered to build an input-output table, economic analysis of market demand and forecasting can be studied in great detail. However, the cost of obtaining data to build an input-output table is very high. Even at the State level, it will normally be too high for the benefit gained.

If the State had an input-output table, the effect of shortages and high prices of gasoline and fuel oil, for example, could be followed through the economy. The points of stress on other segments of the economy would be very clear. Such a table would be very useful in predicting the effects of the closure of a major rock material resource throughout a local economy, when, for example, a price rise could be anticipated to cover transportation costs from the next closest supply.

THE TWO MOST USEFUL TECHNIQUES

Because least-squares time trend modeling and econometrics/multiple regression analysis are the two most useful techniques for projecting local- and State-level rock material demand, we shall now discuss them in some detail. The discussion of the least-squares time trend technique relies mainly on those of Schlicker and others (1978) and Gray and others (1978). Discussion of the econometrics modeling is based mainly on its use by Friedman and others (1979).

Least-squares correlations are easy to perform with a modern, handheld, programmable calculator. With the manufacturer's instructions, the calculator can be programmed and a correlation run in a very short time. Econometrics/multiple regression analysis cannot be performed very easily with a calculator. Most computer centers, however, have standard programs for executing multiple regressions, and the cost is quite reasonable.

Least-squares time trending

An example of least-squares time trending is the correlation of the State's output of sand and gravel and stone with time, using different lengths of base years (Figure 6), as done by Gray and others (1978). For this example, the State's annual production tonnages for sand and gravel and stone were plotted on semilog graph paper to show the pattern of production over the period from 1940 to 1976.

The next step was to choose the most desirable length of the data base. The exponential-type curve of least squares produces a simple straight line on semilog paper; therefore, this type was used to determine the length of the data base. The general formula for the exponential-type curve of least squares is $\text{Log}_e\ Y = \text{Log}_e\ a + bX$, leading, in the case of using the total time span, to the formula $\text{Log}_e\ Y = 15.77 + 0.057X$, when $n = 36$ and $X_0 = 1940$. In these formulas, Y is the dependent variable (production tonnages), a is the constant where the curve crosses the x-axis, b is the slope of curve, and X is the independent variable (time). The n is the number of years used in the least-squares correlation, and X_0 is the starting year.

Four models were developed: the first model spanned the total time from 1940 through 1975; for the second model, the time span was shortened by 10 years to 1950 through 1975; the third model was shortened by another 10 years to 1960 through 1975; and the fourth model was again shortened by 10 years to 1970 through 1975. The r^2 values ranged from 0.01 to 0.83. Perfect correlation between time and production is 1.0, and no correlation is 0.0.

Each trend was projected to the year 1990. Figure 6 shows that the length of the data base influences the projection for the year 1990. The range of projections using different data base lengths was from 38 to 122

