FERC/DEIS-0038

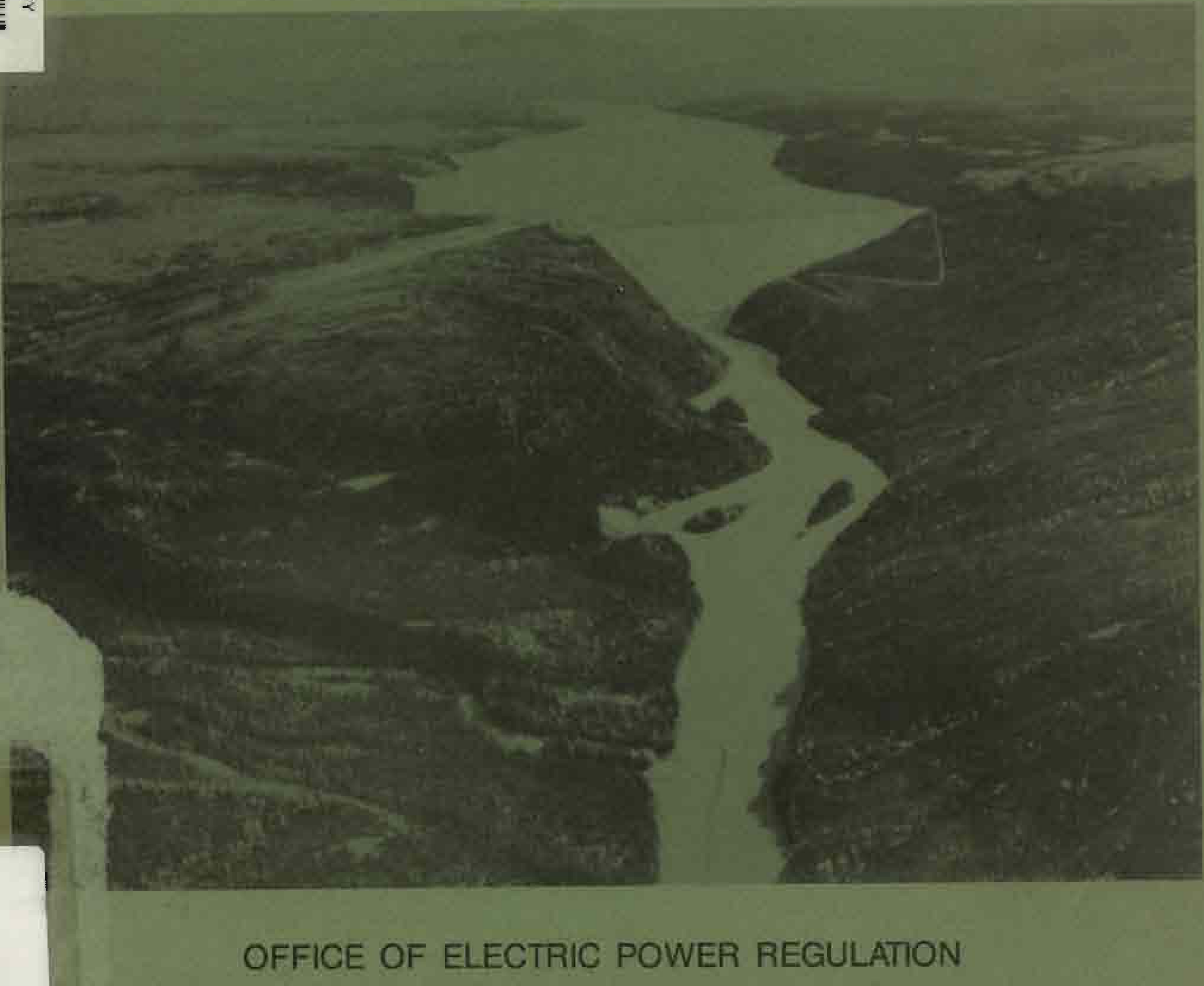
# SUSITNA HYDROELECTRIC PROJECT

FERC No. 7114

## ALASKA

## Draft Environmental Impact Statement

### Volume 2: Appendices A through D



OFFICE OF ELECTRIC POWER REGULATION
FEDERAL ENERGY REGULATORY COMMISSION

MAY 1984

FERC/DEIS-0038

# FEDERAL ENERGY REGULATORY COMMISSION
# OFFICE OF ELECTRIC POWER REGULATION

# DRAFT ENVIRONMENTAL IMPACT STATEMENT

## SUSITNA HYDROELECTRIC PROJECT
## FERC NO. 7114 - ALASKA

## Volume 2.

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# APPENDIX A

# LOAD GROWTH FORECAST: THE ALASKA POWER AUTHORITY FORECASTS

prepared by
Federal Energy Regulatory Commission Staff

# APPENDIX A. LOAD GROWTH FORECAST: THE ALASKA POWER AUTHORITY FORECASTS

## A.1 METHODOLOGY

The Applicant has submitted a number of alternative load forecasts for the Railbelt, based on varying world oil price scenarios. All these forecasts were generated by means of the same modeling structure. That structure employs three computer-operated models that provide projections of: (1) regional demographic, and state economic and fiscal variables, (2) regional electricity demands given specific energy price assumptions, and (3) least-cost generation expansion programs given a demand forecast. The last two models are iterated to determine a consistent electricity demand forecast given the cost of power projected by the generation expansion program appropriate to that demand forecast.

The first computer model--the Man in the Arctic Program (MAP) Economic Model--operates for each of 20 regions within the state; the Railbelt consists of six of those regions. Region-specific projections are produced by disaggregating a statewide projection of employment, population, and household formation variables. The state-level economic, fiscal, and population portions of MAP are solved algebraically in simultaneous fashion. That is, equations within the economic portion of the model are dependent, for instance, on projections within the population portion of the model. The population projections also are dependent on the economic projections. This interdependence, or simultaneity, requires the MAP model to solve iteratively for each year's set of projections. The fourth portion of MAP--the household formation portion--is not interdependent with any of the other projections, but merely produces projections based on the results of the population forecast.

While the many simultaneous and recursive relationships, as well as the large number of equations (more than 1,000) contained in MAP, suggest a highly complex forecasting system (which it is), it is also the case that a great deal of critical information concerning the Railbelt economy has to be forecast exogeneous to the MAP model. For instance, employment projections for the most important sectors of the basic economy have to be assumed. Similarly, large components of the state's projected revenues--a dominant influence in the Railbelt economy--have to be assumed in order to generate forecasts with MAP. The inability of MAP to generate projections for some of these economic variables is due in part to their dependence on influences outside the economy of Alaska. (For instance, employment within the fishing industry is determined in the main by demand for Alaska's fish products in the export markets.) In other instances, independent modeling efforts conducted by unaffiliated organizations have been used to formulate assumed values for some of the MAP data inputs. The MAP projections rely, for instance, on some forecasted data prepared by the Alaska Department of Revenue.

The MAP model operates to produce annual forecasts through the year 2010. Output from the MAP model that is used subsequently by the Railbelt Electricity Demand (RED) Model as input data consists of annual population projections by load center, total annual employment by load center, and annual household formation projections by load center. The RED model requires exogeneous forecasts of retail prices for fuel oil, natural gas, and electricity. The projections of electricity demand produced by the RED model are customer-class-specific for three categories of customers--residential, business and miscellaneous--and represent total annual kilowatt-hour (kWh) consumption at the customer's meter for five-year intervals. Linear interpolation of these forecasts is used to derive annual projections.

The residential consumption portion of RED employs an end-use approach that recognizes nine major end uses and one catch-all category of end use appropriate to this group of consumers. The total stock of electricity-consuming appliances and equipment is a function of time and the type-of-household-formation projections generated with RED. (The latter are consistent with MAP model input data for households.) Vintage-specific electricity consumption profiles for the various end uses are combined with the stock projections to compute energy usage before making adjustments for fuel price changes. The price-induced consumption adjustments are premised on assumed values for Railbelt own- and cross-price elasticities associated with electricity, natural gas, and fuel oil prices.

The business consumption portion of the RED model actually encompasses the commercial, small industrial, and government sectors of the Railbelt. Aggregate electricity consumption in the absence of any change in fuel prices is forecast as a function of regional commercial floor space, which is derived from an <u>ad hoc</u> assumption regarding future trends in the relationship between floor space and total employment. The price-induced changes in consumption of electricity by the business sector are modeled in a fashion similar to that used in the residential sector. That is, the values for own- and cross-price elasticity terms are assumed.

The miscellaneous sector electricity consumption projections represent use for street lighting, vacation homes, and vacant dwellings. These consumption projections are forecast by assuming a multiplier for total residential and business sector kWh consumption representative of street lighting requirements, a multiplier for total number of households times a constant kWh consumption factor to represent vacation home electrical consumption, and a multiplier for the total number of vacant houses representing vacant-dwelling kWh consumption. The sum of these three products is the projected miscellaneous-section consumption.

In addition to the residential, business, and miscellaneous sectors, a fourth component of electricity consumption is appended to each year's kWh projection. This component is identified as "exogenous industrial load." The kWh load projected for this customer category is an ad hoc forecast based on the judgment of a consulting firm that participated in the preparation of the license application.

The Applicant's projections of annual peak demand within the Railbelt are computed by means of a load factor multiplier that operates on the kWh projections to produce the peak kW demand. Load factor is defined as the ratio between the average hourly kW demand for the year and the annual peak kW demand for the year. Thus, dividing the annual kWh load projection from a RED model forecast by the number of hours in the year (i.e., 8,760 in a non-leap year) and then dividing by the load factor results in a figure for peak demand. The load factors used in the Applicant's projections are assumed values specific to the Anchorage area and to the greater Fairbanks area of the Railbelt. These assumed load factors are the simple averages for the period 1971-1980 for each of the two regions. The project variation over time in the implied load factor for the Railbelt as a whole derives from the varying contributions to total kWh load attributable to Anchorage and Fairbanks over the forecast period.

## A.2 LOAD PROJECTION

The Applicant has prepared load projections for 1983-2010 under a wide range of alternative scenarios. Each forecast scenario is characterized by a specific trajectory for the price that crude oil will command in world markets over the forecast horizon.

There are at least three reasons that the world oil price is chosen as the single exogenous variable to be altered in attempting to bracket the load growth in the Railbelt. First, world oil prices affect the level of petroleum revenues to the State of Alaska, mainly through severance taxes and royalty payments. These revenues account for more than 80% of total state revenues, and the state is the single largest economic force acting on the Railbelt economy. Second, world oil prices affect directly the costs of electricity generated in the Railbelt because of the linkage between prices of crude and other fossil fuels. As demonstrated in Section 1.2, the Railbelt depends heavily on fossil-fired electric generation. Third, world oil prices, through their influence on other fuel prices, affect the substitution possibilities that exist for electricity in the Railbelt.

## A.3 WORLD OIL PRICE

### A.3.1 Some Current Views

There is little consensus in views concerning future world oil prices. Oil price forecasts for the year 2010 range from as low as about $12 per barrel to $110 per barrel ($88 to $809 per metric ton) (in 1983 dollars). Clearly, there is considerable uncertainty concerning future oil prices. The uncertainty can be traced back to one fact--since late 1973, the price of oil has contained a large element of monopoly profit.* The high oil price projections are all based on an inherent assumption that the OPEC nations will maintain their market power and continue to extract large monopoly profits from the price of oil.** The lower oil price projections derive from an inherent assumption that the OPEC nations will lose much of their market power and that prices will fall toward the marginal cost of finding and producing new oil. The OPEC nations already have lost most of the market power they possessed before 1979. The rapid decline in

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*As used here, monopoly profit is defined as the difference between the actual price of oil and the price it would bring in a fully competitive market. For example, assume that the actual price of a barrel of oil is $29/barrel ($213/metric ton), that it would only be $15/barrel ($110/metric ton) in a fully competitive market (its cost to the marginal cost producer), and that the cost to actually produce a barrel of Middle East crude oil is only $3/barrel ($22/metric ton). A Middle Eastern country would thus extract $14 ($103) monopoly profit and $12 ($88) economic rent (or producer surplus) from each barrel produced and sold. Its total profit (economic rent and monopoly profit) would be $26/barrel ($195/metric ton).

**Market power is possessed whenever a group of producers, by restricting production, are able to maintain the price of a product higher than it would otherwise be in a fully competitive market. Market power is a requirement for extracting monopoly profits.

OPEC oil demand (from 31 million barrels per day [mmb/d] [4.2 million metric tons per day (MT/d)] in 1979 to 14.3 mmb/d [1.9 million MT/d] in February 1983) forced these nations to reduce the price of oil during March 1983. A further decline in OPEC oil demand would likely cause further price cuts.

Consequently, the key question in predicting future oil prices relates to whether demand for OPEC oil will remain strong enough to allow the OPEC nations to continue to extract monopoly profits from the price of oil. If so, how much can they extract and for how long? If not, then how far will prices fall? Those individuals forecasting higher oil prices assume that a strong upturn in the world economy will increase world oil consumption and cause increased prices. Forecasters projecting lower oil prices assume that the demand for OPEC oil will continue to fall in spite of an improving world economy due to continuing fuel switching, conservation, and a growth in non-OPEC oil production, causing a loss of market power and a further oil price decline. Most forecasters expecting oil prices to rise acknowledge that if the demand for OPEC oil continues to decline, then oil prices also will fall. The differences in oil price forecasts, therefore, stem from different expectations of future demand for OPEC oil.

### A.3.2 Masking Effect of Inventory Changes

Oil prices have stabilized and OPEC oil production has increased since the March 1983 oil price reduction. While OPEC oil production has risen, oil consumption likely has continued to fall. This discrepancy between production and consumption results from inventory changes. Throughout most of 1982, world petroleum inventories were reduced by about 1.5 mmb/d (200,000 MT/d). Thus, 1982 oil consumption was actually higher than indicated by production data. In addition, about 200 million barrels (27 million MT) were withdrawn from storage immediately prior to the March 1983 official oil price reduction. This abnormal inventory drawdown resulted in about a 4.5 mmb/d (600,000 MT/d) reduction in OPEC oil demand during a season when demand normally increases. Actual oil consumption during the period was several million barrels per day higher than oil production.

Recent OPEC oil production levels of 17.5 to 18.5 mmb/d (2.4 to 2.5 million MT/d) should not be viewed from the perspective of OPEC's February 1983 production level [14.3 mmb/d (1.9 million MT/d)], which was abnormally low due to rapid inventory withdrawals, but from the perspective of the approximately 20 mmb/d (2.7 million MT/d) average rate that OPEC would have produced during 1982 had it not been for inventory drawdowns. OPEC's recent production is about equal to its expected oil demand, assuming world oil consumption has continued to decline relative to energy consumption as it did in 1982. Thus, the true demand for OPEC oil still appears to be declining. If so, then OPEC may have difficulty maintaining the current oil price structure.

### A.3.3 Some Recent Trends and Their Meaning*

- Spot-market oil prices have declined approximately 27% (in nominal dollars) since they peaked in 1981. There is considerable speculation that they may fall again soon. Thus, the OPEC nations have lost much (but not yet all) of their market power.

- Oil has rapidly lost its share of the world's energy consumption. It lost a 6% share during the last three years. The free world's oil production declined 10.1 mmb/d (1.4 million MT/d) from 1979 through 1982. Adjustments for inventory changes indicate that oil consumption declined 7.2 mmb/d (980,000 MT/d). Of this, 5.7 mmb/d (775,000 MT/d) (79%) resulted from a reduction in oil's share of total energy consumption.

- Oil production has declined 7% per year during the recent world economic recession compared with a decline of only 2% in total energy production (5% and 1% when adjustments are made for inventory changes). The rapid loss in market share indicates that oil is currently overpriced relative to other fuels.

- Oil's share of the world's energy consumption was declining slightly, prior to 1979 [when its price was around $17.60 per barrel ($129/MT) expressed in 1983 dollars]. The price at which oil would not lose market share may be as low as $14 per barrel ($103/MT), but likely is somewhat higher.

- Conservation has reduced world energy consumption per unit of economic output. Since 1979, world energy consumption per unit of the world's Gross Domestic Product (GDP) has declined at a rate of about 2% per year. Prior to 1973 the growth in the world's energy consumption was about equal to the growth in the world's GDP. From 1974 through 1979 it fell below growth in the GDP by about 1%. The statistical evidence currently available does not indicate that the rate of conservation is declining.

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*All statistics and analyses in this section are based on Essley, 1983.

- Non-OPEC oil production has risen 6 mmb/d since 1976 at a compound growth rate of 5.3% per year. It increased 5% during the first six months of 1983 compared with 1982. Unless oil prices fall further, the large profit from oil production should continue to draw large capital funds for exploration and development in non-OPEC countries.

- OPEC oil production may continue to fall. It dropped 12 mmb/d (1.6 million MT/d) during 1980 through 1982. If the world economic recovery is weak, if fuel switching and conservation continue at near their recent rates, and if non-OPEC oil production continues to rise, then OPEC oil production could decline another 3 to 7 mmb/d (400,000 to 950,000 MT/d) during 1983 and 1984.

Even a cursory analysis of recent trends indicates that oil prices could decline further. Some analysts believe that market forces affecting oil prices will be so strong that it is only a question of "when" prices fall rather than "if" they fall. Of course, military conflict could disrupt oil supplies and even cause an increase in oil prices. However, any supply disruption and subsequent price increase would be temporary. Once supplies were restored, the same forces currently tending to cause oil prices to fall, but amplified by the supply disruption and higher prices, would again exert a strong pressure for a lower oil price.

To assume that OPEC oil production will increase in the near term to the extent that some analysts have projected requires assumptions of:

- Strong world economic recovery and future growth (i.e., higher than most economists are generally projecting),

- Reduced fuel switching,

- Reduced energy conservation, and

- A leveling or decline in non-OPEC oil production.

Such events are possible, and some analysts projecting increased oil prices (or even stable oil prices) obviously consider them more likely than a continuation of recent trends. Nevertheless, almost all analysts agree that there is so much uncertainty that any oil price projection, whether up or down, should be viewed with circumspection.

Figure A-1 shows the oil price range that FERC considers to be most likely. FERC's mid-range projections, expressed in 1983 dollars, are as follows:

| Year | 1983 | 1985 | 1990 | 1995 | 2000 | 2010 |
|---|---|---|---|---|---|---|
| Oil price ($/barrel)* | 29 | 24 | 20 | 22 | 24 | 29 |

FERC's projection is based on an assumption that the strength of economic forces now acting in the direction of reducing oil prices (fuel switching, conservation, and the growth of non-OPEC oil production) will continue to exceed the strength of economic forces tending to increase oil prices (renewed world economic growth). Figure A-2 shows several oil price projections by Alaska's Department of Revenue; Sherman H. Clark, Associates (SHCA), consultants to the Alaskan Power Authority; and DOE. The SHCA and DOE projections are all postulated on an assumption that the combination of economic forces will cause a sufficient growth in demand for oil to allow OPEC to increase its output, and hence maintain its market power.

