TECHNICAL MEMORANDUM

SUBJECT: **Green River Basin Plan II**
Industrial Water Use Projections

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Introduction

This technical memorandum draws heavily on the work done by Gary Watts of Watts and Associates, Inc. for the Green River Basin Plan completed in 2001. Revisions to this document were made where significant changes have occurred since Watts and Associates work was completed in 2000.

This memorandum presents projections of industrial water needs in the Green River Basin for the period from 2005 through 2055. These projections provide a basis for gaging the adequacy of current surface water and groundwater supplies in the Basin to meet potential future needs. The Wyoming Water Development Commission (WWDC), requires that projections be developed for three planning scenarios:

1. Low Growth
2. Moderate Growth
3. High Growth

Industrial surface water users can be divided into three groups, electric power generation, trona mining and refining, and miscellaneous industrial use. The industries that obtain their primary water supply from surface water are:

1. Electric Power Generation
   a. Jim Bridger Power Plant (PacifiCorp)-Green River
   b. Naughton Power Plant (PacifiCorp)-Ham's Fork River

2. Soda Ash Production and Related Products
   a. FMC Granger-Green River
   b. FMC Westvaco-Green River
   c. General Chemical-Green River
   d. OCI Wyoming-Green River
   e. Solvay Minerals Inc.-Green River
   f. Church and Dwight-baking soda production-Green River

3. Miscellaneous
    a. Exxon Shute Creek Plant-natural gas processing-Green River
    b. Simplot Phosphates-chemical fertilizer production-Green River

Projections for each scenario are made based upon a review of available literature and personal interviews with representatives of large industrial water users in the Basin. Econometric modeling as a means of projecting future industrial growth, was rejected as the factors that influence the rates of growth among water intensive industries in the Basin are quite volatile and are not amenable to quantification.

Many of the Green River Basin smaller industrial water users obtain the water they use as a part of their operations from municipal systems. Their usage rates are low and they have not developed dedicated water supply facilities for their operations. Projections of water needs for these small industrial water users are included in projections of municipal demands for the communities in the Basin.

The large industrial water users do not depend on municipal water supplies for their operations. There is one exception to this and that is the fertilizer plant at Rock Springs. This memorandum focuses on the future water needs of the three groupings listed above.

Currently, electric power generation and soda ash production make up sixty-eight (68%) percent and twenty-eight (28%) percent respectively of the total industrial water use in the Green River Basin (WWC, 2008). Future water needs for electric power production will be influenced by deregulation of the industry and response to environmental issues concerning the discharge of carbon and its contribution to perceived global warming. Future growth of the soda ash industry is largely dictated by the ability of Wyoming producers to compete in the international market in the face of volatile international economic conditions and the protective tariffs imposed by some foreign countries. The factors that influence the competitiveness of the Basin's two largest water users, power production and soda ash production, are difficult to incorporate into economic models.

The following sections of this memorandum discuss future growth prospects of the significant water using industries in the Basin and present low, moderate, and high growth projections of future water use. The last section summarizes future industrial water needs.

Future Electric Power Production

Two coal-fired electric power plants are located in the Green River Basin; the Jim Bridger Power Plant near Point of Rocks in Sweetwater County and the Naughton Power Plant south of Kemmerer in Lincoln County. Both are owned and operated by PacifiCorp. PacifiCorp was acquired by MidAmerican Energy Holding Company in 2006 and operates as Rocky Mountain Power in Wyoming, Utah and Idaho. The Naughton Plant has a production capacity of 710 megawatts and consumptively used approximately 11,114 acre-feet of water in the 2005-2006 water year from the Ham's Fork River (SEO, 2006). The Jim Bridger Plant has a production capacity of 2,000 megawatts and consumptively used approximately 28,600 acre-feet of water in the 2005-2006 water year from the Green River (SEO, 2006). Actual reported diversions from

2006 are a total of 39,714 acre-feet. This number is less than the 47,820 acre-feet estimated in 2000 (Purcell, 2000). Differences in demand can be attributed to generation load on the plant as well as environmental issues such as temperature. Much of the power from the Naughton Plant is exported via transmission lines to Utah, while much of the power from the Jim Bridger Plant is exported to Pacificorp customers in the Pacific Northwest (PacifiCorp Website, 2008).

Historically, the electric utility industry has been composed of vertically integrated monopolies under the regulation of state agencies who set the rates (prices) at which power can be sold to consumers. These power rates typically include charges for the three services that electric utilities provide - power generation, transmission, and distribution.

The 2000 Industrial Projections Technical Memorandum discussed restructuring proposals for the industry as a major potential change in the industry. Restructuring, while still important, has to some degree been replaced by environmental issues including global warming and the "carbon footprint" issue. Additional information on restructuring is contained in the "Technical Memorandum, Green River Basin Plan, Industrial Water Needs Projections" (Watts, 2000).

Development of renewable energy sources such as wind powered generation has replaced fossil fuel powered generation for the near term. However, coal fired or other thermal generating capability will need to be developed to insure a consistent supply of power when renewable power generation is unable to produce to meet demand (Conder, 2008) (Allred, 2008).

Large industrial power users in other states may develop co-generation facilities to meet their own needs and to sell excess power to retail consumers. If such developments take place on a large scale, electric utilities might be reluctant to make large investments in new generating facilities in the Green River Basin (Watts, 2000). There is already evidence of this in the basin as 4 of the 5 trona plants have their own onsite electrical generation capability (Purcell, 2000).

Transmission has been considered a roadblock to developing new generating capacity in the Basin. However, PacifiCorp has indicated in their latest Integrated Resource Plan (IRP) that they intend to invest $4 billion dollars in transmission over the next ten years (PacifiCorp IRP, 2008). This action would tend to indicate an increased potential for new generation development, however, the IRP shows relatively flat demand for the next ten years. Increased transmission capability coupled with increased renewable energy generation will tend to push new thermal generation farther into the future.