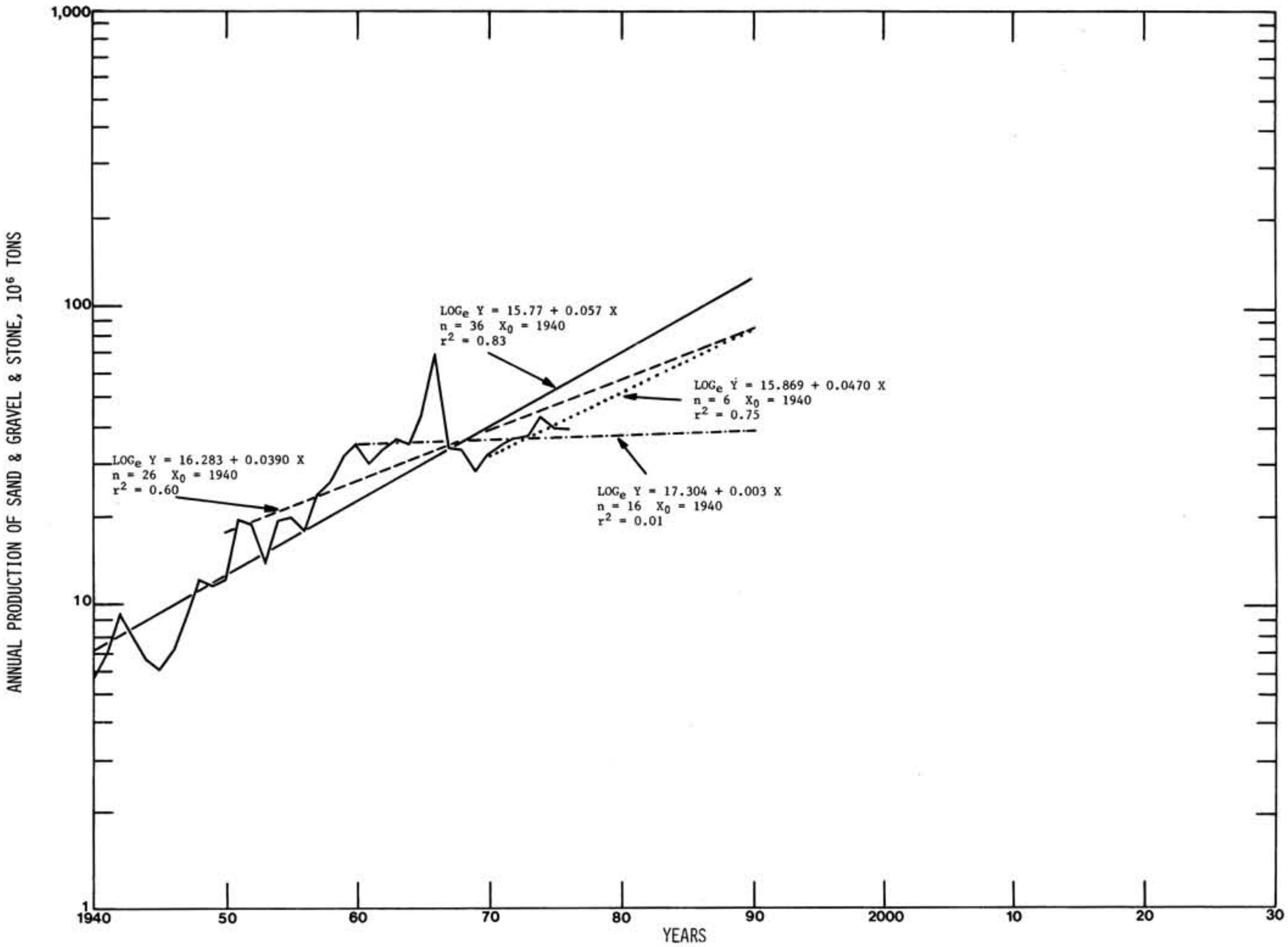

Figure 6. Oregon's annual production tonnages of sand and gravel and stone vs. time. Four exponential least-squares curves with different data base lengths are also plotted, with trend lines extending to the year 1990.

million tons per year. The model that gave the highest r^2 value (0.83) used the total length of the time series.

The model with the highest r^2 value in Figure 6 and the historic series were replotted as the top model in Figure 7. The arithmetic least-squares type of curve with the general formula of $Y = a + bX$ was tried in the bottom model. It had an r^2 value of 0.73. Finally, the power-curve least-squares type of curve with the general formula $\text{Log}_e\ Y = a + b\ \text{Log}_e\ Y$ was tried (middle model). It had an r^2 value of 0.88 and therefore was accepted as best for projecting the State's future consumption.

In the six least-square correlations shown in Figures 6 and 7, the forecasts for the year 2030 range between 43 and 1,193 million tons. The most reasonable forecast and the one with the highest r^2 is the middle model in Figure 7. It predicts production of 150 million tons.

In Special Paper 5, Friedman and others called least-squares modeling "growth rate modeling" and used the exponential-type curve with the general formula of $\text{Log}_e\ Y = \text{Log}_e\ a + bX$.

The final forecasting results of the two studies under consideration (Gray and others, 1978; Friedman and others, 1979) are shown in Table 2. Production statistics used by Friedman and others in their study did not include those listed under various counties (Table 45, Special Paper 5) and those used for dams (Table 46, Special Paper 5). Therefore, to make the two studies comparable in this paper, the forecasts for Oregon by Friedman and others were expanded by the statistical means listed in Table 3b.

Statistical models should be evaluated in terms of their consistency with the real world. In both studies, the forecasts for 1990 range from 17 to 31 million tons for the Portland area and from 39 to 88 million tons for the State. The forecasts for the year 2030 range from 35 to 639 million tons for the Portland area and from 53 to 548 million for the State. Because three of the five forecasts indicate that the Portland area will have a larger annual demand than will the State as a whole, they do not conform to the real world and are therefore not valid.

A further way to judge the models is to examine over time the percentage of annual demand that the Portland area of Clackamas, Columbia, Multnomah, and Washington Counties added to the State total. As Table 4b shows, the average percentage for the years

