

# APPENDIX A

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## Assessment of the Availability Of Natural Gas in The Northern Rocky Mountain Area

Edward H. Feinstein

1 I. INTRODUCTION

2  
3 Edward H. Feinstein has prepared this report on conventional natural gas  
4 supplies of the Northern Rocky Mountain Area. In this report, specific reviews  
5 were made of the history, gas production, estimates of proven reserves and  
6 estimates of undiscovered resources.

7 The principal purpose of this report is to present estimates of the availability  
8 or productive capability of natural gas in certain regions of the Rocky Mountain  
9 Area. Forecasts of the area-wide natural gas productive capability were based  
10 upon estimates of proven reserves, discovery process estimates of reserve  
11 additions, pipeline connection parameters and deliverability profiles. Discovery  
12 process is the relationship between the efforts (drilling) and the potential for natural  
13 gas discoveries.

14 II. SUMMARY AND CONCLUSIONS

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

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

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

8           The availability of supplies from future sources was added to the availability  
9 of current proven sources to arrive at the overall productive capability of natural  
10 gas supplies from the various Rocky Mountain areas.

11

12           These supply areas are currently reliable, active and viable in providing  
13 adequate throughput for the network of pipelines connected to them. In the long-  
14 term, however, the current grade of natural gas accumulations will be exhausted,  
15 giving way to the discovery of smaller deposits. The result will be a gradual  
16 decline in the productive capability from existing and future connected supply  
17 sources. (See Figures -1 through -3).

### 18 III. BACKGROUND

19           The Northern Rocky Mountain area is made up of the states of Colorado,  
20 Utah, Wyoming, Montana and North Dakota. The Rocky Mountain area of  
21 Colorado, Utah and Wyoming is one of only two oil and gas provinces in North

1 America that have been growing in gas production over the past 10 years.  
2 Productive areas of Montana and North Dakota, while not in a growth stage,  
3 presently remain in a constant state of gas discoveries and production. The Rocky  
4 Mountain region will continue to grow in gas production for 10 more years. The  
5 Rocky Mountain area is a large, gas prone, geologically heterogeneous area that  
6 contains numerous gas productive basins. Numerous oil and gas prone formations  
7 and prospective reservoirs are present. Productive reservoirs include carbonates  
8 (limestone) and sandstones with all types of porosity and permeability as well as  
9 naturally fractured reservoirs and coalbed methane reservoirs. The Potential Gas  
10 Committee (PGC) has estimated (2002) potential gas resources of 104 Tcf.

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

#### 15 IV. METHODOLOGY

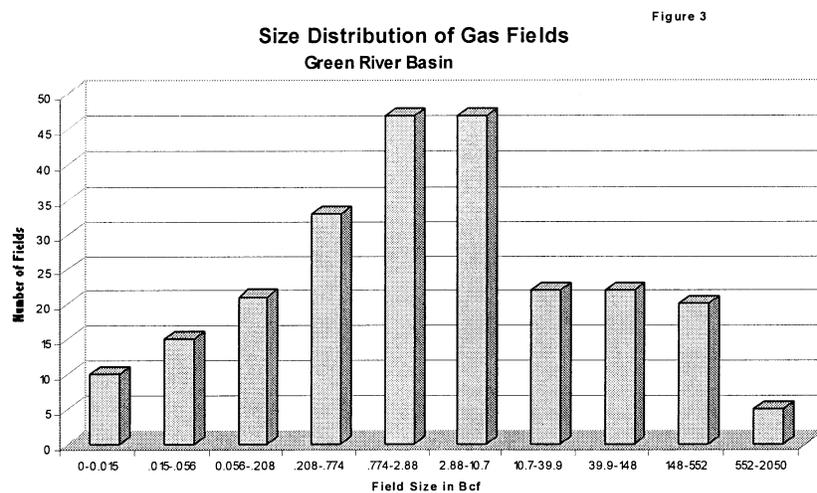
##### 16 Proven Reserves

17 An analysis of the producibility of proven gas reserves was made using  
18 information obtained from the Energy Information Administration (EIA) and the  
19 Potential Gas Committee (PGC). EIA's proven reserves are as of the end of 2002.  
20 The productive availability of those proven reserves was obtained from data  
21 assembled by the (PGC) and extrapolated employing a constant percentage decline

1 until the reserves are exhausted. The proven gas reserves were obtained from  
2 EIA, which in turn collected the data from producers. The PGC provided the  
3 production rate of those reserves.