The issue of how electrical utility industry restructuring evolves in the western U.S. and the global warming and carbon footprint issues associated with coal fired thermal power plants will play an important role in determining the magnitude of future water requirements for electrical power generation in the Green River Basin. Three scenarios for future growth are described below.

<u>Low Growth Scenario</u>

The low growth scenario for future power generation projects current levels of water consumption for power generation to remain relatively constant over the next fifty years. Both the existing Jim Bridger and Naughton Power Plants have been running at nearly full capacity in recent years, and expanding power production at either facility would require significant capital investments in both generation and transmission facilities. The low growth scenario is based upon the assumption that additional power needs in the western U.S. over the next 50 years will be met by the construction of new renewable energy generating facilities in the Basin such as the new wind generation planned at the Jim Bridger Plant site (Casper Star, 2007). The PacifiCorp Integrated Resource Plan (IRP) indicates there is 900 mega watts of wind generation planned for their Eastern Division (Wyoming, Idaho, and Utah) (PacifiCorp IRP, 2008). Another potential is that the nuclear plant planned for Idaho and presently shelved will be constructed and will take a portion of the load in the Northwest (Conder, 2008). As a result, water requirements for power generation in the Basin will remain at or near current levels over the planning horizon. That level ranged from approximately 47,800 acre-feet annually in 2000 to about 40,000 acre-feet annually in 2005-2006 (Purcell, 2000) (SEO, 2006). The low level use is assumed to level out at about 50,000 acre-feet annually.

Moderate Growth Scenario

The moderate growth scenario is based upon the reasonably foreseeable possibility that co-generation facilities will not be sufficient to meet regional power needs over the next 50 years, and that PacifiCorp's planned $4 billion investment in transmission over the next ten years plus actions by the State of Wyoming and/or the Federal Energy Regulatory Commission will solve the transmission bottleneck out of Wyoming and thus encourage the construction of additional electrical generating capacity in the Basin. These actions, combined with the potential resolution of other industry restructuring issues over the next 50 years, provide a reasonable basis for expecting at least a moderate expansion of electrical generating capacity in the Basin over the planning horizon.

The logical location for a moderate expansion of generating capacity is the Jim Bridger Power Plant near Point of Rocks, east of Rock Springs. The facility was originally designed for up to six coal-fired generating units, although only four 500 MW units have been installed. The existing units are among the most cost-efficient in the Pacific Power generating system, and an expansion to six coal-fired units at Jim Bridger would be a logical step to increase regional power production in a cost effective manner. According to PacifiCorp engineers, the water requirements for two new 750 MW coal-fired generating units would be supplied from a 50 cfs direct flow water right from the Green River (Conder, 2008). The 750 MW units would each consume about 12,300 acre-feet per year (Allred, 2008). The present plan is to develop one 750 MW unit in the next ten years and the second 750 MW unit over the next 30 years. Thus, the moderate growth scenario for electric power production projects a 75 percent increase in power generation and water requirements for the Jim Bridger Power Plant over the next 30 years, with water requirements at the Naughton facility remaining constant at current levels. Total water use for the moderate growth scenario is projected to grow from a current rate of about 40,000 acre-feet annually to approximately 52,300 acre-feet annually by the year 2015 and to approximately 65,000 acre-feet annually by 2035. Power generation is then projected to remain stable for the next 20 years or the remainder of the planning period to 2055.

High Growth Scenario

The rapid economic growth that occurred in the Green River Basin during the 1970s and early 1980s was partially a result of political events that occurred beyond the Basin's boundaries. The threat of curtailed oil imports led the U.S. to mount a campaign for energy independence that emphasized developing and utilizing the nation's own energy resources, including oil and gas, uranium, and coal. The Green River Basin has abundant reserves of all of these natural resources. Recent high-energy prices are stimulating development plans for these resources. This development could lead to a period of rapid growth in the Basin similar to the 1970s and early 1980s.

There is a possibility that over the planning horizon international events will transpire in a manner that would place increasing emphasis on domestic energy production because of shortages of imported oil and surging energy prices. Such developments could lead the U.S. to institute incentives for developing new coal-fired electrical generating facilities or coal to liquid fuels plants to reduce the nation's dependence on foreign oil. The Green River Basin's water and coal reserves make it a natural place for such developments. In fact, at least two electric utilities have studied the possibility of locating new generating facilities at a site in the Basin near Creston Junction (Wyoming Water Development Commission [WWDC], 1981).

The high growth scenario for electrical energy production is based upon the reasonable possibility that high international energy prices and/or a disruption of oil imports into the U.S. will stimulate the construction of a significant addition to current electric generating capacity in the Basin. This scenario assumes that in addition to a 1,500-megawatt expansion of the Jim Bridger Power Plant, a new 3,000-megawatt coal-fired generating facility will be built in the vicinity of coal deposits near Creston Junction, utilizing water piped from the Green River. The Little Snake River would also be a potential source of water for such a plant. However, the lack of storage facilities for industrial water in the Little Snake River Basin makes the Green River, with its already developed storage water in Fontenelle Reservoir and Flaming Gorge Reservoir, a more likely source of water for future power production.

The two existing coal-fired generating facilities in the Basin use approximately 40,000 acre-feet of water annually. The addition of 4,500 megawatts of generating capacity over the next 50 years would raise total water use for power production to 115,000 acre-feet annually. This figure represents about a 188 percent increase over current utilization levels.

Table 1 summarizes the projected water use by the electric power generation industry for the three growth scenarios. Figure 1 depicts the power generation projected water use for the planning period.

