# Assessment of the Availability Of Natural Gas in The Northern Rocky Mountain Area of Colorado, Utah and Wyoming

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## I. INTRODUCTION

Edward H. Feinstein has prepared this report on conventional natural gas supplies of the Northern Rocky Mountain Area. In this report, specific reviews were made of the history, gas production, estimates of proven reserves and estimates of undiscovered resources.

The principal purpose of this report is to present estimates of the availability or productive capability of natural gas in certain regions of the Rocky Mountain Area. An assessment of the unconventional resource, coal-bed methane is also included in this report. Forecasts of the area-wide natural gas productive capability were based upon estimates of proven reserves, discovery process estimates of reserve additions, pipeline connection parameters, and deliverability profiles. Discovery process is the relationship between the efforts (drilling) and the potential for natural gas discoveries.

## II. SUMMARY AND CONCLUSIONS

The gas supply regions of the Northern Rocky Mountain Area are in both an intermediate and mature stage of development. The assessment of gas supply herein is based on three ingredients: remaining reserves, reserves appreciation, and undiscovered resources. Remaining reserves are the proved and economically producible gas discoveries. Reserves appreciation are resources believed to exist that are directly related to reserves already discovered. Undiscovered resources are estimated gas accumulations that are believed to exist, but have not yet been proven by drilling.

The productive capacities of proven gas reserves of each producing region of the Rocky Mountain Area vary considerably. Reserves-to-production ratios in each area presently are at their lowest level, reflecting only modest surplus pipeline gas.

Estimates of future annual gas discoveries were made employing a discovery - process model as described below. Productive capacity decline rates were applied to determine the availability of gas from new supply sources.

The availability of supplies from future sources was added to the availability of current proven sources to arrive at the overall productive capability of natural gas supplies from the various Rocky Mountain areas. These supply areas are currently reliable, active and viable in providing adequate throughput for the network of pipelines connected to them. In the long-term, however, the current grade of natural gas accumulations will be exhausted, giving way to the discovery of smaller deposits. The result will be a gradual decline in the productive capability from existing and future connected supply sources.

## III. BACKGROUND – NORTHERN ROCKY MOUNTAIN AREA

The Northern Rocky Mountain area is made up of the states of Colorado, Utah, Wyoming, Montana and North Dakota. The Rocky Mountain area of Colorado, Utah and Wyoming is one of only two oil and gas provinces in North America that have been growing in gas production over the past 10 years. Although relatively small, productive areas of Montana and North Dakota, while not in a growth stage, presently remain in a constant state of gas discoveries and production. The Rocky Mountain region will continue to grow in gas production for 10 more years. The Rocky Mountain area is a large, gas prone, geologically heterogeneous area that contains numerous gas productive basins. Numerous oil and gas prone formations and prospective reservoirs are present. Productive reservoirs include carbonates (limestone) and sandstones with all types of porosity and permeability as well as naturally fractured reservoirs and coalbed methane reservoirs. The Potential Gas Committee (PGC) has estimated (2004) potential gas resources of 123 Tcf.

A challenge for certain gas resources in the region is to exploit technically available gas in locations where reserves are characterized by "tight" matrix porosity and permeability, naturally fractured reservoirs and coalbed methane and make them economically recoverable resources.

