C. ACTION ALTERNATIVES: COMBINATION (MULTI-COMPONENT) OPTIONS

After analyzing various single action Features the next step was to develop scenarios that meet the requirements set forth by the North Dakota Steering Team. These scenarios involved a combination of the Features described in the last chapter of this document. These scenarios or Feature combinations were referred to as Alternatives. The primary requirement for any Alternative was that it had to meet all participating city M&I demands (including the Cargill and Cargill-type industrial demands). A secondary requirement was for the Alternative to meet rural demands in the Red River Valley.

This section will discuss the modeling results of eight Alternatives that have the potential of meeting nearly all or all of the M&I and rural demands in the basin. This discussion will center on the hydrologic aspects of the simulation results. Costs and impacts (recreational, environmental, etc.) will be discussed in the main study report and other Appendices. It should be noted that a change to the modeling was made when simulating the Alternative scenarios. This was a change requested by the Steering Committee. The change involved placing the city of Lisbon on ground water and off its current water storage allocation. Its storage allocation was left intact in Lake Ashtabula and only used when a modification of the Thomas-Acker storage plan was a component of an Alternative. Ground water returns from Lisbon were considered in the surface water simulations. The following Alternatives will be discussed:

? **BASELINE:** This is the Year 2050 Reclamation demand scenario without any Features. This run is the same as the "Future Without" Alternative (Alternative #1).

? **ALTERNATIVE #1:** This alternative is referred to as the Future Without Scenario. This Alternative represents 2050 Reclamation demand conditions without any enhancements for increased supply. This Alternative was run both with and without rural M&I demands (ALTERNATIVE 1 and ALTERNATIVE 1R respectively).

? **ALTERNATIVE #2:** This alternative represents conditions with:

1. Development of Lake Kindred on the Sheyenne River.
2. A ring-dike to re-regulate flows on the lower Sheyenne River**.**
3. A pipeline to the upper Red River is also included to meet upper Red River demands with excess water in the Sheyenne River.
4. Modification of storage allocations in Lake Ashtabula.
5. A minimum pool in Lake Ashtabula of 28,000 acre-feet.
6. Rural demands were included.

? **ALTERNATIVE #3:** This alternative represents conditions with:

1. Enlargement of Lake Ashtabula.
2. A ring-dike on the Red River near Fargo for re-regulation of upper Red River flows.
3. A ring-dike on the Sheyenne River for re-regulation of Sheyenne River flows.
4. A pipeline from the lower Sheyenne River to the upper Red River near Wahpeton. The pipeline was used to take advantage of the new storage in the Sheyenne to meet upper Red River demands.
5. Modification of storage allocations in Lake Ashtabula (including some water right priority modification in the upper Sheyenne).
6. A minimum pool of 28,000 acre feet in Lake Ashtabula.
7. Rural demands were supplied by groundwater and not included in the HYDROSS simulation.

? **ALTERNATIVE #4:** This alternative represents conditions with:

1. Groundwater augmentation to surface water supplies from the Spiritwood, Sheyenne Delta, Page, Galesburg, North Fargo Valley, Elk Valley, and Dakota aquifers.
2. A ring-dike located near Fargo to re-regulate upper Red River flows.
3. Modification of Lake Ashtabula storage allocations.
4. This alternative was simulated with a minimum pool in Lake Ashtabula as well as without minimum pool restrictions.
5. Rural demands were included.

? **ALTERNATIVE #5:** This alternative represents conditions with:

1. An import pipeline from Bismarck to Fargo supplying Fargo and Moorhead demands.
2. A spur pipeline from the main import pipeline to the upper Red River to meet shortages from Wahpeton to above the Fargo-Moorhead demand center.
3. A ring-dike for re-regulation of pipeline import water.
4. Modification of Lake Ashtabula storage allocations.
5. Rural demands were included.

Two versions of this Alternative were simulated with HYDROSS, one with two half size ring-dikes and one with one ring-dike (ALTERNATIVE #5A1R and ALTERNATIVE #5BR respectively).

? **ALTERNATIVE #6:** This alternative represents conditions with:

1. An import pipeline from the Oahe Reservoir on the Missouri River to Wahpeton supplying upper Red River demands.
2. A ring-dike for re-regulation of the pipeline import water.
3. Modification of Lake Ashtabula storage allocations.
4. A minimum pool of 28,000 acre-feet in Lake Ashtabula.
5. Rural demands were included.

? **ALTERNATIVE #7A:** This alternative represents conditions with:
1. Import to the upper Sheyenne River via the McClusky Canal and the New Rockford Canal connected via the Missouri Coteau Route.
2. A supply pipeline from the lower Sheyenne River to the upper Red River near Wahpeton.
3. Modification of Lake Ashtabula storage allocations.
4. A minimum pool of 28,000 acre-feet in Lake Ashtabula.
5. Rural demands were included.

? **ALTERNATIVE #7B:** This alternative represents conditions with:
1. Import to the upper Sheyenne River via the McClusky Canal with import directly to the Sheyenne River. The New Rockford Canal is not used.
2. A supply pipeline from the lower Sheyenne River to the upper Red River near Wahpeton.
3. Modification of Lake Ashtabula storage allocations.
4. A minimum pool of 28,000 acre-feet in Lake Ashtabula.
5. Rural demands were included.

? **ALTERNATIVE #7C:** This alternative represents conditions with:
1. Import to the upper Sheyenne River via the McClusky Canal and the New Rockford Canal connected via the Northern Route.
2. A supply pipeline from the lower Sheyenne River to the upper Red River near Wahpeton.
3. Modification of Lake Ashtabula storage allocations.
4. A minimum pool of 28,000 acre-feet in Lake Ashtabula.
5. Rural demands were included.

? **ALTERNATIVE #7D:** This alternative represents conditions with:
1. Import from the Missouri River to the upper Sheyenne River via the McClusky Canal. This import will supply water to the upper Sheyenne and continue on to supply Grand Forks.
2. An extension of the import pipeline sized at 25 cfs directly to the City of Grand Forks. This pipeline will supply Grand Forks and local rural demands and “free-up” the Grand Forks storage allocation in Lake Ashtabula for use by other cities and industry.
3. A supply pipeline from the lower Sheyenne River to the upper Red River near Wahpeton.
4. Modification of Lake Ashtabula storage allocations.
5. A minimum pool of 28,000 acre-feet in Lake Ashtabula.
6. Rural demands were included.

? **ALTERNATIVE #8:** This alternative represents conditions with:

1. Import from the Missouri River to several entities via various pipelines.
    a. Pipeline to Grand Forks (will free up the Lake Ashtabula Grand Forks storage allocation for use by other cities.
    b. Pipeline to the Cargill Plant and north valley rural centers near Wahpeton.
    c. Pipeline to the New Industry demand near Abercrombie.
    d. Pipeline to Fargo, Moorhead, and New Industry near Fargo.
5. Modification of Lake Ashtabula storage allocations.
6. A minimum pool of 28,000 acre-feet in Lake Ashtabula.
7. Rural demands were included.

These alternatives and their respective modeling results will now be discussed in detail.

1. BASELINE: Year 2050 Reclamation demands under existing operation/storage allocation criteria. The HYDROSS model run designation for this simulation was BASELINE.

Baseline Run Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria. This model run was assumed to represent a baseline condition (similar to Alternative 1 No-Action alternative) to which all other alternatives could be compared. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. No future rural demands were included in the simulation.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at one-half of the active conservation pool (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 47,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was utilized. This was accomplished by splitting Lake Ashtabula into five separate reservoirs to represent the water allocations for the cities of Fargo, Grand Forks, West Fargo, Valley City, and Lisbon. Each city's allocation contributed proportionately to evaporation. A 6th reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Each city's allocation contributed proportionately to this release. No other instream flow criteria were used in this simulation.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 101 through 104.

Baseline Run Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal and industrial demands in the Red River Valley. The model run demonstrated that city shortages could occur 13 out of 54 years and industrial shortages could occur in 47 of the 54 years simulated (not including small miscellaneous industry). In the worst case year, 1934 a total M&I shortage 53,190 acre feet was computed. City shortages totaled 31,030 acre feet and “other” industrial shortages (including the New Industry plants) totaled 22,160 acre-feet in 1934.

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir’s full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from <1 cfs to 2400 cfs. The average monthly release was computed at 102 cfs. The reservoir reached its minimum pool of 28,000 acre-feet in 13 of the 648 months simulated (2 percent).

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

Table 101: Future City Shortage Summary

Alternative: BASELINE

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2,4]	Valley City[2]	West Fargo[2]
No. years with shortages:	1	0	9	10	2	0	0	2	13
Average annual shortage for 54-year simulation period (acre-feet):	1	0	1982	461	7	0	0	14	96
Average annual shortage for years with shortages (acre-feet):	60	0	11893	2487	190	0	0	385	401
Largest annual shortage (acre-feet) and year:	60 (1937)	0	24950 (1934)	5360 (1934)	290 (1937)	0	0	580 (1940)	1400 (1940)
Largest shortage percent of total surface raw water demand (percent):	8	0	68	60	23	0	0	46	25

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.

[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).

[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only

[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 102: Industrial Shortage Summary
Alternative: BASELINE

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	14	21	21	5	47
Average annual shortage for 54-year simulation period (acre-feet):	787	1006	1016	93	962
Average annual shortage for years with shortages (acre-feet):	3035	2587	2611	1000	1105
Largest annual shortage (acre-feet) and year:	5500 (1934)	5500 (1934)	5500 (1934)	1500 (1934)	4080 (1934)
Largest shortage percent of Total surface water demand (percent):	92	92	92	25	68

Table 103: River Flow Activity for Selected Flow Points[3]
Alternative: BASELINE

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	**Number Of Months Above Channel Capacity**	**Average Monthly Flow (cfs)**	**Highest Simulated Monthly Flow (cfs)**	**Lowest Simulated Monthly Flow (cfs)**
Sheyenne River Near Warwick	600	11	49	1418	0
Sheyenne River Below Baldhill Dam	4000	0	113	2400	<1
Sheyenne River Near Valley City	2500	3	110	2885	0
Sheyenne River Near Lisbon	2250	5	130	3214	0
Sheyenne River Near Kindred	2800	1	159	2985	0
Red River Near Fargo	3000	19	510	9831	0
Red River Near Halstad	15000	4	1295	20549	<1
Red River Near Grand Forks	21000	8	2623	36081	0
Red River Near Emerson	26000	11	3532	72351	15

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 104: Storage Activity Summary

Alternative: BASELINE

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	26300	59520	13	2400	<1	102
Lake Ashtabula (Fargo Portion)	37362	15708	32639				
Lake Ashtabula (West Fargo Portion)	999	420	867				
Lake Ashtabula (Grand Forks Portion)	20846	8764	19136				
Lake Ashtabula (Lisbon Portion)	400	668	385				
Lake Ashtabula (Valley City Portion)	6993	2940	6525				
	Maximum Storage	**Minimum Storage**	**Average Monthly Storage**				
Lake Ashtabula Combined Elevation (feet)	1266	1257	1265				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5222				

2. **ALTERNATIVE 1 (No Action): Year 2050 Reclamation demands under existing operation/storage allocation criteria. This simulation was used to represent future conditions with no action. No rural water needs were included in this simulation.**

   a. The HYDROSS model run designation for this simulation was ALT1.

Run ALT1 Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria. This model run was assumed to represent a the "future without action" condition (identical to the BASELINE simulation) to which all other alternatives could be compared. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. No rural demands were included in this simulation.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at one-half of the active conservation pool (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 47,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was utilized. This was accomplished by splitting Lake Ashtabula into five separate reservoirs to represent the water allocations for the cities of Fargo, Grand Forks, West Fargo, Valley City, and Lisbon. Each city's allocation contributed proportionately to evaporation. A 6^{th} reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Each city's allocation contributed proportionately to this release. No other instream flow criteria were used in this simulation.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 105 through 108.

Run ALT1 Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal and industrial demands in the Red River Valley. The model run demonstrated that city shortages could occur 13 out of 54 years and industrial shortages could occur in 47 of the 54 years simulated (not including small miscellaneous industry). In the worst case year, 1934 a total M&I shortage 53,190 acre feet was computed. City shortages totaled 31,030 acre feet and "other" industrial shortages (including the New Industry plants) totaled 22,160 acre-feet in 1934.

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from <1 cfs to 2,400 cfs. The average monthly release was computed at 102 cfs. The reservoir reached its minimum pool of 28,000 acre-feet in 13 of the 648 months simulated (2 percent).

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

Table 105: Future City Shortage Summary

Alternative: ALTERNATIVE 1

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	1	0	9	10	2	0	0	2	13
Average annual shortage for 54-year simulation period (acre-feet):	1	0	1982	461	7	0	0	14	96
Average annual shortage for years with shortages (acre-feet):	60	0	11893	2487	190	0	0	385	401
Largest annual shortage (acre-feet) and year:	60 (1937)	0	24950 (1934)	5360 (1934)	290 (1937)	0	0	580 (1940)	1400 (1940)
Largest shortage percent of total surface raw water demand (percent):	8	0	68	60	23	0	0	46	25

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.

[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).

[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only

[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 106: Industrial Shortage Summary
Alternative: ALTERNATIVE 1

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	14	21	21	5	47
Average annual shortage for 54-year simulation period (acre-feet):	787	1006	1016	93	962
Average annual shortage for years with shortages (acre-feet):	3035	2587	2611	1000	1105
Largest annual shortage (acre-feet) and year:	5500 (1934)	5500 (1934)	5500 (1934)	1500 (1934)	4080 (1934)
Largest shortage percent of Total surface water demand (percent):	92	92	92	25	68

Table 107: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 1

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	**Number Of Months Above Channel Capacity**	**Average Monthly Flow (cfs)**	**Highest Simulated Monthly Flow (cfs)**	**Lowest Simulated Monthly Flow (cfs)**
Sheyenne River Near Warwick	600	11	49	1418	0
Sheyenne River Below Baldhill Dam	4000	0	113	2400	<1
Sheyenne River Near Valley City	2500	3	110	2885	0
Sheyenne River Near Lisbon	2250	5	130	3214	0
Sheyenne River Near Kindred	2800	1	159	2985	0
Red River Near Fargo	3000	19	510	9831	0
Red River Near Halstad	15000	4	1295	20549	<1
Red River Near Grand Forks	21000	8	2623	36081	0
Red River Near Emerson	26000	11	3532	72351	15

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 108: Storage Activity Summary

Alternative: ALTERNATIVE 1

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	26300	59520	13	2400	<1	102
Lake Ashtabula (Fargo Portion)	37362	15708	32639				
Lake Ashtabula (West Fargo Portion)	999	420	867				
Lake Ashtabula (Grand Forks Portion)	20846	8764	19136				
Lake Ashtabula (Lisbon Portion)	400	668	385				
Lake Ashtabula (Valley City Portion)	6993	2940	6525				
	Maximum Storage	**Minimum Storage**	**Average Monthly Storage**				
Lake Ashtabula Combined Elevation (feet)	1266	1257	1265				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5222				

2. **ALTERNATIVE 1-RURAL (No Action with Rural Demands): Year 2050 Reclamation demands under existing operation/storage allocation criteria. This simulation was used to represent future conditions with no action. Rural water needs were included in this simulation.**

   b. The HYDROSS model run designation for this simulation was ALT1R.