Table 1 - Projected Electrical Power Generation Industrial Water Use

Electric power Industry	Consumptive Use (Acre-Feet/Year)			
	2005	2015	2035	2055
Low Growth	39,700	41,600	45,600	50,000
Moderate Growth	39,700	52,300	65,000	65,000
High Growth	39,700	52,300	75,100	115,000

Future Soda Ash Production

The trona patch West of Green River, Wyoming is the site of five industrial facilities that mine and convert trona to soda ash, an industrial product that is used in manufacturing glass, detergents, baking soda, and several other industrial and consumer products. General Chemical, OCI Wyoming, and Solvay each operate one facility in the Basin. FMC Wyoming, the largest soda ash producer, operates two facilities; FMC Westvaco and FMC Granger. As a group, these five facilities mined 19.5 million tons of trona (Equality State Almanac, 2007) and produced approximately 10.53 million tons of soda ash in 2005. The soda ash industry consumptively used about 16,400 acre-feet of water from the Green River during 2005-2006 water year (SEO, 2006). Not all of this water is used in soda ash production, however; some soda ash facilities use cooling water for on-site electric power generation and sell their excess power. Furthermore, the FMC Westvaco facility uses water for manufacturing processes associated with their bicarbonate, sodium cyanide, sodium hydroxide, and sodium phosphate plants. In addition, Church and Dwight, the manufacturer of Arm and Hammer products, used about 160 acre-feet of water in 2005-2006 water year for post-processing soda ash, bringing total industry usage for all purposes to about 16,600 acre-feet annually.

World soda ash consumption is estimated to be approximately 40.6 million tons annually, meaning that the Green River patch supplies about 26 percent of world's needs. The two other domestic producers of natural soda ash are located in Colorado and California, and have a combined name plate capacity of 2.4 million tons annually. The Colorado plant has been idle since 2003. Roughly 56 percent of current production in the Basin is used domestically, and the remainder is exported. The major foreign markets for Wyoming soda ash are in Asia and South America, although Europe, Mexico, the Middle East, and Africa also import significant quantities (Kostick, 2008).

Future growth in soda ash production in the Basin will be largely dependent upon export markets. Domestic consumption has been relatively flat in recent years and is expected to grow by only .5 percent annually for the foreseeable future (USGS, 2006). This relatively low growth rate is attributable to the fact the U.S. market is relatively mature in terms of per capita consumption of soda ash products. The glass container market is one of the largest consumers of soda ash. The recent increases in oil prices and the resultant impact on plastics price could result in increased demand in the glass container market and result in increased consumption of soda ash.

Foreign demand for soda ash, especially in developing countries, is expected to increase at a more rapid rate than in the U.S. over the next 50 years. The near term growth is forecast to be between 2.0 percent and 2.5 percent per year for the next several years.

Three scenarios for future water needs for the Basin's soda ash industry are described below.

Low Growth Scenario

The low growth scenario for future soda ash production projects no significant changes in the structure of domestic or international markets for soda ash over the 50 year planning horizon, and no significant changes in production and transportation costs for Wyoming producers. Under these conditions, Green River Basin producers would be expected to maintain their current shares of both domestic and international markets, and their production would be expected to grow roughly proportional to growth in consumption.

According to the United States Geological Survey (USGS) 2006 Minerals Yearbook, future domestic consumption is expected to grow by .5 percent annually, and world consumption is expected to grow by 2.0 to 2.5 percent annually for the foreseeable future (USGS, 2006). Using the mid-point of these estimates gives a projected domestic growth rate of .5 percent annually and projected export growth rate of 2.25 percent annually. Based on current production estimates, approximately 56 percent of soda ash from the Green River patch is consumed domestically and 44 percent is exported (USGS, 2006). Using these percentages as weighting factors, the overall future growth rate for soda ash production in the Basin is projected to be 1.27 percent annually for the low growth scenario.

The amount of water used for soda ash production varies widely among producers for numerous reasons, including the type of production technology used, whether power is generated on-site and how it is generated, how much water is used to inject process insolubles back into the mining void, how much water is lost to evaporation in holding and settling ponds, how much water is used for dust control, and how much water is recycled for various process purposes. Using the industry reported use figures, reported to the SEO, for the 2005 – 2006 water year, the industry consumed an average of 507 gallons of water per ton of soda ash produced.

Total US production of natural soda ash in 2005 and again in 2006 was 11 million metric tons (USGS, 2006) or about 12.13 short tons. If the Searles Valley production is assumed to equal its name plate capacity of 1.45 million metric tons (USGS, 2006), the total Wyoming production is estimated at 9.55 million metric tons or about 10.53 million short tons. At a 1.27 percent annual growth rate, soda ash production in the Basin will grow from 10.53 million short tons in 2005 to 19.8 million short tons by the year 2055. The production increase of 9.26 million short tons annually will require an estimated 4.695 billion gallons of additional water annually, the equivalent of approximately 14,400 acre-feet. That increase would bring total consumptive use in the patch up to about 30,800 acre-feet by the year 2055, an increase of 88 percent over current levels.

<u>Moderate Growth Scenario</u>

The moderate growth scenario, like the low growth scenario, projects no significant changes in the structure of domestic or international markets for soda ash over the next 50 years. Unlike the low growth scenario, however, this scenario projects the reasonably foreseeable possibility that producers will be able to achieve an additional competitive advantage in the export marketplace through reductions in rail transportation costs and the implementation of solution mining for a portion of their future production. The construction of a new rail line into the patch would introduce competition into the transportation arena for the first time, and could be expected to reduce the delivered cost of Wyoming soda ash in overseas markets. The implementation of solution mining on a limited scale should also have some cost reduction implications that would give Wyoming soda ash an additional competitive advantage in overseas markets (Watts, 2000).