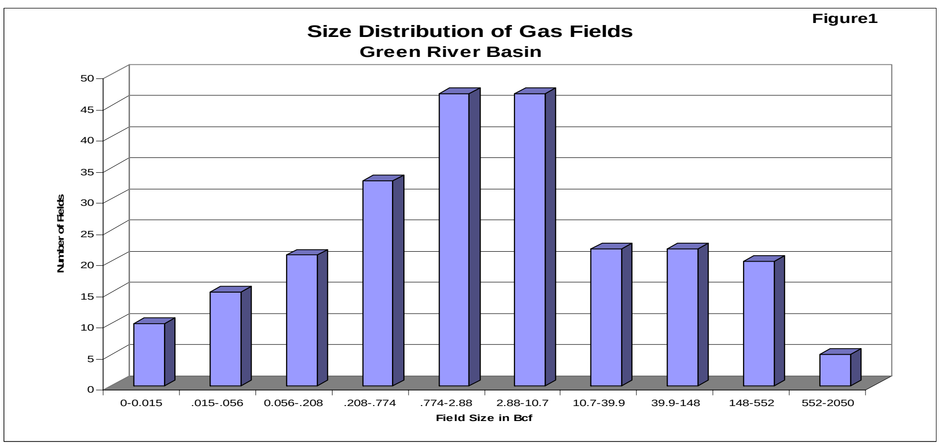
## IV. METHODOLOGY

<u>Proven Reserves</u>

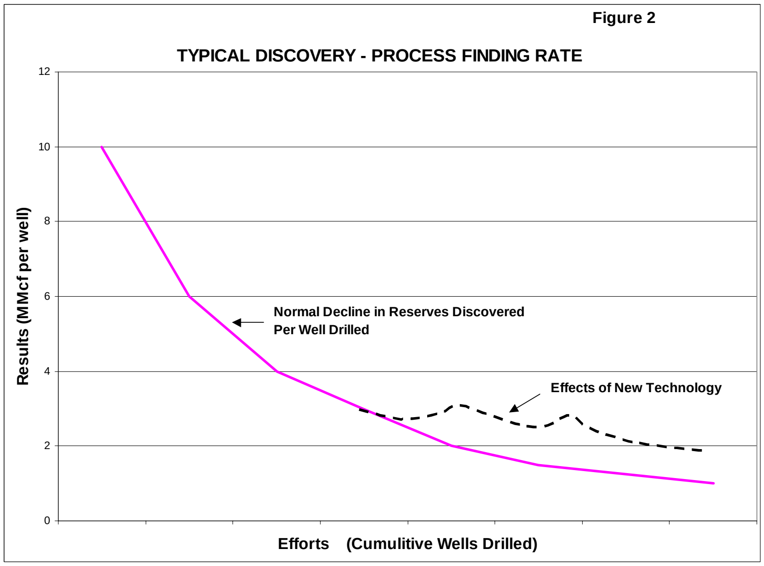
An analysis of the producibility of proven gas reserves was made using information obtained from the Energy Information Administration (EIA) and the Potential Gas Committee (PGC). EIA's proven reserves are as of the end of 2004. The productive availability of those proven reserves was obtained from data assembled by the (PGC) and extrapolated employing a constant percentage decline until the reserves are exhausted. The proven gas reserves were obtained from EIA, which in turn collected the data from producers. The PGC provided the production rate of those reserves.

<u>Future Reserve Additions</u>

A characteristic observed in the petroleum producing areas of the Northern Rocky Mountain Area is a rapid drop off in size from the largest known field to the smaller ones. Hydrocarbon accumulations are the result of complex geological processes. Furthermore, the actual quantities of producible reserves are further defined on the basis of technological and economic considerations. As a consequence of all these independent influences and the multiplicative nature of the factors affecting the size of a gas accumulation, field sizes in producing basins are typically log normally distributed (Figure 1).




That is, a few very large fields contain the bulk of the reserves and many, many small fields contain, in aggregate, a smaller portion of the reserves. Also, another characteristic of gas supply basins is that large fields are discovered early in the exploration process, and subsequent discoveries are smaller and the product of increasingly greater efforts. This is demonstrated in illustrative form in Figure 2, below.




Since some of the basins in the Rocky Mountain Area, unlike other producing regions, contains both mature and intermediate supply regions, perhaps some large field discoveries remain undiscovered and will become available for exploitation and some portion of resource estimates may prove to have been too optimistic.

<u>The Finding Rate Methodology</u>

One measure of the discoverability of resources is the rate at which resources are found. This method compares the drilling footage in a particular year with the related discoveries. This method depicts the normal stage of events that take place when a gas-bearing province graduates past its initial discovery stage and enters its more or less mature stage. The degree of maturity of the producing life of the supply areas can be determined by comparing the amount of gas resources already discovered with an estimate of the ultimate resources.

The nature of oil and gas accumulations creates a distribution of fields and reservoirs made up of a small number of large fields, a larger number of medium size fields, and a seemingly unending amount of small fields. The Rocky Mountain Area is no exception. An example of the distribution of gas reserves in the a portion of the Rocky Mountain Area referred to as the Greater Green River Basin is shown on Figure 1. This is typical of the exploratory events of an oil and gas province.

The basic concept of this Finding Rate Methodology is shown on Figure 2. At times, the declining rate of effectiveness is mitigated by: better technologies for discovery and resource recovery, greater understanding of the geophysics, and reservoir performance of the field in the province. This mitigation is also shown on Figure 2.