Run ALT1R Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria. This model run was assumed to represent a the "future without action" condition with the addition of rural water system needs. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      ? Agassiz Water Users, Inc.
      ? Tri-County Water Users, Inc.
      ? Walsh Water Users
      ? Grand Forks-Traill Water Users, Inc.
      ? Traill Water Users, Inc.
      ? Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      ? Cass Rural Water Users, Inc.
      ? Southeast Rural Water Users, Inc.
      ? Ransom-Sargent Water Users, Inc.
      ? Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at one-half of the active conservation pool of 38,600 acre-feet (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 47,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was utilized. This was accomplished by splitting Lake Ashtabula into five separate reservoirs to represent the water allocations for the cities of Fargo, Grand Forks, West Fargo, Valley City, and Lisbon. Each city's allocation contributed proportionately to evaporation. A 6^{th} reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Each city's allocation contributed proportionately to this release. No other instream flow criteria were used in this simulation.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 109 through 112.

Run ALT1R Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal and industrial demands in the Red River Valley. The model run demonstrated that city and industrial shortages could occur in 47 of the 54 years simulated (not including small miscellaneous industry). In the worst case year, 1934 a total M&I shortage 53,630 acre feet was computed. City shortages totaled 31,470 acre feet and "other" industrial shortages (including the New Industry plants) totaled 22,160 acre-feet in 1934.

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from <1 cfs to 2,400 cfs. The average monthly release was computed at 102 cfs. The reservoir reached its minimum pool of 28,000 acre-feet in 13 of the 648 months simulated (Two percent).

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

Table 109: Future City Shortage Summary
Alternative: ALTERNATIVE 1-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	1	0	9	10	2	0	0	2	13
Average annual shortage for 54-year simulation period (acre-feet):	1	0	2084	461	7	0	0	14	115
Average annual shortage for years with shortages (acre-feet):	60	0	12501	2487	190	0	0	385	479
Largest annual shortage (acre-feet) and year:	60 (1937)	0	25390 (1934)	5360 (1934)	290 (1937)	0	0	580 (1940)	1880 (1940)
Largest shortage percent of total surface water demand (percent):	8	0	69	60	23	0	0	46	33

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.
[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).
[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only
[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 110: Industrial Shortage Summary
Alternative: ALTERNATIVE 1 – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	14	21	22	5	47
Average annual shortage for 54-year simulation period (acre-feet):	787	1006	1016	93	962
Average annual shortage for years with shortages (acre-feet):	3035	2587	2493	1000	1105
Largest annual shortage (acre-feet) and year:	5500 (1934)	5500 (1934)	5500 (1934)	1500 (1934)	4080 (1934)
Largest shortage percent of Total surface water demand (percent):	92	92	92	25	1500

Table 111: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 1 – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	Number Of Months Above Channel Capacity	Average Monthly Flow (cfs)	Highest Simulated Monthly Flow (cfs)	Lowest Simulated Monthly Flow (cfs)
Sheyenne River Near Warwick	600	11	49	1418	0
Sheyenne River Below Baldhill Dam	4000	0	102	2400	<1
Sheyenne River Near Valley City	2500	3	110	2885	0
Sheyenne River Near Lisbon	2250	5	130	3214	0
Sheyenne River Near Kindred	2800	1	159	2985	0
Red River Near Fargo	3000	19	510	9831	0
Red River Near Halstad	15000	4	1290	20549	<1
Red River Near Grand Forks	21000	8	2613	36069	0
Red River Near Emerson	26000	11	3522	72339	15

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 112: Storage Activity Summary

Alternative: ALTERNATIVE 1 – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	26300	59480	13	2400	<1	102
Lake Ashtabula (Fargo Portion)	37362	15708	32572				
Lake Ashtabula (West Fargo Portion)	999	420	865				
Lake Ashtabula (Grand Forks Portion)	20846	8764	19135				
Lake Ashtabula (Lisbon Portion)	400	668	385				
Lake Ashtabula (Valley City Portion)	6993	2940	6524				
	Maximum Storage	**Minimum Storage**	**Average Monthly Storage**				
Lake Ashtabula Combined Elevation (feet)	1266	1257	1265				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5222				

3. **ALTERNATIVE 2 – RURAL (In-Basin, Kindred Dam (Large Size) Alternative with Rural Demands): Year 2050 Reclamation demands with the addition of Lake Kindred, located downstream of Lake Ashtabula for water supply. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT2R.**

Run ALT2R Description: This model run was developed to represent year 2050 demand conditions with in-basin water supplies developed in the form of new storage at Lake Kindred, located downstream of Lake Ashtabula. This model run was assumed to represent the "future with additional in-basin storage condition. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      ? Agassiz Water Users, Inc.
      ? Tri-County Water Users, Inc.
      ? Walsh Water Users
      ? Grand Forks-Traill Water Users, Inc.
      ? Traill Water Users, Inc.
      ? Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      ? Cass Rural Water Users, Inc.
      ? Southeast Rural Water Users, Inc.
      ? Ransom-Sargent Water Users, Inc.
      ? Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at one-half of the active conservation pool (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 47,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was utilized. An option to this run was to modify the Thomas-Acker allocation plan if needed – this was not necessary. This was accomplished by splitting Lake Ashtabula into five separate reservoirs to represent the water allocations for the cities of Fargo, Grand Forks, West Fargo, Valley City, and Lisbon. Each city's allocation contributed proportionately to evaporation. A 6th reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Each city's allocation contributed proportionately to this release. No other instream flow criteria were used in this simulation.

g. Lake Kindred was considered to be operational and was set at one-half of conservation capacity (42,000 acre-feet) at the start of the simulation to represent average antecedent moisture conditions prior to the start of the 1930s drought.. The reservoir used in this simulation was assumed to represent the maximum size (84,000 acre-feet). This was the maximum effective size of the reservoir to meet all in-basin demands. No specific allocations were assigned to the reservoir, rather as shortages occurred in the basin, they were assigned to Lake Kindred (after all other supplies were exhausted) in an upstream-to-downstream process based on several sub-runs of this alternative.

h. No operational release was made from Lake Kindred. This was done for several reasons. First, it was determined that this type of non-mandatory release would be consistent with current policy in North Dakota in which no minimum instream flow requirements exist in the basin (except for the operational release from Lake Ashtabula). Second, it was determined that a constant release could "waste" water downstream when not needed in some month. Third, Lake Kindred releases into a gaining portion of the Sheyenne River which could add to "wasting". Finally, since the reservoir was operated on a demand driven basis, it was assumed that all downstream needs would already be met on an on-call basis.

i. Lake Kindred operated with no minimum pool.

j. A pipeline to the upper Red River from Lake Kindred was included in the simulation. This pipeline (24 cfs capacity) was used to meet upper Red River shortages (Cargill, New Industry at Abercrombie, and South Valley Rural (6 cfs)) from the Sheyenne River and Lake Kindred.

k. A 22,000 acre-foot ring-dike located southwest of the city of Fargo was included to re-regulate flows in the upper Red River (natural, return, and flows imported from the Sheyenne River). The ring-dike was designed to serve Fargo, Moorhead, and the New Industry near Fargo. This facility was proven effective in limiting the import from the Sheyenne to the Fargo-Moorhead demand center.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 113 through 116. Figure 21 illustrates the layout of this alternative.

Run ALT2R Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal and industrial demands in the Red River Valley. The model run demonstrated that city and industrial demands were met in all of the 54 years simulated (not including small miscellaneous industry).

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from <1 cfs to 2,400 cfs. The average monthly release was computed at 113 cfs. The reservoir reached its minimum pool of 28,000 acre-feet in 3 of the 648 months simulated (<1 percent).

Lake Kindred reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from the reservoir ranged from 2 cfs to 2,960 cfs. The average monthly release was computed at 145 cfs. The reservoir reached 0.0 acre-feet in 7 of the 648 months simulated (1 percent).

A ring-dike was used as offstream storage along the Red River near Fargo was utilized during the 1930s critical drought. Inflows to the reservoir ranged from 0.0 cfs to 400 cfs. The average monthly inflow was computed at 70 cfs. The reservoir reached less than 100 acre-feet in 22 of the 648 months simulated (3 percent).

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

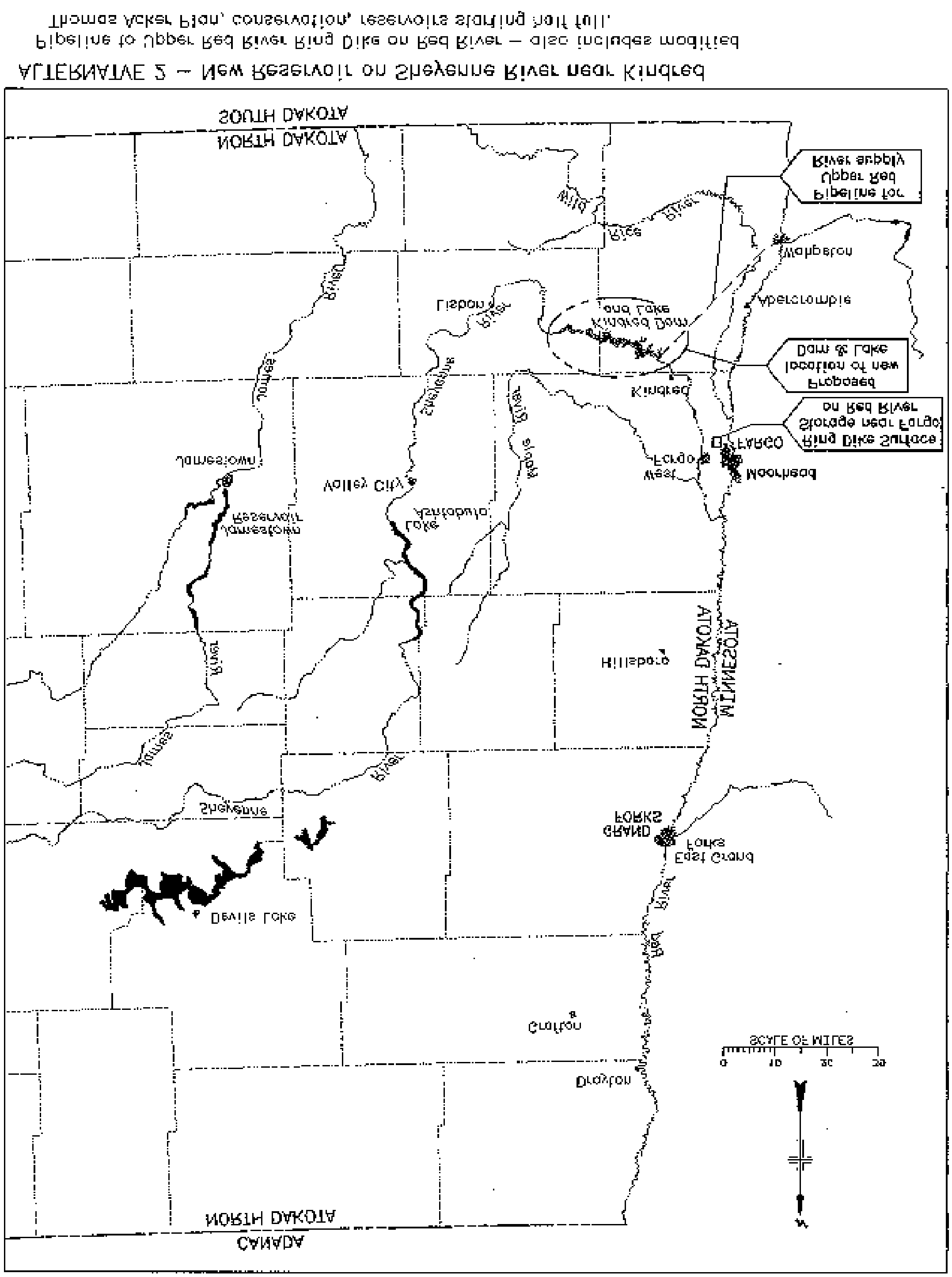

ALTERNATIVE 2 – New Reservoir on Sheyenne River near Kindred
Pipeline to Upper Red River Ring Dike on Red River – also includes modified
Thomas Acker Plan, conservation, reservoirs starting half full.
SOUTH DAKOTA
NORTH DAKOTA
Pipeline for Upper Red River supply
Wahpeton
Abercrombie
Lisbon
Kindred Dam and Lake
Proposed location of new Dam & Lake
Kindred
Ring Dike Surface Storage near Fargo on Red River
FARGO
West Fargo
Moorhead
Jamestown
Jamestown Reservoir
Valley City
Lake Ashtabula
Hillsboro
NORTH DAKOTA
MINNESOTA
GRAND FORKS
East Grand Forks
Devils Lake
Grafton
Drayton
SCALE OF MILES
CANADA

Figure 21

Table 113: Future City Shortage Summary
Alternative: ALTERNATIVE 2 – RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.
[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).
[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only
[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 114: Industrial Shortage Summary
Alternative: ALTERNATIVE 2 – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 115: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 2 – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	**Number Of Months Above Channel Capacity**	**Average Monthly Flow (cfs)**	**Highest Simulated Monthly Flow (cfs)**	**Lowest Simulated Monthly Flow (cfs)**
Sheyenne River Near Warwick	600	11	49	1418	0
Sheyenne River Below Baldhill Dam	4000	0	113	2,400	<1
Sheyenne River Near Valley City	2500	3	110	2885	0
Sheyenne River Near Lisbon	2250	5	130	3214	0
Sheyenne River Near Kindred	2800	1	145	2963	2
Red River Near Fargo	3000	19	502	9829	0
Red River Near Halstad	15000	4	1274	20392	6
Red River Near Grand Forks	21000	8	2596	36086	5
Red River Near Emerson	26000	11	3504	72357	31

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3 Rounded to nearest whole cfs.