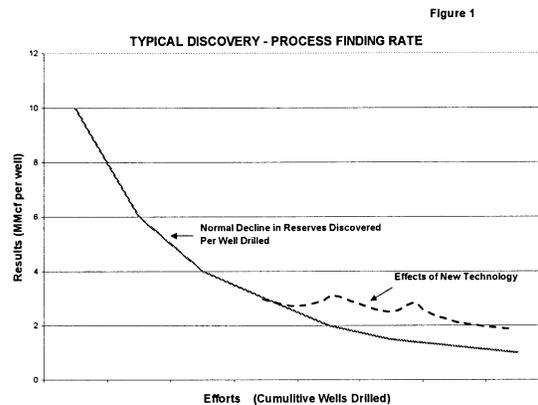
#### 4 Future Reserve Additions

5 A characteristic observed in the petroleum producing areas of the Northern  
6 Rocky Mountain Area is a rapid drop off in size from the largest known field to the  
7 smaller ones. Hydrocarbon accumulations are the result of complex geological  
8 processes. Furthermore, the actual quantities of producible reserves are further  
9 defined on the basis of technological and economic considerations. As a  
10 consequence of all these independent influences and the multiplicative nature of  
11 the factors affecting the size of a gas accumulation, field sizes in producing basins  
12 are typically log normally distributed (Figure 3).



13  
14 That is, a few very large fields contain the bulk of the reserves and many, many  
15 small fields contain, in aggregate, a smaller portion of the reserves. Also, another

1 characteristic of gas supply basins is that large fields are discovered early in the  
2 exploration process, and subsequent discoveries are smaller and the product of  
3 increasingly greater efforts (Figures 1).



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

#### 14 The Finding Rate Methodology

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

1           The nature of oil and gas accumulations creates a distribution of fields and  
2 reservoirs made up of a small number of large fields, a larger number of medium  
3 size fields and a seemingly unending amount of small fields. The Rocky Mountain  
4 Area is no exception. An example of the distribution of gas reserves in the a  
5 portion of the Rocky Mountain Area referred to as the Greater Green River Basin is  
6 shown on Figure 3. This is typical of the exploratory events of an oil and gas  
7 province.

8           The basic concept of this Finding Rate Methodology is shown on Figure 1.  
9 At times, the declining rate of effectiveness is mitigated by: better technologies for  
10 discovery and resource recovery, greater understanding of the geophysics, and  
11 reservoir performance of the field in the province. This mitigation is also shown on  
12 Figure 1.

13           Advances in technology are, however, a double-edged sword with respect to  
14 extending the life of gas resources and ultimately the life of associated producing  
15 equipment and pipeline facilities. Exploration and production (E&P) technology  
16 varies throughout the industry, from increasing the success ratio in exploration to  
17 more efficient production techniques. While some advances in technology may  
18 allow the commercialization of heretofore unproduceable hydrocarbon deposits,  
19 most others relate to the profitability of technically discoverable oil and gas  
20 resources. For example, four causes for the accelerated production of a given gas

1 resource in the Rocky Mountain area and the accelerating decline rates in the  
2 WCSB, relate to technology. They are:

- 3 • 3-D seismic
- 4 • Horizontal wells
- 5 • Efficient completion techniques
- 6 • General miscellaneous technology

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

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

16 I first determined if the supply areas paralleled the premise of this model  
17 (that large initial field discoveries give way to smaller ones). In addition to the field  
18 size facts cited earlier, further analysis confirmed that indeed most of the larger  
19 fields have been discovered as well as many of the medium size fields. This can be  
20 observed by inspecting the relationship between the new fields discovered and the  
21 exploratory efforts as shown on Figure 2. This can also be seen by analysis of

1 the finding rate methodology in terms of exploratory effort. Most of the significant  
 2 gas discoveries are actually associated with fields previously discovered. See the  
 3 historical data shown on Tables 1 and 2, and Figure 2. The exploratory effect is  
 4 the accumulation of wells drilled over time. The above effectiveness data is a 3-  
 5 year snapshot of a long trend from higher levels of effectiveness in prior years. I  
 6 observed both exploratory wells and development wells. Development wells do not  
 7 reflect the effort to find new discoveries. However, they contribute significantly to  
 8 the reserve base. "Results" (in terms of annual gas discoveries) of the drilling  
 9 effort are also shown on Tables 1 and 2 for all the areas.