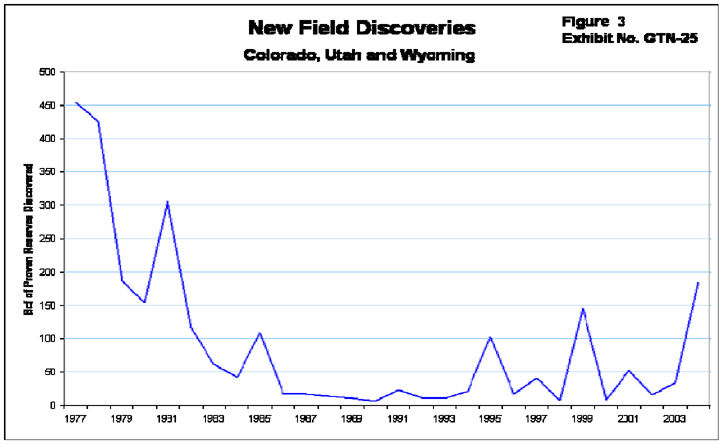
Advances in technology are, however, a double-edged sword with respect to extending the life of gas resources and ultimately the life of associated producing equipment and pipeline facilities. Exploration and production (E&P) technology varies throughout the industry, from increasing the success ratio in exploration to more efficient production techniques. While some advances in technology may allow the commercialization of heretofore unproduceable hydrocarbon deposits, most others relate to the profitability of technically discoverable oil and gas resources. For example, four causes for the accelerated production of a given gas resource in the Rocky Mountain area and to a certain extent, the accelerating decline rates in various regions, relate to technology. They are:

- 3-D seismic
- Horizontal wells
- Efficient completion techniques
- General miscellaneous technology

An example of the effect of new geophysical technology (*e.g*. 3-D seismic) on E&P is basically an improvement in the exploration success ratio. With advances in geophysical technology, producers are better able to locate oil and gas deposits and also to determine whether they should be explored or bypassed as a viable project.

Technology advances do not come cheap. Its application must be in terms of the potential value of the resource. This assessment takes into account technology, in that the forecasts were based upon the employment of various trends, which included advances in technology.

I first determined if the supply areas paralleled the premise of this model (that large initial field discoveries give way to smaller ones). In addition to the field size facts cited earlier, further analysis confirmed that indeed most of the larger fields have been discovered as well as many of the medium size fields. This can be observed by inspecting the relationship between the new fields discovered and the exploratory efforts as shown on Figure 3, below.




This can also be seen by analysis of the finding rate methodology in terms of exploratory effort. Most of the significant gas discoveries are actually associated with fields previously discovered. *See* the historical data shown on Tables 1 and 2, and Figures 4, 5, 6 and 7. The exploratory effort is the accumulation of wells drilled over time. The above finding rate data is a 5-year snapshot of a long trend from higher levels of how effective exploration and development was in prior years. I observed both exploratory wells and development wells. Development wells do not reflect the effort to find new discoveries. However, they contribute significantly to the reserve base. "Results" (in terms of annual gas discoveries) of the historical drilling effort are also shown on Tables 1 and 2 for the Northern Rocky Mountain areas.

When these "results" or annual gas discoveries are divided by the annual exploratory wells drilled, a more focused relationship develops as to the size of the discovery for the effort expended. This confirms that the large fields have already been discovered and that new discoveries are going to be generally confined to a considerably more moderate size.

This concept of discoveries per well drilled is referred to by the EIA as the Finding Rate Methodology. The Finding Rate Methodology began in the late 1950s and early 1960s and continues to be used today. The famous oil and gas forecaster, M. King Hubbert developed various aspects of it and used it in his presentations and forecasts. The renowned petroleum engineer and recipient of the C. C. Uren Award from the Society of Petroleum Engineers, J.J Arps also developed the Finding Rate Methodology in the early 1960s, referring to it as the Effectiveness of Exploration. The methodology was, and continues to be, employed widely by those forecasting oil and gas resources. I employed the methodology in 1973 in various proceedings at the FPC and the FERC and continue to do so. The EIA exclusively uses the Finding Rate Methodology to forecast long-range oil and gas discoveries in its state-of-the art Annual Energy Outlook publication.

The model used the relationship between annual reserve additions and both exploratory and development well drilling over time in years and cumulative feet drilled from a base of 1990. For the most likely case, I extrapolated the exploratory finding rate at a constant level using the 5-year mean value developed in Tables 1 and 2 and employed in Tables 3, 4 and 5 until 90 percent of the total endowment is reached. The total endowment is defined as all the gas that will eventually be discovered (past discoveries plus the PGC’s estimates of potential resources). PGC's estimates of potential gas resources are shown on Table 7.

