APPLICATION OF

THE FOUR CORNERS GAS PRODUCERS ASSOCIATION

FOR DESIGNATION OF THE FIVE LAKES CANYON AREA

OF THE PICTURED CLIFFS FORMATION

AS A TIGHT FORMATION

RIO ARRIBA AND SANDOVAL COUNTIES, NEW MEXICO

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Prepared by:

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APPLICATION OF THE FOUR CORNERS GAS PRODUCERS ASSOCIATION FOR DESIGNATION OF THE FIVE LAKES CANYON AREA OF THE PICTURED CLIFFS FORMATION AS A TIGHT FORMATION, RIO ARRIBA AND SANDOVAL COUNTIES, NEW MEXICO

The Four Corners Gas Producers Association is applying for portions of the Ballard Pictured Cliffs and South Blanco Pictured Cliffs gas pools to be designated as a tight formation under Section 107 of the Natural Gas Policy Act of 1978. The proposed Five Lakes Canyon Tight Gas Area is located in the southeastern portion of the San Juan Basin. The area is located in Rio Arriba and Sandoval Counties, approximately 40 miles southeast of the town of Bloomfield in northwestern New Mexico.

Exhibit No. 1 displays the proposed Five Lakes Canyon Tight Gas Area on a map showing the Pictured Cliffs formation wells in the San Juan Basin. The Five Lakes Canyon Tight Gas Area includes approximately 234,240 acres described as follows:

T22N R2W	Acreage
All	23,040
T22N R3W	
All	21,120
T22N R4W	
All	23,040
T22N R5W	
All	23,040
T23N R2W	
Sections 5 thru 9 16 thru 21 25 thru 36	14,720
T23N R3W	
All	21,120
T23N R4W	
All	23,040
T23N R5W	
All	23,040

T24N R3W	
Sections 19 and 20 29 thru 32 W½ of 33	3,200
T24N R4W	
Sections 3 thru 10 13 thru 36	20,480
T24N R5W	
All	23,040
T25N R4W	
Sections S½ of 30 31 and 32	1,600
T25N R5W	
Sections 15 thru 23 S½ of 24 25 thru 36	13,760
TOTAL ACREAGE	234,240 acres

The Pictured Cliffs formation in the Five Lakes Canyon Area meets the criteria established in Section 107 of the Natural Gas Policy Act of 1978 to be designated as a tight gas formation in that (1) the estimated average in situ gas permeability throughout the pay section is expected to be 0.1 millidarcy or less, (2) the stabilized gas production rates, without stimulation, at atmospheric pressure of these gas wells are not expected to exceed the maximum allowable production rate of 79 MCFPD for an average depth of 2685 feet to the top of the Pictured Cliffs formation in this area, and (3) no well drilled into the Pictured Cliffs formation in this area is expected to produce more than five barrels of crude oil per day prior to stimulation.

Exhibit No. 2 is a Pictured Cliffs formation completion and production map of the proposed Five Lakes Canyon Tight Gas Area. The production figures presented for each producing well are initial potential, date of initial potential, natural gas production for 1981, and January 1, 1982 cumulative production of gas for the well. Exhibit No. 2 also presents completion and production data from some wells surrounding the proposed tight gas area.

The Five Lakes Canyon Tight Gas Area is bounded to the southwest by the sparsely drilled portion of the basin and to the northeast by the extensively developed South Blanco Pictured Cliffs field. Included within

the proposed area is the moderately developed southeastern extension of the Ballard Pictured Cliffs field.

The Five Lakes Canyon Tight Gas Area contains 466 Pictured Cliffs formation gas wells, 94 of which are abandoned in the Pictured Cliffs at this time. The average depth to the top of the Pictured Cliffs formation in these wells is 2685 feet. A list of operator, well name and production figures for Pictured Cliffs wells in the Five Lakes Canyon Tight Gas Area is presented as Exhibit No. 3.

Geology

The Pictured Cliffs formation is a marine, clay-filled sandstone whose source was to the southwest. The formation was deposited as near-shore bars aligned northwest-southeast with each sand body becoming progressively younger from the southwest to the northeast by the regressive late Cretaceous sea.

The form of gas entrapment in the Five Lakes Canyon Tight Gas Area is stratigraphic. Sediments within this area are seaward deposits of the Ballard Pictured Cliffs field rather than landward deposits of the South Blanco Pictured Cliffs field.