Table 1 □

Success Ratio and Effectiveness of Drilling  
 Exploratory Wells  
 Rocky Mountain Area  
 Colorado, Utah and Wyoming

Year	Wells Drilled				Success Ratio	Gas Target Wells	Gas Target Footage	Gas Target Wells as a % of Total	Discoveries		Effectiveness	Cumulative Exploratory Wells	Effectiveness	Exploratory Wells Drilled
	Oil	Gas	Dry	Total					Total Bcf	Per Gas Compl. Bcf/Well				
	1,000 Ft													
1990	112	332	420	864	0.514	646	1962	74.77	835	2.52	1.292	646	1.292	646
1991	62	264	324	650	0.502	526	1642	80.98	513	1.94	0.975	1172	0.975	526
1992	47	182	315	544	0.421	432	1329	79.48	993	5.46	2.297	1605	2.297	432
1993	30	224	270	524	0.485	462	1566	88.19	1,046	4.67	2.264	2067	2.264	462
1994	37	437	212	686	0.691	632	1447	92.19	960	2.20	1.518	2699	1.518	632
1995	36	450	213	699	0.695	647	1545	92.59	508	1.13	0.785	3347	0.785	647
1996	38	279	186	503	0.630	443	1287	88.01	688	2.47	1.554	3789	1.554	443
1997	40	195	209	444	0.529	368	1431	82.98	2,377	12.19	6.452	4158	6.452	368
1998	40	294	201	535	0.624	471	1901	88.02	1,352	4.60	2.871	4629	2.871	471
1999	39	156	126	321	0.607	257	1630	80.00	1,855	11.89	7.224	4885	7.224	257
2000	27	91	116	234	0.504	180	1298	77.12	3,051	33.53	16.907	5066	16.907	180
2001	34	191	142	367	0.613	312	2139	84.89	5,076	26.58	16.293	5377	16.293	312
2002	17	125	92	234	0.607	206	1521	88.03	4,735	37.88	22.987	5583	22.987	206
2003	18	242	86	345	0.752	321	2,951	93.06	3402	14.09	10.596	5904	10.596	321

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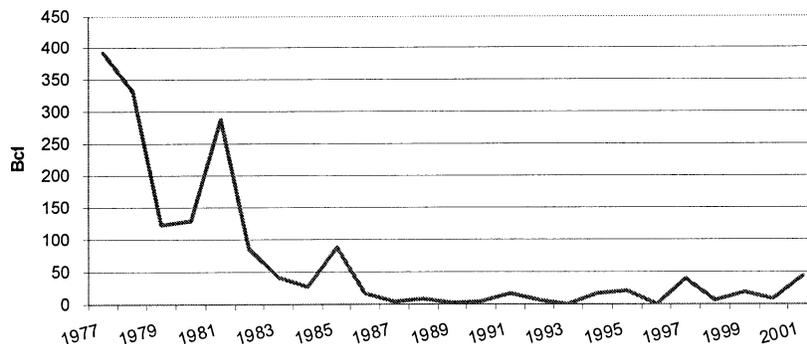
Table 2.

Success Ratio and Effectiveness of Drilling  
 Development  
 Rocky Mountain Area  
 Colorado, Utah and Wyoming