The United States has historically been the Worlds leading producer of soda ash, however, over the previous 4 years China has emerged as the number one producer in the World producing 12 million tons in 2005. China is also one of the top consumers of soda ash. Chinese soda ash is produced by the Solvay process, a synthetic process that is much more expensive than natural soda ash produced from trona (Kostick, 2006).

Foreign soda ash consumption in 2005 is estimated to be roughly 28.9 million tons annually (Kostick, 2006), of which approximately 18 percent is supplied by Wyoming producers. If foreign consumption increases at the projected rate of 2.25 percent annually, it will reach 87.9 million tons by the year 2055. Wyoming producers could reasonably expect to increase their share of foreign market penetration from 18 to 20 percent as a result of efficiencies described above, meaning that total foreign sales would approach 17.6 million tons annually by the year 2055. Assuming that domestic sales continue to grow at the project rate of .5 percent, total soda ash production from the patch would be 25.15 million tons by the year 2055, an increase of 14.62 million tons over current output levels.

The water requirements associated with this scenario are more difficult to estimate than for the low growth scenario because of the assumption that solution mining would be employed for a portion of future production. Only one of the Basin's current soda ash producers has production experience with solution mining, and good estimates of historical water utilization are not available. The only natural soda ash producing plant using only solution mining techniques is the plant at Parachute, Colorado and it has been idle since 2003(USGS, 2006). Potential improvements in the process, such as the use of directional drilling techniques, may make future production more water efficient than past efforts. For purposes of estimating water requirements for this scenario the same technique used in the 2001 Green River Plan was used. It was assumed that 50 percent of future production increases would come from solution mining, and that solution-mining techniques would require 750 gallons of water per ton of soda ash produced (Watts, 2000). Based upon these assumptions, the consumptive use of water by the soda ash industry in the Basin would grow by about 32,000 acre-feet annually by the year 2055 to a total of about 48,500 acre-feet. This figure represents almost a 200 percent increase over current water consumption levels.

High Growth Scenario

The high growth scenario for soda ash production in the Basin, like the moderate growth scenario, projects increasing efficiencies in production and transportation through solution mining and competition in rail transportation of the finished product. In addition, this scenario projects the possibility of structural changes in some overseas markets that will result from falling tariffs and the elimination of certain other trade barriers. These changes could come about through pressure from the World Trade Organization and the U.S. Government to eliminate punitive tariffs on imported soda ash in countries such as China and India. They could also come about if other countries, particularly in Eastern Europe, become convinced that their antiquated synthetic soda ash plants are not efficient and worthy of further investment or tariff protection. If trade barriers to U.S. exports of soda ash are gradually lowered or eliminated over the next 50 years, Wyoming producers could be expected to benefit enormously because they have a competitive advantage with respect to production costs that few other suppliers can equal (Watts, 2000).

With a projected gradual elimination of trade barriers, it is not unreasonable to assume that U.S. producers could eventually capture 50 percent of the foreign market for soda ash. Wyoming producers may face increasing competition from other domestic suppliers under this scenario however, especially if solution-mining techniques make it more cost effective to develop less accessible deposits of trona in other states. For this reason, the high growth scenario for Wyoming producers is based upon the assumption that they could reasonably capture one-third of the total world market of 87.9 million tons by the year 2055.

Assuming that domestic production in the patch will grow at 1.00 percent annually, and that exports will grow to one-third of foreign consumption by the year 2055, total estimated soda ash production in the Basin would be 38.97million tons in 50 years. That figure represents an increase of 28.44 million tons annually over current production levels. Assuming that 50 percent of the increased production comes from solution mining (750 gallons per ton) (Watts, 2000) and 50 percent from conventional processes (507 gallons per ton) (SEO, 2006), the increase in annual water requirements for the industry by the year 2055 will be about 42,300 acre-feet. Total water requirements for the industry would be about 58,800 acre-feet annually, an increase of 260 percent over current levels.

Table 2 summarizes the projected water use by the trona and soda ash industry. Figure 2 graphically shows the projected trona and soda ash industrial water use for the three scenarios.

Table 2 - Projected Soda Ash Industrial Water Use

Soda ash Industry	Consumptive Use (Acre-Feet/Year)			
	2005	2015	2035	2055
Low Growth	16,400	18,600	23,900	30,800
Moderate Growth	16,400	24,200	34,236	48,500
High Growth	16,400	26,400	44,500	75,200

Other Surface Water Uses

Electrical power generation and soda ash production constitute the current major uses of surface water for industrial purposes in the Green River Basin. The only other surface water user of significance is Simplot Phosphates, which manufactures phosphate fertilizer in a plant near Rock Springs. This plant's current average consumptive use is about 600 acre-feet of water annually, which is purchased from the Green River, Rock Springs, Sweetwater County Joint Powers Board System (Bracken, 2008). Phosphate is delivered to the facility via a slurry pipeline from a mine near Vernal, Utah. An expansion of production at this facility is probable over the next 50 years.

According to plant officials, with the increased demand for food and agriculture products, the facility is projected to increase production over the next fifty years and to increase water use accordingly. Under all three growth scenarios production is projected to increase (Gronski, 2008).

For purposes of projecting future water needs, the low growth scenario for this facility assumes that water needs over the 50 year planning horizon would increase to about 1,500 gallons per minute on an average annual basis. Under this scenario the plant would be using about 2,400 acre-feet per year in 2055 (Gronski).

For the moderate growth scenario, consumptive use is projected to increase to 10,000 acre-feet annually by the year 2055. This scenario assumes that the plant will expand and use its complete contract allocation from Fontenelle Reservoir over the 50 year period. During the first 30 years water would be conveyed from Fontenelle Reservoir to the City of Green River via the river, however, due to the conveyance loss assigned to transporting the water, a pipeline would be constructed from Fontenelle Reservoir directly to the plant (Gronski, 2008).