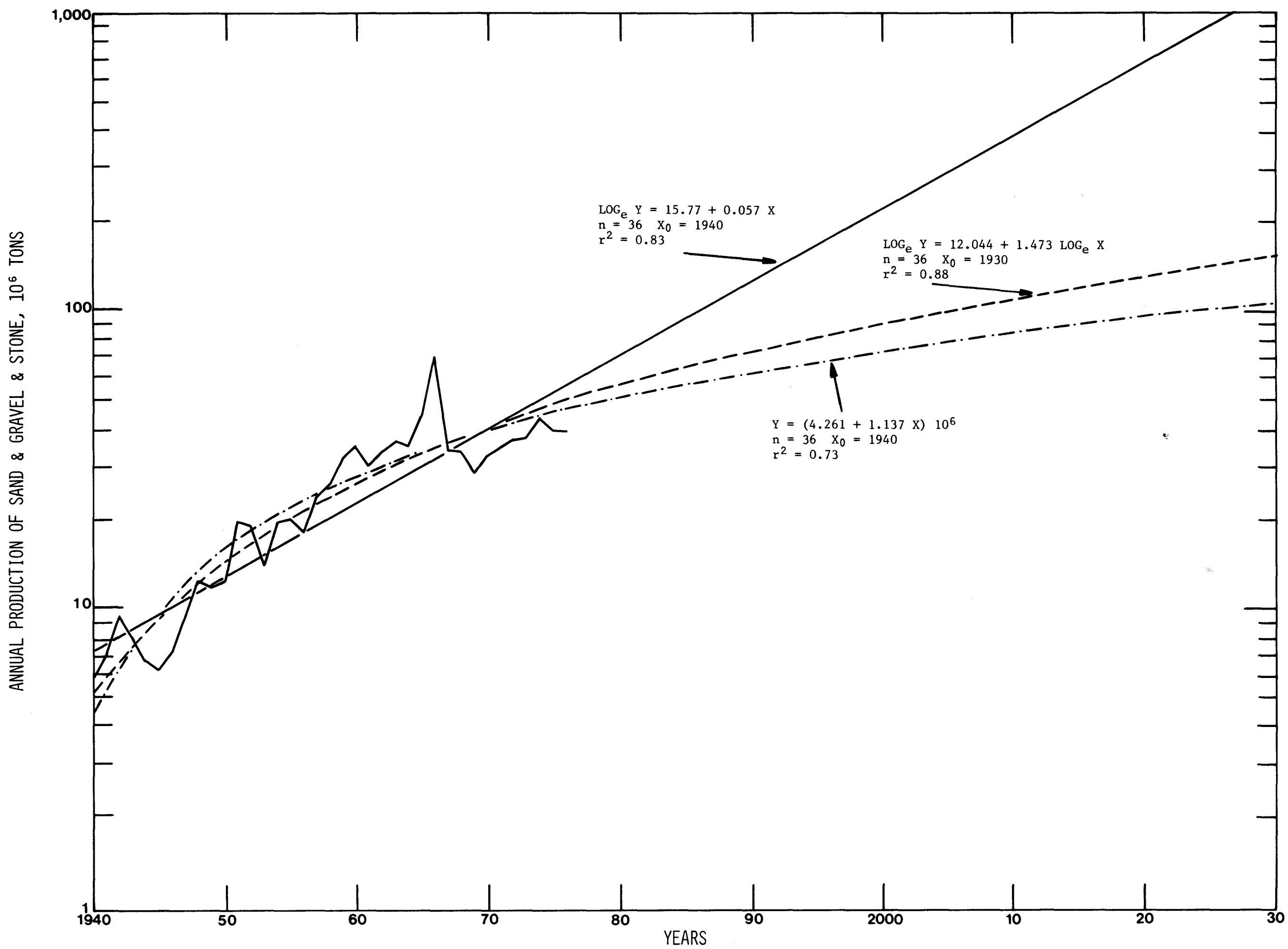

Figure 7. Oregon's production tonnages of sand and gravel and stone vs. time, with different types of least-squares curves and their trend lines extended to the year 2030.

1940 to 1976 was 24.4 percent. The range of limits for a 99-percent confidence interval around that mean is from 21.1 to 27.6 percent. The average percentage for the years 1964 to 1976 was 25.4, and the 99-percent confidence interval range is from 18.4 to 32.4. As the statistics show, there has been no great change in the Portland area's annual production percentage of the State's total. Also, there is nothing in the annual production data to indicate that the percentage will change radically between 1976 and 2030.

Therefore, any forecast which makes the Portland area's demand less than 18 percent or more than 33 percent of the State's total should be viewed cautiously. Using this test as a guide, we find only the first two of the forecasts given in Table 2 to be reasonable.

A note of caution is appropriate for such time-trend modeling. In times of marked change in construction, population, or other factors which determine demand, projections which appear valid in terms of r^2 may nevertheless fail to be accurate indicators of future demand. Forecasts should be tested and updated as new data become available.

Econometrics/multiple regression analysis

With econometrics/multiple regression, the correlation of least squares is taken a step further. A dependent variable such as the production of sand and gravel and stone is correlated to two or more explanatory variables such as price or population. The correlation can be simultaneous or by one variable at a time. This correlation allows periodic updating of the model as revised figures for the independent variables are obtained.

Econometric models have the following general form: $Y = b_0 = b_1X_1 + b_2X_2 + \ldots b_nX_n$, where Y = the dependent variable; b_0 = the intercept term (a constant); $X_1, X_2, X_3, \ldots X_n$ = explanatory variables; and $b_1, b_2, \ldots b_n$ = the coefficients of $X_1, X_2, \ldots X_n$.

The explanatory variables employed in Special Paper 5 by Friedman and others were population, employment, price, State highway expenditures, and real income. These were the only economic variables available with adequate historical data.

In essence, multiple regression analysis results in an equation of the best straight line formed by the mathe-

Table 2. *Projections of annual demand for sand and gravel and stone, determined by the least-squares method*

Models by base years and commodity	Portland area* 1990 forecast** (million tons)	Portland area* 2030 forecast** (million tons)	Oregon 1990 forecast** (million tons)	Oregon Portland area* demand as percent of Oregon demand	Oregon 2030 forecast** (million tons)	Oregon Portland area* demand as percent of Oregon demand
$\log_e Y = a + b \log_e X$ (Gray and others, 1978)						
Base years 1940-76 (sand and gravel and stone)†	17(1)	35(1)	71(2)	24	150(2)	23
$\log_e Y = \log_e a + bX$ (Friedman and others, 1979)						
Base years 1950-76 (sand and gravel and stone)†	20(3)	116(3)	71(4) × 1.205‡ = 86	23	379(4) × 1.205‡ = 457	25
Base years 1964-76 (sand and gravel and stone)	31(5)	356(5)	34(6) × 1.138‡ = 39	80	98(6) × 1.138‡ = 112	318
Base years 1950-76 (sand and gravel)	11(7)	40(7)	37(8)	—	167(8)	—
Base years 1950-76 (stone)	16(9)	599(9)	36(10)	—	288(10)	—
Subtotal (1950-76)	27	639	73 × 1.205‡ = 88	31	455 × 1.205‡ = 548	117
Base years 1964-76 (sand and gravel)	21(11)	269(11)	18(12)	—	17(12)	—
Base years 1964-76 (stone)	8(13)	80(13)	18(14)	—	31(14)	—
Subtotal (1964-76)	29	349	36 × 1.138‡ = 41	71	47 × 1.138‡ = 53	659

* Clackamas, Columbia, Multnomah, and Washington Counties.

** Each forecast was derived from one of the models listed below. Number in parentheses indicates model number:

1. $\log_e Y = 11.025 + 1.377 \log_e X$
2. $\log_e Y = 12.044 + 1.473 \log_e X$
3. $\log_e Y = 15.08 + 0.0436X$
4. $\log_e Y = 16.41 + 0.0418X$
5. $\log_e Y = 15.64 + 0.0614X$
6. $\log_e Y = 17.21 + 0.0053X$
7. $\log_e Y = 14.93 + 0.032X$
8. $\log_e Y = 15.94 + 0.0374X$
9. $\log_e Y = 12.93 + 0.091X$
10. $\log_e Y = 15.32 + 0.052X$
11. $\log_e Y = 15.18 + 0.064X$
12. $\log_e Y = 16.74 - 0.0015X$
13. $\log_e Y = 14.44 + 0.057X$
14. $\log_e Y = 16.37 + 0.013X$

† Most reasonable projections.