Year	Wells Drilled				Success Ratio	Gas Target Wells	Gas Target Footage 1,000 Ft	Gas Target Wells as a % of Total	Discoveries		Effectiveness	Effectiveness Per Well Drilled	Cumulative Development Wells	Effectiveness
	Oil	Gas	Dry	Total					Total Bcf	Per Gas Compl. Bcf/Well				
1990	409	866	184	1459	0.874	991	5068	67.92	150	0.17	0.151	0.000153	991	0.151
1991	320	943	182	1445	0.874	1079	5654	74.66	701	0.74	0.650	0.000602	2070	0.650
1992	263	1468	140	1871	0.925	1587	8800	84.81	632	0.43	0.398	0.000251	3657	0.398
1993	324	2018	117	2459	0.952	2119	12671	86.17	927	0.46	0.438	0.000206	5775	0.438
1994	257	1619	138	2014	0.931	1738	10933	86.30	459	0.28	0.264	0.000152	7514	0.264
1995	310	909	128	1347	0.905	1004	6314	74.57	2,101	2.31	2.092	0.002082	8518	2.092
1996	325	723	148	1196	0.876	825	5112	68.99	1,074	1.49	1.302	0.001578	9343	1.302
1997	434	1326	217	1977	0.890	1489	9254	75.34	215	0.16	0.144	0.000097	10833	0.144
1998	335	1831	134	2300	0.942	1944	12045	84.53	1,699	0.93	0.874	0.005121	12777	0.874
1999	100	2879	109	3088	0.965	2984	14541	96.64	2,607	0.91	0.874	0.010090	15761	0.874
2000	241	5731	140	6112	0.977	5865	28189	95.96	2,118	0.37	0.361	0.019578	21627	0.361
2001	222	7108	155	7485	0.979	7258	36212	96.97	940	0.13	0.130	0.000018	28885	0.130
2002	126	4417	114	4657	0.976	4528	25003	97.23	918	0.21	0.203	0.000045	33413	0.203
2003	231	4,266	143	4640	0.969	4401	27,935	94.86	1017	0.24	0.231	0.000053	37814	0.231
							5007				0.231			

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 Finding Rate Methodology.

NEW FIELD DISCOVERIES  
 Wyoming



The model used the relationship between annual reserve additions and both exploratory and development well drilling over time in years and cumulative feet

1 drilled from a base of 1990. For the most likely case, I extrapolated the  
 2 exploratory effectiveness at a constant level using the 3-year Mean value  
 3 developed in Tables 1 and 2 until a point is reached where 90 percent of the total  
 4 endowment is reached. The total endowment is defined as all the gas that will  
 5 eventually be discovered (past discoveries plus the PGC's estimates of potential  
 6 resources). PGC's estimates of potential gas resources are shown on Table 8.

Table 8

**Estimate of Potential Gas Resources  
 As of End of 2002  
 Volumes in Bcf**

Producing Province	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	-	6,872	2,153	-	20,015
Big Horn Basin	672	170	-	530	616	25
Wind River Basin	2,115	1,527	-	4,497	3,401	50
Greater Green River Basin	8,632	979	-	5,940	5,696	375
Denver Basin and Environs	1,380	-	-	1,012	-	-
Ulna/Piceance Basin and Environs	14,568	500	133	14,922	200	4,115
Thrust Belt	800	-	-	1,000	-	-
<b>Total Colorado, Utah and Wyoming</b>	<b>29,602</b>	<b>3,176</b>	<b>6,805</b>	<b>30,054</b>	<b>9,913</b>	<b>24,580</b>
Williston Basin	653	-	-	931	98	-
Sweetgrass Arch	435	-	-	945	-	-
Montana Folded Belt	-	-	-	4,000	-	-
<b>Total Montana and North Dakota</b>	<b>1,088</b>	<b>-</b>	<b>-</b>	<b>5,876</b>	<b>98</b>	<b>-</b>

Source: Potential Gas Committee

Note: CBM - Coalbed Methane

15 Table 7 shows the total endowment as of 2002 for the gas provinces of Colorado,  
 16 Utah, Wyoming, Montana and North Dakota.

Table 7

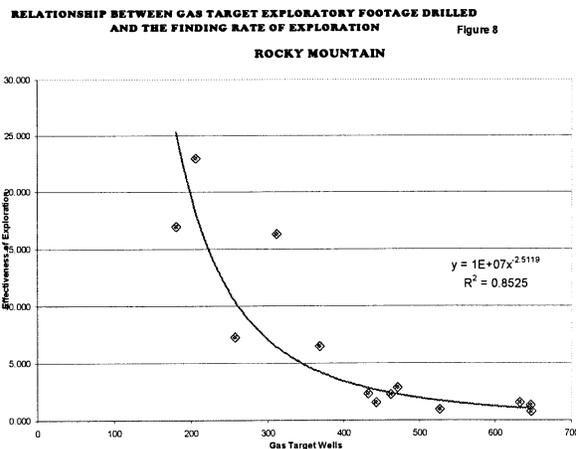
**ULTIMATE REMAINING GAS RESOURCES**  
 Volumes in Trillion Cubic Feet