Sample examination indicates the Pictured Cliffs in this area is predominately siltstone rather than sandstone which, with clay-filling, is the contributing factor to the low permeability found in the Five Lakes Canyon Tight Gas Area.

The sand deposition within the tight gas area is more limited than it is in the South Blanco field. The near shore bars within the proposed area are extremely lenticular, ribbon-like deposits with a very limited southwest-northeast areal extent as evidenced by the Ballard Pictured Cliffs field. This compares to the better developed, more blanket-like deposits of the South Blanco field. The ribbon-like nature of the sands within the proposed area results in linear well development with limited numbers of better producing wells being drilled on the near shore bar crests ("sweet spots") where the sand is best developed. Once off the bar crest the sands become siltier and more clay filled which drastically reduces the effective permeability.

Exhibit No. 4 is a type log of the Pictured Cliffs formation in the Five Lakes Canyon Tight Gas Area. This well is the John Schalk Cinco Diablos No. 6 well and is located in the NW¼ of Section 14, T23N, R4W. The top of the Pictured Cliffs formation on this type log is 3046 feet and is overlain by a 7 foot coal bed. The base of the Pictured Cliffs is at 3141 feet and is underlain by the Lewis Shale. This type log is representative of the Pictured Cliffs formation in the Ballard Pictured Cliffs pool. Some of the wells in the vicinity of this type log have exhibited better than average producing characteristics than the the remainder of the area. Therefore, wells in the remaining portion of the Five Lakes Canyon Tight Gas Area would be expected to have the same, or poorer, log characteristics than this type log.

Exhibit No. 5 presents cross section A-A' which shows Pictured Cliffs development in the tight gas area in a general north-south direction. Exhibit No. 6 is log cross section B-B' which shows Pictured Cliffs development in a general west-east direction in the area. The log reference datum shown on these cross sections is the Pictured Cliffs formation. The cross sections illustrate the Pictured Cliffs formation to be a continous lithologic unit throughout the Five Lakes Canyon Tight Gas Area. Both cross sections indicate that the good productive sands from this formation are not continous throughout the area. This lenticular sand development makes drilling in this area considerably risky.

Stabilized Unstimulated Gas Production Rate

Obtaining stabilized unstimulated gas production rates for Pictured Cliffs wells is not a standard procedure used by companies when completing their wells in the San Juan Basin. Past experience has shown that these low permeability Pictured Cliffs wells must be stimulated to obtain commercial production. However, in preparation for this Five Lakes Canyon tight gas study, Amerada Hess performed unstimulated natural gas production tests on eight wells scattered throughout the tight gas area. Exhibit No. 7 gives the location of these test wells and indicates that the average unstimulated natural gas production rate for the tight gas area is 16.5 MCFGPD. This rate is well below the 79 MCFGPD allotted for tight formation gas wells having an average depth of 2685 feet.

Not all of the natural production tests taken were used to calculate an average unstimulated natural production rate for the Five Lakes Canyon Tight Gas Area. Wells number 8 and 3 were not considered to be representative tests for the tight gas area.

Well number 8, Amerada Hess' Jicarilla C No. 3 well is located in a localized high production area referred to earlier as a "sweet spot". Exhibit No. 2 shows the location of this well at NW/NW Section 35, T24N, R5W. These sweet spots are generally near shore bar crests of the linear developed sand trends. They have very good sand development associated with them and tend to have very limited pockets of high porosity and permeability with some associated natural fracturing. All of these factors contribute to very good well producing characteristics in these limited areas.

A large problem with developing these "sweet spots" with further drilling is that an operator may find these localized well developed lenticular sands are often not more than 1 or 2 locations wide. This is shown in the area of the Jicarilla C-3 well on Exhibit No. 2. There are very good wells in this "sweet spot" area, however, drilled and abandoned locations appear one drillsite away. Another problem with development drilling of "sweet spots" is that one well may adequately drain the limited areal extent of the well developed sand. The second well penetrating the "sweet spot" often has reduced reservoir pressure which substantially reduces gas reserves for the second well. These two factors often make the drilling of the "sweet spots" risky, making the initial well very economical, with the second well often times uneconomical.

The Jicarilla C-3 had an unstimulated natural production test of 259 MCFGPD which is very good for a Pictured Cliffs well in this area. This very high production rate can only be attributed to a "sweet spot" and cannot be thought of as average for the area. For this reason this high natural production rate was not used to calculate an average unstimulated natural production rate for the area.