If oil prices decline, then the magnitude of fuel switching and conservation should diminish, less exploration and development should occur in non-OPEC countries, and the world's economic growth should be stimulated. In short, a reduction in oil prices will reduce the magnitude of forces tending to further reduce oil prices and will increase the magnitude of forces tending to cause prices to rise. As a consequence, even if oil prices decline in the near term, they eventually will start to rise again. Almost all analysts project increasing prices after about a decade or less. Conversely, if oil prices rise, then the economic forces tending to cause oil prices to fall will be strengthened, whereas the degree of the world's economic recovery will tend to be reduced.

### A.3.4 APA Oil Price and Load Projection

The APA takes as its reference case for the world oil price scenario a projection made by Sherman H. Clark Associates, a California-based energy consulting firm. The forecasters responsible for this oil price projection have assigned a 35% probability of occurrence to this

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*$1/bbl = $7.35/metric ton.

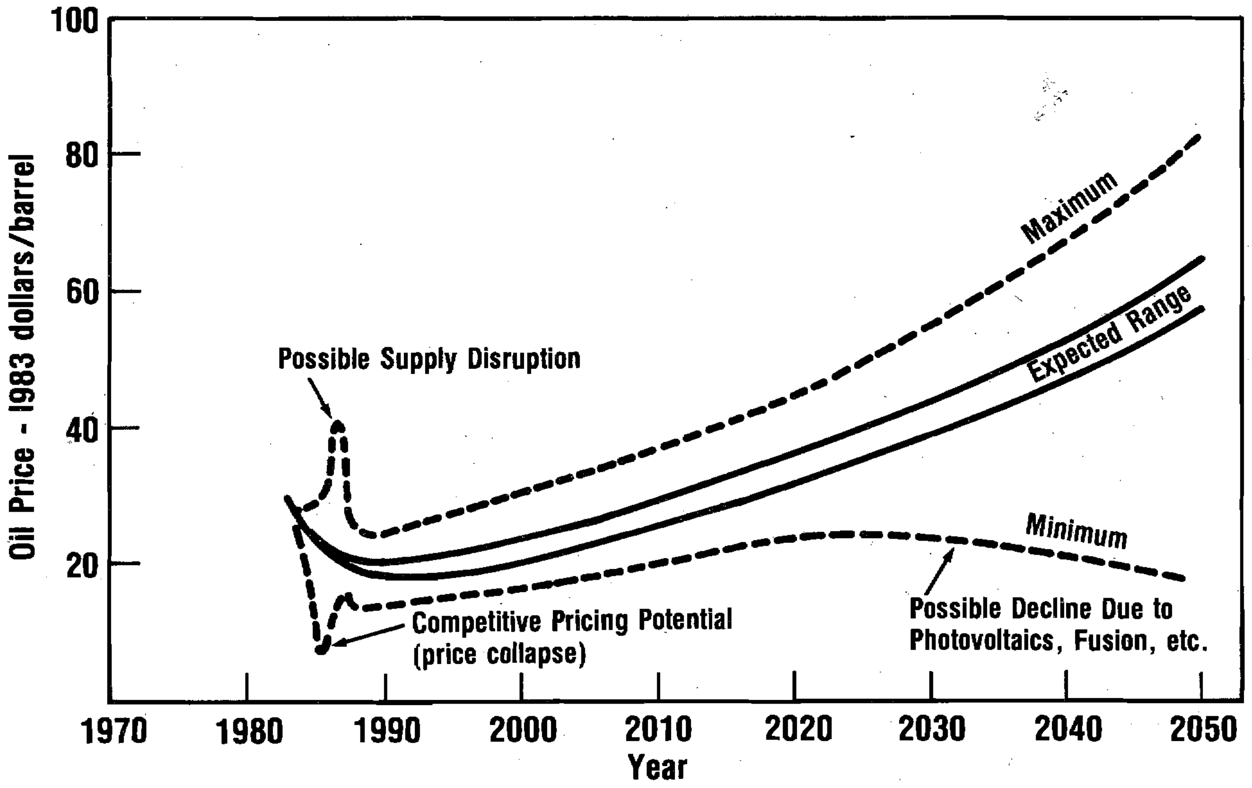

Figure A-1. Projected World Oil Prices.

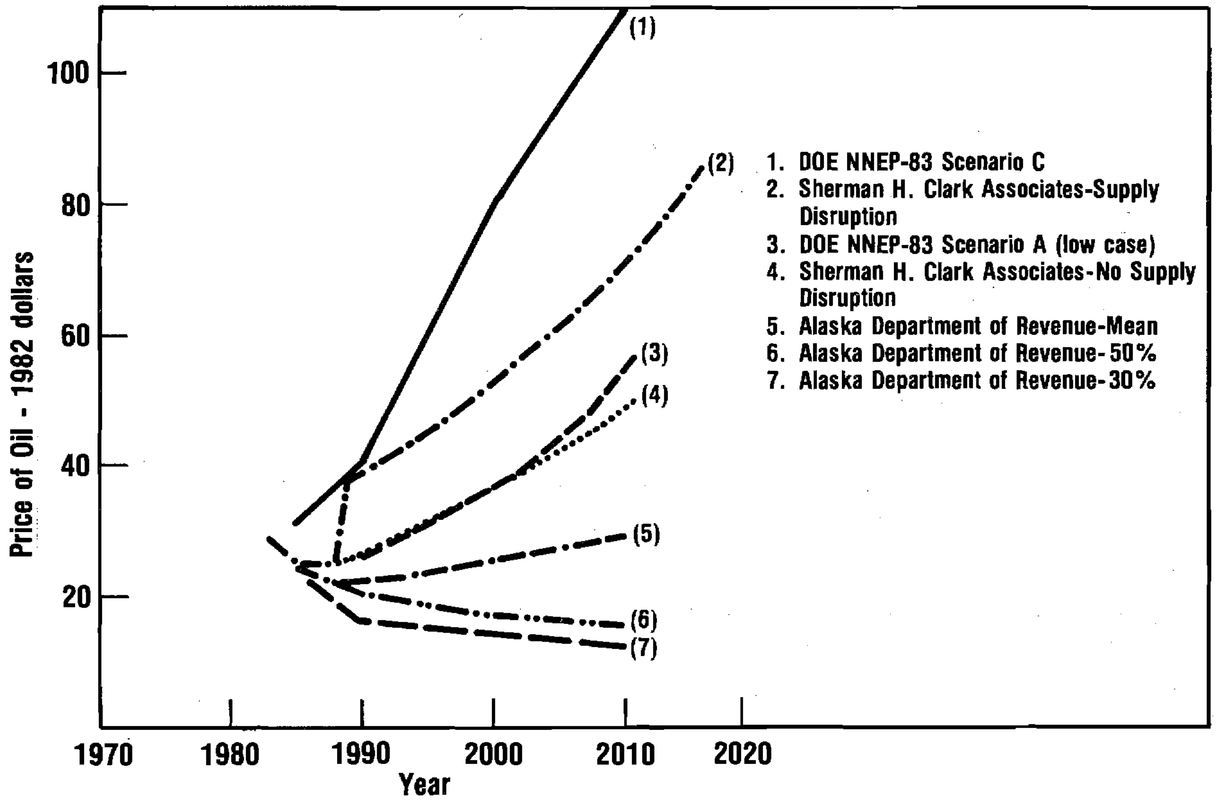

Figure A-2. Price of Oil Under Various Forecasts.

particular scenario. Among other things, this forecast, according to APA, assumes "that OPEC will continue operating as a viable entity and will not limit production during the forecasted period. Recent trends in economic growth in the United States and the free world will continue at reasonable rates." The particular prices for world crude associated with this reference case are shown in Table A-1. State petroleum revenues consistent with this world oil price trajectory are computed and are input to the MAP model to begin the load forecasting sequence. The results of that forecast procedure are shown in Table A-2.

Table A-1. APA's Reference Case World Oil Price Scenario

| Year(s) | Price in Final Year of Period (1983$/bbl) | Annual Rate of Change in Price (%) |
|---|---|---|
| 1983 | 28.95 | -14.9 |
| 1984 | 27.61 | -4.7 |
| 1985-1988 | 26.30 | -1.2 |
| 1989-2010 | 50.39 | 2.6 |

Conversion: $1/ bbl= $7.35/metric ton

Source: Based on data from Application Volume 2a.

Table A-2. APA's Reference Case Railbelt Load Projection, 1983-2010

| Year | Energy (Gwh) | Peak Demand (MW) |
|---|---|---|
| 1983 | 2,803 | 579 |
| 1985 | 3,096 | 639 |
| 1990 | 3,737 | 777 |
| 1995 | 4,171 | 868 |
| 2000 | 4,542 | 945 |
| 2005 | 5,093 | 1,059 |
| 2010 | 5,858 | 1,217 |

Source: Based on data from Application Volume 2C.

Load projections also are made that use the "base case" forecast of world oil price constructed by Data Resources, Inc. (DRI). According to APA, the DRI forecast makes assumptions similar to the Sherman Clark projections regarding the continued influence that OPEC will yield on world oil markets, as well as the economic growth to be exhibited by the U.S. economy. DRI's forecast of world oil prices are, however, noticeably different than the reference case scenario, as is shown in Table A-3.

State petroleum revenue inputs to the MAP model are prepared similarly to the procedure described above, and the load forecasts result is shown in Table A-4.

Table A-3. APA's DRI "Base Case" World Oil Price Scenario, 1983-2005

| Year(s) | Price in Final Year of Period (1983$/bbl) | Annual Rate of Change in Price (%) |
|---|---|---|
| 1983 | 28.95 | -14.9 |
| 1984 | 25.17 | -13.1 |
| 1990 | 36.99 | 6.6 |
| 2000 | 53.43 | 3.7 |
| 2001-2005 | 56.54 | 1.1 |

Conversion: $1/bbl = $7.35/metric ton

Table A-4. APA's DRI "Base Case" Railbelt Load Projection, 1983-2010

| Year | Energy (Gwh) | Peak Demand (MW) |
|---|---|---|
| 1983 | 2,811 | 580 |
| 1985 | 3,109 | 642 |
| 1990 | 3,717 | 773 |
| 1995 | 4,341 | 904 |
| 2000 | 5,041 | 1,050 |
| 2005 | 5,857 | 1,220 |
| 2010 | 6,965 | 1,450 |

A third load projection is presented by APA that is premised on the Alaska Department of Revenue's (DOR) mean probability estimates of state petroleum revenues. These petroleum revenue figures are translated into implicit prices for world oil that are presented in Table A-5. The load projections associated with this trajectory of world oil prices are summarized in Table A-6.

A fourth projection, which repeats the process just described for the DOR's mean probability case, is made using the DOR's "30% probability" case. That is, the Department of Revenue has forecast a level of state petroleum revenues that their model projects has a 30% chance or less of not being exceeded. (A more straightforward way of interpreting this is that there is a 70% chance that state petroleum revenues will exceed the amount forecast under this case.) Again, the implicit world oil prices consistent with these petroleum revenue projections are derived, and the inputs to MAP are calculated. The world oil price trajectory and associated load forecast for this scenario are shown in Tables A-7 and A-8.

For comparison, all four of these alternative load projections are depicted in Figure A-3.

Using APA's "Reference" case as a standard for comparison, it should be noted that there is little to distinguish these projections in the near term. Variation around that Reference case load projection is less than 3.5% in 1985, as shown in Table A-9. By 1990, however, significant differences exist in the forecasts. Implied annual growth rate in kWh loads during that period range from a high of 3.8% in the Reference case to a low of 2.2% in the DOR 30% scenario, as shown in Table A-10.

Table A-5. Implicit World Oil Price Scenario for DOR Mean Projection

| Year(s) | Price in Final Year of Period (1983$/bbl) | Annual Rate of Change in Price (%) |
|---|---|---|
| 1983 | 28.95 | -14.9 |
| 1984 | 23.96 | -17.2 |
| 1985 | 22.67 | -5.4 |
| 1986 | 22.35 | -1.4 |
| 1987 | 21.95 | -1.8 |
| 1988-1999 | 25.60 | 1.3 |

Conversion: $1/bbl = $7.35/metric ton

Table A-6. APA's DOR Mean Case Railbelt Load Projection, 1983-2010

| Year | Energy (Gwh) | Peak Demand (MW) |
|---|---|---|
| 1983 | 2,776 | 573 |
| 1985 | 3,050 | 630 |
| 1990 | 3,508 | 730 |
| 1995 | 3,849 | 801 |
| 2000 | 4,228 | 879 |
| 2005 | 4,726 | 982 |
| 2010 | 5,399 | 1,121 |

Table A-7. World Oil Price Scenario Implicit in DOR's 30% Case Projection

| Year(s) | Price in Final Year of Period (1983$/bbl) | Annual Rate of Change in Price (%) |
|---|---|---|
| 1983 | 28.95 | -14.9 |
| 1984 | 22.74 | -21.5 |
| 1985 | 21.00 | -7.7 |
| 1986 | 20.32 | -3.2 |
| 1987 | 19.52 | -3.9 |
| 1988-1999 | 14.76 | -2.3 |

Conversion: $1/bbl = $7.35/metric ton

Table A-8. APA's DOR 30% Case Railbelt Load Projection, 1983-2010

| Year | Energy (Gwh) | Peak Demand (MW) |
|---|---|---|
| 1983 | 2,753 | 568 |
| 1985 | 3,014 | 622 |
| 1990 | 3,364 | 699 |
| 1995 | 3,560 | 740 |
| 2000 | 3,890 | 808 |
| 2005 | 4,343 | 926 |
| 2010 | 4,950 | 1,026 |

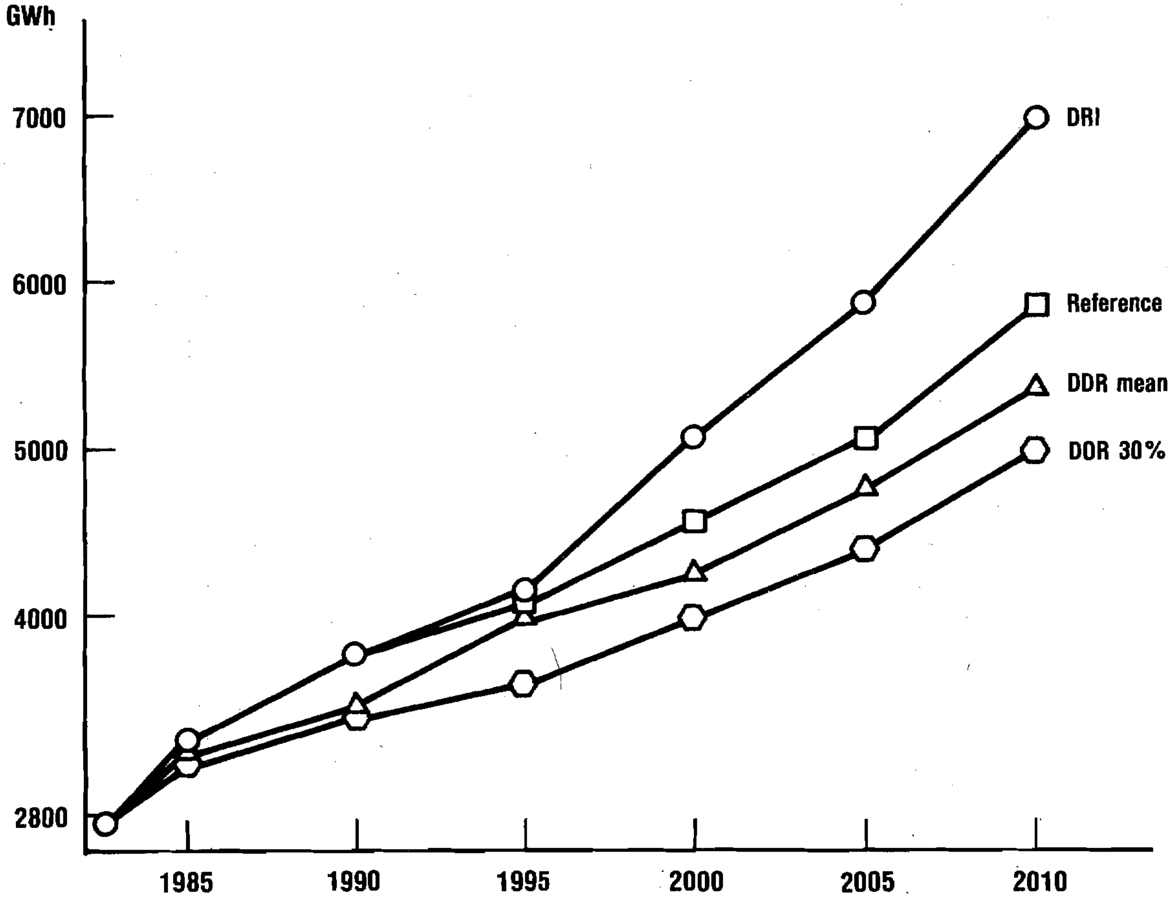

Figure A-3. Alternative APA Load Projections for 1983-2010.

Table A-9. APA's Load Projections Relative to the Reference Case Forecast

| Forecast Scenario | 1985 | 1990 | 1995 | 2000 | 2010 |
|---|---|---|---|---|---|
| DRI | 1.00 | 0.99 | 1.04 | 1.11 | 1.19 |
| Reference | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| DOR Mean | 0.99 | 0.94 | 0.92 | 0.93 | 0.92 |
| DOR 30% | 0.97 | 0.90 | 0.85 | 0.86 | 0.85 |

Table A-10. Annual Load Growth Implied by APA Forecasts
(percent)

| Forecast Scenario | 1985-1990 | 1990-1995 | 1995-2000 | 2000-2010 |
|---|---|---|---|---|
| DRI | 3.64 | 3.15 | 3.04 | 3.29 |
| Reference | 3.84 | 2.22 | 1.72 | 2.60 |
| DOR Mean | 2.84 | 1.87 | 3.80 | 2.47 |
| DOR 30 | 2.22 | 1.14 | 1.79 | 2.44 |

By 1995, the differences are more pronounced. The DRI base case scenario is higher than the Reference case by 4%, and the DOR 30% case is lower by some 15%. The average annual growth in kWh load implied by the high and low cases in 1995 varies by more than 175%.

Between 1995 and 2000, the APA Reference case exhibits the lowest average annual load growth of any of the scenarios, despite being 7% and 14% higher in absolute terms than the DOR mean and 30% cases, respectively. The DRI-based scenario continues to exhibit better than 3% annual growth during this period.

There is little change in the relationships among these alternative forecasts during the period 2000-2010. The Reference and both the DOR cases have converged on average annual growth rates of near 2.5%. The DRI-based increases its growth slightly to 3.3% per year. An important implication in the relationships among these scenarios is the insulation exhibited between electricity load growth and world oil prices in the event that those prices are assumed to decline. Note that the Reference case is characterized by world oil prices that grow at 2.6% annually in real terms during this interval. The DOR 30% case has world oil prices that decline throughout the period. Under both scenarios, however, electricity growth is virtually the same during the ten-year period. The reasons for this behavior in the model forecasts have been analyzed by the APA and are discussed below.