‡ Expansion factor taken from Table 3b.

matical regression of the dependent variable. In other words, it provides the equation which best describes the dependent variable (annual sand and gravel and stone output) as a function of the explanatory variables.

Friedman and others (1979) tried many econometric models for the State; for the Portland area of Clackamas, Columbia, Multnomah and Washington Counties; and for other substate areas. For some models, the dependent variable was sand and gravel combined with stone; for other models, the dependent variable was either sand and gravel or stone. For economic and statistical reasons, very few models were usable. Table 5 contains the 1990 forecasts from the most usable models.

Of the six unmodified models (models 1, 2, 3, 4, 6, and 7 in a footnote to Table 5), only four have r^2 values high enough to be useful for making planning decisions. The models for the Portland area are good, with r^2 values in the 0.90's. The 1990 forecasts are the same for all rock material, either directly by the all-rock material model (sand and gravel and stone) or by adding the sand and gravel model forecast to the stone model forecast.

We find the State's forecasts are low, when compared to those of the Portland area. As discussed earlier, the Portland area should account for only 25 percent of Oregon's total demand; and for a 99-percent confidence interval, its share should be 18 to 33 percent. The Portland area forecasts have high r^2 values and fall within the range indicated by the two usable forecasts listed in Table 2. If an assumption is made that the Portland area will have 25 percent of the demand for all rock materials, then the Oregon demand will be four times the 19 million tons listed for the Portland area in Table 5. This figure of 76 million tons falls within the State's range of 71 to 86 million tons shown in Table 2. The sand and gravel unmodified model in Table 5 has an r^2 of 0.75 and a forecast of 31 million tons. The stone unmodified model has an r^2 of 0.25, which is too low to be useful. Therefore, if the stone forecast is discarded and the sand and gravel forecast is subtracted from the 76-million-ton forecast for all-rock material, the 1990 stone forecast is 45 million tons.

Based on the above figures, the ratio of sand and gravel demand over sand and gravel and stone is 0.408. This statistic compares very favorably with the three ratios of 0.421, 0.436, and 0.485 obtained by using the three least-squares forecast models of Gray and others (1978), as shown in Figure 8.

The 1990 range of forecast from Tables 2 and 5 is from 17 to 20 million tons of all rock material for the

Table 3a. *Factors needed to expand the adjusted Oregon annual production of sand and gravel and stone**

Year	Expansion factor	Year	Expansion factor	Year	Expansion factor	Year	Expansion factor	Year	Expansion factor	Year	Expansion factor
1940	1.692	1947	1.383	1953	1.302	1959	1.100	1965	1.141	1971	1.130
1941	1.866	1948	1.643	1954	1.351	1960	1.177	1966	2.063	1972	1.094
1942	1.403	1949	1.348	1955	1.029	1961	1.157	1967	1.116	1973	1.027
1943	1.392	1950	1.604	1956	1.033	1962	1.132	1968	1.126	1974	1.128
1944	1.208	1951	2.008	1957	1.069	1963	1.127	1969	1.107	1975	1.146
1945	1.235	1952	1.210	1958	1.078	1964	1.205	1970	1.204	1976	1.227
1946	1.138										

* Factors used by Friedman and others (1979) to make their figures compatible with figures published by Gray and others (1978) and Friedman and others (1979).

Table 3b. *Means of expansion factors for base-year intervals and 99-percent confidence intervals determined by* K *and* t *statistics*

						K statistic		*t* statistic	
						$\bar{X} \pm K_{\alpha/(2\sigma/\sqrt{n})}$*		$\bar{X} \pm t_{\alpha/2;\,(n-1)s/\sqrt{n}}$*	
Years**	n	Mean	s or σ	$K_{\alpha/2}$	$t_{\alpha/2;\,n-1}$	Lower limits	Upper limits	Lower limits	Upper limits
1940-76	36	1.259	0.235	0.500	2.727	1.239	1.279	1.152	1.366
1950-76	26	1.205	0.203	0.500	2.787	1.185	1.225	1.094	1.316
1963-76	13	1.137	0.052	0.500	3.055	1.130	1.144	1.093	1.181
1964-76	12	1.138	0.055	0.500	3.106	1.130	1.146	1.089	1.187

* Two-tailed test.
** 1966 expansion factor omitted.

Portland area and from 71 to 86 million tons for the State as a whole. Sand and gravel contributes 41 percent of all rock material demand, and stone the remaining 59 percent.

Friedman and others (1979) describe a method of modifying the Portland-area models to fit the State by substituting a State-level intercept. By applying this method, we arrive at the 1990 forecasts as developed in modified models 3 and 8 of Table 5, which predict that the sand and gravel production (or demand) will be greater than that of stone. The case illustrates the importance of the supply factor; the current State-wide tightening of the sand and gravel supply will result in future production of less sand and gravel than stone. Supply may not function directly as an explanatory variable for demand, but indirectly it does so. A forecast that does not reflect supply may therefore not be valid.

The concept of price

The analysis by Friedman and others (1979) of the relative price relationship between sand and gravel and stone for the Portland area can be viewed in light of the area's supply situation. The published annual values given for the commodities are measured at the pit or plant and therefore omit most transportation costs. If there are ample supplies of sand and gravel and stone, the delivered value may be twice that of the pit or plant value. If the supply of a commodity becomes tight, the price based on the published value may not change, but the delivered price may be three or four times the pit or plant price. The extra cost is transportation.