Table 116: Storage Activity Summary
Alternative: ALTERNATIVE 2 – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	28000	60331	3	2400	<1	113
Lake Ashtabula (Fargo Portion)	37362	15708	33661				
Lake Ashtabula (West Fargo Portion)	999	420	900				
Lake Ashtabula (Grand Forks Portion)	20846	8764	19194				
Lake Ashtabula (Lisbon Portion)	400	668	355				
Lake Ashtabula (Valley City Portion)	6993	2940	6229				
	Maximum Storage	**Minimum Storage**	**Average Monthly Storage**				
Lake Ashtabula Combined Elevation (feet)	1266	1257	1265				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5222				

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Kindred Storage Activity (acft) (see above headings)	84000	0*	72,190	7	2960	2	145
Lake Kindred Elevation (feet)	985	950	983				
Lake Kindred Surface Area (acres)	5800	0	5400				

Fargo ring-dike Storage Activity (acft)					Maximum Inflow (cfs)	Minimum Inflow (cfs)	Average Inflow (cfs)
Red River (see above headings)	22000	100*	19260	22	400	0.0	70

* No designated minimum storage capacity

4. **ALTERNATIVE 3 (In-Basin, Enlarged Lake Ashtabula Alternative): Year 2050 Reclamation demands with the addition of added storage in Lake Ashtabula (raised dam) for water supply. Lake Ashtabula's minimum pool of 28,000 acre-feet was maintained and storage allocations were modified (some modification of water right priorities was also done in conjunction with the allocation modifications). Rural water needs were supplied by ground water and not included in this simulation. The HYDROSS model run designation for this simulation was ALT3-28B.**

Note: Two versions of this alternative was completed that did not met the team criteria.
*** HYDROSS model run ALT3 was run with no shortages. Rural water was supplied by the model. Lake Ashtabula went to a minimum of 11,440 acre-feet.**
*** HYDROSS model ALT3R28A was run with rural water included. Shortage to city was 11,540 acre-feet and industry was 6,130 acre-feet for a total of 17,670 acre-feet.**

Run ALT3-28B Description: This model run was developed to represent year 2050 demand conditions with in-basin water supplies developed in the form of new storage at Lake Ashtabula. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were not included in this simulation, but was supplied by securing additional water from the Spiritwood Aquifer and from purchase of existing irrigation water rights in the Sheyenne Delta, Page/Galesburg, and Elk Valley aquifers. No return flows were simulated from rural water users as it was assumed these flows would not make it to any main waterways. See figure 11 for location of these aquifers. Figure 23 illustrates the potential layout of conveyance facilities.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with an enlarged Lake Ashtabula (includes additional storage of 56,000 acre-feet above the original capacity of 66,600 acre-feet for a total reservoir capacity of 122,600 acre-feet). Lake Ashtabula was set at one-half of the active conservation pool (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 75,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). As a last resort, this pool could be used to meet shortages. This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to minimize various city shortages with excess allocation water. The original cities participating in the Thomas-Acker Plan had priority to their supplies. As shortages mounted, excess water from these allocations were passed to other cities in an upstream-to-downstream iterative process. As in the BASELINE simulation, Lake Ashtabula was split into five separate reservoirs to represent the water allocations for the cities of Fargo, Grand Forks, West Fargo, Valley City, and Lisbon. Each city's allocation contributed proportionately to evaporation. A 6th reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option. In addition, some modification of upstream water right priorities was done in conjunction with storage allocation modification. This allowed upstream users such as New Industry 5 at Kindred to utilized natural flow and stored water so that downstream users such as the city of Grand Forks could benefit from return flows.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Each city's allocation contributed proportionately to this release. The added excess storage did not contribute to this release. No other instream flow criteria were used in this simulation.

g. A pipeline to the upper Red River from the lower Sheyenne River was included in the simulation. This pipeline (18 cfs capacity) was used to meet upper Red River shortages (Cargill, and New Industry at Abercrombie) from the Sheyenne River and Lake Ashtabula's added capacity.

h. A 22,000 acre-foot ring-dike located southwest of the city of Fargo was included to re-regulate flows in the upper Red River (natural, return, and flows imported from the Sheyenne River). The ring-dike was designed to serve Fargo, Moorhead, and the New Industry near Fargo. This facility was proven effective in limiting the import from the Sheyenne to the Fargo-Moorhead demand center.

i. A 22,000 acre-foot ring-dike located upstream of the Fargo intake on the Sheyenne River was also included to re-regulate flows in the Sheyenne River (natural, stored and return flows). The ring-dike was designed to serve Fargo, Moorhead, and the New Industry near Fargo and West Fargo

j. Augmentation of supplies determined from shortages to New Industry 5 came from groundwater. An 8.0 cfs "pumped" inflow into Lake Ashtabula from Spiritwood Aquifer was used for supply to New Industry 5. Lake Ashtabula was allowed to regulate this inflow. This supply was assumed to be a constant inflow to the surface water system. This was modeled by placing "dummy" no-loss reservoir along the river that released a constant flow. This New Industry 5 could be located near Valley City, which is closer to the Spiritwood Aquifer.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 117 through 120. Figure 22 illustrates the layout of this alternative.

Run ALT3-28B Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal and industrial demands in the Red River Valley. The model run demonstrated that city and industrial demands would be satisfied in all of the 54 years simulated .

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 5 cfs to 2,400 cfs. The average monthly release was computed at 98 cfs. The reservoir reached its minimum pool of 28,000 acre-feet in 1 of the 648 months simulated.

A ring-dike was used as offstream storage along the Red River near Fargo was utilized during the 1930s critical drought. Inflows to the reservoir ranged from 0.0 cfs to 400 cfs. The average monthly inflow was computed at 70 cfs. The reservoir reached less than 100 acre-feet in 10 of the 648 months simulated (2 percent).

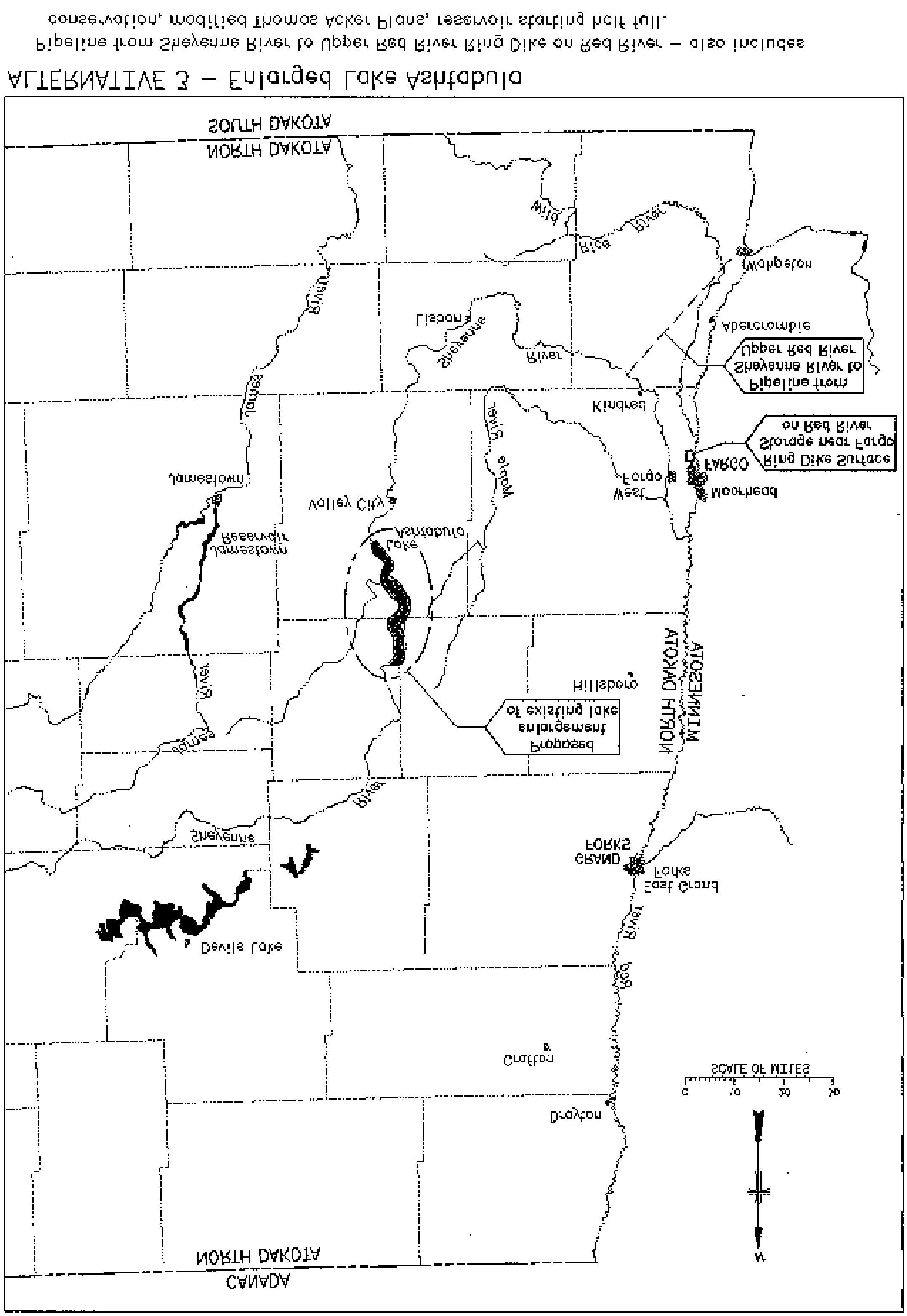

ALTERNATIVE 3 – Enlarged Lake Ashtabula
Pipeline from Sheyenne River to Upper Red River Ring Dike on Red River – also includes
conservation, modified Thomas Acker Plans, reservoir starting half full.
SOUTH DAKOTA
NORTH DAKOTA
CANADA
NORTH DAKOTA
MINNESOTA
Wild Rice River
Wahpeton
Abercrombie
Pipeline from Sheyenne River to Upper Red River
Ring Dike Surface Storage near Fargo on Red River
FARGO
Moorhead
West Fargo
Kindred
Lisbon
Sheyenne River
James River
Jamestown
Jamestown Reservoir
Valley City
Lake Ashtabula
Maple River
Proposed enlargement of existing lake
Hillsboro
GRAND FORKS
East Grand Forks
Red River
Devils Lake
Grafton
Drayton
SCALE OF MILES
0 10 30 50
N

Figure 22

A ring-dike was used as offstream storage along the Sheyenne River near Fargo was utilized during the 1930s critical drought. Inflows to the reservoir ranged from 0.0 cfs to 200 cfs. The average monthly inflow was computed at 10 cfs. The reservoir reached less than full storage of 22,000 acre-feet in 15 of the 648 months simulated (2 percent).

Surface water irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

Table 117: Future City Shortage Summary

Alternative: ALTERNATIVE 3-28B

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.

[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).

[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only

[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 118: Industrial Shortage Summary
Alternative: ALTERNATIVE 3-28B

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 119: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 3-28B

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	**Number Of Months Above Channel Capacity**	**Average Monthly Flow (cfs)**	**Highest Simulated Monthly Flow (cfs)**	**Lowest Simulated Monthly Flow (cfs)**
Sheyenne River Near Warwick	600	11	49	1418	0
Sheyenne River Below Baldhill Dam	4000	0	97	2400	2
Sheyenne River Near Valley City	2500	3	106	2883	0
Sheyenne River Near Lisbon	2250	5	126	3219	0
Sheyenne River Near Kindred	2800	1	158	2970	1
Red River Near Fargo	3000	19	502	9829	0
Red River Near Halstad	15000	4	1292	20533	6
Red River Near Grand Forks	21000	8	2619	36101	3
Red River Near Emerson	26000	11	3529	72371	36

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 120: Storage Activity Summary
Alternative: ALTERNATIVE 3-28B

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	122600	27590	107850	1	2400	4	97
Lake Ashtabula (Fargo Portion)	37362	14170	66116				
Lake Ashtabula (West Fargo Portion)	999	390	907				
Lake Ashtabula (Grand Forks Portion)	20846	9400	19359				
Lake Ashtabula (Lisbon Portion)	400	170	371				
Lake Ashtabula (Valley City Portion)	6993	3170	6537				
Lake Ashtabula (Added Storage)	56000	0	48916				
	Maximum Storage	**Minimum Storage**	**Average Monthly Storage**				
Lake Ashtabula Combined Elevation (feet)	1276	1257	1274				
Lake Ashtabula Combined Surface Area (Acres)	7750	3373	7300				

Ring-dike Storage Activity (acft)					Maximum Inflow (cfs)	Minimum Inflow (cfs)	Average Inflow (cfs)
Red River	22000	100*	19270	10	400	0.0	70
Sheyenne River	22000	1590*	21810	15[1]	200	0.0	10
(see above headings)							

* No designated minimum storage capacity
[1] Months below maximum storage

5. ALTERNATIVE 4-RURAL (In Basin – Utilization of Groundwater Supplies): Year 2050 Reclamation demands under existing operation/storage allocation criteria. This simulation was used to represent future conditions with no action. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT41LAR.

Run ALT41LAR Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria. This model run was assumed to represent the "in-basin groundwater" condition with the addition of rural water system needs. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
    1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
        ? Agassiz Water Users, Inc.
        ? Tri-County Water Users, Inc.
        ? Walsh Water Users
        ? Grand Forks-Traill Water Users, Inc.
        ? Traill Water Users, Inc.
        ? Langdon Rural Water Users, Inc.
    2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
        ? Cass Rural Water Users, Inc.
        ? Southeast Rural Water Users, Inc.
        ? Ransom-Sargent Water Users, Inc.
        ? Dakota Water Users, Inc.

    More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at one-half of the active conservation pool of 38,600 acre-feet (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 47,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257) until all basin supplies were exhausted. When this occurred, the pool was utilized to meet shortages only when necessary. This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to meet shortages. In addition, this simulation run deviated from other runs in that Lake Ashtabula was simulated at one single reservoir rather than splitting the reservoir into separate allocation reservoirs for cities on the Thomas-Acker Plan. This was done as a result of the model not properly re-regulating the augmentation water from the Spiritwood Aquifer proportionally through all five allocation reservoirs. The program tended to bypass all reservoirs that were in series and only utilized the last reservoir resulting in some "wasting" of water downstream. It was assumed that the program was confusing the different "project" and "natural" flow assignments in the Lake Ashtabula complex. The single reservoir approach, with equal priority dates on the Thomas-Acker cities and junior rights on other cities appeared to yield more appropriate results.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. The single Ashtabula configuration simply provided the 13 cfs each month. No other instream flow criteria were used in this simulation.

g. Augmentation of supplies determined for the no-action alternative came from groundwater. Several aquifers were used for supply in several parts of the basin. These supplies were assumed to be a constant inflow to the surface water system. They were modeled by placing "dummy" no-loss reservoirs where needed in along the mainstem rivers that released a constant flow. When shortages occurred under conditions without the new inflow, cities were assigned supply from nearby aquifers in an upstream-to-downstream iterative process. The following aquifers and their respective "pumped" inflow to the surface water supply system were included in this simulation:
    ? Spiritwood Aquifer – 9.11 cfs inflow into Lake Ashtabula. Lake Ashtabula was allowed to regulate this inflow.
    ? Sheyenne Delta Aquifer (derived from the purchase of irrigation rights) – 3.56 cfs inflow upstream of the Fargo intake on the Sheyenne River.
    ? Page/Galesburg Aquifer (derived from the purchase of irrigation rights) – 4.6 cfs inflow upstream of the Fargo intake on the Sheyenne River.
    ? Elk Valley Aquifer (derived from the purchase of irrigation rights) – 3.84 cfs inflow above the city of Grand Forks on the Red River.
    ? Dakota Aquifer coupled with a desalinization plant – 3.10 cfs inflow above the city of Grand Forks on the Red River.

h. A 22,000 acre-foot ring-dike located southwest of the city of Fargo was included to re-regulate flows in the upper Red River (natural, return, and flows imported from the Sheyenne River). The ring-dike was designed to serve Fargo, Moorhead, and the New Industry near Fargo. This facility was proven effective in limiting the import from the Sheyenne to the Fargo-Moorhead demand center.

i. A 22,000 acre-foot ring-dike located upstream of the Fargo intake on the Sheyenne River was also included to re-regulate flows in the upper Red River (natural, stored and return flows). The ring-dike was designed to serve Fargo, Moorhead, and the New Industry near Fargo and West Fargo.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 121 through 124. Figure 23 illustrates the layout of this alternative.