### A.3.5 FERC Projections

The FERC has judged the world oil price trajectories described earlier to be more plausible than the oil price scenarios recommended by the Applicant. As a consequence, an additional series of load projections have been made using these world oil price forecasts. The projections use the same modeling apparatus constructed by the APA and require conversion of the world oil price forecast to a forecast of state petroleum revenues for use in the MAP model.* This conversion was carried out in a manner consistent with the one used by APA. Further, the RED model input requirements for end-user fuel prices were made consistent with FERC world oil price trajectories. The load projections that resulted for the medium and high world oil price assumptions are shown in Tables A-11 and A-12. No projections consistent with the low world oil price trajectory could be generated. The state economic model component of MAP was unable to compute a solution given the drastic reductions in state revenues implied by the low oil price in 1985. This should not be viewed as a failure of the MAP model. The result is indicative of the very serious economic problems the world and Alaska, in particular, are likely to face if the price of oil collapses to the $10 barrel range in 1985.

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*It should be noted that in addition to the changes in world oil price scenarios that FERC chose to make, alterations to the MAP model also were pursued. The objective in making these alterations was to improve what FERC judged to be the economic consistency of what appears to be a sophisticated forecasting tool. Nevertheless, where the specification of an equation could be altered to add economic content, as well as improve both the statistical fit and significance of coefficients in the equation, then such a modification was made. In those instances when an equation was successfully altered, it was also the case that substitution of the new equation into the model caused the system to become unstable. This was the case because critical linkages within the system of equations were broken as a consequence of the changes made by FERC. This can occur despite the changes' having improved the particular equation viewed in isolation. This is not an unreasonable circumstance given a model with the complexity of the MAP system. For this reason, FERC has judged that the forecasting models employed by the Applicant could not be improved on in the time allotted, and these same models have been adopted for purposes of generating the FERC Railbelt forecasts.

Table A-11. Railbelt Load Forecast, FERC High World Oil Price Scenario, 1983-2022

| Year | Energy (Gwh) | Peak Demand (MW) |
|---|---|---|
| 1983 | 2,814 | 581 |
| 1985 | 3,116 | 644 |
| 1990 | 3,567 | 742 |
| 1995 | 3,927 | 817 |
| 2000 | 4,447 | 925 |
| 2005 | 4,793 | 996 |
| 2010 | 5,371 | 1,115 |
| 2020 | 6,591 | 1,367 |
| 2022 | 6,866 | 1,424 |

Table A-12. Railbelt Load Forecast, FERC Medium World Oil Price Scenario, 1983-2022

| Year | Energy (Gwh) | Peak Demand (MW) |
|---|---|---|
| 1983 | 2,802 | 579 |
| 1985 | 3,094 | 639 |
| 1990 | 3,474 | 722 |
| 1995 | 3,788 | 788 |
| 2000 | 4,168 | 866 |
| 2005 | 4,623 | 960 |
| 2010 | 5,234 | 1,086 |
| 2020 | 6,424 | 1,332 |
| 2022 | 6,693 | 1,388 |

There are a number of ways to put these alternative projections into perspective. Three approaches are used here. The first is a simple comparison of the FERC projections and the APA projections. The second is a comparison of both sets of forecasts with other projections made previously for the Railbelt. The third is an examination of the changes in both electricity intensity and electricity expenditure implied by these forecasts.

A graphical comparison of APA and FERC projections is shown in Figure A-4. It is apparent that the modest differences between the APA forecasts and the FERC forecasts are the result of the relative insensitivity of the forecast mechanism to the price of world oil. This feature merits some scrutiny. As explained in previous sections, the current dependence of the state, and particularly the Railbelt economy, on the revenues generated from petroleum is dramatic. The state government's expenditures are one of the largest single components of total state income, and more than 80% of the state's revenues are directly attributable to petroleum taxes and royalty fees. The MAP model employed in the generation of these various load forecasts has two features that act to insulate the state economy from the impact of lower severance and royalty payments that are the direct consequence of declining world oil prices.

First, a spending rule is implemented that establishes a constant per capita state government appropriation, adjusted for inflation. This fiscal rule reflects a state constitutional amendment scheduled to become effective with the 1984 fiscal year budget. In the event that this spending limit cannot be financed from current state revenues, plus the state's general fund balance, then MAP imposes several plausible fiscal fixes in an effort to maintain the appropriation level. Those fixes are: (1) imposition of a state personal income tax, (2) elimination of the state's Permanent Fund dividend program, and (3) transfer of earnings from the state's Permanent Fund into the General Fund, where they supplement that fund's revenues.

The second insulating mechanism is that the MAP model is provided state petroleum revenue forecasts that contain a corporate income tax component reflective of Alaska's newly enacted unitary tax on corporate profits. The unitary tax subjects multistate corporations to an income tax based on the state's "share" of total corporate profits from firms' worldwide operations. The method of allocating the state's share of those profits is based on jurisdictional sales, employment, and capital investment relative to the corporatewide totals for those items. Because total corporate profits for petroleum firms operating within Alaska cannot be forecast, much less Alaska's share of their sales, employment, and capital investment, a simplified forecast rule was adopted. The rule was to escalate petroleum-related corporate income taxes by 7% per year for a designated world oil price scenario, referred to as an index case. For the other world oil price scenarios, the corporate income taxes are higher or lower by the ratio of the severance taxes for those scenarios relative to severance taxes for the index case. In the DOR 30% case, for instance, these income taxes grow by 5.5% per year, even though world oil prices fall throughout the 27-year forecast period (and severance taxes and royalties combined decline by 2.8% per year during that period).

An additional reason MAP model results are relatively insensitive to the variation in world oil price trajectories is that no direct impacts on the petroleum industry within Alaska are included in the alternative scenarios. That is, there are no variations in the assumed activity levels for oil exploration, development, transportation, and refining. (This would appear consistent with the forecast procedure used for the petroleum-related corporate income taxes, described above. However, such consistency demonstrates nothing with respect to the basic plausibility of the employment assumptions.)

By way of demonstrating this insensitivity feature of the forecast system, it will be noticed that the oil price in the FERC high case differs from the FERC medium case in 1990 by more than 50%, and between then and 2010, never by less than 30%. Yet, the Railbelt load forecasts associated with these two scenarios exhibit a maximum difference over that period of less than 7%.

Comparison of these projections with previous Railbelt load forecasts is informative from several standpoints (see Table A-13). Beginning with the Henry J. Kaiser Company load forecast done in 1974, and continuing through a recent projection made by Battelle for APA in the original Susitna license application, the history of load forecasting for the Railbelt would appear to be one of nearly continual revision downward. The current APA and FERC projections appear consistent with that trend. The other feature of some significance is the apparent lack of optimism with regard to load factor improvement that has come to characterize the more recent projections.

The final means of putting the APA and FERC load forecasts in perspective is to examine the implied electricity intensity levels, as well as the implied electricity expenditure levels, reflected in the forecasts. First, it should be noted that there are no significant differences across the various forecast alternatives with respect to energy intensiveness as measured by kWh consumption per-capita and kWh consumption per household. There is, however, a significant upward trend in energy intensiveness over the forecast period. The average annual rate of increase in per-capita usage implied by these forecasts is 0.6% over the 1985-2010 period. The per household rate of increase over the same period averages 0.45%.

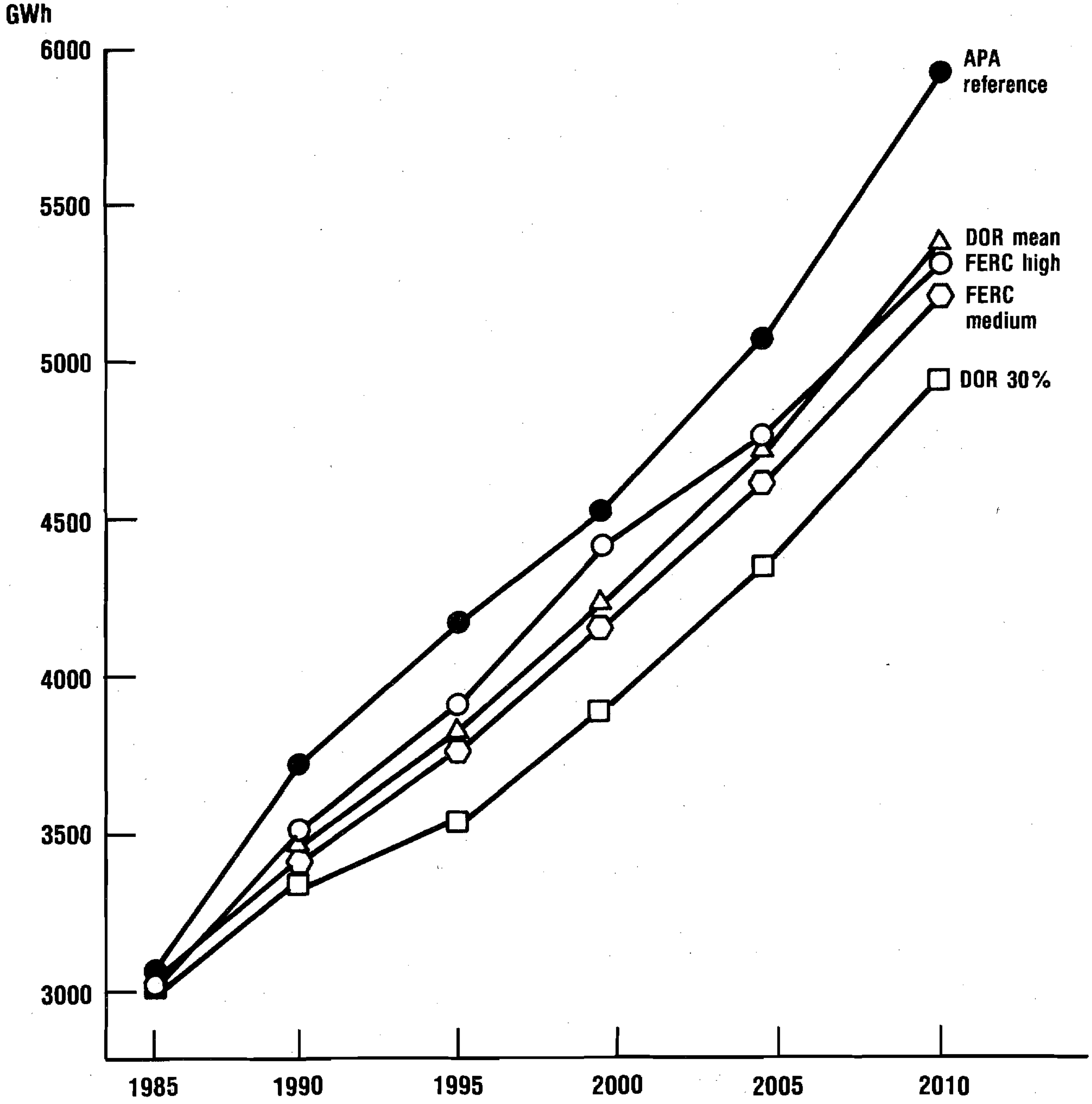

Figure A-4. FERC Staff Load Projections and Selected APA Load Projections--1983-2010.

There are significant differences in the implied expenditures for electricity across the various load forecasts. Average electricity expenditures per household are shown in Table A-14 for a representative of the projections.

The variation in the real per household expenditures for electricity should presumably be reflected in the usage intensity figures discussed previously.

Table A-13. Railbelt Load Forecasts of the Last Decade
(GWh and MW)

| Forecast | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| H. J. Kaiser Co.<br>1974 | 3,543<br>(677)†[1] | 6,434<br>(1,194) | 11,701<br>(2,155) | -- | -- |
| Railbelt Utilities<br>1974 | 3,514<br>(537) | -- | 10,377<br>(1,560) | -- | -- |
| Corps of Engineers<br>1975 | 3,240<br>(740) | -- | 6,840<br>(1,480) | -- | 11,650<br>(2,660) |
| Alaska Power Administration<br>1976 | 3,155 | -- | 6,110 | -- | 10,940 |
| ISER<br>1980 | 2,790<br>(510) | -- | 4,030<br>(735) | 5,170<br>(934) | 6,430<br>(1,175) |
| Battelle<br>1981 | -- | -- | 4,456<br>(892) | 4,922<br>(983) | 5,469<br>(1,084) |
| Battelle<br>1982 | -- | -- | 4,482 | 4,894 | 4,728 |
| Battelle<br>1983 | -- | 3,096 | 3,737 | 4,171 | 4,542 |
| FERC | -- | 3,094 | 3,474 | 3,788 | 4,168 |

†[1] Numbers in parentheses are peak load forecast.

Table A-14. Average Annual Expenditures for Electricity per Residential Household in the Railbelt
(1982 $)

| Forecast | 1985 | 1995 | 2005 |
|---|---|---|---|
| APA Reference Case | 713 | 834 | 955 |
| FERC Medium Case | 712 | 774 | 869 |
| DOR 30% Case | 709 | 706 | 706 |

## REFERENCE FOR APPENDIX A

Essley, P.L., Jr. 1983. Future World Oil Prices--Will They Rise or Fall? ORA/FERC. (November 21).

# DRAFT ENVIRONMENTAL IMPACT STATEMENT
# SUSITNA HYDROELECTRIC PROJECT, FERC NO. 7114

## APPENDIX B

## FUTURE ENERGY RESOURCES

Prepared by

Federal Energy Regulatory Commission Staff

# APPENDIX B. FUTURE ENERGY RESOURCES

## B.1 INTRODUCTION

The physical availability of energy resources in the Railbelt is not a significant issue. There are sufficient reserves of oil, gas, and coal, each taken individually, to meet the most optimistic projections of internal Railbelt energy use from now until well past the mid-21st Century. The cost at which any of these resources will be made available to Railbelt consumers is what is at issue, and it is the means of measuring such cost that is central to this discussion.

The real cost of consuming an energy resource within the Railbelt is not necessarily the sum of the labor, capital, materials, and assorted other production expenses required to extract and convert the resource to usable energy. The real cost is what that resource will command in the market that values it most. That market can, and often does, lie outside the region. Where the export price (i.e., value) exceeds the cost of producing the resource for local consumption, it is the export markets' payment foregone that is the cost of consuming the resource locally. By consuming the energy locally, in this instance, the opportunity to receive the export value is lost. Therefore, depending on what assumptions are made about the "highest valued use" to which the Railbelt's energy resources can be put, there will be radically different circumstances that characterize both the economic availability of energy resources and the most efficient means of meeting the energy requirements of the region.

Although the Railbelt has been able to meet its current energy requirements at reasonable cost (in certain cases, at comparatively modest cost), the issue of future energy cost is subject to debate. The major source of controversy stems from the future course of world oil prices and their relationship to the supply and demand for fossil fuels of all types. For this reason a discussion of the world oil price and its probable future range is necessary.

## B.2 PETROLEUM FUELS

The supply of petroleum fuel is related to the supply of crude oil. From Alaska's point of view, its crude oil reserves are so large relative to its internal needs that supply should not be a constraint on the use of petroleum fuels for the foreseeable future. Price is another matter. If oil prices rise relative to other energy resources, which also are abundant in Alaska, then the state may receive the greatest economic benefit from "exporting" its petroleum resources while consuming its lower-cost resources. Petroleum fuel consumption could become "demand-constrained".

The prices of petroleum fuels obviously are related to the price of crude oil. However, refining costs are independent of the price of crude oil; hence, fluctuations in crude oil prices will not cause similar fluctuations in refining costs. The cost of refining is unlikely to change appreciably over time (in real dollars). As a consequence, variation in crude oil prices should result in equivalent dollar variations in petroleum fuel prices (but not equivalent percentage changes).

Various petroleum fuels exceed crude costs by different amounts, due to different refining costs and differences in demand. Normally, gasoline has the highest refinery markup of the high-volume petroleum fuels. Residual fuels normally are by-products and generally are sold for less than the cost of crude oil. Recently, however, high-sulfur residual fuels have commanded a higher price than low-sulfur crude oil on the U.S. West Coast and in Alaska. This abnormal condition appears to be a result of the peculiarity of U.S. export laws (Tussing, 1983). Projections of future residual fuel prices thus are even more uncertain than projections of crude oil prices, since an additional political uncertainty is added.

## B.3 NATURAL GAS

### B.3.1 Reserves/Resources

Alaska's proven gas reserves far exceed its internal needs for the foreseeable future under even the most extremely optimistic projections of growth. Further, its potential gas resources may materially exceed its proven reserves. The amount of gas required to generate all the Railbelt's electric power needs for the next half century [about 3 trillion cubic feet (Tcf)] is likely less than 10% of Alaska's proven gas reserves and perhaps 4% of its potential gas resources. Paradoxically, some have suggested that Alaska's gas reserves may not be sufficient to prudently plan to use gas for future electric power generation.

This paradox results from the location of Alaska's gas reserves and its potential gas resources. The bulk of Alaska's gas may not be accessible for use to generate power in the Railbelt area, may be accessible only after it is needed, or may be accessible only at a cost that prohibits its use. Unless oil prices increase materially, a pipeline to transport Prudhoe Bay gas may not be constructed. If oil prices follow FERC's projections, for instance, Prudhoe Bay gas may remain locked in place well into the next century. The Cook Inlet proven reserves, while readily accessible to the lower Railbelt area, may not be sufficient to meet the area's power needs for more than about 20 years if consumption continues at the present rate.

However, in addition to the approximately 3.4 Tcf of proven reserves in the Cook Inlet area, the United States Geological Survey indicates that there is likely another 1.3 to 13 Tcf of gas as yet undiscovered. If so, then there should be more than adequate gas to meet the Railbelt's power needs for the next half century. But since such potential reserves are not proven, and may not materialize, it is argued that it would be imprudent to plan on the use of the as yet undiscovered gas. Further, it is argued that even if the gas is present, gas prices will have to rise materially to ensure that it is discovered and developed. If Prudhoe Bay gas reserves remain locked in place, and if no new reserves are discovered in the Cook Inlet area, then a strategy by Anchorage area electric utilities to rely on natural gas as a fuel for power generation could result in their turbines running out of fuel early in the 21st Century.

However, there is another side to the paradox that presents a dilemma to Alaska. It is quite possible that Alaska's remote location may result in Alaskans receiving abundant gas supplies at appreciably less than the cost of alternative energy supplies. If so, then the use of gas as a fuel for power generation could result in, by far, the least costly power for Alaska. The questions Alaska must answer with regard to future power generation, therefore, are (1) will gas be available where it is needed, and (2) will it be available at a price that allows economic power generation?

The reason natural gas may be an abundant, low-cost fuel in the future is similar to the reason natural gas currently is an abundant, low-cost fuel in Alaska. Anchorage residents enjoy the lowest natural gas rates in the United States, and because natural gas is used to generate electricity, they enjoy some of the lowest electricity rates as well. The reason relates to circumstances that determine natural gas prices.

### B.3.2 Pricing of Natural Gas

Natural gas often is described as a "superior" fuel because it is clean-burning and does not require user storage. Traditionally, however, when price distortions due to regulation are stripped away, natural gas has never commanded as high a price at the wellhead as crude oil. This paradox results from the fact that natural gas has higher long-distance transportation costs as well as higher distribution costs than oil. Natural gas often is discovered during exploration for crude oil, and produced with crude oil. Until sufficient gas reserves are discovered to justify construction of transportation facilities to distant markets, gas production often greatly exceeds local needs, and gas sells at distressed prices. When gas is transported a long distance to markets, net-back prices from the point of competition generally cause gas to sell for less than alternative fuels.