The other well not used to average the unstimulated natural production test for the tight gas area is Amerada Hess' Jicarilla I-10 well, located in the NW/SW Section 2, T23N, R3W. This well had an unstimulated natural production test of gas that was too small to measure.

This well was subsequently abandoned. This well is not representative of the producing portion of this tight gas area, therefore it is not used in the averaging.

The remaining 6 producing wells have unstimulated natural production tests that seem reasonable for the area. The majority of these test wells, wells 1, 3, 5, 6, 7, and 8, were open hole completions. These wells had 5½" casing set at the top of the Pictured Cliffs formation and the pay zone was drilled with air. When total depth was reached, 24 hour tests were taken to measure the unstimulated natural production from each well. The remaining 2 wells, wells 2 and 4, had casing set through the Pictured Cliffs pay interval. These wells were evacuated of fluid in the wellbore and perforated across the pay interval. The wells were then tested for 24 hours to obtain an unstimulated natural production test for each well.

The averaging of these unstimulated natural production tests results in a 16.5 MCFGPD natural production rate for an average well in the Five Lakes Canyon Tight Gas Area. This 16.5 MCFGPD unstimulated gas production rate is well below the 79 MCFGPD rate allowed to qualify an area for tight formation gas prices at an average formation depth of 2685 feet.

Stabilized Unstimulated Oil Production Rate

The natural gas produced from the Pictured Cliffs formation in the Five Lakes Canyon Tight Gas Area is virtually dry gas. There has been very little oil and condensate reported for any of the wells now producing in the area. Some of these wells will have associated water production with the gas, but condensate production is not common. These dry gas production figures indicate a well drilled in the Pictured Cliffs formation in the Five Lakes Canyon Tight Gas Area is not expected to produce, without stimulation, more than 5 barrels of crude oil per day.

Permeability

The Pictured Cliffs formation in the San Juan Basin is dependent on stimulation techniques to be commercially productive due to the low permeability of the reservoir rock. Exhibit Nos. 8 through 16 present core analysis data used to determine the average laboratory permeability to air for Pictured Cliffs formation pay zones in this area. The exhibits

contain the actual core analysis reports plus summary tables showing the analysis of cores taken from only the productive portion of the Pictured Cliffs formation for each well. The cored intervals chosen for permeability averaging were determined by log examination of the interval cored for each well. Only cored intervals of sand which were perforated by the operator of the well were used for permeability averaging. On wells which were not perforated, a reasonable pay interval was chosen for the well and this cored interval was used for permeability averaging. The average permeability values determined in Exhibits 8 through 16 are average laboratory determined permeability values. The actual in situ permeability of the formation is less than this laboratory determined value due to water saturation and net confining pressures found in the Pictured Cliffs reservoir.

Exhibit No. 17 presents a technical paper entitled "Effect of Overburden Pressure and Water Saturation on Gas Permeability of Tight Sandstone Cores" written by Thomas and Ward of the U.S. Bureau of Mines. This paper presents relationships between laboratory determined permeability in cores and actual in situ permeability found in reservoirs. Exhibit No. 18 explains how in situ permeability is calculated from the core analysis using the technical paper presented.

Exhibit 19 is a summary of all laboratory core analysis results for the Five Lakes Canyon Tight Gas Area. Not all of the wells which had core analysis available were used to obtain an average permeability for the tight gas area from core data. Exhibit No. 19 shows that core data from wells 1 through 4 was used to obtain the best permeability average for the Tight Gas Area. The core data from well no. 5 was not used as this well is also located in a "sweet spot" area. The higher average permeability value shown for this well is not considered normal for the area. The core data from wells 6 through 9 also was not used as these wells have not produced from the Pictured Cliffs formation. These dry holes are also not indicative of the average producing well in this tight gas area.

The average laboratory permeability to air obtained for the Five Lakes Canyon Tight Gas Area from the four wells shown is 0.47 millidarcy. An average in situ permeability value of 0.009 millidarcy

was calculated from the average laboratory permeability value of 0.47 millidarcy. This 0.009 millidarcy permeability value calculated from core data is well below the 0.10 millidarcy cutoff for tight gas reservoirs.