Run ALT41LAR Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal and industrial demands in the Red River Valley. The model run demonstrated that city and industrial shortages could occur in 6 of the 54 years simulated (not including small miscellaneous industry). In the worst case year, 1934 a total M&I shortage of 7,590 acre feet was computed. City shortages totaled 6,990 acre feet and "other" industrial shortages (including the New Industry plants) totaled 600 acre-feet in 1934.

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 5 cfs to 2,400 cfs. The average monthly release was computed at 111 cfs. The reservoir reached its minimum pool of 28,000 acre-feet in 45 of the 648 months simulated (7 percent).

A ring-dike was used for an offstream storage along the Red River near Fargo was utilized during the 1930s critical drought. Inflows to the reservoir ranged from 0.0 cfs to 400 cfs. The average monthly inflow was computed at 70 cfs. The reservoir reached less than 1,000 acre-feet in 75 of the 648 months simulated (12 percent). Another offstream ring-dike along the Sheyenne River was utilized during the 1930's critical drought. The reservoir reached less than 1,000 acre-feet in 9 of the 648 months simulated (1 percent).

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

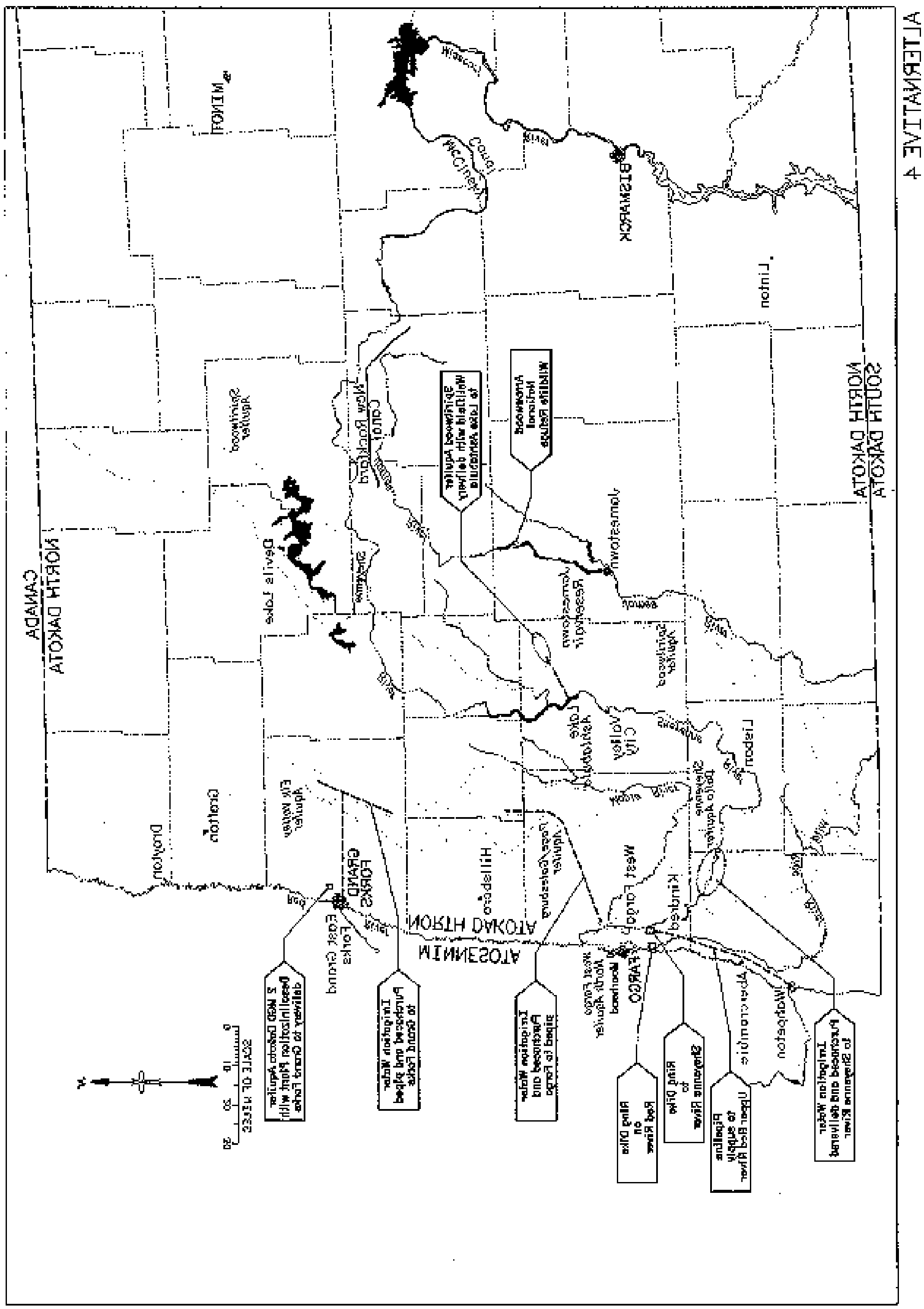

ALTERNATIVE 4
CANADA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
MINOT
BISMARCK
Linton
Devils Lake
Jamestown
Valley City
Lisbon
GRAND FORKS
East Grand Forks
FARGO
Moorhead
West Fargo
Kindred
Wahpeton
Breckenridge
Hillsboro
Grafton
Drayton
SCALE OF MILES

Figure 23

Table 121: Future City Shortage Summary

Alternative: ALTERNATIVE 4-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	5	0	0	0	0	2	3
Average annual shortage for 54-year simulation period (acre-feet):	0	0	271	0	0	0	0	11	2
Average annual shortage for years with shortages (acre-feet):	0	0	2930	0	0	0	0	295	40
Largest annual shortage (acre-feet) and year:	0	0	6630	0	0	0	0	300	60
Largest shortage percent of total surface water demand (percent):	0	0	18	0	0	0	0	24	1

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.

[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).

[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only

[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 122: Industrial Shortage Summary

Alternative: ALTERNATIVE 4 – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	1	0	0	2
Average annual shortage for 54-year simulation period (acre-feet):	0	<1	0	0	21
Average annual shortage for years with shortages (acre-feet):	0	10	0	0	555
Largest annual shortage (acre-feet) and year:	0	10	0	0	610
Largest shortage percent of Total surface water demand (percent):	0	<1	0	0	10

Table 123: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 4 – RURAL

	Estimated Non-Damaging Channel Capacity[1] (cfs)	Number Of Months Above Channel Capacity	Average Monthly Flow (cfs)	Highest Simulated Monthly Flow (cfs)	Lowest Simulated Monthly Flow (cfs)
Sheyenne River Near Warwick	600	11	48	1418	0
Sheyenne River Below Baldhill Dam	4000	0	111	2400	5
Sheyenne River Near Valley City	2500	3	119	2894	0
Sheyenne River Near Lisbon	2250	5	138	3223	0
Sheyenne River Near Kindred	2800	1	167	3013	<1
Red River Near Fargo	3000	19	490	9827	0
Red River Near Halstad	15000	4	1304	20579	7
Red River Near Grand Forks	21000	8	2637	36114	2
Red River Near Emerson	26000	11	3547	72384	13

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 124: Storage Activity Summary

Alternative: ALTERNATIVE 4 – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	27220	59400	45	2400	5	111
Lake Ashtabula Combined Elevation (feet)	1266	1257	1265				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5222				

Ring-dike Storage Activity (acft)					Maximum Inflow (cfs)	Minimum Inflow (cfs)	Average Inflow (cfs)
Red River (see above headings)	23000	1000*	19190	75	400	0.0	70
Sheyenne River (see above headings)	23000	1000*	22430	9	400	0.0	70

* No designated minimum storage capacity

6. **ALTERNATIVE 5-RURAL (Import – Pipeline from Bismarck to the Fargo): Year 2050 Reclamation demands with an import pipeline from the Missouri River near Bismarck to a ringdike near Fargo. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT5A1R.**

Note: A version of this model run (ALT5BR) was done with a single ringdike system on the import pipeline from Bismarck to Fargo with a separate unregulated pipeline to the upper Red River. The model run ALT5A1R was done with a two ringdike system (one near Fargo and one near Wahpeton), which regulated the import more efficiently and was easier to track. The total import from Alt5BR was actually 5 cfs higher (total import of 70 cfs), however it was deemed a more realistic representation of how this alternative may be operated. Resultant flows were the same as the ALT5A1R model run in the Sheyenne River, but showed the higher 5 cfs in the Red River. The ALT5A1R run give the best flow results and is presented here.

Run ALT5A1R Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria with the exception of a pipeline from the Missouri River near Bismarck to a ringdike near Fargo (this will supply Fargo, Moorhead, and New Industry near Fargo). This import allows the release of some of Fargo's Lake Ashtabula water, which can then be used to meet other shortage demands. This feature also includes a pumping plant and pipeline to supply Missouri River water to meet shortages on the upper Red River at Abercrombie and Wahpeton. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      - Agassiz Water Users, Inc.
      - Tri-County Water Users, Inc.
      - Walsh Water Users
      - Grand Forks-Traill Water Users, Inc.
      - Traill Water Users, Inc.
      - Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      - Cass Rural Water Users, Inc.
      - Southeast Rural Water Users, Inc.
      - Ransom-Sargent Water Users, Inc.
      - Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at one-half of the active conservation pool (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 47,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to minimize various city shortages with excess allocation water. One major change to the plan was the exchange of all of Fargo's to other cities for import water from the pipeline. The original cities participating in the Thomas-Acker Plan had priority to their supplies. As shortages mounted, excess water from these allocations were passed to other cities in an upstream-to-downstream iterative process. As in the BASELINE simulation, Lake Ashtabula was split into five separate reservoirs to represent the water allocations for the cities of Fargo, Grand Forks, West Fargo, Valley City, and Lisbon. Each city's allocation contributed proportionately to evaporation. A 6th reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Each city's allocation contributed proportionately to this release. No other instream flow criteria were used in this simulation.

g. A steady flow import pipeline from the Missouri River near Bismarck to a ringdike near Fargo was included to supply Fargo, Moorhead and New Industry at Fargo.

h. A spur to the import pipeline was included to meet upper Red River demands above Fargo.

i. Two half-sized (11,000 acre-feet each) ring-dikes slaved to the import and upper Red River spur pipeline were also included in this simulation to regulate import flows. These ring-dikes served to decrease the size of the import pipe. Several configurations of these ring-dike/pipeline combinations were attempted with the model. The end result was to spilt the import flow and ring-dike size in half for each delivery point, and then fine tune the import need.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 125 through 128. Figure 24 illustrates the layout of this alternative.

Run ALT5A1R Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal and industrial demands in the Red River Valley. The model run demonstrated that city rural and industrial demands will be satisfied in all of the 54 years

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 9.0 cfs to 2,400 cfs. The average monthly release was computed at 102 cfs. The reservoir did not go below its minimum pool of 28,000 acre-feet in the 648 months simulated.

Two 12,000 acre-feet ring-dikes with a 1,000 acre-feet minimum pool were used for import storage was utilized during the 1930s critical drought. This was to avoid non-convergence problems with the HYDROSS model when out of water. The pipeline size for the ALT 5A1R run is 65 cfs from Bismarck to ring-dike near Fargo and the Fargo-Moorehead spur is 33 cfs with the Wahpeton spur of 32 cfs. The reservoir reached less than 1,000 acre-feet in 11 of the 648 months simulated (2 percent). The ALT5BR run utilizing one 22,000 acre-feet ring-dike the pipeline size is 70 cfs from Bismarck to ring-dike near Fargo and the Fargo-Moorehead spur is 46 cfs with the Wahpeton spur of 24 cfs. The reservoir reached 12,860 acre-feet in 1 of the 648 months simulated (<1 percent).