Natural gas prices normally are determined by one of the following methods:

1. The marginal cost of production from previously discovered reserves. This condition prevails whenever there is a large surplus, and producers compete to sell their gas in a limited market.
2. The marginal cost to discover and develop new reserves (when no surplus exists).
3. A net-back price from a distant marginal point of competition (where gas competes with other fuels). This condition normally prevails when local supply greatly exceeds local needs and the gas is shipped to distant markets.

The first condition results in the lowest price. The second condition may allow (require) a higher price than the third. However, when large volumes of gas are transported long distance from a producing area, net-back pricing may either set a limit on the price of gas or pull it higher.

Gas reserves discovered in the Cook Inlet area were large compared with local needs, but were not sufficient to justify construction of a pipeline to distant markets. As a consequence of the large gas surplus, Anchorage area electric and gas utilities have been able to purchase gas on long-term contracts at low cost in a buyer's market. In an attempt to obtain a higher price for their gas, Cook Inlet producers constructed two export facilities. One facility liquefies the gas and ships it to Japan as liquefied natural gas (LNG); the other facility converts gas to urea and ships the urea to the U.S. West Coast and foreign markets. Currently these two facilities consume about two-thirds of the gas produced from Cook Inlet gas fields, excluding field use and losses. However, reserves are still large compared with local needs, and producers have not yet obtained the market power to substantially raise prices.

Present gas contracts in Alaska were negotiated in a buyer's market. Future gas contracts will more likely be negotiated under less ideal conditions from the buyer's point of view, although it is possible that the reserve/production (R/P) ratio in the Cook Inlet area may, as a result of new discoveries, remain high enough to keep prices low.

### B.3.3 Future Price of Natural Gas

There are four possible scenarios of events that could result in somewhat different gas prices in the Railbelt area. These are:

1. Completion of the Alaskan Natural Gas Transportation System (ANGTS) as currently proposed. (This would make natural gas available in the northern Railbelt area.)
2. Completion of a gas pipeline to the Gulf of Alaska and construction of LNG facilities for shipment to Japan or the U.S. West Coast.
3. North Slope gas not available to the Railbelt area but facilities are constructed to export additional volumes of Cook Inlet gas.
4. North Slope gas not available to the Railbelt and no additional facilities are constructed to export additional Cook Inlet gas.

Under the first two scenarios, the adequacy of supply is not a factor, and price is the only consideration relative to whether or not gas should be used for power generation. Under the last two scenarios, both price and adequacy of supply are considerations.

#### B.3.3.1 Completion of the ANGTS

If the ANGTS is completed, North Slope gas will compete with residual fuel oil for industrial markets in the northern United States. The cost of gas in the Fairbanks area will be the net-back price at the marginal point of competition, likely in the Chicago area. It should also be equal to the North Slope wellhead price (determined on a net-back basis) plus the cost of transportation to the Fairbanks area. Under present market conditions and projected costs of the ANGTS, the net-back price to Fairbanks would be negative--which is why plans for the pipeline have been "temporarily" delayed. If projected transportation costs do not decline significantly, or if oil prices do not rise appreciably, then the "temporary" delay could extend for several decades.

Assuming that the North Slope producers will not agree to sell their gas until the net-back price is positive, present transportation cost projections require market prices of approximately $10 per thousand cubic feet (Mcf) (in 1983 dollars) to ensure marketability of the gas and construction of the pipeline. In such a case the net-back price at Fairbanks would likely be close to $5.00 per Mcf, or higher. However, the Incentive Rate-of-Return (IROR) regulation adopted by FERC provided a strong incentive for the Applicant to inflate the cost estimates. It is quite possible that under the changed market circumstances the Applicant and producers will now discover methods to reduce the cost of construction. Tussing et al. (1983) discuss such a possibility. In addition to the possibility of building a pipeline at less cost than currently projected, the cost per Mcf transported could also be reduced if additional reserves are discovered on the North Slope and the size of the pipeline is increased to handle a large volume.

Any projection of net-back prices in Fairbanks following completion of the ANGTS at this point in time is speculative. However, considering the possibilities for reducing costs, an initial net-back price as low as $3.00 per Mcf or less seems conceivable. Although high compared with current gas prices paid by Railbelt utilities, such a price would be appreciably less than alternative fuel prices, and could allow electric power generation at considerably less cost than is likely to be supplied by any other means. Even if cost reductions are not possible, and the net-back price would be as high as indicated by current price projections, power could still be generated at less cost than is likely to be supplied by any other potential source of power.

If one assumes that the ANGTS (or an equivalent pipeline) will be constructed, when is it likely to be completed? If cost reductions are not possible, then the projected pipeline is unlikely to be completed prior to gas prices rising to approximately $10 per Mcf in the Midwest industrial market (expressed in 1983 dollars). This is unlikely to happen before oil prices rise to approximately $60 per barrel (in 1983 dollars), which could be a long time in the future. If substantial pipeline cost reductions are possible, and additional reserve discoveries allow transportation of greater volumes to achieve economies of scale, then a market price of $6 to $7 per Mcf might be sufficient to provide an economic incentive to construct a pipeline. This would require oil prices of $35 to $40 per barrel. If FERC oil price projections are correct, it could be well into the 21st Century before such an oil price is reached. Although oil prices could rise above those projected by FERC, there appears sufficient doubt concerning future oil prices to cast considerable uncertainty on the potential availability of North Slope gas as a potential fuel for power generation in the Railbelt.

### B.3.3.2 Completion of Gas Pipeline to Alaskan Gulf and Construction of LNG Export Facilities

Should the gas pipeline be completed, gas would become available in essentially unlimited quantities in both the Fairbanks and Anchorage areas. The net-back price in Fairbanks would be the same as if the ANGTS were constructed, since it would still be equal to the net-back wellhead price plus the transportation cost to Fairbanks. The cost in the Anchorage area could be as low as $4 per Mcf or less, although this, too, is speculative. The principal difference from the ANGTS case is that liquefaction and transportation costs to Japan could be less than transportation costs to Chicago, which could allow an LNG project to become economic at a lower world oil price, and hence sooner, than for the ANGTS case. However, considering the problems LNG projects have had recently, and the risk that would be involved with a project of the magnitude necessary to market the large volumes of North Slope gas within a period of time that the sponsors would consider to be a reasonable market life, the prospects for completion of a pipeline to transport North Slope gas to the Alaskan Gulf may be even more remote than the prospects for the ANGTS.

### B.3.3.3 Construction of Facilities to Export Additional Volumes of Cook Inlet Gas

A plan to export Cook Inlet gas to the U.S. West Coast has been actively considered and is still pending. Two California utilities and their subsidiaries, PacAlaska LNG and PacIndonesia LNG, filed applications with the Federal Power Commission (now FERC) in 1974. The utilities have defended their application against challenges on siting, environmental, economic, and safety issues, and the application is still pending before the FERC (Docket 75-140). However, the Indonesian reserves originally dedicated to the project have been relinquished and recent LNG sales from Indonesia have been at prices that could make export to the United States uneconomic. In addition, the option period for the 950 billion cubic feet (Bcf) of Cook Inlet gas dedicated to the contract has expired and the producers can now sell the gas to other bidders should they so desire (in fact, some gas appears to have been sold recently). Further, under the presiding Administrative Law Judge's initial decision (August 13, 1979, Docket CP75-140), Phase 1 of the project cannot be authorized until 1.6 Tcf of proven reserves are dedicated to it. Phase 2 (contemplated to start a year after Phase 1) can be authorized only when another 1.0 Tcf are dedicated to the project. The 2.6 Tcf required represent only 78% of the project's requirements. Thus, the total requirements for the project are approximately equal to the present proven reserves in the Cook Inlet area.

Currently, the necessary reserves are not dedicated to the project, declining oil prices are inhibiting sale of the gas in California, and there is still strong opposition to the project there. As a consequence, the short-term prospects of initiating the project certainly are not encouraging. However, conditions could change, and the PacAlaska project (or a similar project) could provide effective competition to electric utilities in bidding for additional volumes of Cook Inlet gas. In any such bidding, the consortium wishing to export the gas would have a distinct advantage, since they could offer contracts to the producers for much larger gas volumes.

If large additional reserves are discovered in the Cook Inlet and export facilities are authorized, the likely net-back price in Alaska theoretically could be quite low. A producer might consider even a wellhead price of less than $1 per Mcf preferable to leaving the gas shut in. However, at present the necessary reserves are not available, and prices will have to rise above current levels to ensure exploration.

### B.3.3.4 No Additional Facilities for Export of Cook Inlet Gas

The condition of no additional facilities being built for export of Cook Inlet gas is likely if no new gas reserves are discovered, or if additional reserves are not discovered at a sufficiently rapid rate to justify new export facilities, or if gas and oil prices are not sufficient to justify liquefaction of the gas and its transport as LNG. If oil prices fall, it may be close to a decade before the economics of LNG export begin to look favorable again. If so, the electric utilities may be successful in obtaining contracts for gas previously dedicated to PacAlaska. However, they will have to compete with the existing LNG and urea plants in bidding for the gas. Such competition for uncommitted gas should cause gas prices to rise, likely resulting in additional exploration. What would happen then would depend on the results of the exploration. If very large volumes were discovered, there would likely be sufficient gas to supply both the local market and an export market. In such a case, adequate quantities of gas should be available for electric power generation at relatively low net-back prices. If sufficient gas were discovered to justify export, but not enough for both export and the local market, the producers likely would opt for the larger volumes of the export market. In this case, gas might not be available for power generation. If insufficient gas is discovered to justify export facilities, there could still be sufficient gas to supply local needs well into the 21st Century. In such an event, the price of the gas would depend on the magnitude of reserves relative to consumption. With reserve/production (R/P) ratios greater than about 15/1, gas prices would be low (relative to oil prices). If R/P ratios fell below about 15/1, prices would start rising toward equivalent oil prices. This in turn would stimulate additional exploration, which, depending on results, could cause gas prices to decline.

### B.3.3.5 Future Gas Prices

From the above discussion, it should be apparent that predicting future gas prices in the Railbelt is even more difficult and uncertain than predicting future oil prices. It seems likely that gas prices in the Railbelt will continue to be less than oil prices. What is not certain is how much less, and if sufficient gas will be available for extended use in electric power generation. On the other hand, there seems to be an excellent possibility that the necessary volumes of gas will be available, and at a price sufficiently low to be the least expensive fuel for electric power generation. This, of course, is Alaska's current dilemma. Opting to use gas for power generation could be expensive if sufficient volumes of gas do not become available when needed. Conversely, choosing any other alternative could result in much higher power costs than necessary, should gas be available.

FERC's gas price projections are based on an assumption that sufficient volumes of gas will be discovered in the Cook Inlet to meet the future power requirements of the lower-Railbelt area, and that the electric utilities will be able to obtain several contracts for such gas. The price projections are higher than net-back prices should be for decades, but eventually are projected to be somewhat lower. While the Staff considers its gas price projection to be reasonable, and sufficient to ensure additional exploration, there is considerable uncertainty in both the underlying assumption of gas availability and the gas price projections.

## B.4 COAL

Because the only significant market for coal within the Railbelt is as a boiler fuel for production of electricity, it does not compete with electricity as an end-use energy source. Furthermore, unlike petroleum fuels and natural gas, coal as an energy source is not linked as directly to the price of crude oil. The reason that this has been and will likely continue to be the case is that coal is not a close substitute for oil. The major uses to which coal is likely to be put are the conventional ones--as a boiler fuel for producing industrial process heat and for powering steam turbines for generating electricity by the utility industry. It is the latter use that is the internal market for coal within the Railbelt. The export market for the Railbelt's coal will likely entail both uses for this resource. The developing export market in the near term is, however, as a fuel used in generating electric power.

Within the Railbelt, coal will compete with other sources of electric power generation--residual fuel oil, distillate fuel, natural gas, and hydroelectricity. Even here, however, coal is not a close substitute in certain applications. Coal can only be used in plants using steam as the prime mover. Thus, it is not as well suited to providing peaking or load-following generation. Coal transportation and fuel-handling facilities typically require significant investments, and there are emissions problems with combustion of coal that dictate constraints on its use in electric generation.

The minimum scale coal-fired generating plants foreseen for the Railbelt area are on the order of 200 megawatts (MW). Plants this size constitute significant increments to the stock of total generating capacity in the region and would require substantial lead times to construct. The decision by a utility in the Railbelt to invest in such capacity is thus a major one, and no coal plants are currently under construction. Therefore, internal Railbelt coal consumption faces an upper bound during the present decade, as determined by the fuel requirements of existing capacity.

The export market, on the other hand, does not suffer from the same constraints. First, there are industrial concerns, as well as utilities, that are potential customers. Second, much of the current interest by utilities stems from their decisions to convert existing capacity from alternative fuels to coal-fired generation. The lead times for such conversions are not as great as those for new plant construction.

It is this fuel conversion activity that is indicative of the manner in which coal markets are indirectly tied to the price of world oil. The industrialized nations of the world saw the costs of making coal a substitute for other fuels (particularly petroleum fuels) suddenly fall relative to the costs of continued dependence on those other fuels. This change was, of course, due to the escalation in the price of world oil, beginning in 1973. Added to the price escalation, however, was the uncertainty of oil supplies for a number of major industrialized countries. Thus, initiatives were undertaken by some to diversify their reliance on alternative energy sources. This has had the impact of increasing the worldwide demand for coal, and prices have climbed as a result, although not nearly as much as prices for petroleum fuel and gas. This represents the major link between coal markets and the price of crude oil. If crude prices climb, then the economic potential for substitution of coal for both oil and gas will continue to increase; the market for coal will expand, and there will be upward pressure on the price of coal. The converse is equally true and, perhaps, more likely.

With respect to the export market for Alaskan Railbelt coal resources, the same economic forces are at work. The industrialized nations looking to substitute alternative fuels for their uncertain supplies of crude oil are the Pacific Rim countries of Japan and South Korea. Coal has been one of the fuels these nations have chosen to use as substitute, and currently they import coal from South Africa, Australia, Canada, China, and the contiguous United States. These other sources of supply, as well as potential supplies from mines being opened in eastern Siberia, have made for substantial competition in Alaska's attempts to expand its Pacific Rim exports.

Should the market develop for Railbelt coal exports, then the export price that coal commands will constitute the real cost of consuming that fuel locally. The outlook for such expansion is mixed. First, the competition among coal suppliers to the Pacific Rim is substantial and will increase in the near future. Second, the motivating factor for the diversification away from petroleum and into coal, among other fuels, has diminished measurably during the last 18 months as the outlook for real escalation in world prices has moderated and the prospects for falling crude prices have become reality. Thus, the value of the coal available for electricity generation within the Railbelt is likely to be the cost of extracting and transporting it to the generator. Given the vast supplies available to serve both the domestic as well as export markets, there is no persuasive reason to anticipate that the real costs of supplying the coal will escalate.

## B.5 PEAT

Alaska contains permafrost-free peat deposits estimated at 27-107 million acres [109-433 billion square meters ($m^2$)] that represent more than half the total U.S. peat reserves. Forty-seven million acres (190 billion $m^2$) are located 5 feet (ft) [1.5 meters (m)] or less from the surface. Some 30 million acres (121 billion $m^2$) show promise as an energy resource. A 1980 survey by the U.S. Department of Energy investigated large peat fields located in three separate locations within the Railbelt (the Matanuska-Susitna Valleys, Fairbanks, and the Kenai Peninsula) and concluded that they constituted a potentially valuable source of fuel, particularly for remote communities. According to the Division of Energy and Power Development of Alaska, peat for use in steam electric generation plants appears competitive with coal priced at $2.00 per million Btu; however, developmental and operational issues associated with prototype plants would have to be addressed before commercial plants could be contemplated.

## B.6 GEOTHERMAL ENERGY

Several areas of Alaska have geothermal potential, particularly areas near or within the Railbelt. To date, however, only a fraction of that potential has actually been tapped--in the form of hot springs used for space heating and resort spas. Such springs are located at Manley Hot Springs, Chenea Hot Springs, and Tolovana. A number of geothermal sites are being investigated for their thermal energy and electric generation potential. Areas containing hot igneous systems, in or bordering on the Railbelt, include Mt. Drum, Mt. Wrangell, and Double Peak. In most cases, however, geothermal heating systems currently are not economically competitive with conventional heating alternatives. Drilling costs are extremely high, and the resource value of geothermal energy is critically dependent on the proximity to the end user. The heat distribution system for these wells can increase costs by a factor of five or six. According to the Division of Energy and Power Development, estimates of heat distribution piping average about $150/ft ($500/m), so even a small village of 50 residences, each about 150 ft (50 m) apart, would pay more than $1 million for the distribution system alone.

## B.7 TIDAL POWER

Tidal energy is potentially available in Alaska, primarily in the Cook Inlet areas of the Railbelt, where the height of tidal variation and the volume of tidal flow are sufficient to make tidal power projects practical. Tidal energy can be converted into electricity by capturing both the potential energy associated with the height of tidal fluctuations and the kinetic energy associated with the flow of tidal water in and out of a contained area. If all the potential and kinetic energy of Cook Inlet were captured and made available to users in the Railbelt area of Alaska, it would provide electric power for the entire region well beyond the year 2050. A study prepared by Acres American identified 16 sites in the Cook Inlet area whose total energy capacity exceeded 186,000 gigawatt-hours (GWh), with a total potential capacity of 73 GW. The Division of Energy and Power concluded, early in 1983, that development of commercial tidal power is more than a decade away.

## B.8 SOLAR ENERGY

Solar energy is not regarded as a potential source of power within the Railbelt, either in the form of photovoltaic energy or solar heat. Despite the long hours of daylight that characterize the summers in the Railbelt, the periods of greatest energy need are during the winter, when solar energy production in Alaska would be negligible. To justify even the projected low investment costs in solar devices, it would be necessary for such equipment to make substantial contributions to the supply of energy when energy requirements are greatest.

## REFERENCES FOR APPENDIX B

Tussing, A.R. 1983. ARTA energy insights. Pacific Oil Insights. (November).