The Portland-area sand and gravel forecast model 3 of Table 5 shows that if all explanatory variables are kept constant except price and if price rises $1.00, demand will fall by 4.6 million tons. Under the same conditions, the Portland-area stone demand (model 6 of Table 5) will fall only 2.5 million tons. This indicates that the supply is tighter for sand and gravel than it is for stone. The tight supply of sand and gravel is causing a price rise in all rock material resources. The stone industry is benefitting the most because the centrally located pits of sand and gravel are being depleted, while the stone quarries still have reserves.

Using an econometric model design to analyze the relative price relationship between sand and gravel and stone, Friedman and others (1979) state: "For example, the model indicates that a 10-percent increase in the price of sand and gravel relative to the price of stone occurring in the absence of changes in the other explanatory variables would produce a 3-percent decrease in the quantity of sand and gravel demanded and an 11-percent increase in the quantity of stone demanded" (p. 37).

Alternatively, one could state that, as the supply of sand and gravel tightens another 3 percent, the price of sand and gravel will rise by 10 percent and the output of stone will rise by 11 percent. The downward trend in sand and gravel's portion of total output of sand and

Table 4a. *The Portland area's* annual production of rock material as a percent of Oregon's total annual production*

Year	Percent	Year	Percent	Year	Percent	Year	Percent
1940	18.4	1950	27.0	1960	17.6	1970	28.9
1941	24.7	1951	19.7	1961	17.2	1971	29.2
1942	22.0	1952	45.6	1962	12.6	1972	35.5
1943	28.2	1953	26.0	1963	15.4	1973	36.0
1944	28.3	1954	21.1	1964	16.9	1974	26.6
1945	27.0	1955	27.7	1965	13.9	1975	24.6
1946	30.6	1956	28.5	1966	8.3	1976	28.1
1947	22.3	1957	20.0	1967	21.3		
1948	25.9	1958	21.7	1968	31.3		
1949	26.5	1959	16.8	1969	29.9		

* Clackamas, Columbia, Multnomah, and Washington Counties.

Table 4b. *Means of Portland area's* total annual production for base-year intervals and 99-percent confidence intervals determined by* K *and* t *statistics*

						K statistic		t statistic	
						$\bar{X} \pm K_{\alpha/(2\sigma/\sqrt{n})}$**		$\bar{X} \pm t_{\alpha/2;\,(n-1)s/\sqrt{n}}$**	
Years	n	Mean (percent)	s or σ	$K_{\alpha/2}$	$t_{\alpha/2;\,n-1}$	Lower limits	Upper limits	Lower limits	Upper limits
1940-76	37	24.36	7.23	0.500	2.722	23.77	24.95	21.12	27.60
1950-76	27	23.98	8.21	0.500	2.779	23.19	24.77	19.59	28.37
1964-76	13	25.42	8.26	0.500	3.055	24.28	26.57	18.42	32.42

* Clackamas, Columbia, Multnomah, and Washington Counties.
** Two-tailed test.

Table 5. *1990 projections of annual demand for sand and gravel and stone, determined by the econometric method*

		Oregon			
		Unmodified models		Modified models	
Commodity with base years of 1963-76	Portland area* forecast** (million tons)	Forecast** (million tons)	Portland area as percent of Oregon	Forecast** (million tons)	Portland area as percent of Oregon
Sand and gravel and stone	19(1)	41(2) × 1.137† = 47	40	—	—
Sand and gravel	11(3)	31(4)	—	27(5)	—
Stone	8(6)	13(7)	—	25(8)	—
Subtotal	19	44 × 1.137 = 50	38	52 × 1.137 = 59	32

* Clackamas, Columbia, Multnomah, and Washington Counties.

** Each forecast was derived from one of the models listed below, using medium estimates given in Friedman and others (1979, Table 12) for the explanatory variables. Number in parentheses indicates model number. Models 5 and 8 are the same as models 3 and 6 modified by changing the intercept to fit Oregon rather than the Portland area. The r^2 values are given for each model, except for the modified two.

1. $Y = 1{,}440{,}651 - 6{,}667{,}195$ (price) $+ 0.39$ (population) $+ 39.54$ (employment) $+ 0.046$ (highway expenditures) $r^2 = 0.91$
2. $Y = 1{,}272{,}446 + 5{,}473{,}334$ (price) $- 0.80$ (population) $+ 21.93$ (employment) $+ 0.064$ (highway expenditures) $r^2 = 0.17$
3. $Y = 3{,}572{,}790 - 4{,}616{,}027$ (price) $+ 5.50$ (population) $+ 8.61$ (employment) $+ 0.033$ (highway expenditures) $r^2 = 0.93$
4. $Y = -8{,}280{,}846 + 4{,}146{,}131$ (price) $- 11.99$ (population) $+ 45.39$ (employment) $+ 0.086$ (highway expenditures) $r^2 = 0.75$
5. $Y = 2{,}329{,}623 - 4{,}616{,}027$ (price) $+ 5.50$ (population) $+ 8.61$ (employment) $+ 0.033$ (highway expenditures) —
6. $Y = -1{,}601{,}970 - 2{,}502{,}933$ (price) $- 5.52$ (population) $+ 3.19$ (employment) $+ 0.014$ (highway expenditures) $r^2 = 0.70$
7. $Y = 29{,}836{,}530 - 9{,}335{,}489$ (price) $+ 2.20$ (population) $- 7.34$ (employment) $- 0.023$ (highway expenditures) $r^2 = 0.25$
8. $Y = -157{,}972 - 2{,}502{,}933$ (price) $- 5.52$ (population) $+ 3.19$ (employment) $+ 0.014$ (highway expenditures) —

† Expansion factor taken from Table 3b.