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

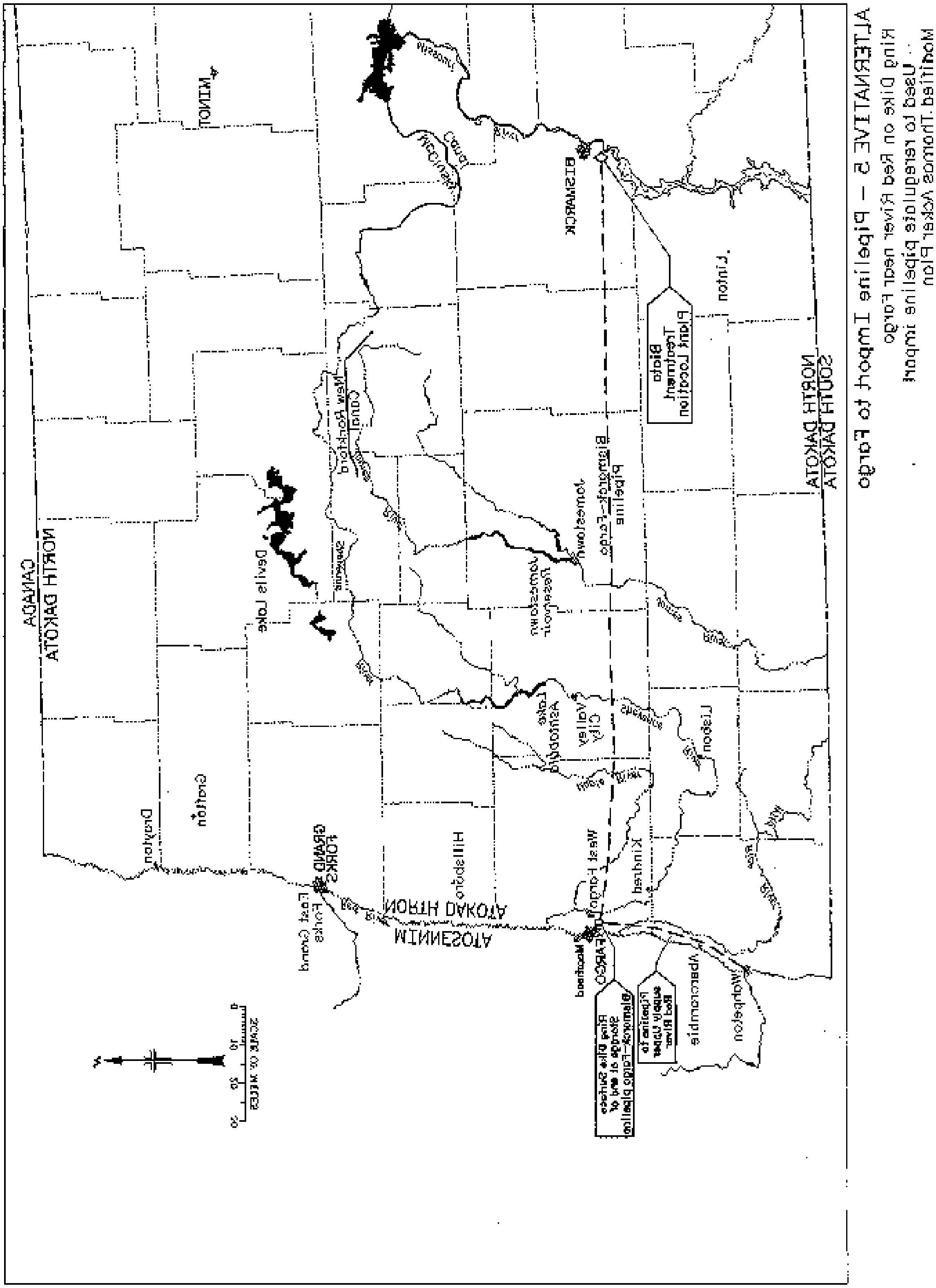

ALTERNATIVE 5 — Pipeline Import to Fargo
Ring Dike on Red River near Fargo
Used to regulate pipeline import
Modified Thomas Acker Plan
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
CANADA
BISMARCK
FARGO
GRAND FORKS

Figure 24

Table 125: Future City Shortage Summary
Alternative: ALTERNATIVE 5-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.
[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).
[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only
[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 126: Industrial Shortage Summary
Alternative: ALTERNATIVE 5 – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 127: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 5 – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	**Number Of Months Above Channel Capacity**	**Average Monthly Flow (cfs)**	**Highest Simulated Monthly Flow (cfs)**	**Lowest Simulated Monthly Flow (cfs)**
Sheyenne River Near Warwick	600	11	49	1418	0
Sheyenne River Below Baldhill Dam	4000	0	102	2400	9
Sheyenne River Near Valley City	2500	3	110	2885	3
Sheyenne River Near Lisbon	2250	5	130	3214	2
Sheyenne River Near Kindred	2800	1	158	2977	0
Red River Near Fargo	3000	19	553	9883	0
Red River Near Halstad	15000	4	1324	20597	38
Red River Near Grand Forks	21000	8	2671	36137	33
Red River Near Emerson	26000	11	3580	72408	42

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 128: Storage Activity Summary
Alternative: ALTERNATIVE 5 – RURAL

Storage Facility	**Maximum Storage (acft)**	**Minimum Storage (acft)**	**Average Monthly Storage (acft)**	**Months below or at Minimum Storage**	**Maximum Outflow (cfs)**	**Minimum Outflow (cfs)**	**Average Outflow (cfs)**
Lake Ashtabula Combined Storage	66600	30490	62220	0	2400	9	102
Lake Ashtabula (Fargo Portion)	37362	15708	35000				
Lake Ashtabula (West Fargo Portion)	999	420	947				
Lake Ashtabula (Grand Forks Portion)	20846	8764	19306				
Lake Ashtabula (Lisbon Portion)	400	668	384				
Lake Ashtabula (Valley City Portion)	6993	294	6581				
	Maximum Storage	**Minimum Storage**	**Average Monthly Storage**				
Lake Ashtabula Combined Elevation (feet)	1266	1257	1265				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5222				

Alt 5A1R Ring-dike Storage Activity (acft)					Maximum Inflow (cfs)	Minimum Inflow (cfs)	Average Inflow (cfs)
Import Fargo-Moorehead (see above headings)	12000	1000*	11300	11	33	33	33
Import Cargill (see above headings)	12000	5480*	11930	1	32	32	32

Alt 5BR Ring-dike Storage Activity (acft)					Maximum Inflow (cfs)	Minimum Inflow (cfs)	Average Inflow (cfs)
Import Fargo-Moorehead (see above headings)	22,000	1000*	---	1	70	70	70

* No designated minimum storage capacity

7. **ALTERNATIVE 6-RURAL (Import to the Upper Red River): Year 2050 Reclamation demands with an import pipeline from Lake Oahe on the Missouri River near Linton to the upper Red River at Wahpeton. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT6R.**

Run ALT6R Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria with the exception of a pipeline from Lake Oahe on the Missouri River to the upper Red River near Wahpeton (this will supply Fargo, Moorhead, New Industry near Fargo, Cargill, New Industry at Abercrombie, and South Valley Rural needs). The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      ? Agassiz Water Users, Inc.
      ? Tri-County Water Users, Inc.
      ? Walsh Water Users
      ? Grand Forks-Traill Water Users, Inc.
      ? Traill Water Users, Inc.
      ? Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      ? Cass Rural Water Users, Inc.
      ? Southeast Rural Water Users, Inc.
      ? Ransom-Sargent Water Users, Inc.
      ? Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at one-half of the active conservation pool (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 47,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to minimize various city shortages with excess allocation water. One major change to the plan was the exchange of all of Fargo's to other cities for import water from the pipeline. The original cities participating in the Thomas-Acker Plan had priority to their supplies. As shortages mounted, excess water from these allocations were passed to other cities in an upstream-to-downstream iterative process. As in the BASELINE simulation, Lake Ashtabula was split into five separate reservoirs to represent the water allocations for the cities of Fargo, Grand Forks, West Fargo, Valley City, and Lisbon. Each city's allocation contributed proportionately to evaporation. A 6th reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Each city's allocation contributed proportionately to this release. No other instream flow criteria were used in this simulation.

g. A steady flow import pipeline from Lake Oahe on the Missouri River to the upper Red River near Wahpeton included to supply all upper Red River shortages including South Valley Rural needs.

h. A 22,000 acre-feet ring-dike located near Wahpeton was slaved to the import pipeline was also included in this simulation to regulate import flows. This ring-dike served to decrease the size of the import pipeline.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 129 through 132. Figure 25 illustrates the layout of this alternative.

Run ALT6R Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal rural and industrial demands in the Red River Valley. The model run demonstrated that city and industrial demands would be satisfied in all of the 54 years simulated.

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 9.0 cfs to 2,400 cfs. The average monthly release was computed at 102 cfs. The reservoir did not go below minimum pool of 28,000 acre-feet in the 648 months simulated.

One 23,000 acre-feet ring-dike with a 1,000 acre-feet minimum pool was utilized for regulating the import for downstream Red River demands during the 1930s critical drought. The pipeline size for this run is 60 cfs continuous import from Oahe Reservoir on the Missouri River near Linton to a ring-dike near Wahpeton. The reservoir did not go below 1,860 acre-feet during the 648 months simulated.

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

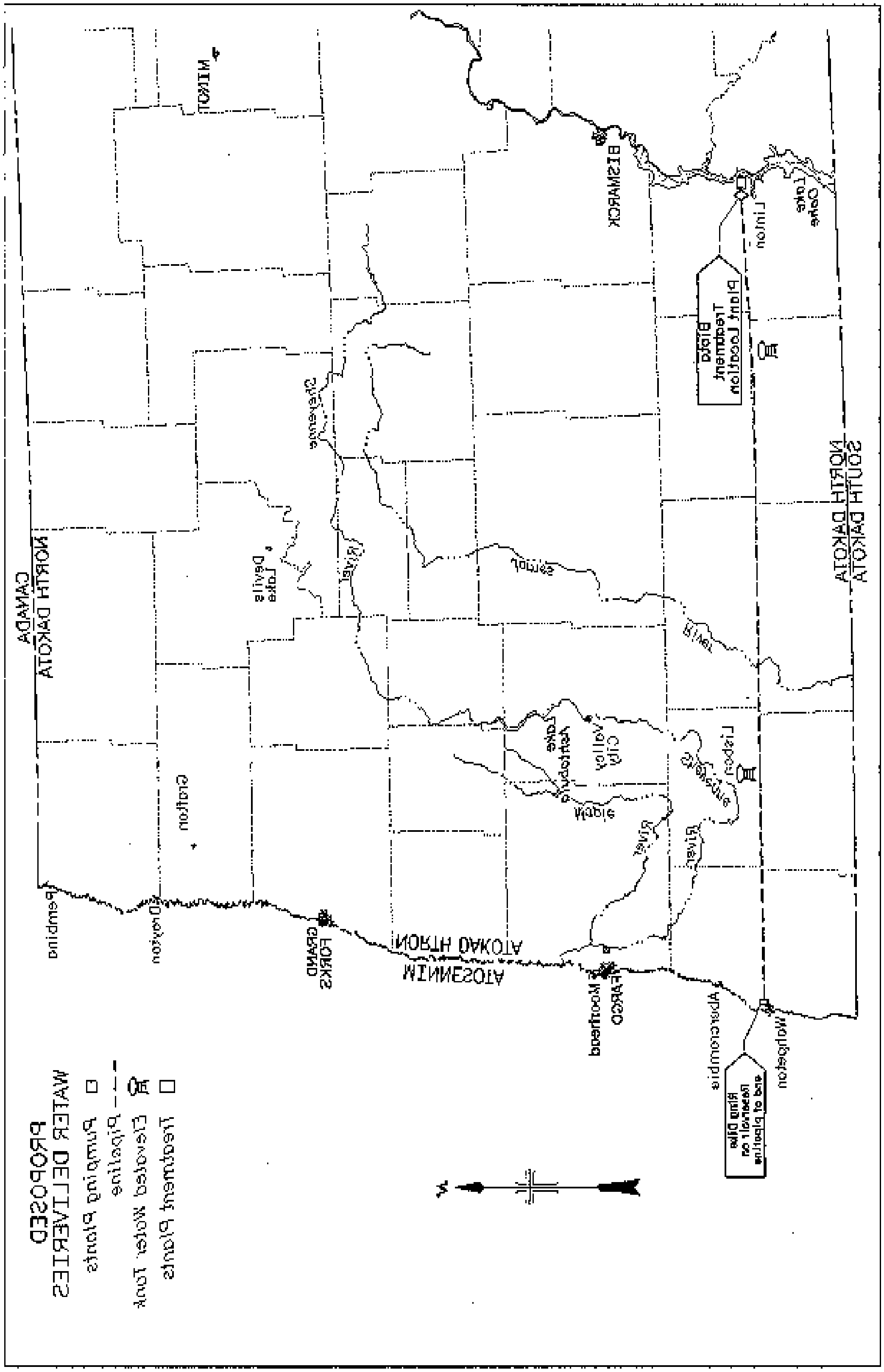

ALTERNATIVE 6 -- Import to Upper Red River
Modified Thomas-Acker Plan to meet Sheyenne River needs.
PROPOSED WATER DELIVERIES
Pumping Plants
Pipeline
Elevated Water Tank
Treatment Plants
CANADA
NORTH DAKOTA
MINOT
BISMARCK
Linton
Lake Oahe
Biota Treatment Plant Location
NORTH DAKOTA
SOUTH DAKOTA
Devils Lake
Sheyenne
River
James
River
Lake Ashtabula
Valley City
Lisbon
Maple
River
Grafton
Pembina
Drayton
GRAND FORKS
NORTH DAKOTA
MINNESOTA
FARGO
Moorhead
Abercrombie
Wahpeton

Figure 25

Table 129: Future City Shortage Summary

Alternative: ALTERNATIVE 6-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.

[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).

[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only

[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 130: Industrial Shortage Summary

Alternative: ALTERNATIVE 6 – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 131: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 6 – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	**Number Of Months Above Channel Capacity**	**Average Monthly Flow (cfs)**	**Highest Simulated Monthly Flow (cfs)**	**Lowest Simulated Monthly Flow (cfs)**
Sheyenne River Near Warwick	600	11	49	1418	0
Sheyenne River Below Baldhill Dam	4000	0	102	2400	9
Sheyenne River Near Valley City	2500	3	110	2885	3
Sheyenne River Near Lisbon	2250	5	130	3214	2
Sheyenne River Near Kindred	2800	1	158	2977	0
Red River Near Fargo	3000	19	548	9878	0
Red River Near Halstad	15000	4	1344	20592	41
Red River Near Grand Forks	21000	8	2666	36132	33
Red River Near Emerson	26000	11	3575	72403	45

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 132: Storage Activity Summary
Alternative: ALTERNATIVE 6 – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	30790	62260	0	2400	9	102
Lake Ashtabula (Fargo Portion)	37362	15708	35039				
Lake Ashtabula (West Fargo Portion)	999	420	948				
Lake Ashtabula (Grand Forks Portion)	20846	8764	19306				
Lake Ashtabula (Lisbon Portion)	400	668	384				
Lake Ashtabula (Valley City Portion)	6993	294	6583				
	Maximum Storage	**Minimum Storage**	**Average Monthly Storage**				
Lake Ashtabula Combined Elevation (feet)	1266	1258	1265				
Lake Ashtabula Combined Surface Area (Acres)	5300	3500	5222				

Ring-dike Storage Activity (acft)					Maximum Inflow (cfs)	Minimum Inflow (cfs)	Average Inflow (cfs)
Import (see above headings)	23000	1860*	21930	1	60	60	60

* No designated minimum storage capacity

8. **ALTERNATIVE 7A-RURAL (Import – Pipeline to Upper Sheyenne using GDU Facilities – Coteau Route): Year 2050 Reclamation demands with an import pipeline from the Missouri River using Garrison Diversion Unit Facilities (McClusky and New Rockford Canals) to the upper Sheyenne River. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT7ABCR (Note: This model run was used to represent Alternatives 7A, 7B, and 7C).**

Run ALT7ABCR (ALT7A) Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria with the exception of a pipeline from the Missouri River to the upper Sheyenne River via the McClusky Canal and the New Rockford Canal connected via the Missouri Coteau Route. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      ? Agassiz Water Users, Inc.
      ? Tri-County Water Users, Inc.
      ? Walsh Water Users
      ? Grand Forks-Traill Water Users, Inc.
      ? Traill Water Users, Inc.
      ? Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      ? Cass Rural Water Users, Inc.
      ? Southeast Rural Water Users, Inc.
      ? Ransom-Sargent Water Users, Inc.
      ? Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at the full active conservation pool (above the 28,000 acre-foot minimum pool) based on the assumption that the upstream import could conceivable keep Lake Ashtabula full even if pre-1930 conditions are dry. This represents a total reservoir starting capacity of 66,600 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand. The import demand was adjusted so that this minimum pool could always be maintained.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to meet shortages. In addition, this simulation run deviated from other runs in that Lake Ashtabula was simulated at one single reservoir rather than splitting the reservoir into separate allocation reservoirs for cities on the Thomas-Acker Plan. This was done as a result of the model not properly re-regulating the augmentation water from the upstream import proportionally through all five allocation reservoirs. The program tended to bypass all reservoirs that were in series and only utilized the last reservoir resulting in some "wasting" of water downstream. It was assumed that the program was confusing the different "project" and "natural" flow assignments in the Lake Ashtabula complex.