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# DRAFT ENVIRONMENTAL IMPACT STATEMENT
# SUSITNA HYDROELECTRIC PROJECT, FERC NO. 7114

## APPENDIX C
## ENERGY CONSERVATION

Prepared by

Federal Energy Regulatory Commission Staff

# APPENDIX C. ENERGY CONSERVATION

## C.1 ENERGY CONSERVATION AND THE NATIONAL ENERGY ACT OF 1978

Provisions of the National Energy Conservation Act (NECA) of 1978 may have relevance to demand forecasts and other matters with which this environmental impact statement is concerned. The NECA provides for the following selected items:

1. Utility Conservation Program for Residences. A program requiring utilities to offer to their residential customers energy audits that would identify appropriate energy conservation and solar energy measures and estimate their likely costs and savings. Utilities also will be required to offer to arrange for the installation and financing of any such measures.
2. Weatherization Grants for Low-Income Families. Extension through 1980 of the U.S. Department of Energy (DOE) weatherization grants program for insulating lower-income homes at an authorized level of $200 million in FY 1979 and 1980.
3. Solar Energy Loan Program. A $100 million program administered by the Department of Housing and Urban Development (HUD) that will provide a support for loans of up to $8,000 to homeowners and builders for the purchase and installation of solar heating and cooling equipment in residential units.
4. Energy Conservation Load Programs. A $5 billion program of Federally supported home-improvement loans for energy conservation measures; $3 billion for support of reduced-interest loans up to $2,500 for elderly or moderate income families, and $2 billion for general standby financing assistance.
5. Grant Program for Schools and Hospitals. Grants of $900 million over the next three years to improve the energy efficiency of schools and hospitals.
6. Energy Audits for Public Buildings. A two-year, $65 million program for energy audits in local public buildings and public care institutions.
7. Appliance Efficiency Standards. Energy efficiency standards for major home appliances, such as refrigerators and air conditioning units.
8. Grants and Standards. Grants and standards for energy conservation in Federally assisted housing.
9. Loans. Federally insured loans for conservation improvements in multifamily housing.
10. Solar Demonstration Program. $100 million for a solar demonstration program in Federal buildings.
11. Conservation. Conservation requirements for Federal buildings.
12. Solar Photovoltaic System. $98 million for solar photovoltaic systems in Federal facilities.
13. Objectives and Reports. Industrial recycling targets and reporting requirements.
14. Labeling. Energy-efficient labeling of industrial equipment.

## C.2 CONSERVATION OF OIL AND NATURAL GAS--THE POWERPLANT AND INDUSTRIAL FUEL USE ACT OF 1978

The Powerplant and Industrial Fuel Use Act (PPIFUA) of 1978 has as its principal objective the conservation of oil and natural gas supplies. The following provisions of the PPIFUA should effect substantial reductions in the nation's oil and natural gas consumption and should accelerate the conversion of oil-fired and gas-fired electric utility plants to coal-fired facilities:

1. Prohibition of New Oil- and Gas-Fired Boilers. Prohibition against use of oil or natural gas in new electric utility generation facilities or in new industrial boilers with a fuel heat input rate of 100 million Btu's per hour or greater, unless exemptions are granted by DOE.

2. Restrictions on Existing Coal-Capable Large Boilers. DOE authority to require existing coal-capable facilities, individually or by categories, to use coal and to require non-coal-capable units to use coal/oil mixtures.

3. Restrictions on Users of Natural Gas for Boiler Fuel. Limitation of natural gas use by existing utility power plants to the proportion of total fuel used during 1974-1976, and a requirement that there be no switches from oil to gas. There is also a requirement that natural gas use in such facilities cease by 1990 (with certain exceptions).

4. Pollution Control Loan Program. An $800 million loan program to assist utilities to raise necessary funds for pollution control.

5. Supplementary Authority. Supplemental authority to prohibit use of natural gas in small boilers for space heating and in decorative outdoor lighting and to allocate coal in emergencies.

6. Other Provisions. Funding of several programs to reduce negative impacts from increased coal production, energy impact assistance, and railroad rehabilitation.

## C.3 THE PUBLIC UTILITY REGULATORY POLICIES ACT OF 1978--RATE DESIGN, LOAD MANAGEMENT, AND REDUCTION OF THE GROWTH RATES IN THE DEMAND FOR ELECTRIC POWER

The Public Utility Regulatory Policies Act (PURPA) of 1978 is directed at reducing the growth rate in the demand for electric power, the reduction in the need for new generating capacity, and conservation of fuels in short supply. The PURPA provides for the following:

1. Rate Design Standards. Eleven voluntary standards on rate design and other utility practices for consideration by state regulatory authorities and non-regulated utilities--including time-of-day-rates, seasonal rates, cost of service pricing, interruptible rates, prohibiting of declining block rates, and lifeline rates.

2. Consideration of Rate Design Standards. A requirement that state regulatory authorities and utilities consider each standard within prescribed periods and determine if the standards are appropriate for conservation, efficiency, and equity, as well as consistent with state laws. Voluntary guidelines with respect to the standards may be prescribed.

3. Retail Policies for Natural Gas Activities. Consideration by gas utilities of two standards--i.e., service termination procedures and advertising expenditures. A DOE study of the best rate design for gas utilities is also required.

4. Cogeneration. FERC rules favoring industrial cogeneration facilities and requiring utilities to buy or sell power from qualified cogenerators at just and reasonable rates.

5. Wholesale Provisions. FERC authority to require interconnections of electric power transmission facilities, to order utilities to provide transmission services between two noncontiguous utilities, and to report anticipated power shortages; FERC review of automatic rate-adjustment clauses.

6. Aid to States and Consumer Representation. Funding to assist state implementation and consumer intervention in proceedings.

7. Small Hydroelectric Facilities. Loan program to aid development of small hydroelectric projects.

8. Significant Miscellaneous Provisions. Authorization funding for the National Regulatory Research Institute; establishment of three additional university coal research laboratories; rules for conversion from use of natural gas to use of less desirable heavy fuel oils; emergency conversion of utilities and other facilities during natural gas emergencies; natural gas transportation policy, and rules for treatment of conserved natural gas.

## C.4 RATE DESIGN AND LOAD MANAGEMENT--THE NARUC RESOLUTION NO. 9 STUDY

A study of rate design and load management as potential expedients for the reduction of demand peaks and the associated need for additional peaking capacity in electric utility systems was initiated in 1974 by the National Association of Regulatory Commissioners (NARUC).

Resolution No. 9, Appendix A (1974), of this Commission called for "a study of the technology and cost of time-of-day metering and electronic methods of controlling peak-period usage of electricity, and also a study of the feasibility and cost of shifting various types of usage to off-peak periods." It resulted in a detailed research plan that focused on shifting and controlling loads in a way that would lessen the growth of peak demand. The ensuing research emphasized the development of time-differentiated rates based on alternative costing methodologies and the evaluation of various direct load control techniques. In mid-1976, NARUC requested a continuation of the research.

A Rate Design and Load Control Study was sponsored by the Edison Electric Institute (EEI), the American Public Power Association (APPA), the National Rural Electric Cooperative Association (NRECA), and the Electric Power Research Institute (EPRI). These sponsors and NARUC encouraged representatives of their groups to participate in the study.

The November 1977 report states that "--the research findings confirm a generally held but heretofore untested hypothesis that load management may yield benefits." The research findings indicate the desirability of load management techniques in some cases, as discussed below.

First, for a small but diverse sample of companies, bulk power supply costs were found to vary markedly by time of day and season. The study established that time-differentiated rates, which reflect these costs much better than non-time-differentiated or seasonally differentiated rates, are administratively feasible.

Second, the study found that customer use of electricity is responsive to time-differentiated rates, although the exact degree of change is uncertain. Whether based on accounting or marginal costs, time-differentiated rates should, therefore, tend to reduce peak demand growth and the average bulk power supply cost. If electricity rates reflect marginal costs or if these rates diverge from marginal costs to recognize that the prices of other relevant commodities (e.g., fuels) are not based on marginal costs, economic logic suggests that the resulting use patterns should conserve society's scarce economic resources. It remains, however, a matter for further research, experimentation, and analysis to determine whether, for individual customers in individual systems, the sensitivity of consumption to price is high enough to yield total benefits commensurate with the total costs of time-differentiated rates.

Third, the research established that direct loan controls have, in selected instances, benefits that exceed their costs. It should follow that individual systems should investigate load controls as a cost-effective method for curbing peak demand growth and the consequent capacity expansion requirement.

The final report on Phase II of the NARUC Study will supposedly emphasize critiques of proposed methodologies applicable to rate design and load management. Results of cost-benefit analyses to be included in the Phase II Report are expected to provide a better understanding of the potential impacts of rate design and load management on future load shapes.

Recognized experts in the field of rate-making and load management were quick to respond to the Phase II Report on the NARUC Study and their comments clearly indicated that the study left many unanswered questions and raised many new ones. Some of these comments appear in the December 1, 1977, issue of "Electrical World," pp. 21-22.

# DRAFT ENVIRONMENTAL IMPACT STATEMENT
# SUSITNA HYDROELECTRIC PROJECT, FERC NO. 7114

## APPENDIX D
## 345-kV TRANSMISSION LINE ELECTRICAL ENVIRONMENTAL EFFECTS

Prepared by
Federal Energy Regulatory Commission Staff

# APPENDIX D. 345-kV TRANSMISSION LINE ELECTRICAL ENVIRONMENTAL EFFECTS

## D.1 INTRODUCTION

Transmission lines of practical design create high electric field gradients at the conductor surface that cause ionization of the surrounding air layers when the field intensity exceeds the breakdown strength of this air. The resulting corona formation on the conductors (along with random gap discharges on other line hardware) gives rise to radio noise, audible noise, and generation of ozone ($O_3$) and oxides of nitrogen ($NO_x$). Corona formation is a function of line voltage, conductor radius, line geometry, conductor surface condition (roughness, adherence of foreign particles, etc.), relative air density, humidity, wind, and precipitation. Corona and its associated audible and radio noise levels increase substantially during periods of foul weather, especially rain. Hence, it is neither practical nor economically feasible to design extra-high-voltage (EHV) lines such that they will never be in corona, as is accomplished at lower voltages, although lines are commonly designed with sufficient conductor size or bundling to limit surface gradients, within the normal operating voltage range, below the critical level at which corona begins to sharply increase.

Energized, load-carrying transmission lines also generate electric and magnetic fields that permeate the surrounding medium and induce voltages and currents in conducting objects in the vicinity, including persons and animals. The question of potential hazards of these fields from a biological and environmental standpoint has been given increasing attention in recent years, particularly with regard to lines designed for operation in the EHV range [345 to 1,000 kilovolt (kV)] and for future lines being considered for operation in the ultra-high-voltage (UHV) range (above 1,000 kV).

In assessing the environmental impact of the expected levels of these electrical effects for the Susitna project 345-kV transmission lines, due recognition should be made of the fact that such lines have been in existence in other parts of the United States for some 30 years now. These lines traverse sparsely settled rural regions as well as high-density populated areas. As a result of this development, the design of these lines with regard to known electrical effects and other environmental aspects has become well established. Furthermore, the 345-kV operating voltage lies near the lower threshold voltage level at which many of the electrical effects associated with higher voltage lines become of marginal significance.

Nevertheless, the Alaska Power Authority (APA) had an analysis made to predict levels of electrical effects from the proposed project transmission lines, calculated using methods developed at Project UHV (Electric Power Research Inst., 1975a). A survey also was made of existing radio and television broadcast signal strengths and ambient radio noise levels along the Anchorage-Fairbanks transmission corridor* for use in evaluating the influence of some of these line-generated electrical effects. In addition, a survey was made of sensitive communication facility locations in the vicinity of the corridor, such as microwave installations and air navigational radio beacons. Recommended minimum separation distances of those facilities from the lines were developed, based on existing guidelines and criteria. This study was performed by APA's consultant, Commonwealth Associates, Inc. (CAI). The results are presented in the "Electrical Environmental Effects Report R-2394" (Commonwealth Assoc., 1982).

The presently planned routes and number of circuits ultimately to be installed as part of the Susitna project 345-kV transmission system are indicated in Figure D-1. The calculations used to develop the predictions of electrical effects discussed in Report R-2394 were based on three single-circuit 345-kV transmission lines on a common 400-foot (ft) [120-meter (m)] right-of-way (ROW), as shown in Figure D-2, operating at a voltage of 362.5 kV. This would be typical of the structure placement for the Knik Arm-Gold Creek section of the Anchorage-Fairbanks transmission corridor. Electrical effects generated by this particular transmission link should be representative of the entire 345-kV transmission configuration ultimately to be installed as part of the Susitna project, and the Report calculations should be conservative due to the multiple-circuit ROW occupancy represented and the upper limit of the normal operating voltage range, 362.5 kV (5% above nominal 345-kV level). Both of these factors tend toward increased intensity of such effects as audible and radio noise, and ozone production.

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*Hereinafter referred to as the "Anchorage-Fairbanks corridor," or simply "corridor" where the meaning is clear from the context.

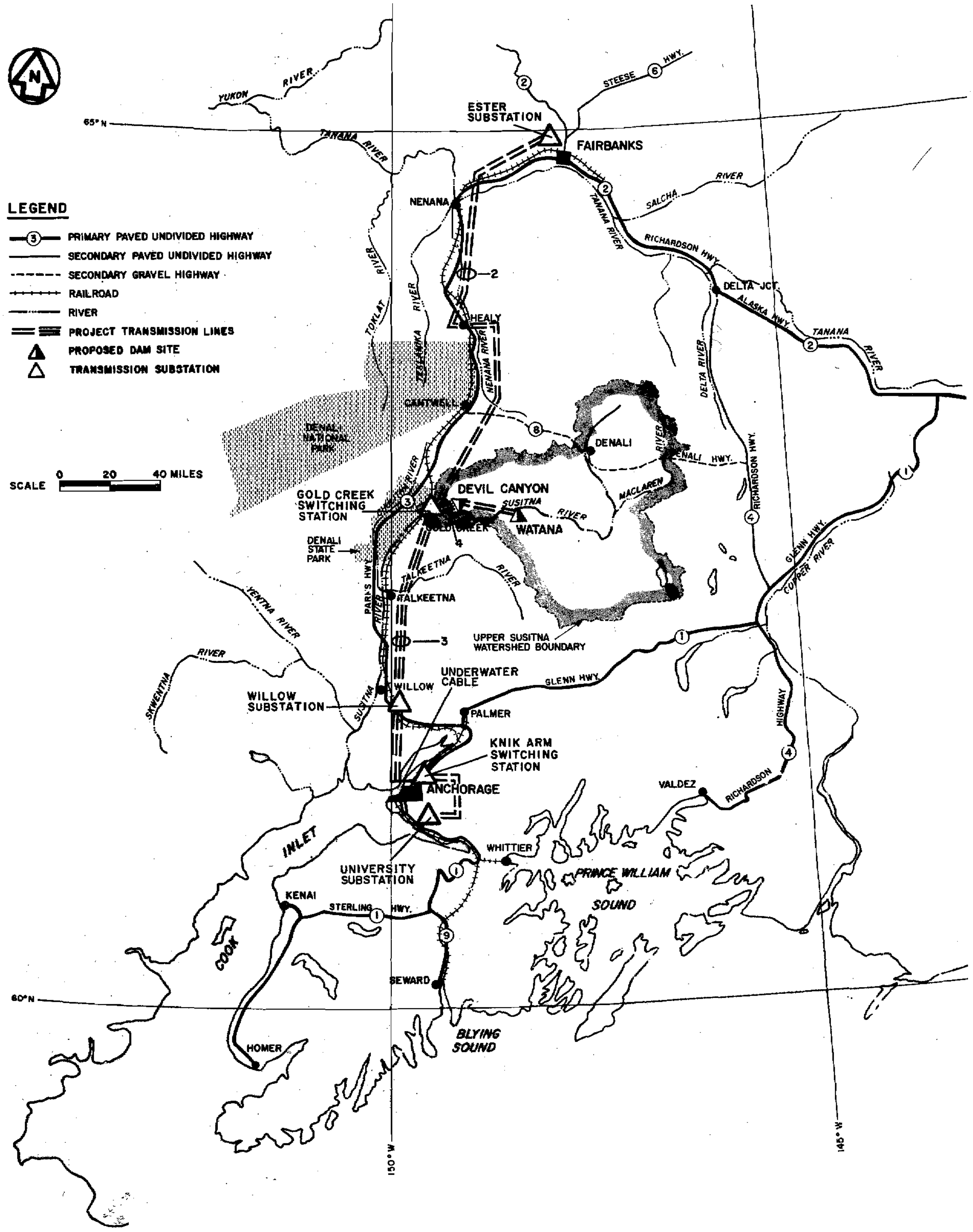
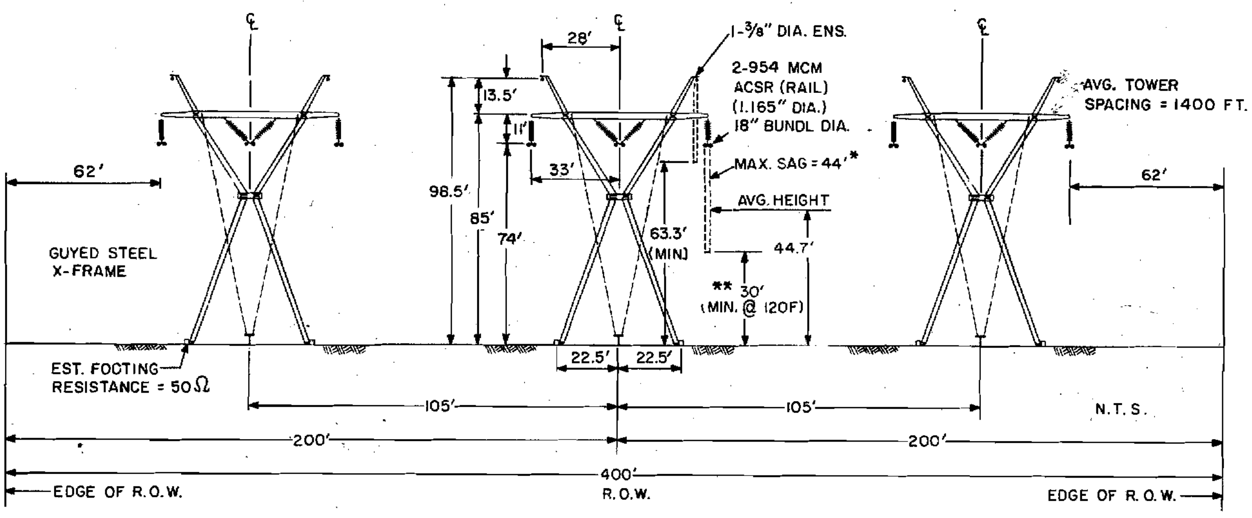


Figure D-1. Susitna Project 345-kV Transmission System (ultimate configuration).



Notes:

- Dimensions indicated are in feet (') and inches ("). 1 ft. = 0.305 m.
- Average Conductor Sag = 37 ft. **Minimum Ground Clearance at RR Crossing = 38 ft.
- The 30-ft minimum phase-to-ground clearance is recommended in the APA Anchorage-Fairbanks Transmission Intertie basic design criteria, dated September 1981, pg. 6 (Prepared by Commonwealth Assoc., Inc.). This will be the design clearance at 120°F. For railroad crossings, this clearance will be increased to 38 ft.
- The 44.7-ft minimum average height is equal to the minimum conductor-to-ground clearance (30-ft) plus one-third the conductor sag. (Transmission Line Reference Book, 345 kV and above, 2nd. ed., 1982, Electric Power Research Inst., pg. 219.) This is the height commonly chosen on which to base line electrical performance design curves, such as radio noise generation.
- The 63.3-ft minimum shield wire height is based on a shield wire sag of 80% of the shown maximum conductor sag (44 ft) (the APA Shielding and Shield Wire Coordination Study for the Anchorage-Fairbanks Transmission Intertie, January 1982, pg. 4.)
- The subconductor and bundle size for the phase conductors and the shield wire size to be used are given in the APA Environmental Assessment Report, R-2422, dated March 1982, pp. 18, 27.
- All other information taken from Application, dated February 1983, Exhibit F (Plates F80, F81), and from the APA structure study for the Anchorage-Fairbanks Transmission Intertie, dated September 1981.