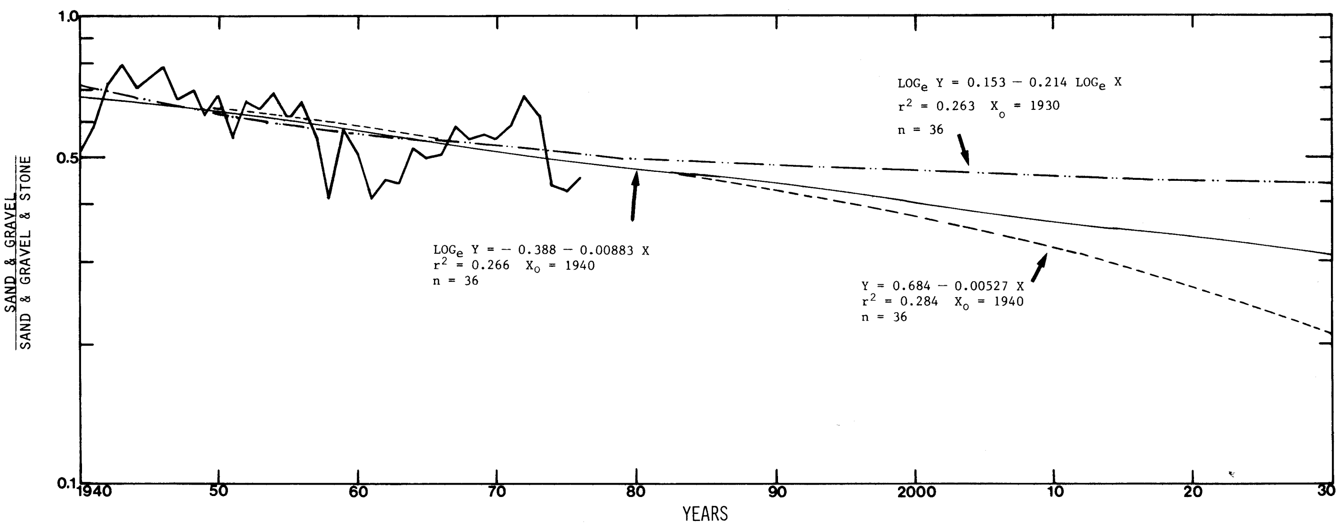

Figure 8. Oregon's annual production tonnage ratios of sand and gravel to sand and gravel and stone vs. time.

gravel and stone shown by Gray and others (1978, Figure 8) also reflects the tightening of sand and gravel supplies compared to those of stone.

STEPS TO FORECAST MODELING

1. **State the problem.** For most of the State, the problem is to determine how much land will be needed for rock material production to supply present and future needs of the local area and of the State. To answer this question, an inventory of rock material supplies must be made, and the rate at which those supplies are being depleted must be shown. Rock resource assessments and demand modeling address the two main aspects of the problem.

2. **Obtain production statistics for all-rock material (sand and gravel and stone) and other economic statistics for the State and for the substate marketing area.** The rock material data can be found in the appendix of Special Paper 5. The substate areas were chosen so that imports into and exports out of the substate areas were in balance, and production statistics consequently represented consumption. One of the major findings in Special Paper 5 is that forecast modeling does not work for areas smaller than a substate marketing area. In areas smaller than a marketing area, imports do not equal exports. Also, because of the small size of the economic base, output of rock material can vary widely. Consequently, forecasting should not be performed at the city level.

3. **Plot the all-rock material production statistics against time for both the substate marketing area and the State.** This gives a graphic picture of the peaks and valleys of substate area output in comparison to that of the State. From the graph, the extent to which the substate area is in step with the State can be determined.

4. **Plot all-rock material annual production against such other economic variables as population, employment, and price.** If any correlation exists between the rock material annual output and another economic variable, these graphs will show linear trends.

5. **Review the graphics to determine how output has reacted during the past and then decide what length of time should be used for the forecasting base and which level of forecast modeling is needed.** Extending trend lines out into the future can be done by drawing a line freehand through the data points on a graph and extending it into the future or by using the least-squares and/or econometrics/multiple regression methods. After forecasts have been made for all-rock material at the State and substate levels, they should be compared. Demand for a substate cannot grow larger than that for the State as a whole. The past substate percentages should be reviewed in relation to those of the State to see if the percentages changed much during the base years. If they did not change during the base years but show a major change by the end of the forecast, an explanation should be sought.

6. **Separate the two commodities and plot them against time.** There is a good chance that one will show greater growth than the other. The output or growth is a function of supply, not demand, because the two commodities are interchangeable.

In many parts of the State, the supply of gravel is tight because of adverse zoning and land use; therefore, stone often shows faster growth than sand and gravel.

7. **Prepare forecast models for each of the commodities.** The two year-end forecasts should be added together and compared to the forecast obtained by modeling all-rock material. Again, a part cannot become larger than the whole. If the two models do not equal the total, and one model has a much higher r^2 value than the other, use the forecast from that model and subtract it from the all-rock-material forecast to

determine the forecast for the other commodity. Note whether or not supplies of the commodities are large enough so that the past relationships will be able to continue. If supplies for one commodity are tighter than for the other, its prices probably will rise with no increased output. Prices probably will also rise for the other commodity, but its output will rise as well.

SUMMARY AND CONCLUSIONS

This paper reviews forecast modeling techniques and discusses in detail the two methods of building forecast models presented by Gray and others (1978) and Friedman and others (1979). For most forecasting, the two methods, least squares and econometric/multiple regression, are most useful to the local planner.