For the high growth scenario, consumptive use is projected to increase to over 16,000 acre-feet annually by the year 2055. This scenario assume that the 10,000 acre-foot contract from Fontenelle would be fully utilized plus and additional 3,000 acre-feet from the Joint Powers Board and another 3,000 plus acre-feet either from the Joint Powers Board or from Fontenelle Reservoir. This scenario also assumes that a pipeline would be constructed directly to the reservoir (Gronski, 2008)

Table 3 shows the projected industrial water use by the phosphate fertilizer plant at Rock Springs under the three growth scenarios. Figure 3 graphically displays the phosphate fertilizer plant industrial water use.

Table 3 - Green River Basin Phosphate Fertilizer Plant Water Use Projections

	Acre-Feet/Year			
Scenario	**2005**	**2015**	**2035**	**2055**
Low Growth	605	800	1,400	2,400
Moderate Growth	605	4,800	7,500	10,000
High Growth	605	7,700	12,000	16,100

Source: 2005 is from GR/RS/SC JPB actual deliveries 2004 to 2008 average 2015, 2035, and 2055 are Simplot Phosphate's Projections May 2008

Groundwater Uses

The oil and gas industry is an important user of groundwater in the Basin, although water requirements are generally small and spread over a large geographic area. Water is used to create mud during drilling and can be used for waterflooding operations. In the 2000 the number of existing or producing oil and gas wells in the Green River Resource Area (GRRA) was estimated at a total of 1,725 with the number declining to about 1,570 in 2010 (Watts, 2000). The GRRA contained about one-half of the oil and gas activity in the Basin (Watts, 2000). However, the Bureau of Land Management (BLM) National Environmental Policy Act (NEPA) documents have identified numerous drilling projects throughout the Green River and Great Divide Basins. BLM NEPA documents issued since 2000 have identified over 20,000 new wells. This number includes oil, natural gas and coal-bed natural gas wells. Both oil and natural gas production have increased significantly in Sublette and Sweetwater Counties through 2005 while the other basin counties showed stable or slight declines in production (Equality State Almanac, 2007).

There is a potential for coal-bed natural gas development to impact groundwater resources in the Basin over the next 50 years. Coal-bed natural gas (CBNG) development is not considered a consumptive user of groundwater resources, but produces groundwater as a by-product of gas production. Water is pumped to relieve pressure on gas in coal seams so that the gas can be captured at the surface. The BLM has approved the Atlantic Rim CBNG project that allows up to 1,800 new CBNG wells and 200 conventional oil and gas wells in the area. The Atlantic Rim encompasses 270,000 acres in Carbon County, an area that averages 10 miles wide and stretches approximately 40 miles from near Rawlins to near Baggs. The water produced by these wells will likely have a water-to-gas ratio of 4 to 5 barrels of water (Bbls) to every million cubic feet (MCF) of gas. The water-to-gas ratio is expected to decrease over time as more wells are drilled and pumped. The Powder River Basin experiences water-to-gas ratios on the order to 1.5 to 2 Bbls/MCF. The Atlantic Rim project is projected to yield 1.35 trillion cubic feet (TCF) of gas (WSGS, 2007). The resulting water production would be over 500,000 acre-feet over the life of the play and based on a water-to-gas ration of 3 Bbls/MCF. Other areas of development are in the planning stages in the basin as well and they would no doubt produce significant volumes of water.

One limiting factor with respect to future CBNG development are federal laws and programs, collectively known as the Colorado River Basin Salinity Control Program (CRBSCP), which regulate the amount of salt that can be discharged into surface water systems of the Green River Basin. The CRBSCP strictly limits and in some cases prohibits saline discharges from new industrial sources in the Basin. If CBNG developments produce saline groundwater as a by-product of gas production, in all likelihood that water would have to be either re-injected into low quality aquifers, if available, treated, or held and evaporated in disposal ponds that have no hydrologic connection to surface water systems. The Catalina Unit CBNG Produced Water Disposal Projects propose to treat and discharge CBNG produced water to Muddy Creek (BLM website, 2008). CRBSCP requirements may limit the commercial development of CBNG resources in some parts of the Basin.

Natural gas processing facilities in the Basin also use groundwater, but typically in relatively small amounts. For example, the Exxon Shute Creek Plant has two wells permitted for 100 gpm each and a small direct flow surface water permit (0.134 cfs). In the larger picture of industrial water uses in the Basin, groundwater uses for natural gas processing are relatively small and future needs have not been projected.

Several coal mines in the Basin have groundwater permits and use water primarily for drinking water, sanitation, dust control, and mine reclamation activities. The three largest mines are the Black Butte and Bridger Mines that supply coal to the Jim Bridger Power Plant and the Pittsburgh-Midway Mine that supplies the Naughton Power Plant. The groundwater used by these mines does not directly impact surface water flows, and needs have not been projected into the future.
The Kennecott Uranium Company also has a number of groundwater permits for its inactive mine and processing facility in the Great Divide Basin near Rawlins. When it was operational,

the mine used well water in a process solution for extracting uranium from ore. Given current high energy prices, the prospects for uranium production are greatly improved from the situation that existed in the 2001 Green River Basin Plan. The most likely uranium mining developments in the basin are in the Northeast part of the Great Divide Basin. Employee and associated population impacts will likely occur out of the basin in Rawlins or possibly in Jeffrey City (WSGS, 2008).