Figure D-2. Typical Tangent or Light-Angle Structure Placement Along Knik Arm-Gold Creek Section of Anchorage-Fairbanks 345-kV Transmission Corridor.

The following sections contain a brief discussion of the nature of the environmental effects produced by transmission line operation, along with an assessment of the environmental significance of these effects, particularly with regard to the relevant parameters of electrical effects calculated for the Susitna project transmission lines in Report R-2394. Guidelines used in making this assessment consisted of material contained in the referenced report, as well as reference information and data on this subject developed by the Electric Power Research Institute (EPRI) and others. The following topics are covered:

- Ozone and other air pollutants generated by transmission line corona,
- Audible noise generated by transmission line corona,
- Radio noise generated by transmission line corona, and minimum separation distances between the 345-kV lines and existing communication towers,
- Electrostatic and electromagnetic field strengths set up by transmission line operation, and related field effects, and
- Line clearances and electrical safety.

As a result of this review, the Staff concurs with the electrical environmental effects analysis and conclusions reached by APA/CAI; i.e., no adverse environmental consequences of a permanent and irremediable nature should result that could be attributed to the operational performance of the 345-kV transmission lines that would be constructed as part of the Susitna project. Specifically, the following qualitative assessment is made:

1. No environmentally hazardous levels of corona-generated ozone or oxides of nitrogen should result from operation of the lines; in fact, the resulting increment to ambient levels due to line operation would likely not even be measurable.

2. Audible noise generated by corona formation on the lines would not be objectionable and would not contribute significantly to ambient noise levels.

3. Corona-generated radio noise would not likely interfere with AM radio broadcast reception at distances greater than 1,000 ft (300 m) from the centerline of the right-of-way even under worst-case weather conditions for noise generation, viz., during rain. No interference at all would be expected for FM radio reception due to its inherent noise rejection capability. Television reception should be unaffected at locations where television reception is presently good. Problems would be expected to arise only rarely, if at all, and mitigative measures could generally be employed to alleviate them on a case-by-case basis (such as by relocating receiving antennas). The routing of the lines would be adjusted as necessary to allow for industry-recommended separation distances from sensitive microwave and other types of communication facilities to avoid potential interference problems.

4. Results of studies on possible biological harm from exposure to electric and magnetic fields are inconclusive at best, and no general acceptance of such a correlation seems to exist among the scientific community (Bridges, 1975; Sheppard and Eisenbud, 1977; Riog, 1979; Electric Power Research Inst., 1982; Mahmoud and Zimmerman, 1982). Inasmuch as the proposed line design conforms to generally accepted and long-established design practice for 345-kV transmission lines, the same normal levels of field intensity at ground level would result from these lines as for all the other numerous existing lines in this class. It is therefore concluded that no reasonable basis for concern exists on this account. Likewise, no shock hazards from induced potentials due to these fields would be expected.

5. The 30-ft (9-m) minimum phase-to-ground clearances are more than sufficient to satisfy the present requirements of the National Electric Safety Code, including the 5 milliampere induced current limit on large vehicles short-circuited to ground under the lines. Again, this conforms to present and long-established design practice for lines in the 345-kV class.

The foregoing conclusions apply for the Susitna lines operated within the normal ±5% limits of their nominal design voltage level, 345 kV. Initially, the first transmission link, currently being constructed along the Anchorage-Fairbanks corridor, will be operated at 138 kV, at which voltage the levels of the foregoing electrical effects should be entirely negligible.

## D.2 OZONE PRODUCTION

Operation of EHV transmission lines of practical design causes the formation of corona around the line conductors. Corona consists of ionized air particles in the adjacent air layers. Corona is formed when the electric field gradient at the conductor surface exceeds the breakdown strength of the adjacent air. Ozone and oxides of nitrogen, by-products of this ionization, add to the ambient atmospheric concentrations of these oxidants. The latter are created by natural processes, primarily by the action of ultraviolet light from the sun on upper atmospheric air layers and on automotive and industrial emissions near the earth's surface. They also are generated by lightning discharges. Ozone is the most important of these products from an environmental standpoint because it comprises 80% to 90% of the atmospheric oxidants (Electric Power Research Inst., 1975b), whether produced from natural or man-made processes. In concentrated form, it is a powerful oxidizing agent with high chemical reactivity.

Ambient levels of ozone generally vary from about 0.01 to 0.03 parts per million (ppm) in rural areas, although concentrations up to 0.10 ppm have been measured in some rural areas (Bonneville Power Admin., 1977). In urban areas, concentrations of 0.10 ppm can be expected, and in some cities, such as Los Angeles, concentrations as high as 0.5 ppm have been measured, apparently due to the high levels of auto emissions and industrial combustion (Bonneville Power Admin., 1977). However, a number of investigations carried out over the past decade, including both field and laboratory test programs, have shown that practically no measurable incremental contribution to ground-level concentration of ozone and oxides of nitrogen result, under any weather condition, in the immediate vicinity of transmission lines designed for operation not only at 345 kV, but also at voltages through 765 kV (Frydman et al., 1972; Scherer et al., 1972; Frydman and Shik, 1973; Fern and Brabets, 1974; Sebo et al., 1975). These results are based on state-of-the-art instrumentation accuracy of 0.001-0.002 ppm. In interpreting these results, it should be kept in mind that ground-level concentrations of ozone and other oxidants are a function of not only the generation rate (whether by natural or man-induced processes), but also the rate of decay and diffusion in the atmosphere. Ozone, for example, is one of the most chemically reactive agents known. It is therefore very unstable and is readily consumable by plants, animals, nitric oxide in the atmosphere, and by other substances, although at different rates. Under normal atmospheric conditions, ozone has a characteristic half-life of ½ to 1 hr (Frydman and Shik, 1973). Its rates of generation and decay are functions of temperature, humidity, initial concentration level, sunlight, rainfall, and other factors. As a result, ambient ozone concentrations are subject to large daily variations of as much as 0.08 ppm, with the highest concentrations occurring during daylight hours and the lowest at night (Electric Power Research Inst., 1982). The ground-level concentration of ozone near transmission lines is also a function of wind speed, direction of wind relative to the line direction, and line height. Transverse winds result in greater diffusion, and the ground-level concentration diminishes with increases in wind speed and line height. It follows that ground-level concentrations of ozone and other oxidants generated by transmission line operation are not cumulative over time.

Ozone production increases with an increase in corona level, which for a given line design is a function of the operating voltage, surface conditions of the conductor, and atmospheric conditions. As has been indicated, as long as a line is operated within its design voltage limits, the maximum corona generation, and therefore ozone production, is fairly predictable. But a sufficiently high overvoltage, say, on a long line under light loading conditions, could exceed the critical level at which corona generation begins to increase much more sharply with voltage.* Under these conditions, the ozone generated by the line would increase correspondingly. However, sufficient reactive power sources are normally provided for transmission system operation to maintain the voltages within fairly close tolerances (about ±5%), primarily for equipment protection and other operating reasons, but which also attends to the matter of ozone production. However, with the miniscule production of ozone at normal operating voltage, it is unlikely that any degree of sustainable steady-state operating voltage would result in an environmentally objectional production of ozone from the line.

Corona loss in foul weather, particularly rain, is typically at least one order of magnitude greater than the corresponding fair weather loss on a given line, resulting in increased ozone production. However, field tests showed that the actual ozone concentration at ground level under rain conditions decreased, indicating that the accelerated decomposition of the ozone caused by the increased moisture more than compensated for the increased production rate due to the increased corona level (Fern and Brabets, 1974).

The toxicological effect of ozone on humans has been investigated, and a maximum allowable concentration of 0.1 ppm for eight hours continuous exposure per day, five days per week has been established by the American Conference of Government Industrial Hygienists (Fern and Brabets, 1974). However, the EPA air quality standards allow a maximum concentration of ozone of 0.12 ppm, not to be exceeded more than one day per year (U.S. Environmental Protection Agency, National Primary and Secondary Ambient Air Quality Standards for Ozone, 40 CFR 50.9). Reports of studies performed by EPA (Bonneville Power Admin., 1977) and others indicate that human respiratory tract irritation occurs at ozone levels between 0.5 and 0.7 ppm. Small laboratory animals developed chronic bronchitis when exposed to doses of 1 ppm for one year. Insofar as its effect on vegetation and ground foliage is concerned, studies on selected species known to be sensitive to such effects showed that a concentration of 0.07 ppm lasting four hours was

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*Overvoltages from switching surges and lightning strikes could also cause this, although they are much too transitory in nature to be of significance with regard to ozone production.

required to damage eastern white pine, and concentrations of 0.10-0.12 ppm lasting two hours were required to damage sensitive varieties of alfalfa, spinach, clover, oats, radish, corn, and beans (Bonneville Power Admin., 1977). The levels cited are well above the minute incremental concentrations caused by EHV transmission line operation in their immediate vicinity, but are not always above the ambient levels of ozone in some areas, as previously indicated.

In summary, based on results of recent investigations, it appears that no significant levels of ozone would be produced by the project 345-kV transmission lines, even for as many as three 345-kV lines on the same right-of-way. Existing oxidant limits imposed by Federal and state agencies should create no difficulties for these or other EHV transmission lines, although existing ambient levels are close to or exceed the limits being set in some locations.

## D.3 AUDIBLE NOISE

High-voltage transmission lines generate audible noise as a result of corona formation along the line conductors. The noise produced consists of two principal components: (1) a broadband noise created by the random pulse discharges in the air at the surface of the conductor, and (2) a low-frequency pure-tone noise (hum) predominantly at a frequency of 120 Hz and created by the alternate attraction and repulsion of positive and negative ions (generated by the corona) under the action of the alternating electric field. The main contributor to annoyance is from random (broadband) noise in the 1-8 kHz range (Electric Power Research Inst., 1982).

Audible noise, like the corona that produces it, depends significantly on prevailing weather conditions for a given line geometry and operating voltage. A person standing under or near a line built to acceptable design standards for foul weather corona probably would not be aware of any audible noise in fair weather unless he were listening for it. Any appreciable air turbulence probably would mask this effect. The fair weather noise level is, therefore, generally of no concern (Electric Power Research Inst., 1982), typically lying considerably below that for foul weather, particularly for rain when audible noise generation is highest due to the localized high electric field gradients formed at the water droplets. However, in assessing the potential disturbing effect of transmission-line-generated audible noise, account must be taken not only of the generation rate, but also of the rate of attenuation of the noise with distance from the line, the absorption of sound energy by the surrounding air, the masking effect of other environmental noise sources, and the relative level of public activity and degree of exposure to the noise under weather conditions that produce high noise levels (rain and intense fog). The sound pressure level of the noise varies inversely as the square of the lateral distance from the line due to the divergence of the sound pressure waves (Electric Power Research Inst., 1982). However, the actual attenuation is somewhat greater than this due to atmospheric absorption, which increases with frequency and is also a function of air temperature and relative humidity. During rain, background noise from wind, thunder, and the rain itself, combined with reduced outdoor public activity and the reduced possibility of direct public exposure to the noise through open windows near the line, all would tend to reduce any disturbing effect of the increased noise generation rate. However, at other times, such as during periods of snow, heavy fog, or immediately after a rain, the outdoor environment often becomes quiet, making the increased audible noise generated by the water drops on the line relatively more evident, even though the noise generation rate is somewhat less than during heavy rain. This "wet conductor" condition closely corresponds to the mean noise level in rain (Electric Power Research Inst., 1982). For these reasons, it is often used for assessing the audible noise performance of AC transmission lines, at least in the absence of more comprehensive statistics on audible noise.

The range of sound pressure levels that the human ear can detect and assimilate is on the order of 1,000,000/1. For this reason, these levels are customarily expressed on a logarithmic scale by relating the measured sound pressure from a source, in micropascals (μPa), to a reference sound pressure of 20 μPa (where 1 μPa = 1 μN/m$^2$ = 10$^{-5}$ μbar) and taking 20 times the logarithm to the base 10 of this ratio, i.e.,

$$\begin{array}{l}\text{Sound pressure level (SPL)} \\ \quad\text{in decibels (dB)}\end{array} = 20 \log_{10} \frac{\text{SPL (in } \mu\text{Pa)}}{20\ \mu\text{Pa}} \text{ dB.} \qquad \text{(D-1)}$$

Some common noise levels are given in Table D-1.

The range of frequencies audible to the human ear is about 15-20,000 Hz. However, human hearing is more sensitive to the range of frequencies in which most speech information is carried, or from about 500-4000 Hz, and falls off fairly sharply beyond these limits (Electric Power Research Inst., 1982). In measuring broadband noise, it is therefore customary to apply weighting to the different frequencies contained in the monitored noise in accordance with this characteristic such that the overall sound pressure level measured will relate as closely as possible to the ear's perception of the sound. This is commonly referred to as the A-weighting network in standardized sound level instruments, and the corresponding meter scale reading is referred to in units of dB(A), as in Table D-1. Standardized B, C, and D weighting networks also are available that have different frequency response characteristics suitable for measuring impulsive and other types of sound, some of which have been advocated for measuring transmission line noise. However, the A-weighted network is by far the most widely used noise-rating scale.

Table D-1. Noise Levels of Typical Noise Sources

| Noise Source | Operator†[1] [dB(A)] | Community†[2] [dB(A)] |
|---|---|---|
| Air conditioners | 70-96 | 52-77 |
| Power lawn equipment | 80-95 | 59-85 |
| Chain saws | 103-115 | 64-86 |
| Automobiles | 55-87 | 77-87 |
| Snowmobiles | 100-116 | 78-88 |
| Motorcycles | | |
| Less than 240 cc | 90-105 | 70-90 |
| Greater than 240 cc | 95-115 | 78-95 |
| Trucks | 70-100 | 70-95 |

†[1] Operator: Noise levels measured at the position of the operator of the noise source.

†[2] Community: Noise levels measured at locations 50 ft (15 m) from the center line of the path of the source or 50 ft (15 m) from the source.

Source: Anonymous (1974).

Inasmuch as many sounds, including transmission line noise, have sound pressure levels that are not constant with time, they cannot adequately be characterized by a single value of SPL. To deal with this problem, statistical correlation with time is often resorted to, using indices such as $L_5$, indicating the A-weighted sound level that is exceeded only 5% of the time; $L_{50}$ for A-weighted sound levels exceeded 50% of the time, etc. (Electric Power Research Inst., 1982). (The $L_5$ level corresponds to heavy rain generation, and the $L_{50}$ corresponds to wet conductor generation.) If a noise is intermittent or fluctuating, an equivalent sound level, $L_{eq}$, is used, defined as the energy average (usually A-weighted) of a varying sound over a specified period of time; i.e., a steady sound having the same level as the $L_{eq}$ would have the same sound energy as the fluctuating sound. This is a useful measure in connection with transmission line noise measurements; however, it does not account for the more annoying effect of noise at night. For this purpose, a modified $L_{eq}$ has been developed, designated as $L_{dn}$ for day-night level (U.S. Environmental Protection Agency, 1974). It adds a 10 dB penalty for noise occurring between the hours of 2200 and 0700, and is calculated as:

$$L_{dn} = 10 \log_{10} \frac{1}{24} [15 (10^{L_d/10}) + 9 (10^{(L_n + 10)/10})] \text{ dB(A)} , \qquad \text{(D-2)}$$

where

$L_d = L_{eq}$ for daytime hours (0700-2200) and

$L_n = L_{eq}$ for nighttime hours (2200-0700).

Transmission line audible noise levels can be estimated for design purposes based on empirical formulas developed from laboratory and field measurements that correlate such factors as conductor geometry, tower design, conductor surface gradient, and distance from line to the measuring point to determine a value for sound pressure level in dB(A). The audible noise levels for the project 345-kV lines have been calculated using methods developed at Project UHV (Electric Power Research Inst., 1975a). The calculated noise levels at the edge of a right-of-way containing three single-circuit 345-kV lines under heavy rain and wet conductor conditions, and at maximum operating voltage of 5% above normal, or 362.5 kV, are given in Table D-2. Estimated fair weather levels (inaudible) also are given. Using the wet-conductor levels as a measure of the line audible-noise performance, the formulation of Eq. D-2 was used to calculate an equivalent day-night level, $L_{dn}$, at the edge of the right-of-way under the very conservation assumption that the conductors will remain wet for 24 hours, i.e., $L_d = L_n = 44$ dB(A). Allowing for the 10 dB nighttime penalty incorporated in Eq. D-2, this resulted in a day-night average ($L_{dn}$) of 50.4 dB(A). These computer-calculated numbers, taken from Report R-2394, are in reasonably close agreement and are conservative with respect to corresponding values of 41.7/48.1 dB(A) computed by the FERC Staff using manual methods based on design curves and formulas given by the Electric Power Research Institute (1982).

Table D-2. Calculated Audible Noise Levels for the Anchorage-Fairbanks Corridor with Three 345-kV Lines on a Common Right-of-Way Operating at 362.5 kV

| Weather Conditions | $L_{eq}$ at Edge of Right-of-Way [dB(A)]†[1] |
|---|---|
| Heavy rain | 54 |
| Wet conductor | 44 |
| Fair weather | Inaudible†[2] |

†[1] 200 ft (61 m) from centerline.

†[2] Estimated.

Source: Commonwealth Associates (1982).

So far as is known, no existing noise limits specified by ordinance, regulation, or statute specifically refer to transmission lines. However, based on summaries of guidelines developed by the U.S. Environmental Protection Agency as given in Table D-3, by the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) of the American Academy of Sciences as given in Table D-4 and by the Bonneville Power Administration as given in Table D-5 (all of these relate to the effects of noise and community reaction and annoyance), the day-night average of 50.4 dB(A) calculated for the 345-kV lines at the edge of the right-of-way should present no environmental problem. Although this value represents a day-night average, it is unlikely that peak noise levels would exceed the 52.5 dB(A) threshold level given in Table D-5, except possibly for very limited periods in heavy rain when the lines were simultaneously operating at maximum voltage (362.5 kV). A comparison of the 50.4 dB(A) average with the noise levels given in Table D-1, which represent levels to which people are normally exposed, suggests that the audible noise generation by the line should not contribute significantly to these levels.

## D.4 RADIO NOISE

"Radio Noise" (RN), sometimes referred to as "electromagnetic interference" (EMI), is a rather general term used to refer to any unwanted interference of an electromagnetic nature (such as radio static) with any signal or communication channels or devices throughout the radio frequency band of operation (3 kHz to 30,000 MHz). The pulsative corona discharges produced by energized high-voltage transmission line conductors generate such disturbances by virtue of the steep rise and decay rates of the minute components of current feeding this corona and by the rapid and random repetition rate of the corona pulse discharges along the line conductors and other line and substation hardware. Radio noise can also be generated by sparking at loose or broken line hardware parts.

Theoretically, corona-generated radio noise could cause interference with virtually any type of radio reception. However, in practice it has been found that the bands principally affected are the AM (amplitude-modulated) broadcast band (535 to 1,605 kHz) and the video signals of the low television broadcast band (Channels 2 to 6, 54 to 88 MHz). FM (frequency-modulated) radio signals (88-108 MHz), which are also generally used for the sound transmission for television, are virtually immune to the static-type interference generated by transmission line radio noise. This is because (1) the magnitude of the radio noise is generally quite small in the FM broadcast band, and (2) FM radio systems inherently reject this pulsative-type noise.