The single reservoir approach, with equal priority dates on the Thomas-Acker cities and junior rights on other cities appeared to yield more appropriate results.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Due to the combined configuration of Lake Ashtabula in this simulation the 13 cfs was simply released from the reservoir each month. No other instream flow criteria were used in this simulation.

g. A steady flow import pipeline was included from the Missouri River to the upper Sheyenne River via the McClusky Canal and the New Rockford Canal connected via the Missouri Coteau Route.

h. A pipeline from the lower Sheyenne River to the upper Red River near Wahpeton was included to meet upper Red River needs from the import water.

i. No ring-dikes were included in this simulation. Ring-dikes could possibly lower the import need through re-regulation.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 133 through 136. Figure 26 illustrates the layout of this alternative.

Run ALT7ABCR (ALT7A) Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal rural and industrial demands in the Red River Valley. The model run demonstrated that city and industrial demands would be satisfied in all of the 54 years simulated with a steady flow import of 72 cfs to the upper Sheyenne River.

Lake Ashtabula was run with a single reservoir approach for regulating storage for this import alternative. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 13 cfs to 2,400 cfs. The average monthly release was computed at 170 cfs. The reservoir did not go below the minimum pool of 28,000 acre-feet in the 648 months simulated.

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

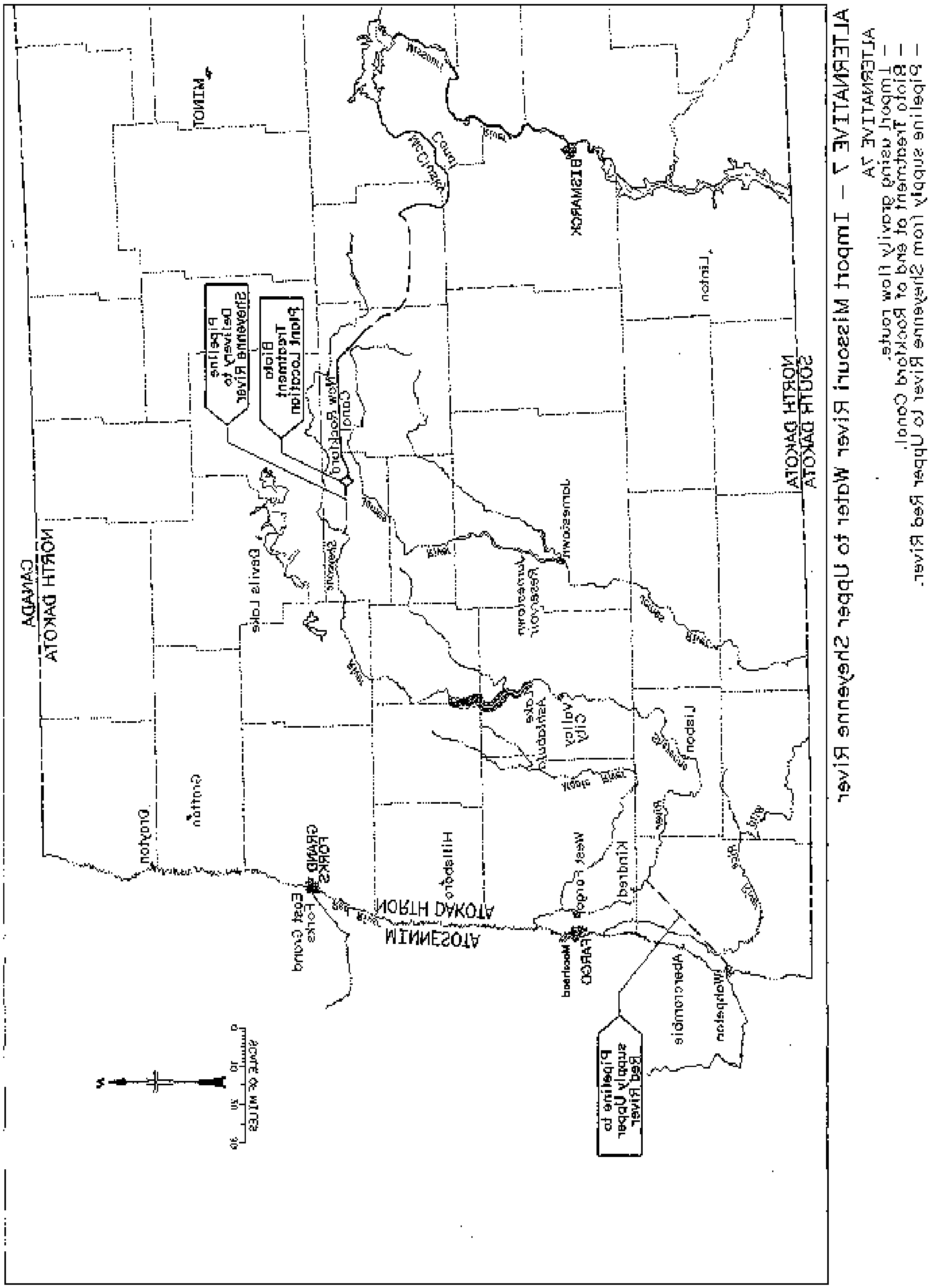

ALTERNATIVE 7 — Import Missouri River Water to Upper Sheyenne River
ALTERNATIVE 7A
– Import using gravity flow route.
– Biota treatment at end of Rockford Canal.
– Pipeline supply from Sheyenne River to Upper Red River.
CANADA
NORTH DAKOTA
MINNESOTA
NORTH DAKOTA
SOUTH DAKOTA
MINOT
BISMARCK
Linton
Pipeline Delivery to Sheyenne River
Biota Treatment Plant Location
New Rockford Canal
Jamestown
Jamestown Reservoir
Devils Lake
Lake Ashtabula
Valley City
Lisbon
Grafton
Drayton
GRAND FORKS
East Grand Forks
Hillsboro
West Fargo
FARGO
Moorhead
Kindred
Abercrombie
Wahpeton
Pipeline to supply Upper Red River
SCALE OF MILES

Figure 26

Table 133: Future City Shortage Summary
Alternative: ALTERNATIVE 7A-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.
[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).
[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only
[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 134: Industrial Shortage Summary
Alternative: ALTERNATIVE 7A – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 135: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 7A – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	Number Of Months Above Channel Capacity	Average Monthly Flow (cfs)	Highest Simulated Monthly Flow (cfs)	Lowest Simulated Monthly Flow (cfs)
Sheyenne River Near Warwick	600	12	116	1489	59
Sheyenne River Below Baldhill Dam	4000	0	170	2400	13
Sheyenne River Near Valley City	2500	4	175	2955	13
Sheyenne River Near Lisbon	2250	5	194	3278	13
Sheyenne River Near Kindred	2800	2	223	3072	13
Red River Near Fargo	3000	19	510	9831	0
Red River Near Halstad	15000	4	1350	20629	19
Red River Near Grand Forks	21000	8	2673	36134	24
Red River Near Emerson	26000	11	3582	72404	47

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 136: Storage Activity Summary
Alternative: ALTERNATIVE 7A – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	28260	64550	0	2400	13	170
Lake Ashtabula Combined Elevation (feet)	1266	1257	1266				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5300				

9. ALTERNATIVE 7B-RURAL (Import – Pipeline to Upper Sheyenne using GDU Facilities): Year 2050 Reclamation demands with an import pipeline from the Missouri River using Garrison Diversion Unit Facilities (McClusky Canal) to the upper Sheyenne River. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT7ABC1 (Note: This model run was used to represent Alternatives 7A, 7B, and 7C).

Run ALT7ABCR (ALT7B) Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria with the exception of a pipeline from the Missouri River to the upper Sheyenne River via the McClusky Canal. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      ? Agassiz Water Users, Inc.
      ? Tri-County Water Users, Inc.
      ? Walsh Water Users
      ? Grand Forks-Traill Water Users, Inc.
      ? Traill Water Users, Inc.
      ? Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      ? Cass Rural Water Users, Inc.
      ? Southeast Rural Water Users, Inc.
      ? Ransom-Sargent Water Users, Inc.
      ? Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at the full active conservation pool (above the 28,000 acre-foot minimum pool) based on the assumption that the upstream import could conceivable keep Lake Ashtabula full even if pre-1930 conditions are dry. This represents a total reservoir starting capacity of 66,600 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand. The import demand was adjusted so that this minimum pool could always be maintained.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to meet shortages. In addition, this simulation run deviated from other runs in that Lake Ashtabula was simulated at one single reservoir rather than splitting the reservoir into separate allocation reservoirs for cities on the Thomas-Acker Plan. This was done as a result of the model not properly re-regulating the augmentation water from the upstream import proportionally through all five allocation reservoirs. The program tended to bypass all reservoirs that were in series and only utilized the last reservoir resulting in some "wasting" of water downstream. It was assumed that the program was confusing the different "project" and "natural" flow assignments in the Lake Ashtabula complex. The single reservoir approach, with equal priority dates on the Thomas-Acker cities and junior rights on other cities appeared to yield more appropriate results.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Due to the combined configuration of Lake Ashtabula in this simulation the 13 cfs was simply released from the reservoir each month. No other instream flow criteria were used in this simulation.

g. A steady flow import pipeline was included from the Missouri River to the upper Sheyenne River via the McClusky Canal.

h. A pipeline from the lower Sheyenne River to the upper Red River near Wahpeton was included to meet upper Red River needs from the import water.

i. No ring-dikes were included in this simulation. Ring-dikes could possibly lower the import need through re-regulation.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 137 through 140. Figure 27 illustrates the layout of this alternative.

Run ALT7ABCR (ALT7B) Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal rural and industrial demands in the Red River Valley. The model run demonstrated that city and industrial demands would be satisfied in all of the 54 years simulated with a steady flow import of 72 cfs to the upper Sheyenne River.

Lake Ashtabula was run with a single reservoir approach for regulating storage for this import alternative. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 13 cfs to 2,400 cfs. The average monthly release was computed at 170 cfs. The reservoir did not go below the minimum pool of 28,000 acre-feet in the 648 months simulated.

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

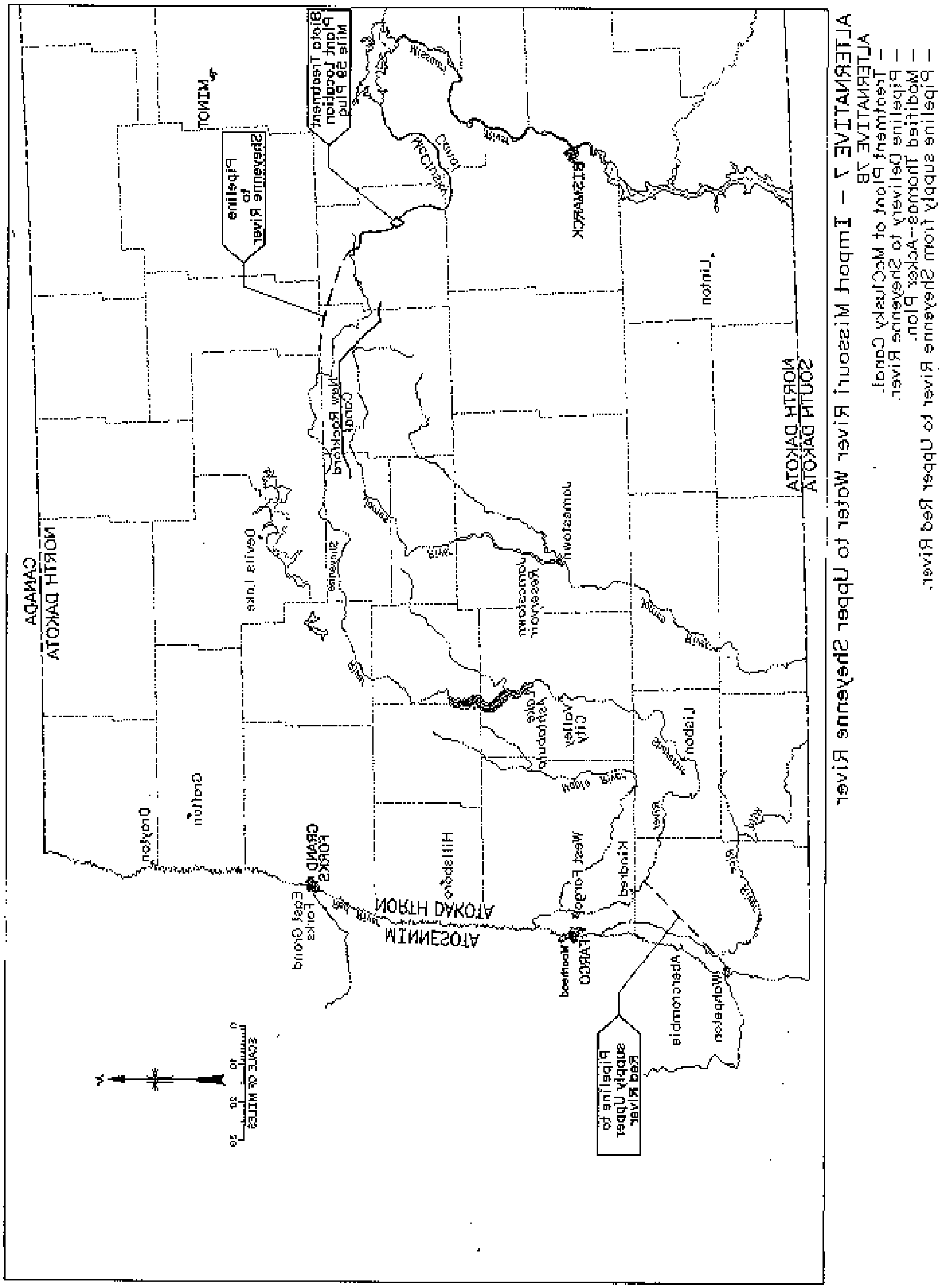

ALTERNATIVE 7 — Import Missouri River Water to Upper Sheyenne River
ALTERNATIVE 7B —
— Treatment Plant at McClusky Canal.
— Pipeline Delivery to Sheyenne River.
— Modified Thomas-Acker Plan.
— Pipeline supply from Sheyenne River to Upper Red River.
Biota Treatment Plant Location Mile 59 Plan
Pipeline to Sheyenne River
Pipeline to supply Upper Red River
CANADA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
MINOT
BISMARCK
Linton
McClusky Canal
New Rockford Canal
Devils Lake
Jamestown
Jamestown Reservoir
Lake Ashtabula
Valley City
Lisbon
Drayton
Grafton
GRAND FORKS
East Grand Forks
Hillsboro
West Fargo
Kindred
FARGO
Moorhead
Abercrombie
Wahpeton
SCALE OF MILES
0 10 30 50

Figure 27

Table 137: Future City Shortage Summary

Alternative: ALTERNATIVE 7B-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.