Table 7
Exhibit No. GTN-25

## ULTIMATE REMAINING GAS RESOURCES

***Volumes in Trillion Cubic Feet***

| | | Rocky Mountain Area<br>Colo, Utah and Wyo |
|---|---|---|
| 1 | Cumulative Production to 12/31/1988 | 23.96 |
| 2 | Incremental Production 1989 to 12/31/2004 | 27.961 |
| 3 | Remaining Proved Reserves at 12/31/2004 | 38.55 |
| 4 | Potential Gas Resources Estimated at 12/31/2004 Wet | 114.86 |
| | Potential Gas Resources Estimated at 12/31/2004 Dry Marketable | 111.41 |
| 5 | Ultimate Estimated Resources (12/31/2004) | 201.88 |
| 6 | Gas Discoveries to 12/31/2004 | 90.47 |
| 7 | Percent Remaining to be Discovered | 55.19 |

Table 8 shows the total endowment as of 2004 for the gas provinces of Colorado, Utah and Wyoming.

Table 8
Exhibit No. GTN-25

**Estimate of Potential Gas Resources**
**As of End of 2004**
**Volumes in Bcf**

| Producing Province | Resource Estimate | | | | | | Total Resource Estimate |
|---|---|---|---|---|---|---|---|
| | Growth in Reserves | | | New Fields | | | |
| | 0-15,000 Feet | 15,000-30,000 Ft | CBM | 0-15,000 Feet | 15,000-30,000 Ft | CBM | |
| Powder River Basin | 1,435 | - | 6,672 | 2,153 | - | 20,015 | 30,275 |
| Big Horn Basin | 657 | 170 | - | 515 | 616 | 25 | 1,983 |
| Wind River Basin | 3,457 | 1,527 | - | 6,180 | 3,401 | 50 | 14,615 |
| Greater Green River Basin | 10,124 | 822 | - | 8,701 | 1,172 | 375 | 21,194 |
| Denver Basin and Environs | 1,479 | - | - | 1,070 | - | - | 2,549 |
| Uinta/Piceance Basin and Environs | 19,222 | | 133 | 17,982 | 989 | 4,115 | 42,441 |
| Thrust Belt | 800 | - | - | 1,000 | - | - | 1,800 |
| Total Colorado, Utah and Wyoming | 37,174 | 2,519 | 6,805 | 37,601 | 6,178 | 24,580 | 114,857 |
| Williston Basin | 846 | | | 2,058 | 98 | | 3,002 |
| Sweetgrass Arch | 504 | | | 1,096 | | | 1,600 |
| Montana Folded Belt | | | | 4,000 | | | 4,000 |
| Total Montana and North Dakota | 1,350 | | | 7,154 | 98 | | 8,602 |

Source: Potential Gas Committee

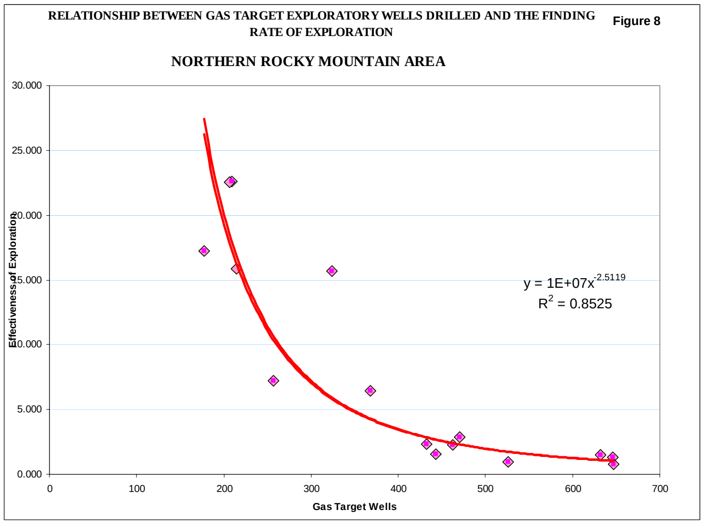
*Note: CBM - Coalbed Methane*

I used the same procedure for the finding rate of development drilling.