Another method of determining reservoir permeability was performed in the Five Lakes Canyon Area, making use of the unstimulated natural production tests taken in the area. The average unstimulated gas flow rate of 16.5 MCFGPD, along with other Pictured Cliffs reservoir data for the tight gas area can be used in Darcy's Law to calculate a reservoir permeability. This Darcy's Law calculation is presented as Exhibit No. 20. Darcy's Law calculations report an average reservoir permeability value of 0.04 millidarcy for the Five Lakes Canyon Tight Gas Area. This permeability value compares to a 0.009 millidarcy permeability value determined by core analysis methods. Both of these values are below the 0.10 millidarcy tight gas cutoff.

In an attempt to obtain even more permeability data for this area, Amerada Hess conducted buildup tests on 7 of the 8 wells which had natural production tests performed on them. Unfortunately, these 7 day buildup tests, as is common with many buildup tests in tight formations, were not long enough to obtain accurate permeability data for this area. Both Horner analysis and type-curve analysis were studied in detail on this data, but no precise permeability information for this area could be obtained. For this reason, no buildup analysis data is presented in this report on the Five Lakes Canyon Tight Gas Area.

From examination of the two sources of permeability data, the reservoir permeability value of 0.04 millidarcy determined by Darcy's Law calculation is thought to be the best estimate of reservoir permeability for the Five Lakes Canyon Tight Gas Area because it involves actual formation flow characteristics and reservoir parameters to determine formation permeability. Therefore, the estimated average in situ gas permeability throughout the Pictured Cliffs formation pay section is expected to be 0.1 millidarcy or less in the Five Lakes Canyon Tight Gas Area.

Fresh Water Protection

Existing State and Federal regulations will assure that development of the Pictured Cliffs formation will not adversely affect or impair any fresh water acquifers that are being used or are expected to be used in the foreseeable future for domestic or agricultural water supplies.

Regulations require that casing programs be designed to seal off potential water bearing formations from oil and gas producing formations. These fresh water zones exist from the surface to the base of the Ojo Alamo Formation. The base of the Ojo Alamo Formation averages 2445 feet in the proposed Five Lakes Canyon Tight Gas Area.

Most Pictured Cliffs wells drilled in the Five Lakes Canyon Area are drilled with natural mud that will not contaminate fresh water zones. Normal casing designs consists of 7" O.D. surface casing being set from the surface to a depth of 120 feet. Production casing normally used is 2-7/8" O.D. and is set from surface to total depth. The open hole completions mentioned earlier have 5-1/2" O.D. production casing set just above the Pictured Cliffs formation and the productive formation is drilled with air and left open to produce.

The surface casing is cemented in place by circulating cement to the surface, protecting the near surface formations from downhole contamination. The production casing is cemented from total depth to the surface or to a depth sufficient to cover the Ojo Alamo formation. This process protects the Pictured Cliffs and other shallow formations from contaminating the Ojo Alamo acquifer. Therefore, all productive and fresh water zones are protected by both casing and cement.

Stimulation of the Pictured Cliffs formation involves varied fracture treatments, depending on the operator. Fracture treatments usually consist of a one or two percent potassium chloride water base fluid with sand, or a nitrogen-water foam base fluid and sand. Either treatment will not harm a fresh water acquifer. Fresh water protection is assured during these fracture stimulation treatments due to zone isolation caused by cementation. A distance of over 200 feet between the Pictured Cliffs formation and the Ojo Alamo fresh water acquifer is additional insurance that no existing fresh water zone will be contaminated by stimulation of Pictured Cliffs wells in this area.

Therefore, New Mexico and Federal regulations will protect any fresh water supply that may be affected by drilling, completing, and producing the Pictured Cliffs formation in the Five Lakes Canyon Tight Gas Area.

Conclusion

Evidence presented in this report substantiates the following for the Four Corners Gas Producers Association proposed Five Lakes Canyon Pictured Cliffs formation Tight Gas Area:

(1) For an average Pictured Cliffs well depth of 2685 feet, the stabilized production rate at atmospheric pressure of wells completed in the Pictured Cliffs formation, without stimulation, is not expected to exceed the maximum allowable rate of 79 MCF of gas per day.

(2) No well drilled into the Pictured Cliffs formation in the Five Lakes Canyon Area is expected to produce, without stimulation, more than five barrels of crude oil per day.

(3) The estimated average in situ gas permeability, throughout the Pictured Cliffs pay section, is expected to be 0.1 millidarcy or less.

The proposed Five Lakes Canyon Tight Gas Area meets all the specifications required as stated above and should be designated a tight formation in the Pictured Cliffs formation under Section 107 of the Natural Gas Policy Act of 1978.