[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).

[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only

[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 138: Industrial Shortage Summary

Alternative: ALTERNATIVE 7B – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 139: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 7B – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	Number Of Months Above Channel Capacity	Average Monthly Flow (cfs)	Highest Simulated Monthly Flow (cfs)	Lowest Simulated Monthly Flow (cfs)
Sheyenne River Near Warwick	600	12	116	1489	59
Sheyenne River Below Baldhill Dam	4000	0	170	2400	13
Sheyenne River Near Valley City	2500	4	175	2955	13
Sheyenne River Near Lisbon	2250	5	194	3278	13
Sheyenne River Near Kindred	2800	2	223	3072	13
Red River Near Fargo	3000	19	510	9831	0
Red River Near Halstad	15000	4	1350	20629	19
Red River Near Grand Forks	21000	8	2673	36134	24
Red River Near Emerson	26000	11	3582	72404	47

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 140: Storage Activity Summary
Alternative: ALTERNATIVE 7B – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	28260	64550	0	2400	13	170
Lake Ashtabula Combined Elevation (feet)	1266	1257	1266				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5300				

10. **ALTERNATIVE 7C-RURAL (Import – Pipeline to Upper Sheyenne using GDU Facilities – North Route): Year 2050 Reclamation demands with an import pipeline from the Missouri River using Garrison Diversion Unit Facilities (McClusky and New Rockford Canals) to the upper Sheyenne River. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT7ABC1 (Note: This model run was used to represent Alternatives 7A, 7B, and 7C).**

Run ALT7ABCR (ALT7C) Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria with the exception of a pipeline from the Missouri River to the upper Sheyenne River via the McClusky Canal and the New Rockford Canal connected via the Northern Route. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      - ? Agassiz Water Users, Inc.
      - ? Tri-County Water Users, Inc.
      - ? Walsh Water Users
      - ? Grand Forks-Traill Water Users, Inc.
      - ? Traill Water Users, Inc.
      - ? Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      - ? Cass Rural Water Users, Inc.
      - ? Southeast Rural Water Users, Inc.
      - ? Ransom-Sargent Water Users, Inc.
      - ? Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at the full active conservation pool (above the 28,000 acre-foot minimum pool) based on the assumption that the upstream import could conceivably keep Lake Ashtabula full even if pre-1930 conditions are dry. This represents a total reservoir starting capacity of 66,600 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand. The import demand was adjusted so that this minimum pool could always be maintained.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to meet shortages. In addition, this simulation run deviated from other runs in that Lake Ashtabula was simulated at one single reservoir rather than splitting the reservoir into separate allocation reservoirs for cities on the Thomas-Acker Plan. This was done as a result of the model not properly re-regulating the augmentation water from the upstream import proportionally through all five allocation reservoirs. The program tended to bypass all reservoirs that were in series and only utilized the last reservoir resulting in some "wasting" of water downstream. It was assumed that the program was confusing the different "project" and "natural" flow assignments in the Lake Ashtabula complex.

The single reservoir approach, with equal priority dates on the Thomas-Acker cities and junior rights on other cities appeared to yield more appropriate results.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Due to the combined configuration of Lake Ashtabula in this simulation the 13 cfs was simply released from the reservoir each month. No other instream flow criteria were used in this simulation.

g. A steady flow import pipeline was included from the Missouri River to the upper Sheyenne River via the McClusky Canal and the New Rockford Canal connected via the Northern route.

h. A pipeline from the lower Sheyenne River to the upper Red River near Wahpeton was included to meet upper Red River needs from the import water.

i. No ring-dikes were included in this simulation. Ring-dikes could possibly lower the import need through re-regulation.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 141 through 144. Figure 28 illustrates the layout of this alternative.

Run ALT7ABCR (ALT7C) Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal rural and industrial demands in the Red River Valley. The model run demonstrated that city and industrial demands would be satisfied in all of the 54 years simulated with a steady flow import of 72 cfs to the upper Sheyenne River.

Lake Ashtabula was run with a single reservoir approach for regulating storage for this import alternative. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 13 cfs to 2,400 cfs. The average monthly release was computed at 170 cfs. The reservoir did not go below the minimum pool of 28,000 acre-feet in the 648 months simulated.

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

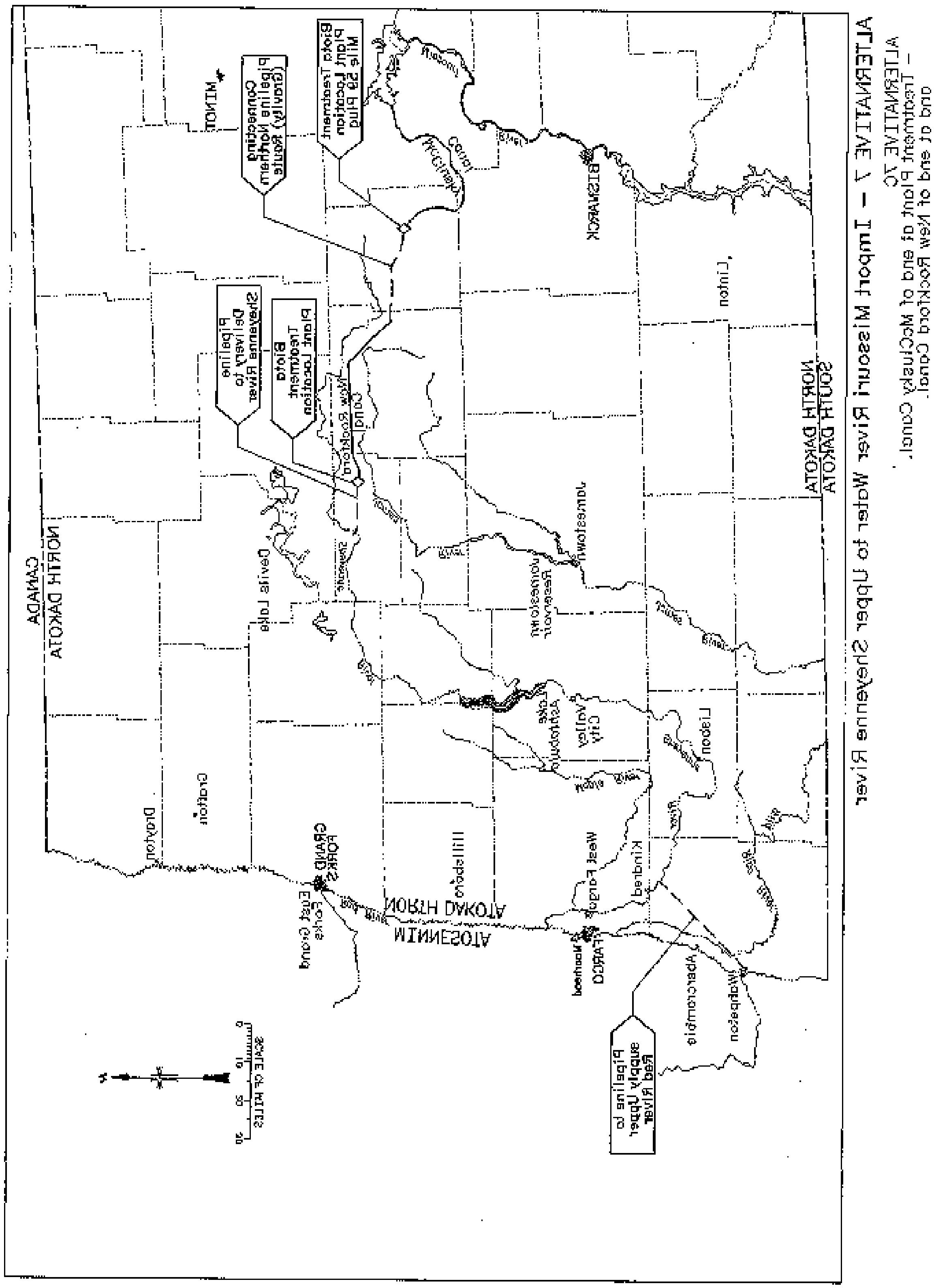

ALTERNATIVE 7 — Import Missouri River Water to Upper Sheyenne River
ALTERNATIVE 7C — Treatment Plant at end of McClusky Canal and at end of New Rockford Canal.
Biota Treatment Plant Location Mile 59 Plug
Connecting pipeline Northern (Gravity) Route
Pipeline Delivery to Sheyenne River
Biota Treatment Plant Location
Pipeline to supply Upper Red River
CANADA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
MINOT
BISMARCK
Linton
Jamestown
Jamestown Reservoir
Devils Lake
New Rockford
Valley City
Lake Ashtabula
Lisbon
Grafton
Drayton
GRAND FORKS
East Grand Forks
Hillsboro
West Fargo
FARGO
Moorhead
Kindred
Abercrombie
Wahpeton
SCALE OF MILES
0 10 20 30

Figure 28

Table 141: Future City Shortage Summary

Alternative: ALTERNATIVE 7C-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.

[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).

[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only

[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 142: Industrial Shortage Summary

Alternative: ALTERNATIVE 7C – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 143: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 7C – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	Number Of Months Above Channel Capacity	Average Monthly Flow (cfs)	Highest Simulated Monthly Flow (cfs)	Lowest Simulated Monthly Flow (cfs)
Sheyenne River Near Warwick	600	12	116	1489	59
Sheyenne River Below Baldhill Dam	4000	0	170	2400	13
Sheyenne River Near Valley City	2500	4	175	2955	13
Sheyenne River Near Lisbon	2250	5	194	3278	13
Sheyenne River Near Kindred	2800	2	223	3072	13
Red River Near Fargo	3000	19	510	9831	0
Red River Near Halstad	15000	4	1350	20629	19
Red River Near Grand Forks	21000	8	2673	36134	24
Red River Near Emerson	26000	11	3582	72404	47

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 144: Storage Activity Summary
Alternative: ALTERNATIVE 7C – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	28260	64550	0	2400	13	170
Lake Ashtabula Combined Elevation (feet)	1266	1257	1266				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5300				

11. **ALTERNATIVE 7D-RURAL (Import – Pipeline to Upper Sheyenne using GDU Facilities – Continuing to Grand Forks): Year 2050 Reclamation demands with an import pipeline from the Missouri River using Garrison Diversion Unit Facilities to the upper Sheyenne River for water supply, then continuing to Grand Forks. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT7DR.**

Run ALT7DR Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria with the exception of a pipeline from the Missouri River to the upper Sheyenne River which will import water to the upper Sheyenne River. A continuation of the pipeline will supply water to Grand Forks, allowing Grand Forks Lake Ashtabula allocation to be used by other entities. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      ? Agassiz Water Users, Inc.
      ? Tri-County Water Users, Inc.
      ? Walsh Water Users
      ? Grand Forks-Traill Water Users, Inc.
      ? Traill Water Users, Inc.
      ? Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      ? Cass Rural Water Users, Inc.
      ? Southeast Rural Water Users, Inc.
      ? Ransom-Sargent Water Users, Inc.
      ? Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at the full active conservation pool (above the 28,000 acre-foot minimum pool) based on the assumption that the upstream import could conceivably keep Lake Ashtabula full even if pre-1930 conditions are dry. This represents a total reservoir starting capacity of 66,600 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand. The import demand was adjusted so that this minimum pool could always be maintained.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to meet shortages. The biggest deviation from the plan is to free the Grand Forks allocation (in place of a pipeline from the Missouri River) for use by other cities. In addition, this simulation run deviated from other runs in that Lake Ashtabula was simulated at one single reservoir rather than splitting the reservoir into separate allocation reservoirs for cities on the Thomas-Acker Plan. This was done as a result of the model not properly re-regulating the augmentation water from the upstream import proportionally through all five allocation reservoirs. The program tended to bypass all reservoirs that were in series and only utilized the last reservoir resulting in some "wasting" of water downstream. It was assumed that the program was confusing the different "project" and "natural" flow assignments in the Lake Ashtabula complex. The single reservoir approach, with equal priority dates on the Thomas-Acker cities and junior rights on other cities appeared to yield more appropriate results.

f. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Due to the combined configuration of Lake Ashtabula in this simulation the 13 cfs was simply released from the reservoir each month. No other instream flow criteria were used in this simulation.

g. A steady flow import pipeline was included from the Missouri River via the McClusky Canal. This pipeline will follow the New Rockford Canal and supply water to the upper Sheyenne River. A 25 cfs continuation of this pipeline will supply 20 cfs to Grand Forks and 5 cfs to the North Valley Rural.

h. A pipeline from the lower Sheyenne River to the upper Red River near Wahpeton was included to meet upper Red River needs from the import water.

i. No ring-dikes were included in this simulation. Ring-dikes could possibly lower the import need through re-regulation.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 145 through 148. Figure 29 illustrates the layout of this alternative.

Run ALT7DR Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal rural and industrial demands in the Red River Valley. The model run demonstrated that city and industrial demands would be satisfied in all of the 54 years simulated with a steady flow import of 72 cfs to the upper Sheyenne River. A 25 cfs pipeline will supply 20 cfs to Grand Forks and 5 cfs to the North Valley Rural. This would be a combined supply from McClusky Canal of 97 cfs.

Lake Ashtabula was run with a single reservoir approach for regulating storage for this import alternative. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 13 cfs to 2,400 cfs. The average monthly release was computed at 170 cfs. The reservoir did not go below the minimum pool of 28,000 acre-feet in the 648 months simulated.