Potential New Industrial Uses

The industrial water use projections for the Green River Basin described above focus on existing industries and their future water needs. The potential for new industries to locate in the Basin to take advantage of available water resources also merits discussion. According to the U.S. Department of Commerce (1992), four industry groups account for over 95 percent of all of the industrial water used in this country each year. These industries are (1) electric power producers, (2) chemical and allied products manufacturers, (3) primary metals producers, and (4) paper and
allied products manufacturers (Watts, 2000). Electric power producers alone consume over 80 percent of all industrial water used in this country each year. In the Green River Basin this industry accounts for about 70 percent of the industrial water use. The other three industry groups account for roughly 14 percent of all industrial water use in this country. Trona mining and processing account for almost 29 percent of the industrial water use in the Basin.

The other two intensive water use industries, primary metals and paper producers, tend to locate near the source of their largest process inputs -- metals and wood respectively. Although the Basin does have a large timber inventory on National Forest lands, water requirements for timber harvesting and lumber production are minimal. If a pulp and paper mill were to locate in the Basin, water requirements could be substantial. This possibility seems remote at the present time, however, given recent trends of reduced timber harvests on federal lands in the west. It appears likely that any new water intensive industrial developments in the Basin will fall into the electric power generation and/or chemical products categories (Watts, 2000).

Expansion of electric power production in the Basin is considered in an earlier section of this memorandum, as is the potential for expansion by the soda ash and phosphate fertilizer industries. The possibility remains that new industrial water uses not discussed in this report will develop over the next 50 years, but the nature and extent of such developments is not foreseeable at this time and water requirements for such developments are not included in the projections described in this memorandum.

Summary of Findings

Projected industrial water requirements for the Green River Basin are summarized and presented in Table 4 and are also graphically presented in Figure 4. These projections are for surface water requirements for large industrial water users. Industrial uses of groundwater are discussed qualitatively in a previous section of this memorandum. Requirements for small industrial users dependent upon municipal water supplies are included in projected municipal water requirements.

Figure 1 depicts current water use for electric power generation in the Basin, along with low, moderate, and high growth projections of water needs. The results show a wide range of potential future water needs for this industry. This range reflects the uncertainty surrounding how future power generation requirements in the western United States will be met by an industry that is restructuring itself to operate in a more competitive marketplace. It also reflects uncertainty concerning international events that may affect the price and availability of foreign oil that is used to satisfy much of the energy demand in this country.

The results in Figure 1 show that water requirements for power generation in the Basin could increase slightly to about 50,000 acre-feet annually under the low growth scenario. For the high growth scenario, water requirements could increase substantially to over 115,000 acre-feet annually. The moderate growth scenario presents a reasonably foreseeable projection of 65,000 acre-feet annually.

Figure 1 Green River Basin Electric Power Industry Water Use

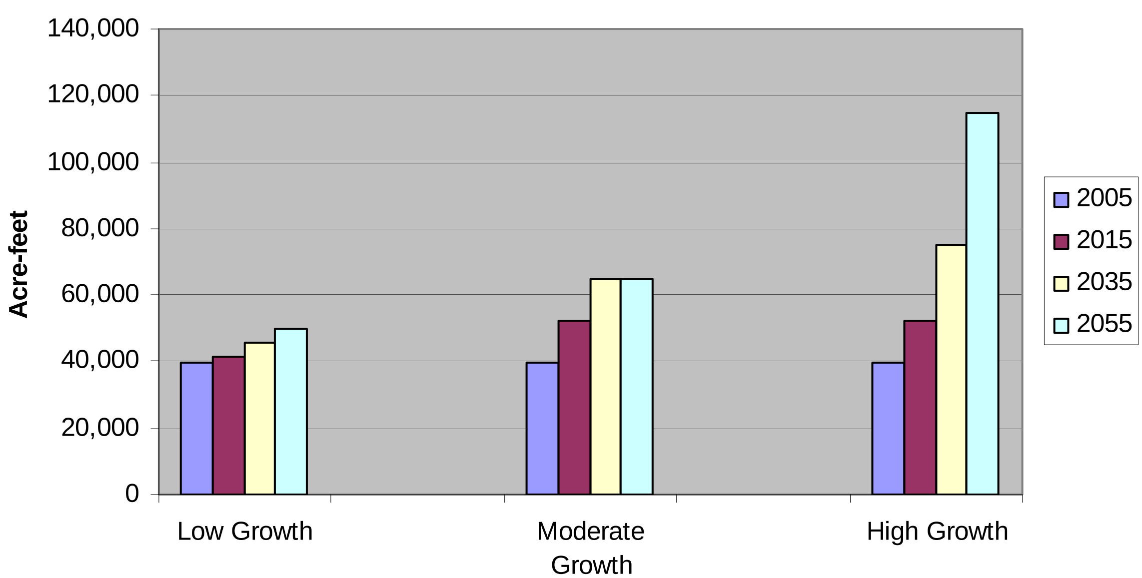


Figure 2 shows that future water requirements for the soda ash industry are projected to grow under all scenarios as the industry responds to projected increases in worldwide demand over the next 50 years. The low growth scenario projects no structural changes in production techniques, transportation costs, or trade barriers over the 50-year planning horizon, meaning that the industry should maintain its current share of domestic and international markets. The moderate growth and high growth scenarios project various reasonably foreseeable changes that would give producers in the Basin greater access to international markets.
The results in Figure 2 show that soda ash industry water requirements for the low growth scenario are expected to increase from about 16,400 acre-feet currently to almost 31,000 acre-

feet by the year 2055. Under the moderate growth scenario, water requirements could reach 48,500 acre-feet by 2055. The high growth scenario projects a reasonably foreseeable estimate of 71,200 acre-feet annually.