For general modeling techniques, modeling should start at the State level and proceed down to the substate area and ultimately to the local area. The demand of a local area cannot grow larger than that of the substate area, and the substate demand cannot grow larger than the State's demand. Modeling should proceed from all-rock material down to each of the commodities. The demand for one commodity cannot grow larger than the total rock material demand.

The economic activities of man create demand for all rock material, but it is the adequacy of supply for the two commodities that determines their price and output. By comparing the least-squares technique to the econometric technique, we conclude that the Portland area will have a 17- to 20-million-ton demand for all rock material by 1990 and Oregon 71 to 86 million tons. By the year 2030, Portland's demand will have grown to between 35 and 116 million tons and Oregon's to between 150 and 457 million tons.

The adequacy of supply must also be viewed from the standpoint of the one-time-only, nonrecurring demand such as that created by a major dam project. This type of demand shows up as peaks in the time trend graphs for the State as a whole and is part of the demand forecast for the State. It is impossible, however, to predict when and where such a demand surge will occur again. If the possibility exists that this type of project may occur within a planning area, then supplies must be large enough to meet the extra demand.

To properly address the problem of supplying adequate rock material resources, demand models and resource assessments are both needed. Knowledge of the constraints defined by the resource assessments and of the nature and the current status of the industry allow proper selection and realistic interpretation of the demand models.

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meeting announcements

Each month, space permitting, upcoming meetings will be announced in this column. Information should reach this office no later than six weeks before a meeting. Please be specific and give full name of the organization; exact subject, location, and time of the meeting; and the name, address, and phone number of person to contact for questions or reservations.

GSOC luncheon programs announced

The Geological Society of the Oregon Country announces the following luncheon program schedule. All luncheon programs will take place at noon, in Room A (adjacent to the cafeteria) of the Standard Plaza Building, 1100 SW Sixth Avenue, Portland.

January 18	Speaker:	John Haffnagle, The Nature Conservancy
	Subject:	Oregon's Nature Conservancy program
February 1	Speaker:	Jim Doane, Bureau of Hydroelectric Power, City of Portland
	Subject:	Hydroelectric power installation at Bull Run Dams
February 15	Speaker:	Vernon Newton, Oregon Department of Geology and Mineral Industries
	Subject:	Oil and gas activity in Oregon
March 7	Speaker:	Tom McAllister, Outdoors Editor, The Oregon Journal
	Subject:	Inland passage, north Alaska
March 14	Speaker:	Donald Godard, Oregon Department of Energy
	Subject:	Nuclear energy: The Three Mile Island accident and the storage of spent fuel rods

For further information, contact the luncheon program chairperson, Viola L. Oberson, phone 282-3685. □

DOGAMI staff moves back to remodeled quarters

The remodeling of the ninth and tenth floors of the State Office Building in Portland has been completed, and the State Geologist, Deputy State Geologist, professional staff, cartographers, and editor have moved back to Room 1069. The library and business office are on the ninth floor. Check the directory in the lobby for correct room numbers. □

Regional metals and minerals conference to meet in May

The Pacific Northwest Metals and Minerals Conference will be held May 7-9, 1980, at the Olympic Hotel in Seattle, Washington.

Joint hosts for the conference are the North Pacific Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers and the Puget Sound Chapter of the American Society for Metals.

Theme of the conference will be: "Materials Problems of the 80's." The program will include technical sessions on such subjects as metallurgy, geology, and mining; industrial exhibitions by sixteen exhibitors; mini-courses on items such as business economics, computers, and statistical analysis; and a ladies' program, including tours and luncheons.

Conference chairman is Roger V. Carter, Chief of Metals Technology, Boeing. Further information will be forthcoming in the society publications. □

(C) Punch-ROTHCO

"... *but you can call me Rex.*"

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time we will print abstracts of new acquisitions that we feel are of general interest to our readers.

Stratigraphy, structure, and petrology of Columbia River Basalt in a portion of the Grande Ronde River—Blue Mountains area of Oregon and Washington, by Martin Edward Ross (Ph.D. in Geology, University of Idaho, 1978)

Grande Ronde, Wanapum, and Saddle Mountains Basalts are exposed in the canyons of the Grande Ronde River and its tributaries in northeastern Oregon and southeastern Washington. The detailed stratigraphy of these Miocene to Pliocene basalts has been established in a portion of this area using a combination of flow and interbed mapping and correlations based on chemical, petrographic, and paleomagnetic properties of each flow.

The Grande Ronde flows have only a moderate range of compositions and form a chemical group most likely derived from a homogeneous magma source. Chemical compositions of most of the flows were very similar, but at least six of the flows have relatively distinct chemistries. I have found that at least eight of the Grande Ronde flows contain significant amounts of orthopyroxene and have relatively high mean SiO_2 contents, indicating they might more accurately be considered tholeiitic andesites.

All four of the Grande Ronde magneto-stratigraphic units of Swanson and Wright (1976) are present, with N_2 confined mainly to the central, structurally lowest portion of the study area. This, along with the thickening of the Troy flow and of the R_2 magnetic interval in the same area, suggests that deformation began prior to the end of Grande Ronde volcanism.

Six flows of Wanapum Basalt overlie the Grande Ronde sequence. Four of these occur as two pairs (Dodge flows and Kuhn Ridge flows), with each pair forming a distinct chemical and petrographic unit. Source dikes for the Dodge flows have been recognized and mapped within the area.

Five flows of Saddle Mountains Basalt and three sedimentary interbeds occur above the Wanapum Basalt sequence. Near-vent andesite ejecta and volcanic breccia are associated with the Grouse Creek sedimentary interbed in the southwest portion of the study area. This andesite predates the Wenaha flow and postdates the Eden flow. A source dike for the Wenaha flow was recognized and mapped.