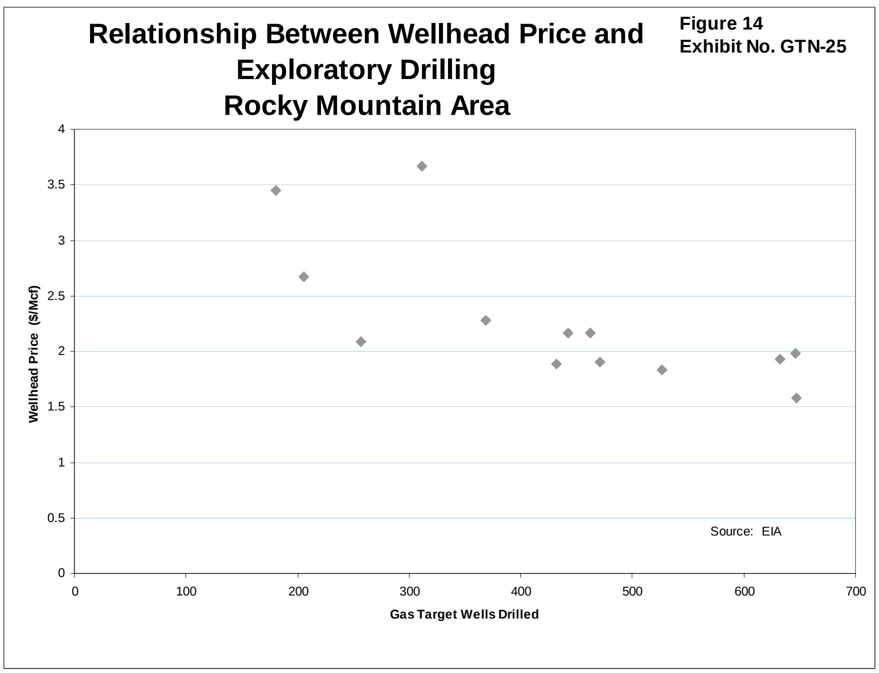
The most likely level represents the mean value of the finding rate from 2000 through 2004.

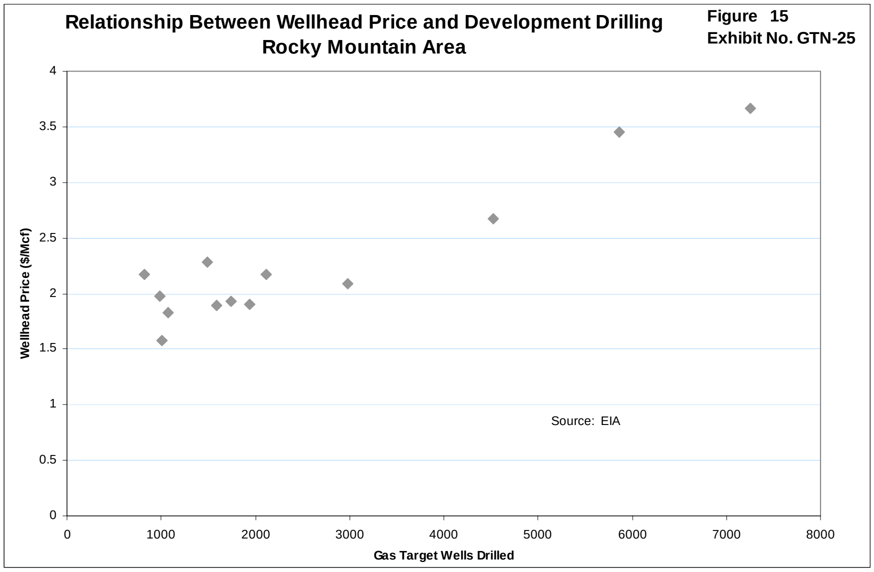
I employed a constant level of effectiveness until 90 percent of the ultimate resources are discovered as I expect some occasional increases in the finding rate due to forces not directly indicated in the data. As mentioned earlier, any decline in the finding rate curve will be mitigated by technological increases in the exploration and drilling techniques along with an increased awareness of the geophysics and reservoir mechanics. Technological increases are included in the 1990-2004 data. I am assuming that future technological increases will occur at the same rate as in the historical statistics. I found, in some cases unsurprisingly, that as drilling exceeds certain levels, the finding rate declines. This is due most likely to the drilling of lower grade prospects in a particular year. *See* Figures 4 and 5 for the number of wells drilled each year and Figures 8 and

9 for the relationship between the number of wells drilled in a particular year and its corresponding finding rate. The relationship between exploratory gas target wells and the finding rate is shown below in Figure 8.