	Rocky Mountain Area Colo, Utah and Wyo
1 Cumulative Production to 12/31/1988	23.96
2 Incremental Production 1989 to 12/31/2002	22.23
3 Remaining Proved Reserves at 12/31/2002	38.55
4 Potential Gas Resources Estimated at 12/31/2002	104.13
5 Ultimate Estimated Resources (12/31/2000)	188.87
6 Gas Discoveries to 12/31/2002	84.74
7 Percent Remaining to be Discovered	55.13

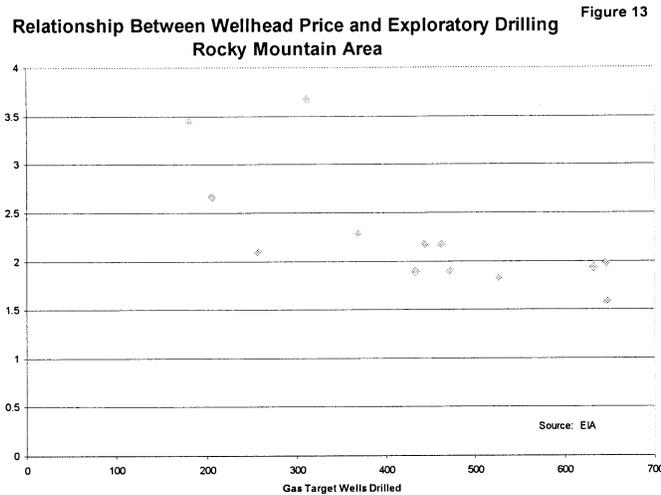
1 I used the same procedure for the effectiveness of development drilling.

2 The most likely level represents the mean value of effectiveness from 2000  
3 through 2002.

4 I employed a constant level of effectiveness until 90 percent of the ultimate  
5 resources are discovered as I expect some occasional increases in the effectiveness  
6 due to forces not directly indicated in the data. As mentioned earlier, any decline  
7 in the effectiveness curve will be mitigated by technological increases in the  
8 exploration and drilling techniques along with an increased awareness of the  
9 geophysics and reservoir mechanics. Technological increases are included in the  
10 1990-2002 data. I am assuming that future technological increases will occur at  
11 the same rate as in the historical statistics. I found, in some cases unsurprisingly,  
12 that as drilling exceeds certain levels, the effectiveness declines. This is due most  
13 likely to the drilling of lower grade prospects in a particular year. See Figures 4 and  
14 5 for the footage drilled and Figures 8 and 9 for the relationship between footage  
15 and effectiveness.



1 I determined the future discoveries from exploratory drilling by applying a  
2 representative constant level of drilling activity to the corresponding effectiveness.  
3 For my determination of the discoveries from development drilling, I also applied a  
4 constant level of annual drilling activity, based upon the most recent 3-year period,  
5 to reflect the development drilling activity response to increases in the wellhead  
6 price of gas. This period included very significant increases in the price of gas at  
7 the wellhead and only one modest decrease. I believe that in the future such  
8 similar increases and decreases will occur eventually leading to a further overall  
9 price increase. My choice of exploratory and development drilling levels fully  
10 reflects an overall average price increase over the pertinent period, all the while  
11 daily, monthly and yearly prices will fluctuate both up and down. Specifically,  
12 based on my experience and studies, I found a relationship to exist between the  
13 price of gas at the wellhead and development drilling effort. No such clear  
14 relationship occurs for exploratory drilling as drilling prospects differ considerably in  
15 many respects as well as inherent risk factors. As such, many factors come into  
16 play with respect to the exploratory drilling response. While an increase in  
17 wellhead gas prices is an inducement to increase exploratory drilling efforts, the  
18 fact is that for the producing areas involved in this proceeding, there is no clear and  
19 concise relationship between wellhead price and the number of exploratory wells  
20 drilled. The graphs shown on Figures 13 and 14, of wellhead gas price and drilling  
21 effort, illustrate this point.