The Wanapum and Saddle Mountains flows and flow pairs are chemically and petrographically distinct from one another. Roza and Umatilla are the only two Wanapum and Saddle Mountains chemical types of Wright and others (1973) that occur in the study area. This compositional diversity requires a complex magmatic history, probably involving more than a single parent magma.

A detailed investigation of chemical variations across each of four Wanapum and Saddle Mountains dikes shows that SiO_2, TiO_2, and K_2O decrease inward from chilled margins as MgO and perhaps CaO and total iron increase. P_2O_5 varies systematically only within the Wenaha dike, in which it decreases inward from the chilled dike margin. Several hypotheses have been considered in my attempt to explain these trends. I favor a model in which progressive partial melting at the magma source produced a series of melts increasingly depleted in silica and incompatible elements.

Petrographic and mineralogic variations across the dikes were also studied in detail. There is substantial evidence of fractional crystallization within the dikes with the following being the most significant: plagioclase becomes increasingly more sodic toward the interior of each dike, and orthopyroxene, when present, is restricted to the chilled margins. These mineralogic trends are superimposed on the more primary chemical trends, indicating that fractional crystallization occurred after partial melting, perhaps during magma ascent and intrusion.

These magmatic processes operating in the formation of each dike might also play significant roles in the evolution of entire groups of flows derived from a common source. This study of trends within the individual dikes provides a new approach to the investigation of Columbia River Basalt magmas.

The presence of broad folds; strike-slip faults showing a second, lesser dip-slip movement; a monocline; and normal faults indicates the area was subjected to a nearly north-south compression followed by relaxation and tensional tectonic forces. This deformation was superposed on the regional subsidence of the Columbia Plateau centered about the Pasco Basin. Subsidence and folding seem to have occurred throughout the period of Yakima Basalt volcanism. The Blue Mountains anticlinal uplift and down-warping of the Grouse Flat syncline accelerated after Wanapum Basalt volcanism. This resulted in Saddle Mountains units being thicker and more confined to the structurally low area toward which they thicken.

The well-formed meanders of the Grande Ronde

(See **Columbia River Basalt**, *p. 18)*

Mined Land Reclamation hearings scheduled

The Governing Board of the Oregon Department of Geology and Mineral Industries has approved the Department's draft of proposed amendments to the Mined Land Reclamation Administrative Rules and has authorized public hearings on it. The proposed rule changes pertain to larger, open-pit mining sites and quarries, but not to placer gold mines in active streams or small-scale recreational mining.

Three public hearings have been or will be conducted around the State by the Department: Portland, January 8, 1980, 9:00 a.m.-4:30 p.m., at the Oregon Department of Fish and Wildlife Building. Roseburg, January 10, 1980, 9:00 a.m.-5:00 p.m., in the Roseburg City Hall Council Chambers. Baker, January 22, 1980, 1:00 p.m.-5:00 p.m. and 7:00 p.m.-9:30 p.m., at the School District Building, 2990 Fourth Street.

Copies of the draft proposal are available at the offices of the Department in Portland, Baker, Albany, and Grants Pass. Written testimony has been received at the hearings held already. More will be received at the last public hearing or may be submitted directly to the Department, c/o Stan Ausmus, 1129 SE Santiam Road, Albany, OR 97321, by February 1, 1980. Comments and questions should be directed to the Albany office, c/o Stan Ausmus or Barbara DeClue, phone: 967-2039. □

(**Columbia River Basalt,** *from p. 17)*
River developed originally on a relatively flat plateau surface. After downcutting of a few hundred feet had occurred, the meanders were able to more easily enlarge and migrate within the thick sedimentary interbeds within the Saddle Mountains sequence prior to significant deformation in the area. Entrenchment of the meanders then occurred during uplift of the Blue Mountains. The absence of more massive and resistant pre-Tertiary rocks along the course of the river allowed it to maintain its meanders within the basalts during entrenchment.

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Wright, T.L., Grolier, M.J., and Swanson, D.A., 1973, Chemical variation related to the stratigraphy of the Columbia River Basalt: Geological Society of America Bulletin, V. 84, no. 2, p. 371-386. □

Geothermal lease regulations: BLM proposes changes

In the interest of expediting the leasing and development of lands with potential geothermal resources, the Bureau of Land Management has proposed two amendments to the Code of Federal Regulations on noncompetitive geothermal leases.

The first change affects existing leasing units which have become available again because they are on lands on which leases have been canceled or relinquished, lands on which leases expired at the end of their primary or extended terms, or lands on which leases have been terminated for nonpayment of rent. Such leases would no longer fall under the requirement for competitive leasing when two or more applications are filed for the same leasing unit. Instead, a public drawing would establish an order of priority among the applications, and leases would be issued on the basis of it.

The second change affects lands designated as Known Geothermal Resource Areas (for competitive bidding), which were so designated solely because of overlapping noncompetitive applications. If, as has been the case too frequently, the competitive leasing attracts no bids, the lands could be reclassified for noncompetitive leasing. With regard to the procedure to be used in awarding the leases, the Department of Energy advocates priority of filing date, and BLM favors a drawing among the applications of the same filing period.

The proposals have been published in the Federal Register, v. 44, no. 228 (Nov. 1979), p. 67598-99. Written comments are due by January 25, 1980. Address: Director (650), Bureau of Land Management, Department of the Interior, 1800 C Street NW, Washington, D.C. 20240. □

We're late

Your copy of the January issue of *Oregon Geology* reached you later than usual this month because we moved back to our remodeled offices during December, making it impossible to meet our usual publication schedule. We apologize. □

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