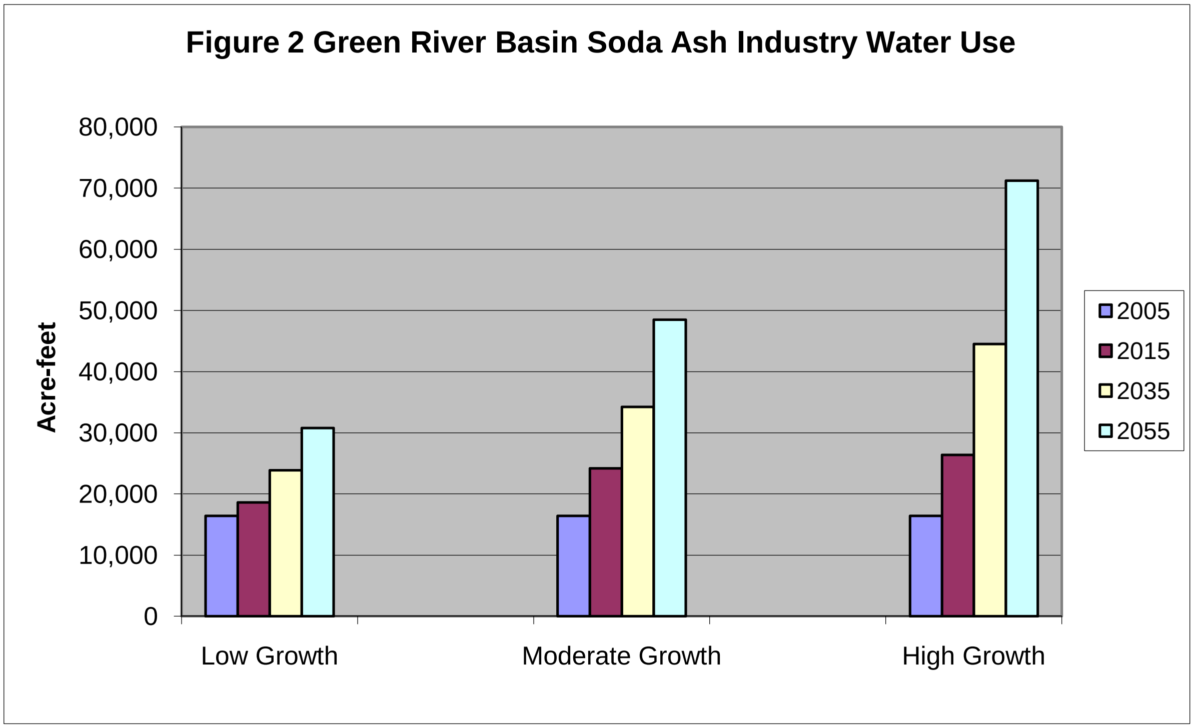
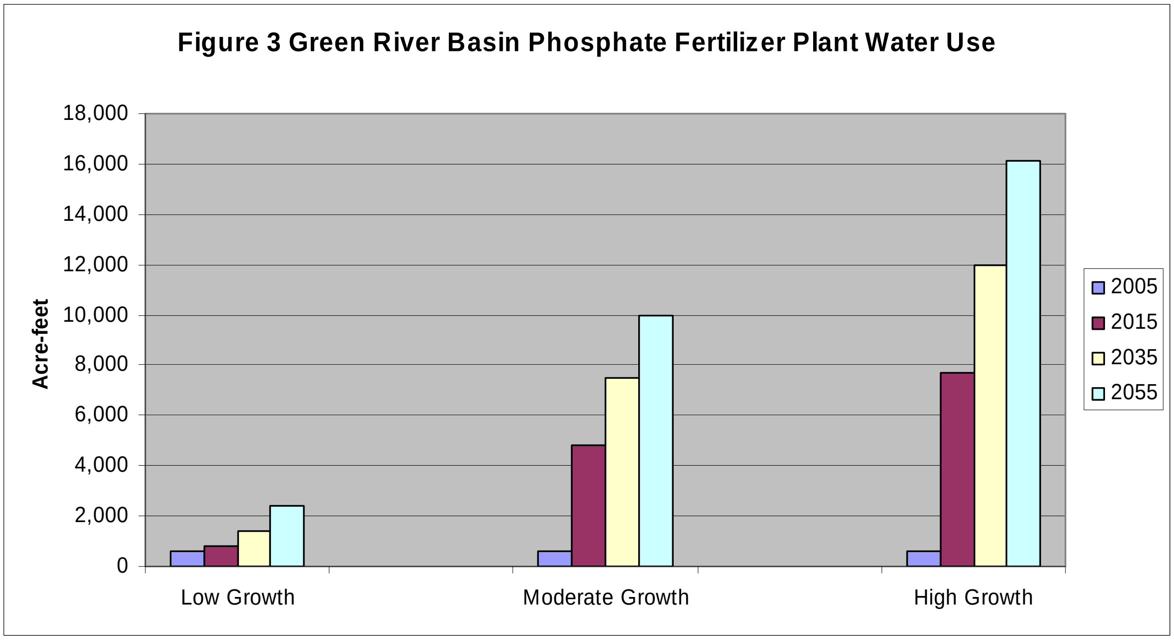


Figure 3 shows the projected growth of the phosphate fertilizer industrial water use for the three growth scenarios. The low growth scenario results show that water requirements would increase from 605 acre-feet per year in 2005 to 2,400 acre-feet per year in 2055. The moderate growth scenario has water requirements for 2055 of 10,000 acre-feet per year. The high growth scenario projects water use to grow to 16,100 acre-feet per year.