I determined the future discoveries from exploratory drilling by applying a representative constant level of drilling activity to the corresponding finding rate. For my determination of the discoveries from development drilling, I also applied a constant level of annual drilling activity, based upon the most recent 5-year period, to reflect the development drilling activity response to increases in the wellhead price of gas. This period included very significant increases in the price of gas at the wellhead and only one modest decrease. I believe that, in the future, such similar increases and decreases will occur eventually leading to a further overall price increase. My choice of exploratory and development drilling levels fully reflects an overall average price increase over the pertinent period, all the while daily, monthly, and yearly prices will fluctuate both up and down. Specifically, based on my experience and studies, I found a relationship to exist between the price of gas at the wellhead and development drilling effort. No such clear relationship occurs for exploratory drilling as drilling prospects differ considerably in many respects as well as inherent risk factors. As such, many factors come into play with respect to the exploratory drilling response. While an increase in wellhead gas prices is an inducement to increase exploratory drilling efforts, the fact is that for the producing areas involved in this proceeding, there is no clear and concise relationship between wellhead price and the number of exploratory wells drilled. The graphs shown on Figures 14 and 15, of wellhead gas price and drilling effort, illustrate this point.



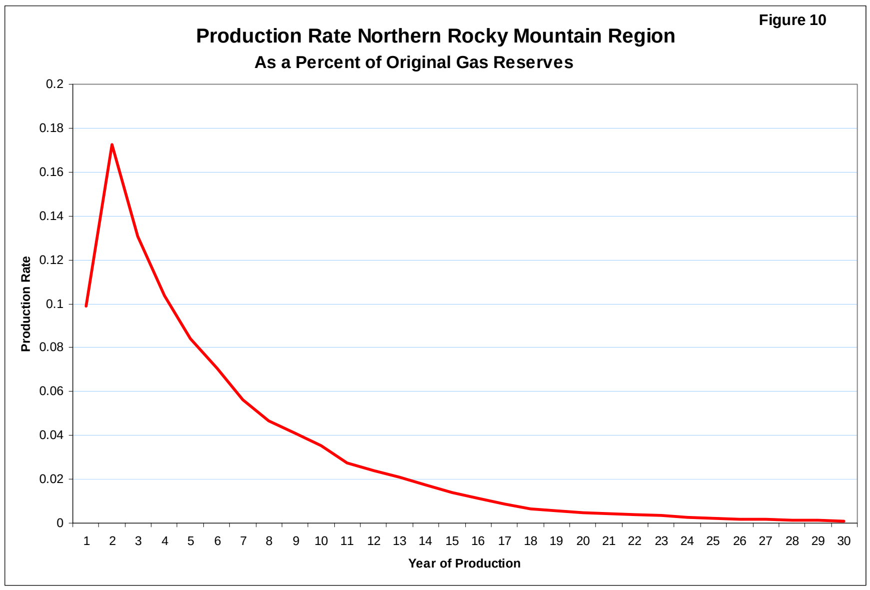



Exploratory wells differ considerably from development wells in the Rocky Mountain area. Exploratory wells are relatively high risk. They are drilled relatively far from existing discoveries. They are high cost. Existing, in-place pipeline facilities may be lacking. They must rely upon financing much different from development wells, *e.g.*, the expenditure of money for geological and geophysical studies. Many factors affect the decision to drill exploratory wells, including, but not exclusively, the prevailing wellhead price.

With respect to development wells and price, the annual relationship between them is not sufficient to forecast future drilling efforts. Instead, I employed high values of such efforts in my calculations. The Most Likely Case level of wells drilled and footage attained was based on an average value for the 2000-2004 period.

The Future Discoveries resulting from the application of the drilling effort to the effectiveness of drilling are shown on Table 3 for exploratory discoveries and Table 4 for development discoveries

To determine the future gas availability, I applied to each determined annual future reserve addition, a productive capacity rate derived by the Potential Gas Committee from data obtained from Petroleum Information/Dwights LLG data base (See Figure 10).




This results in the production capacity from new reserves beginning in 2004.

To the production profile of future reserves, I added the production profile for the beginning of year 2004 proven gas reserves. This is shown on Table 6.

## V. DETERMINATION AND RESULTS -- NORTHERN ROCKY MOUNTAIN AREA

The Northern Rocky Mountain area that I analyzed occupies the states of Wyoming, Utah and Colorado. This is one of the major oil and gas producing regions of the United States. Gas production will come from mostly non-associated gas reservoirs and coal-bed methane deposits. New field discoveries are expected to be found in deposits ranging from 1 to 200 Bcf, with most in the 2 to 20 Bcf range. The profile of the future productive capacity from this area is graphically illustrated on Figure 11, shown below.