For a given operating voltage, radio noise generation from a transmission line is principally a function of conductor geometry, conductor height above ground, phase spacing, and ground resistivity. Since it is a product of the line corona, it also depends on the condition of the conductor surface, increasing with roughness and contamination, and on weather conditions, becoming several orders of magnitude greater in rain than during fair weather. The radiated radio noise is broadband in character, with a decreasing frequency spectrum. For example, the magnitude typically decreases on the order of five to six times (around 15 dB) per decade of frequency, measured 400-500 ft (122-152 m) from the edge of the right-of-way, and becomes quite low in the frequency range above 10 MHz (Electric Power Research Inst., 1982). The radio noise level also attenuates with lateral distance from the line, typically at rates varying from 10 to 30 times (20-30 dB) per decade of distance, depending on the measuring frequency (Electric Power Research Inst., 1982). Interference caused by this noise to radio and television receivers in the vicinity therefore depends on their proximity to the line as well as on the signal strength of the desired

Table D-3. Summary of Noise Levels Identified by USEPA as Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety

| Avoided Effect | Maximum Allowable Level [dB(A)]†[1] | Area |
|---|---|---|
| Outdoor activity interference and annoyance | $L_{dn} \leqq 55$ | Outdoors in residential areas and farms, and other outdoor areas where people spend widely varying amounts of time, and other places in which quiet is a basis of use |
| | $L_{dn} \leqq 61.4$ | Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds |
| Indoor activity interference and annoyance | $L_{dn} \leqq 45$ | Indoor residential areas |
| | $L_{dn} \leqq 51.4$ | Other indoor areas with human activities such as schools |

†[1] Notes:

1. $L_{dn}$ is a weighted day-night average noise level with a 10 dB penalty added to the nighttime equivalent noise level (2200-0700 hours).
2. Anchorage-Fairbanks corridor estimated $L_{dn}$ at edge of right-of-way = 50.4 dB(A).
3. An indoor $L_{dn}$ of 45 dB(A) will permit speech communication in the home, while an outdoor $L_{dn}$ not exceeding 55 dB(A) will permit normal speech communication at approximately 10 ft (3 m).
4. Maintenance of $L_{dn}$ of 55 dB(A) will provide an indoor $L_{dn}$ of approximately 40 dB(A) with windows partly open for ventilation. The nighttime portion of this $L_{dn}$ (indoor level) will be approximately 32 dB(A), which should, in most cases, protect against sleep interference.

Source: U.S. Environmental Protection Agency (1974).

Table D-4. Summary of Human Effects for Outdoor Day-Night Average Sound-Level of 55 dB(A)

| Type of Effect | Magnitude of Effect |
|---|---|
| Speech | |
| Indoors | No disturbance of speech: 100% sentence intelligibility (average) with 5 dB margin of safety |
| Outdoors | Slight disturbance of speech with 100% sentence intelligibility (average) at 0.35 m, or 99% at 1.0 m, or 95% at 3.5 m |
| Average community reaction | None; 7 dB below level of significant "complaints and threats of legal action" and at least 16 dB below "vigorous action" (attitudes and other non-acoustical factors may modify this effect) |
| High annoyance | Depending on attitude and other non-acoustical factors, approximately 5% of the population will be highly annoyed |
| Attitude toward area | Noise essentially the least important of various factors |

Conversion: to convert meters to feet, multiply by 3.28.

Source: National Academy of Sciences (1977).

Table D-5. Audible Noise Complaint Guidelines Developed by Bonneville Power Administration

| Audible Noise Level 100 ft Laterally from Line Centerline $L_{50}$ (wet conductor) [dB(A)] | Probability of Receiving Complaints |
|---|---|
| 0-52.5 | Few or no complaints |
| 52.5-58.5 | Moderate or some complaints |
| >58.5 | High or numerous complaints |

Conversion: To convert feet to meters, multiply by 0.305.

Source: Bonneville Power Administration (1977).

incoming signal, its frequency, and the ambient radio noise level.* Depending on those factors, the magnitude of corona-generated noise can range anywhere from barely discernible levels to a point where reception is completely unintelligible. In lines of modern design, interference is likely to be most noticeable in AM receivers located close to or under a line, such as in an automobile passing under the line, and possibly in television receivers in proximity to the line in the far-fringe areas of reception.

Radio noise is measured with standardized radio noise meters that, in essence, are calibrated radio receivers that function as radio frequency voltmeters. They are capable of measuring radio frequency noise down to fractions of a microvolt. The annoyance level of transmission line radio noise on communication receivers is characterized in terms of a signal-to-noise ratio (SNR), defined as the ratio of the average signal level field strength, in microvolts per meter (μV/m), to the quasi-peak level of the noise, measured in the same units. The quasi-peak is a level intermediate between the peak and average noise levels. It is a standardized measure that accounts not only for the amplitude but also the repetition rate of the noise pulses, and thus more accurately represents the nuisance value of the radio noise field with respect to broadcast reception. Because of the wide range of possible signal and noise levels, a logarithmic scale is used to express these levels in decibels ($dB_s$ and $dB_n$, respectively), based on a 1 microvolt per meter (1 μV/m) reference level, as

$$dB_s = 20 \log_{10} \frac{V_s}{1} \ dB\mu^{**} \qquad (D-3)$$

$$dB_n = 20 \log_{10} \frac{V_n}{1} \ dB\mu \qquad (D-4)$$

whence

$$SNR = dB_s - dB_n = 20 \log_{10} \frac{V_s}{V_n} \ dB\mu \qquad (D-5)$$

where $V_s$ and $V_n$ are the signal and noise field strengths, respectively, in μV/m.

Estimates of expected radio noise levels generated by transmission lines can be calculated from empirical formulas and design curves that have been developed from data obtained in laboratory and field test investigations. In the United States, there are no regulations on a local or Federal level that expressly limit the level of radio noise that a transmission line may produce, although Federal Communications Commission (FCC) rulings require, in general, that no device that radiates radio frequency energy shall endanger or seriously degrade the function of radio navigation services or radio communication services (Federal Communications Commission, 1975). Technically, transmission lines fall within this category. Tolerability criteria for transmission line-generated noise must therefore be based on subjective ratings of listeners and viewers exposed to radio and television programs containing various amounts of injected or measured ambient noise.

A preconstruction survey of signal strengths of AM radio broadcasts was made by the Alaska Power Authority (APA) through their consultant, Commonwealth Associates, Inc. (CAI), at 11 sites near the right-of-way of the 345-kV Anchorage-Fairbanks transmission corridor in the section between Willow and Healy (Commonwealth Assoc., 1982: Fig. A-1). A list of stations received at various sites is given in Table D-6, and the site locations are listed in Table D-7. All of the station signal levels were below the 40 dBμ level required by the FCC for primary service in the northern rural areas of Alaska, defined as those areas in which the ground wave is not subject to objectionable interference or fading (Federal Communications Commission, 1968). The maximum signal strength of any of the stations monitored at the eleven sites was only 37 dBμ (KOFD, in Anchorage). Ambient radio noise levels were also measured at each of these sites at this time at selected frequencies in the AM broadcast band. The measurements were made during daytime under overcast or rain conditions. The resulting SNR varied from about -8 to +12.5 dB. While these readings were being taken, a subjective rating of each radio signal received was made by the team of observers on a scale ranging from "A" ("entirely satisfactory") to "E" ("speech unintelligible"). The results are tabulated in Table D-7. At two of the measuring sites, no AM broadcast signals at all were heard, and, at best, only "C" ("fairly satisfactory") signals were heard, with background noise plainly evident at three locations. Of the total of 32 signal receptions at the 11 monitoring sites (with a given station often received at more than one site), the 18 signals with the "E" quality correlated with an SNR range of -8.8 to -1.2 dBμ. The nine signals with a "D" quality correlated with an SNR range of -4.4 to +3.0 dBμ, and the remaining six signals with a "C" quality correlated with an SNR range of +4.2 to 12.5 dBμ. On this basis, an

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*Ambient radio noise originates from atmospheric or other man-induced sources. A sufficiently high level of ambient noise could render the corona-generated noise component negligible by comparison.

**dBμ signifies dB relative to 1 microvolt per meter.

Table D-6. AM Radio Stations Received During Preconstruction Survey of Anchorage-Fairbanks Transmission Corridor between Willow and Healy, July 1981

| Frequency (kHz) | Station Call | Location | Power†[1] (kW) | Antenna Limitation†[1] | Station Class†[2] |
|---|---|---|---|---|---|
| 550 | KENI | Anchorage | 5 | -- | III |
| 560 | KVOK | Kodiak | 1 | -- | III |
| 580 | KYUK | Bethel | 5 | -- | III |
| 590 | KHAR | Anchorage | 5 | -- | III |
| 650 | KYAK | Anchorage | 50 | DA-2 | II |
| 660 | KFAR | Fairbanks | 10 | -- | II |
| 700 | KBYR | Anchorage | LS-1, N-.5 | -- | II |
| 750 | KFQD | Anchorage | LS-50, N-10 | -- | II |
| 900 | KFRB | Fairbanks | 10 | -- | II |
| 970 | KIAK | Fairbanks | 5 | -- | III |
| 1080 | KANC | Anchorage | 10 | -- | II |
| 1150 | KABN | Long Island (Big Lake) | 5 | -- | III |
| 1170 | KJNP | North Pole | 50 | DA-N | II |

†[1] Key:

DA-2--Directional antenna, different patterns day and night
DA-N--Directional antenna during night only
LS--Local Sunset
N--Night.

†[2] Only Class II and Class III stations were received. Class II stations are licensed by the Federal Communications Commission (FCC) to operate on a clear channel and render primary service over wide areas. Class III stations are licensed by the FCC to operate on a regional channel and render primary service to large cities (municipalities) and surrounding areas. The primary service area is the area in which the radio signal is not subject to objectionable interference or fading.

Source: Commonwealth Associates (1982).

Table D-7. Existing Quality of Reception for AM Radio Stations†[1]

| Site Number | Location | Number of Radio Stations Judged to Have the Following Quality of Audio Reception†[2] A | B | C | D | E |
|---|---|---|---|---|---|---|
| 10 | Willow | -- | -- | 3 | 3 | -- |
| 20 | Trapper Creek | -- | -- | 2 | 2 | 3 |
| 30 | Chase | -- | -- | -- | 1 | 4 |
| 40 | Lane Creek | -- | -- | 1 | 1 | 4 |
| 50A | Curry | -- | -- | -- | -- | 1 |
| 60 | Cantwell | -- | -- | -- | -- | 1 |
| 70 | Carlo Creek | -- | -- | -- | -- | 1 |
| 80 | Deneki Lake | -- | -- | -- | 1 | 3 |
| 90 | McKinley Village | -- | -- | -- | -- | -- |
| 100 | McKinley Park | -- | -- | -- | -- | -- |
| 110A | Healy | -- | -- | -- | 1 | 1 |
| Total | | 0 | 0 | 6 | 9 | 18 |

†[1] Based on field measurements of radio station signal strengths July 9-15, 1981.

†[2] A--entirely satisfactory; B--very good, background unobtrusive; C--fairly satisfactory, background plainly evident; D--background very evident, speech understandable with concentration; E--speech unintelligible.

Source: Commonwealth Associates (1982).

SNR of +4.2 dBμ is about the minimum acceptable level, which was met by only six signal reception points. Reception of the remaining 27 would be considered below par or unsatisfactory under this standard, even with presently existing ambient conditions and without the installation of the Intertie.

An estimated lateral profile of radio noise levels along the corridor was calculated by APA/ CAI (Commonwealth Assoc., 1982) for the ultimate configuration of three single-circuit, 345-kV lines in parallel alignment on common right-of-way (Fig. D-2) and operating at maximum rated voltage of 362.5 kV. The results, calculated by computer program by CAI using algorithms described by Electric Power Research Institute (1975a) and given in Table D-8, agree closely with manual calculations performed by FERC using formulas and design curves given in Electric Power Research Institute (1982). The calculated values apply for a 1 MHz simulated noise measuring frequency, which is centrally located in the AM broadcast band.* Based on a 25 dBμ average level of measured ambient radio noise, this table indicates that clearances of 200, 300, and 600 ft (60, 90, and 180 m) from the edge of the right-of-way would probably be required under fair weather, wet conductor, or heavy rain conditions, respectively, to avoid the possibility of significant adverse impact on AM radio reception due to corona-generated radio noise. This is summarized in Table D-9.

Based on these calculations and survey measurements, it appears reasonably conservative to allow for a 1,000-ft (300-m) minimum separation between the corridor centerline and residences and between the centerline and long parallels with the Parks Highway, as recommended by APA/CAI.** This should be adequate to protect against significant radio noise contributions from the lines on AM broadcast reception under worst-case weather conditions and should ensure that existing quality of AM radio reception is preserved.

However, mitigative measures can be taken to restore AM reception quality should particularly troublesome problems arise after line installation, such as installing a separate receiving antenna beyond the influence zone of the radio noise and connecting it to the receiver by a shielded lead-in cable. This or other means could be resorted to on a case-by-case basis within practical limits. Any problems that conceivably could be traceable to project transmission line operation would have to lie within areas where intelligible reception now exists. For the Willow-Healy section of the Anchorage-Fairbanks transmission corridor, this would include only the portion between Willow and Curry, since, as Table D-7 shows, useful AM radio reception north of Curry is practically nonexistent.

In interpreting the results of this investigation conducted by APA and its consultants, it should be noted that the radio reception analysis applies only to AM radio reception under daytime conditions, i.e., by ground wave transmission. At night, the radiowave propagation characteristics change markedly, which can result in deterioration of reception quality. This influence and the static noise generated from thunderstorm activity can mask the effects of any line-generated noise.

Radio interference to citizens band (CB) communications from a transmission line can come from two sources: (1) from a static-type interference caused by line corona or spark discharges from loose or broken line hardware, which can often be located and repaired; and (2) from the blocking action due to the physical presence of the line itself. The corona noise only causes receiving interference. The signal-to-noise ratio with regard to corona noise is likely to be quite high, since corona-generated radio noise falls off to negligible intensity beyond about 10 MHz, well below the 27 MHz of the CB band, in which region the noise will be about 250 times lower (48 dBμ) than at 1 MHz, the mid-point of the AM broadcast band. Furthermore, atmospheric static will likely mask the radio noise at the time when the latter will be at its maximum (during thunderstorms). Both the sending and receiving modes could be affected by the blocking. However, since CB units are often mobile or portable, they can be easily moved to a location 100 ft (30 m) or more from the line, which should be sufficient to restore good CB communications. Therefore, CB interference from line-generated radio noise would not be anticipated to present a problem of any consequence.

Television interference (TVI) can occur in the AM video portion of the television signal from radio noise.*** As in the case with radio interference (RI), TVI generation on transmission

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*Values at the low frequency end of the broadcast band (550 kHz) are typically about 4.0 dB greater than the value at 1 MHz, and those at the higher end (1600 kHz) are about 5 dB lower, reflecting the dropoff with increasing frequency noted earlier (Electric Power Research Inst., 1982).

**This 1,000-ft (300-m) separation is equivalent to 800 ft (240 m) from the edge of the 400-ft (120-m) right-of-way.

***As previously mentioned, the audio portion of the television signal is broadcast on FM and is not subject to static interference.

Table D-8. Calculated Transmission Line Radio Frequency (RF) Noise Levels (three single-circuit transmission lines on a common right-of-way†[1] simulated noise measuring frequency = 1 MHz)

| Lateral Separation from Edge of Right-of-Way (ft) | Weather Conditions | | |
|---|---|---|---|
| | Heavy Rain†[2] (dBμ) | Wet Conductor†[3] (dBμ) | Fair Weather (dBμ) |
| 0 | 69 | 57 | 49 |
| 100 | 50 | 38 | 30 |
| 200 | 40 | 28 | 20†[4] |
| 300 | 34 | 22†[4] | 14†[4] |
| 400 | 29 | 19†[4] | 9†[4] |
| 500 | 25 | 15†[4] | 5†[4] |
| 600 | 22†[4] | 12†[4] | 2†[4] |
| 700 | 20†[4] | 10†[4] | 0†[4] |
| 800 | 18†[4] | 8†[4] | -2†[4] |

†[1] Configuration along part of the 345 kV Anchorage-Fairbanks transmission corridor.

†[2] "Heavy rain" is considered as a natural rainfall rate on the order of 0.31-0.47 in/hour (8-12 mm/hr) or greater. It is the highest corona and radio-noise-producing condition. For 99% of the total foul-weather period, the radio noise generated by corona can be expected to be below the heavy rain value (Electric Power Research Instit., 1982).

†[3] The "wet conductor" condition represents a natural condition of very light rain, drizzle, or dense fog when the conductor is saturated with pendant water drops and the concentration of moisture in the air is just sufficient to maintain an equilibrium between the loss and replacement of water drops (Electric Power Research Inst., 1982).

†[4] Average value of measured ambient RF noise level during the Intertie route survey was about 25 dBμ. Therefore, the corona-generated transmission line RF noise component is not expected to have a significant impact on the existing quality of radio reception for the noted calculated levels corresponding to the indicated weather conditions and lateral distances from the edge of the right-of-way.

Conversion: To convert feet to meters, multiply by 0.305.

Source: Commonwealth Associates (1982).

Table D-9. Zones of Influence of Radio Frequency Noise (three single-circuit transmission lines on a common right-of-way†[1] operating at 362.5 kV)

| Weather Condition | Width of Zone†[2] (ft) | Distance from Edge of Right-of-Way†[2] (ft)†[3] |
|---|---|---|
| Fair weather | 800 | 200 |
| Wet conductor†[4] | 1000 | 300 |
| Heavy rain†[4] | 1600 | 600 |

†[1] Configuration along part of the 345-kV Anchorage-Fairbanks transmission corridor.

†[2] The right-of-way width is assumed constant at 400 ft.

†[3] At greater distances from the edge of the right-of-way, no impact on the quality of radio reception from the operation of the Intertie is foreseen for the weather conditions cited.

†[4] Defined in Table D-8.

Conversion: To convert feet to meters, multiply by 0.305.

Source: Commonwealth Associates (1982).

lines results from corona formation on the conductors as well as from spark discharges on loose or broken line hardware. TVI in the form of "ghost" images can also result due to the physical presence of the transmission line, causing signal reflections. Since corona-generated radio frequency noise drops off at the higher frequency levels and becomes quite low in intensity above 10 MHz, the TVI, even in the low television band (Channels 2-6, 54-88 MHz), will generally be negligible, particularly if the AM radio reception in the vicinity of the transmission line is acceptable (Commonwealth Assoc., 1982), as is expected to be the case for the corridor lines. Problems resulting from spark discharges on line hardware can generally be attended to satisfactorily on a case-by-case basis by suitable repairs or local minor design modifications. Television signal reflection problems caused by transmission lines traversing sparsely settled rural areas should likewise be few in number and can be relieved by modification or relocation of the antenna on the receiving apparatus.