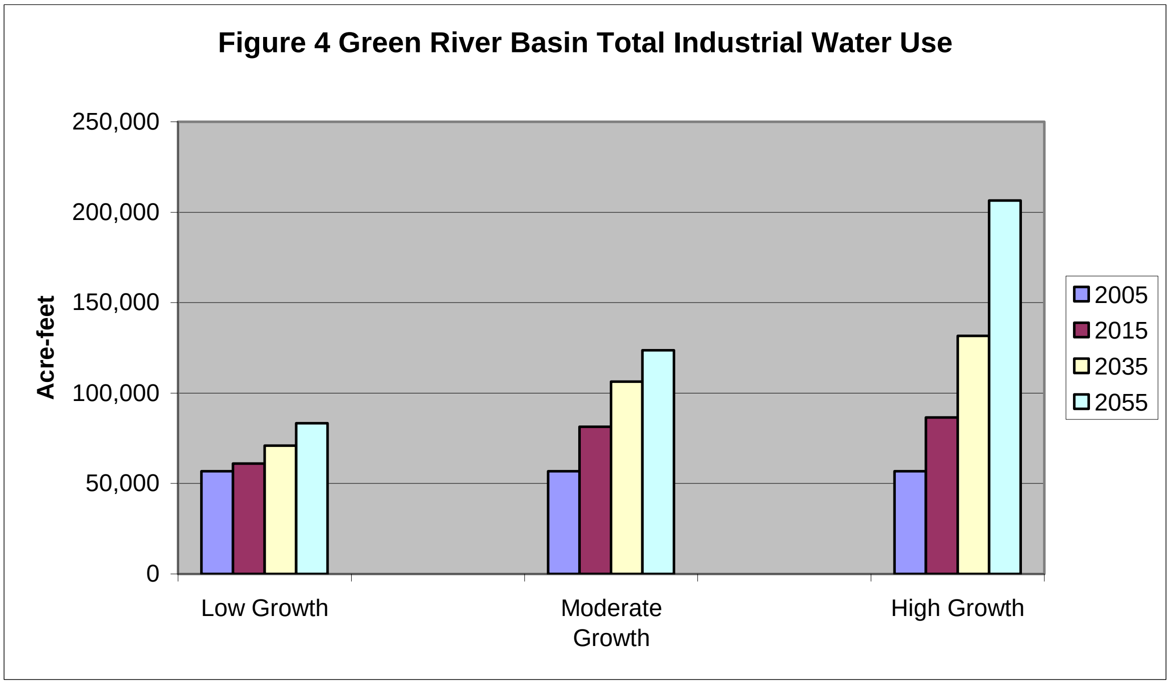


Projections of total industrial water requirements in the Basin are displayed in Table 4 and depicted in Figure 4. The results show that for the low growth scenario, water requirements are expected to increase from a current level of 56,800 acre-feet to 83,300 acre-feet by 2055, an increase of 47 percent. For the high growth scenario, requirements are projected to grow to 206,400 acre-feet, an increase of 173 percent. The moderate growth scenario projects a reasonably foreseeable requirement of 123,700 acre-feet by 2055, an increase of 118 percent.

Table 4 - Green River Basin Industrial Water Use Projections

Scenario/ Industry	Consumptive Use (Acre-Feet/Year)			
	2005	**2015**	**2035**	**2055**
Low Growth				
Electric power	39,700	41,600	45,600	50,000
Soda ash[1]	16,400	18,600	23,900	30,800
Other[2]	700	900	1,500	2,500
Total	**56,800**	**61,100**	**71,000**	**83,300**
Moderate Growth				
Electric power	39,700	52,300	65,000	65,000
Soda ash[1]	16,400	24,200	34,236	48,500
Other[2]	700	4,900	7,600	10,200
Total	**56,800**	**81,400**	**106,400**	**123,700**
High Growth				
Electric power	39,700	52,300	75,100	115,000
Soda ash[1]	16,400	26,400	44,500	75,200
Other[2]	700	7,800	12,100	16,200
Total	**56,800**	**86,500**	**131,700**	**206,400**

[1]Includes related production activities.
[2]Excludes groundwater and small municipal system water users.



The final step in the industrial use projections was to compare the current projections with the projections done for the 2001 Green River Basin Plan. Table 5 shows the 2001 Plan projections and the current plan projections. If the base years, 2000 and 2005, are compared the current plan is lower. Much of this difference can be explained by the better reporting of industrial use to the SEO than was available in 2001. The projected use volumes 30 years into the future are quite comparable for the low growth and moderate growth scenarios. The 30 year projections for the high growth scenario exhibit a larger difference. Much of this is due to a more reserved power generation projection and environmental issues associated with coal fired thermal electric power generation (Conder, 2008).

Table 5 - Comparison of the 2001 Plan to the Current Plan – Industrial Use Projections

	2001 Plan		Current Green River Basin Plan			
Scenario/ Industry	Acre-Feet/Year					
	2000	2030	2005	2015	2035	2055
Low Growth						
Electric power	47,800	47,800	39700	41600	45600	50,000
Soda ash[1]	18,100	29,600	16400	18600	23900	30,800
Other[2]	600	600	700	900	1500	2,500
Total	**66,500**	**78,000**	**56,800**	**61,100**	**71,000**	**83,300**
Moderate Growth						
Electric power	47,800	65,000	39700	52300	65000	65,000
Soda ash[1]	18,100	40,400	16400	24200	34236	48,500
Other[2]	600	1,000	700	4900	7600	10,200
Total	**66,500**	**106,400**	**56,800**	**81,400**	**106,400**	**123,700**
High Growth						
Electric power	47,800	116,500	39700	52300	75100	115,000
Soda ash[1]	18,100	48,300	16400	26400	44500	75,200
Other[2]	600	1,500	700	7800	12100	16,200
Total	**66,500**	**166,300**	**56,800**	**86,500**	**131,700**	**206,400**

[1]Includes related production activities.
[2]Excludes groundwater and small municipal system water users.

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