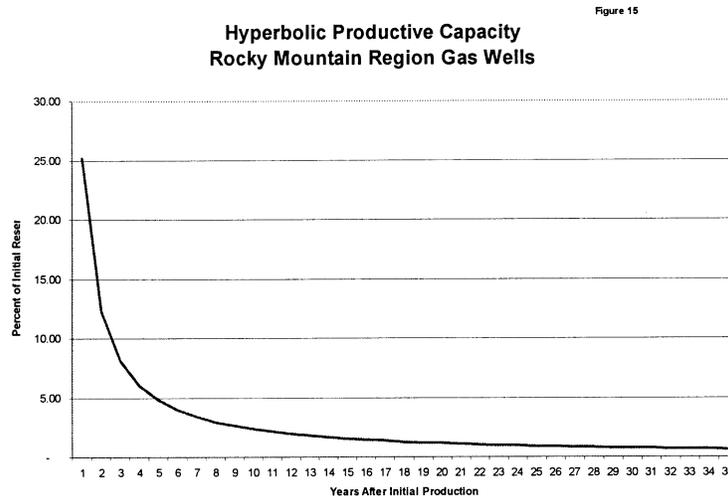
9 Exploratory wells differ considerably from development wells in the Rocky  
10 Mountain area. Exploratory wells are relatively high risk. They are drilled relatively  
11 far from existing discoveries. They are high cost. They must rely upon financing  
12 much different from development wells, e.g., the expenditure of money for  
13 geological and geophysical studies. Many factors affect the decision to drill  
14 exploratory wells, including the prevailing wellhead price.

15 With respect to development wells and price, the annual relationship  
16 between them is not sufficient to forecast future drilling efforts. Instead, I  
17 employed high values of such efforts in my calculations. The Most Likely Case  
18 level of wells drilled and footage attained was based on an average value for the  
19 1998-2002 period.

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

1 To determine the future gas availability, I applied to each determined annual  
2 future reserve addition, a productive capacity rate derived by EIA from data  
3 obtained from Petroleum Information/Dwights LLG (See Figure 15).

4



5

6 This results in the production capacity from new reserves beginning in 2002.

7 To the production profile of future reserves, I added the production profile for  
8 the beginning of year 2000 proven gas reserves. This is shown on Table 6.

9 While Figure 15 represents the rate to determine the productive capacity of  
10 new reserves, the estimated production is determined on Table 9 from a production  
11 rate based on studies performed by the PGC. The production rate is shown on  
12 Figure 16.

13

Table 6

**PRODUCTIVE CAPACITY  
 ROCKY MOUNTAIN AREA**  
 Colorado, Utah, Wyoming, Montana and North Dakota

Year	Productive Capability 1999 Reserves MMcft/day	Productive Capability 2000 - 2002 And Future Reserves MMcft/day	Productive Capability Total MMcft/day	Actual Production MMcft/day
1999				6,113
2000	6,216	3,621	9,837	6,547
2001	5,463	5,877	11,440	6,393
2002	4,898	7,160	12,058	7,357
2003	4,395	7,247	11,642	8,015
2004	4,019	8,279	12,298	
2005	3,579	8,971	12,550	
2006	3,328	9,525	12,853	
2007	3,014	9,995	13,009	
2008	2,763	10,406	13,169	
2009	2,512	10,771	13,283	
2010	2,323	11,100	13,424	
2011	2,135	11,400	13,535	
2012	2,009	11,676	13,685	
2013	1,821	11,931	13,752	
2014	1,695	12,167	13,863	
2015	1,633	12,389	14,021	
2016	1,385	12,597	13,982	
2017	1,266	12,792	14,059	
2018	1,157	12,604	13,761	
2019	1,058	12,260	13,318	
2020	967	11,839	12,805	
2021	883	11,378	12,262	
2022	807	10,902	11,709	
2023	738	10,422	11,160	
2024	674	9,948	10,623	
2025	616	9,486	10,103	
2026	563	9,040	9,603	
2027	515	8,611	9,126	
2028	470	8,201	8,672	
2029	430	7,812	8,242	
2030	393	7,336	7,729	
2031	359	6,866	7,225	
2032	328	6,428	6,756	
2033	300	6,036	6,336	

V. DETERMINATION AND RESULTS

The Rocky Mountain area that I analyzed occupies the states of Wyoming, Utah, Colorado, Montana and North Dakota. 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. 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 10.

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