A preconstruction television reception survey was made by APA/CAI similar to the radio reception survey described above in connection with AM radio reception (Commonwealth Assoc., 1982). The same 11 measuring sites were chosen along the corridor. Thirteen television signals were monitored, as given in Table D-10. Of these, nine were from television translators, which are commonly used among the rural communities that lie along the corridor route. Translators are low-power facilities (normally 10 watts) that receive weak signals from primary television stations located in Anchorage and Fairbanks and rebroadcast the video and audio on a different channel to local small geographical area within a 20- to 30-mi (30- to 50-km) radius. Because the rebroadcasted signal is relatively much stronger than the weak primary signal, it is less susceptible to interference from the transmission lines. Quasi-peak measurements were made of the signal strength of the television signals that could be received at each of the 11 sites along with measurements of the ambient noise level at a clear frequency slightly below the video carrier frequency. The resulting signal-to-noise ratios ranged from 2 to 44 dBμ, with an average of 12 dBμ. Only two of the 34 values of SNR were above 30 dBμ, the minimum level judged acceptable for viewing by a 500-person test group in a study sponsored by the Electric Power Research Institute (1982). However, the quality of audio reception (FM), as judged by the observers making these measurements, was entirely satisfactory (A-rating) in some cases, as shown in Table D-11. This is the same rating scale used in the evaluation of AM radio reception (Table D.7).

In summary, it appears that no significant television reception problems would be likely to develop as a consequence of the installation of the corridor transmission link, and that acceptable TV reception should be preserved where present reception is good.

Insofar as the remaining sections of the project 345-kV transmission are concerned, the results of the analytical study should still be valid [the recommended 1,000-ft (300-m) separation between the lines and residences and between the lines and long parallels with highways, etc.]. In fact, this requirement should be increasingly conservative for rights-of-way containing less than three circuits, although the effect of multiple circuit right-of-way occupancy is secondary

Table D-10. TV Stations Received During Preconstruction Survey of Corridor Route, July 1981

| Channel | Call Letters | Location | Operating Power (kW), Visual/Aural | Antenna Height (ft), AT/AG[†1] |
|---|---|---|---|---|
| 2 | KENI | Anchorage | 26.9/2.69 | 70/173 |
| 2 | KFAR | Fairbanks | 5.37/.676 | 45/200 |
| | | Cantwell translator at earth station operated by Alaska Department of Highways | | |
| 4 | K04CO | Healy translator (Primary Ch. 11, KTVF Fairbanks) | | |
| 4 | K04DO | Talkeetna translator (Primary Ch. 11, Anchorage) | | |
| 6 | K06KG | Talkeetna Translator (Primary Ch. 13, Anchorage) | | |
| 7[†2] | KAKM | Anchorage | 105/20.90 | 143/250 |
| 7 | K0900 | Healy translator (Primary Ch. 9, Fairbanks) | | |
| 9 | KUAC | Fairbanks | 46.7/1.16 | 200/255 |
| 9 | K0900 | Talkeetna translator (Primary Ch. 2, Anchorage) | | |
| 11 | KTVA | Anchorage | 26.3/5.35 | 300/391 |
| 13 | KIMO | Anchorage | 30/6.17 | 90/347 |
| 13 | | Healy translator | | |

[†1] AT--above average terrain; AG--above ground.

[†2] Non-commercial educational station.

Conversion: To convert feet to meters, multiply by 0.305.

Source: Commonwealth Associates (1982).

Table D-11. Existing Quality of Television Reception (audio)[†1]

| Site Number | Location | Number of TV Signals Judged to Have the Following Quality of Audio Reception[†2] A | B | C | D | E |
|---|---|---|---|---|---|---|
| 10 | Willow | 3 | 1 | -- | -- | 1 |
| 20 | Trapper Creek | 1 | 1 | 1 | 1 | 1 |
| 30 | Chase | 2 | 1 | -- | 3 | 1 |
| 40 | Lane Creek | 2 | -- | -- | 3 | -- |
| 50A | Curry | -- | -- | -- | -- | 1 |
| 60 | Cantwell | 1 | -- | -- | 1 | 1 |
| 70 | Carlo Creek | -- | -- | -- | 1 | -- |
| 80 | Deneki Lake | -- | -- | -- | -- | 2 |
| 90 | McKinley Village | -- | -- | -- | -- | 1 |
| 100 | McKinley Park | -- | -- | -- | -- | -- |
| 110A | Healy | 2 | 1 | 1 | -- | -- |
| Total | | 11 | 4 | 2 | 9 | 8 |

[†1] Based on field measurements of radio station signal strengths July 9-15, 1981.

[†2] A--entirely satisfactory; B--very good, background unobtrusive; C--fairly satisfactory, background plainly evident; D--background very evident, speech understandable with concentration; E--speech unintelligible.

Source: Commonwealth Associates (1982).

with regard to radio noise generation. No surveys of radio or television broadcast reception quality have yet been reported by APA along other transmission routes, although there seems to be no reason why reception of acceptable quality should not be preserved in locations where present reception is good, particularly with the 1,000-ft (300-m) recommended separation distance between the lines and receiving antennas.

A survey of existing potentially sensitive communication tower locations along the proposed corridor route was conducted by APA's consultants (Commonwealth Assoc., 1982) to form the basis of determining minimum separation distances between the edge of the 345-kV transmission right-of-way and these towers to preclude the likelihood of static noise or reflective type interference to the operation of these facilities due to corona formation on the conductors and the physical presence of the line conductors and towers. An additional objective was to ensure adequate safety clearance between the towers and the lines in the event of wind toppling and for tower maintenance. Necessary corrective measures could then be carried out prior to construction to minimize these impacts. Altogether, 50 such radio communication facilities were identified along the Anchorage-Fairbanks transmission corridor between Willow and Healy (Commonwealth Assoc., 1982: Fig. B-1). Included were FM translators, TV translators, earth stations (for communications with geostationary satellites), air navigational aids, and point-to-point microwave facilities. These facilities are licensed to various business and governmental agencies in Alaska, including the Federal Aviation Administration, the Alaska Railroad, the Alaska Department of Highways, the Golden Valley Electric Association, the Mantanuska Telephone Association, and Alascom, Inc.

The criteria for minimum clearances for the various types of communication facilities is given in Table D-12. The basis for these criteria take into account both the operational interference and the safety aspects, discussed above. A survey of the owners of these facilities indicated, in general, agreement as to the guidelines outlined in the criteria, and no problems are anticipated to result from their use. The precise locations of the communication towers with respect to the corridor will be verified by aerial photographs.

Surveys of communication facility locations along 345-kV transmission routes other than between Willow and Healy along the corridor have yet to be made by APA. However, the foregoing criteria should be applicable to these lines, also.

## D.5 ELECTRIC AND MAGNETIC FIELDS

### D.5.1 Electric Fields

Energized overhead transmission lines generate electrostatic fields in the surrounding insulating medium that give rise to induced electric charges in other conducting objects in the vicinity of the line, such as vehicles, fences, rain gutters, etc. If these objects are insulated, or semi-insulated from ground, the induced charge accumulation on the object produces a potential difference, or voltage, between the object and ground. Depending on the resistivity of the path between the object and ground, this induced voltage will give rise to a current flow, generally measured in milliamperes. If a person were to approach and touch this object (say, a parked vehicle), a second parallel path to ground would be created and a small current would pass through his body, the amount depending on his internal body resistance and the resistance from his body to ground. This might be accompanied by a mild shock and spark discharge. This mainly constitutes an annoyance and never (or seldom) results in physical injury, except due to a secondary reaction, such as an involuntary muscle contraction.

The foregoing effects vary with the intensity of the electrostatic field, which is generally measured in terms of the field gradient (in kV/m) at "ground level" (or, more precisely, the gradient measured or calculated at 1 m above ground). This standardization permits comparisons to be made between different line designs in this respect. The earth's ambient DC electric field at ground level is 0.13 kV/m, although beneath thunder clouds the fields may reach 3 kV/m even in the absence of lightning (Bonneville Power Admin., 1977). The ground-level gradient is a valid parameter for the prediction of electrostatic effects and, for given conductor-to-ground heights, does not vary more than 10% to 15% for heights up to 10 ft (3 m) (Bonneville Power Admin., 1977). Electric fields under energized lines can be measured with instrumentation, but they also can be accurately calculated, enabling transmission lines to be designed with known field strengths at ground level. For a given line design and measuring point, the field strength varies directly with line voltage. It also varies with conductor bundle geometry, phase spacing, height of the conductors above ground, and lateral distance of the measuring point from the line centerline. As this lateral distance increases, the field strength decreases, dropping rapidly and leveling off at a low value beyond the edge of the right-of-way. Therefore, the effects of the field directly under or very close to the line are of primary interest.

For Anchorage-Fairbanks transmission corridor sections having three 345-kV lines on a common 400 ft (120 m) right-of-way and at maximum operating voltage of 362.5 kV, the maximum calculated

Table D-12. Possible EHV Line Effects on Communications Facilities and Recommended Minimum Clearances†[1]

| Communication Facility | Reflection | Diffraction | Absorption | Ghosting | No Reported Effects | Recommended Minimum Clearance to EHV Lines | Criterion |
|---|---|---|---|---|---|---|---|
| FM Translator | | | | | X | Antenna height plus 200 ft | Antenna Toppling Guy Anchor Maintenance |
| TV Translator | X | X | | X | | Antenna height plus 200 ft | Antenna Toppling Guy Anchor Maintenance |
| Earth Stations | | | | | | 10 tower heights | Line of sight for low zenith of approximately 19° above the horizon |
| NAVAIDS (Enroute) | | | | | | | |
| NDB | | | | | X | 1000 ft | FAA |
| RCAG | | | | | X | 1000 ft | FAA |
| SFO | | | | | X | 1000 ft | FAA |
| SSFO | | | | | X | 1000 ft | FAA |
| NAVAIDS (At Airports) | | | | | | 1.5° | DOT/FAA |
| VOR | X | | | | | 1.5° | FAA (1968) |
| Unicom | | | | | X | | Airport Criterion |
| RCO | | | | | X | | Airport Criterion |
| FSS | | | | | X | | Airport Criterion |
| AAS | | | | | X | | Airport Criterion |
| ALAS | | | | | X | | Airport Criterion |
| Point-to-Point Microwave | X | X | X | | | Antenna height plus 200 ft | Antenna Toppling and Guy Anchor Maintenance<br>0.6 First Fresnel Zone Radius |

†[1] "X" denotes potential exists for specified effect.

Conversion: To convert feet to meters, multiply by 0.305.

Source: Commonwealth Associates (1982).

electric field strength at ground level is 6.9 kV/m,* which occurs within the right-of-way limits near the outside phase conductors. At the edge of the right-of-way, the calculated field is 1.6 kV/m (Commonwealth Assoc., 1982). Other values as a function of distance from the right-of-way centerline are given in Table D-13, which shows the rapid dropoff of field intensity beyond the edge of the right-of-way. Calculations made for a large vehicle [13.5 ft high, 8.5 ft wide, and 70 ft long** (4.1 × 1.6 × 21 m)] parked in this field and oriented transversely to the line indicated that a current of approximately 4.5 milliampere (ma) would flow from the vehicle through a ground connection to earth at a conductor height of 30 ft (9 m) and an operating voltage of 362.5 kV. This is slightly below the 5-ma criterion of the National Electrical Safety Code (NESC). However, the current resulting with this vehicle oriented parallel to and under the line in the maximum field position exceeds the 5-ma limit, although such a circumstance would rarely occur.

Measurements have shown that persons standing on the ground and touching such an object as that described above receive a "short circuit" current of less than 10% of the total induced current prior to the contact about 90% of the time (Inst. of Electrical and Electronic Engineers, 1979). This current, 0.5 ma or less, can be perceived by approximately 1.0% of adult males. The remaining 10% of the time, a person will receive up to 80% of the total induced current (Inst. of Electrical and Electronic Engineers, 1979). However, even this is below the NESC limit of 5.0 ma referenced above. Hence, it can be concluded that no significant shock hazard exists with regard to accidental contact with metallic objects located under, or in the close vicinity of, the Intertie. As an additional precaution, however, such objects could be grounded where considered necessary.

A number of investigations and research projects relative to biological effects of electric fields on people and animals have been conducted over the past decade, and a number of others are underway. To date, however, there seems to be no conclusive evidence of harmful biological effects due to exposure to transmission line-generated electric fields, at least none that has been generally accepted by the scientific community (Bridges, 1975; Sheppard and Eisenbud, 1977; Riog, 1979, Electric Power Research Inst., 1982; Mahmoud and Zimmerman, 1982). Brief reports on recent literature surveys on this subject (Riog, 1979; Electric Power Research Inst., 1982) noted that health complaints were reported by EHV substation workers in the Soviet Union, where work duration limits now exist to limit daily exposure. However, the same survey noted that medical examinations of linemen in the United States, Canada, and Sweden failed to find health problems ascribable to AC electric field exposure. Controlled tests on animals exposed to electric fields have also been performed. One such test was on the effects on hogs raised under a 345-kV line in Iowa (Mahmoud and Zimmerman, 1982). No negative biological effects on these animals were detected as a result of this exposure as compared to a control group not so exposed. On the basis of evidence accumulated to date, there does not seem to be a direct confirmed relationship between electric field exposure and adverse health effects on humans and animals, notwithstanding the experience reported in the Soviet Union. The same results appear to be generally true for plant life for EHV lines operating at 345 kV. It is only at the higher transmission voltages that induction space potentials reach levels such that significant leaf damage and tree and pole burning is likely to occur, and even then only within or adjacent to the right-of-way, as demonstrated by tests at Project UHV (Electric Power Research Inst., 1982). Insofar as corona-induced or spark-induced fuel ignition is concerned, tests have shown (Riog, 1979, Electric Power Research Inst., 1982) that chances for such ignition are extremely remote, and that there have been no reports of the accidental ignition of fuel caused by spark discharges induced from transmission line fields. Nevertheless, it is generally good practice not to refuel under a transmission line.

### D.5.2 Magnetic Fields

Overhead transmission lines carrying load current generate magnetic fields around the line conductors that permeate the surrounding medium. The effect of the continuously changing magnetic fields associated with AC transmission is to induce voltages and currents in surrounding conducting objects. Like electric fields, the magnetic field strength (measured in gauss) can be calculated for a given line design and is proportional to the load current carried by the line conductors. The maximum magnetic field close to heavily loaded 345-kV transmission lines under balanced phase loading conditions is typically only 0.5 gauss or less at a height of 3 ft (1 m) above ground ("ground level"), which is less than the field level in certain industrial environments, especially near high current-carrying conductors (Electric Power Research Inst.,

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*This is a computer-calculated value given in the Report R-2394 (Commonwealth Assoc., 1982), which is in reasonably close agreement and is conservative with respect to the 6.74-kV/m value computed manually by FERC using methods described by the Electric Power Research Institute (1982). The 6.9-kV/m value is also below the 8.0-kV/m limit set in the Anchorage-Fairbanks Intertie Basic Design Criteria (Commonwealth Assoc., 1981).

**The largest size permitted on Alaskan State highways.

Table D-13. Calculated Intertie Electric Field Strengths (three transmission lines operating at 362.5 kV)†[1]

| Lateral Separation from Centerline of Right-of-Way (ft) | Calculated Electric Field Strengths (kV/m) at 1 m above Ground Level†[2] |
|---|---|
| 0 | 5.14 |
| 50 | 3.78 |
| 100 | 3.90 |
| 150 | 6.90†[3] |
| 200 | 1.61†[4] |
| 300 | 0.22 |
| 400 | 0.07 |

†[1] Configuration along part of the Anchorage-Fairbanks 345-kV transmission corridor.

†[2] Values are calculated for a minimum conductor height (at mid-span) of 30 ft and a 33-ft phase-to-phase spacing.

†[3] The maximum value of electric field strength occurs near the outside phase conductors.

†[4] Value of electric field strength at the edge of the right-of-way.

Conversion: To convert feet to meters, multiply by 0.305.

Source: Commonwealth Associates (1982).

1982). Since this is also one to two orders of magnitude smaller then the magnetic fields produced by common household appliances (Bridges, 1975), its effect is considered harmless. Unbalanced phase loading can produce induced voltages up to ten times those of the balanced condition on account of the absence of cancellation in magnetic field coupling caused by the dissymmetry (Electric Power Research Inst., 1975b). However, under normal conditions the phase loadings are nearly perfectly balanced. Significant unbalances are likely to result only during fault conditions and then only for extremely short periods of time necessary for fault clearing. In the balanced loading case, the induced current density in a person standing close to the line from the magnetic field is on the order of 1/10 that resulting from the electric field induction. Furthermore, the magnetic fields do not cause transient currents of high peak value, which can result from electric-field-induced spark discharges (Electric Power Research Inst., 1975b).

As in the case of electric fields, experimental findings with regard to biological effects from continued exposure to magnetic fields are inconclusive (Sheppard and Eisenbud, 1977; Electric Power Research Inst., 1982). Based on a survey of the literature reported by the Electric Power Research Institute (1982), the inconclusive nature of the results is due in part to the wide variation in field strengths, frequencies, and exposure durations used in different studies. One such study noted an increase in triglyceride in humans exposed to a 1-gauss field of 45 Hz for 22.5 hours. However, these findings were not duplicated in more controlled tests on monkeys in fields up to 10-gauss at 45 Hz. Another study in Germany showed no effect on reaction times, pulse frequency, arterial pressure, or electrocardiographic and electroencephalographic traces on three volunteers subjected to a 3-gauss field at 50 Hz. These findings, which generally agree with those from studies of the effects of electrostatic fields, have resulted in little concern for the biological effects of magnetic fields, particularly in view of the relatively lower level of induction from magnetic fields than from electric fields.

## D.6 ELECTRICAL SAFETY

Physical contact with energized transmission line conductors, either directly or through other metallic objects will, of course, be lethal, the same as is likely with accidental contact with residential distribution lines, which operate at much lower voltages. Precautions should therefore be exercised when operating or transporting under the line any kind of apparatus or equipment that exceeds normal vehicle height to prevent accidental contact with the line conductors, either directly or by flashing.

For the proposed project 345-kV transmission lines, the minimum vertical line clearance of phase conductors above ground at 120°F (49°C) would be 30 ft (9 m) for farmland and highways, which exceeds the National Electric Safety Code (NESC) minimum of 27.3 ft (8.3 m) (American National Standards Inst., 1984). This and other dimensions pertinent to safety clearances and right-of-way occupancy are given in Figure D-2 for the Knik Arm-Gold Creek section of the Anchorage-Fairbanks 345-kV transmission corridor. Right-of-way widths and spacing of lines applicable to right-of-way occupancies of one to four single-circuit lines are given in Table D-14.

Table D-14. Right-of-Way Use of Single and Multiple Single-Circuit Transmission Lines

| No. of Single-Circuit Lines | Width of ROW (ft) | Lateral Separation of Line L (ft) | Distance from Line L to Edge of ROW (ft) |
|---|---|---|---|
| 1 | 190 | -- | 95 |
| 2 | 300 | 105± | 95 |
| 3 | 400 | 105± | 95 |
| 4 | 510 | 105± | 95 |

Conversion: To convert feet to meters, multiply by 0.305.

Source: Application Exhibit F, Plate F81.

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