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year*. In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

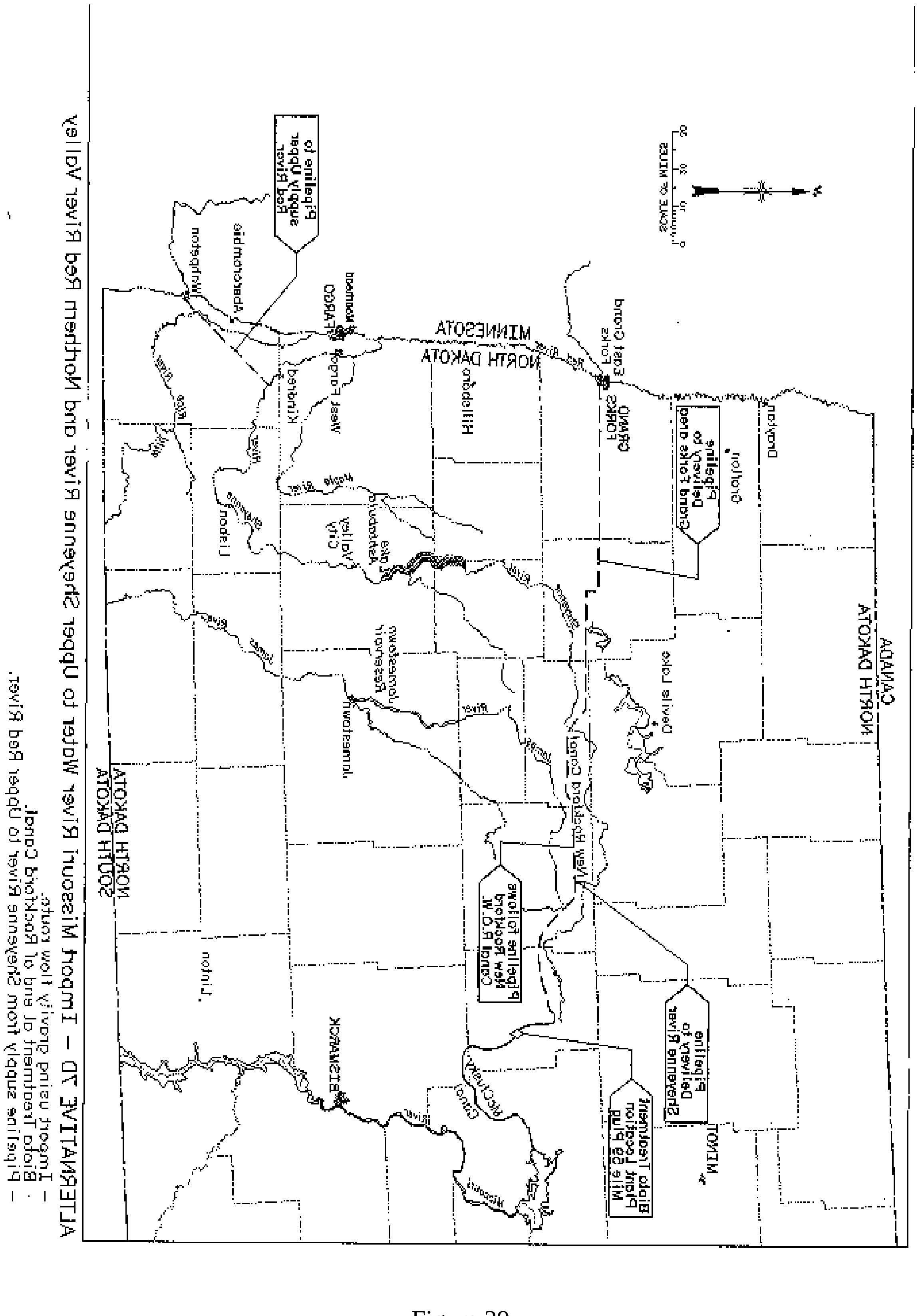

ALTERNATIVE 7D – Import Missouri River Water to Upper Sheyenne River and Northern Red River Valley
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
CANADA
BISMARCK
FARGO
GRAND FORKS
Devils Lake
Jamestown
Valley City
Lisbon
Wahpeton
Minot

Figure 29

Table 145: Future City Shortage Summary

Alternative: ALTERNATIVE 7D-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.
[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).
[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only
[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 146: Industrial Shortage Summary

Alternative: ALTERNATIVE 7D – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 147: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 7D – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	Number Of Months Above Channel Capacity	Average Monthly Flow (cfs)	Highest Simulated Monthly Flow (cfs)	Lowest Simulated Monthly Flow (cfs)
Sheyenne River Near Warwick	600	12	116	1489	59
Sheyenne River Below Baldhill Dam	4000	0	170	2400	13
Sheyenne River Near Valley City	2500	4	175	2955	13
Sheyenne River Near Lisbon	2250	5	194	3279	13
Sheyenne River Near Kindred	2800	2	223	3072	13
Red River Near Fargo	3000	19	510	9831	0
Red River Near Halstad	15000	4	1350	21629	19
Red River Near Grand Forks	21000	8	2698	36159	49
Red River Near Emerson	26000	11	3608	72429	72

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 148: Storage Activity Summary
Alternative: ALTERNATIVE 7D – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	28260	64550	0	2400	13	170
Lake Ashtabula Combined Elevation (feet)	1266	1257	1266				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5300				

12. **ALTERNATIVE 8-RURAL (Import Alternative with Dedicated Pipelines to Shortage Areas): Year 2050 Reclamation demands under with an import from the Missouri River conveyed to several entities via dedicated pipelines. Rural water needs were included in this simulation. The HYDROSS model run designation for this simulation was ALT8R.**

Run ALT8R Description: This model run was developed to represent year 2050 demand conditions under existing river and reservoir operation criteria. This model run was assumed to represent a the "future with import and dedicated pipelines" condition with the addition of rural water system needs. The following assumptions and procedures were used in this simulation:

a. Reclamation M&I demands for the year 2050 were imposed on the Red River system. Rural demands were included in this simulation in the form of two diversion points:
   1. North Valley rural water needs: diverted on the lower Red River near Grand Forks. The rural water systems represented in this diversion include:
      - ? Agassiz Water Users, Inc.
      - ? Tri-County Water Users, Inc.
      - ? Walsh Water Users
      - ? Grand Forks-Traill Water Users, Inc.
      - ? Traill Water Users, Inc.
      - ? Langdon Rural Water Users, Inc.
   2. South Valley rural water needs: diverted on the upper Red River near Fargo. The rural water systems represented in this diversion include:
      - ? Cass Rural Water Users, Inc.
      - ? Southeast Rural Water Users, Inc.
      - ? Ransom-Sargent Water Users, Inc.
      - ? Dakota Water Users, Inc.

   More detail on the computation of demands from these systems can be found in Attachment K.

b. M&I demands used in the simulation were assumed to include conservation measures. For more information on assumptions used to compute conservation demands, refer to Attachment J of this report as well as the main study report.

c. The simulation started with Lake Ashtabula at one-half of the active conservation pool (above the 28,000 acre-foot minimum pool) to simulate near-average moisture conditions prior to the 1930s drought. This represents a total reservoir starting capacity of 47,300 acre-feet.

d. Lake Ashtabula was operated with a minimum pool of 28,000 acre-feet (elevation 1257). This pool was adjusted for sediment inflow from present to the year 2050. The water in this pool was reserved for fish and wildlife purposes and could not be used to meet any MR&I demand.

e. The Lake Ashtabula storage allocation plan (the Thomas-Acker Plan) was modified to meet shortages. The biggest deviation from the plan is to free the Grand Forks allocation (in place of a pipeline from the Missouri River) for use by other cities. In addition, this simulation run deviated from other runs in that Lake Ashtabula was simulated at one single reservoir rather than splitting the reservoir into separate allocation reservoirs for cities on the Thomas-Acker Plan. This was done as a result of the model not properly re-regulating the augmentation water from the upstream import proportionally through all five allocation reservoirs. The program tended to bypass all reservoirs that were in series and only utilized the last reservoir resulting in some "wasting" of water downstream. It was assumed that the program was confusing the different "project" and "natural" flow assignments in the Lake Ashtabula complex. The single reservoir approach, with equal priority dates on the Thomas-Acker cities and junior rights on other cities appeared to yield more appropriate results.

f. Several steady flow pipelines were developed as part of this alternative. Pipelines to individual cities or industries were modeled on a trial and error fashion, working upstream-to-downstream in order to allow return flows from upstream entities to supply downstream entities, thus reducing pipeline sizes when practical. The only pipeline that was not optimized with return flows was the Grand Forks pipeline, sized at 20 cfs as per the city's request (Steve Burian, Advanced Engineering, personal communication). Listed below are the pipelines and their respective sizes included in this alternative:

   ? Abercrombie New Industry (upper Red River): 9.02 cfs
   ? Kindred New Industry (Sheyenne River): 9.02 cfs
   ? Existing Cargill at Wahpeton (Sheyenne River): 9.02 cfs
   ? West Fargo (Sheyenne River): 9.02 cfs
   ? Fargo/Moorhead and New Industry at Fargo (upper Red River): 12.3 cfs
   ? Grand Forks (Red River): 20 cfs

g. A minimum operational release of 13 cfs from Lake Ashtabula for downstream water rights was modeled. Each city's allocation contributed proportionately to this release. No other instream flow criteria were used in this simulation.

A summary of shortage, flow and storage activity computed for this scenario are discussed below and listed in Tables 149 through 152. Figure 30 illustrates the layout of this alternative.

Run ALT8R Results: Results of this simulation indicate that if a drought period occurred prior to a 1930s type drought (worst-case), in basin water supplies would not be adequate to meet all municipal rural, and industrial demands in the Red River Valley, however with an import all could be met.

Lake Ashtabula was a vital supply for cities under the Thomas-Acker Plan. The reservoir's full conservation storage was utilized during the 1930s critical drought. Releases from Lake Ashtabula ranged from 1.0 cfs to 2,400 cfs. The average monthly release was computed at 102 cfs. The reservoir did not go below the minimum pool of 28,000 acre-feet in the 648 months simulated.

Irrigation shortages were also noted for this study. The worse case year (1934) for irrigation totaled over 14,100 acre-feet. The average annual shortage for the 54-year simulation was approximately 1,600 acre-feet. Shortages were observed in the basin each year. *These irrigation shortages should be viewed with caution. They are representative of an attempt to meet water right crop production each year.* In reality, during dry years, irrigators with junior water rights may be forced to limited their irrigation levels to fewer acres. Also, this analysis does not consider lands placed out of production as part of a variety of soil conservation and agricultural programs. The irrigation portion of this study merely demonstrates a worse case situation with maximum acreage under cultivation.

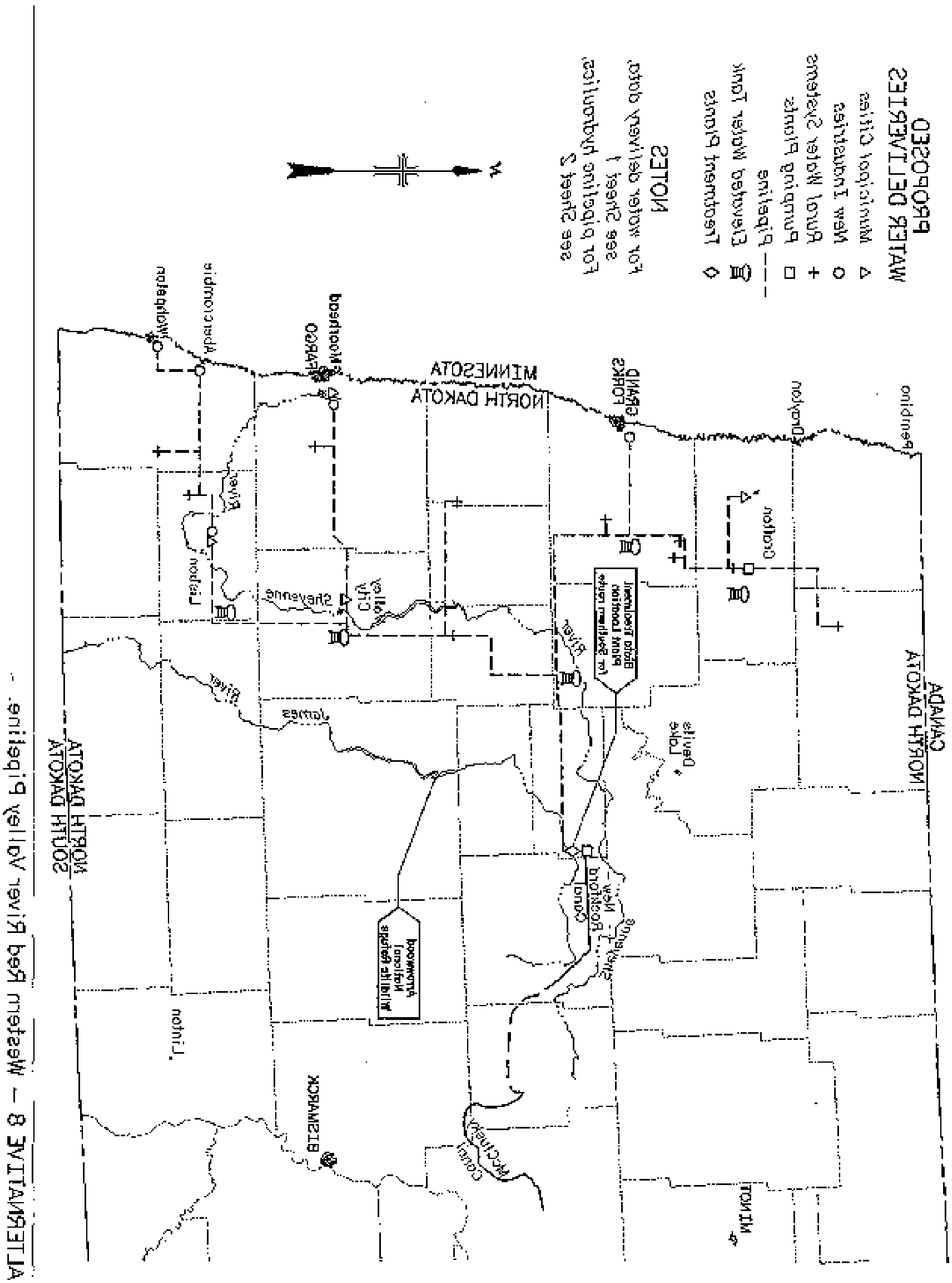

ALTERNATIVE 8 – Western Red River Valley Pipeline
PROPOSED WATER DELIVERIES
NOTES
MINNESOTA
NORTH DAKOTA
SOUTH DAKOTA
CANADA
BISMARCK
MINOT
FARGO
GRAND FORKS

Figure 30

Table 149: Future City Shortage Summary
Alternative: ALTERNATIVE 8-RURAL

	Drayton	East Grand Forks[1]	Fargo[2]	Moorhead[3]	Grafton	Grand Forks[2]	Lisbon[2, 4]	Valley City[2]	West Fargo[2]
No. years with shortages:	0	0	0	0	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0	0	0	0	0
Largest shortage percent of total surface water demand (percent):	0	0	0	0	0	0	0	0	0

[1] East Grand Forks potentially could have shortages on the Red Lake River. Since limited detail was included in the model on the Red Lake River watershed, only shortages pertaining to the Red River of the North are listed.
[2] Fargo, Grand Forks, Lisbon, Valley City, and East Grand Forks storage shortages based on storage allocations as set forth in the Thomas-Acker Plan (North Dakota State Water Commission [NDSWC] memorandum to Director, Hydrology Division dated, November 27, 1992).
[3] The city of Moorhead is not supplied by Lake Ashtabula. Shortages indicated are for the Red River only
[4] Although Lisbon is not one of the original "Participant communities" of this effort, the city did experience shared storage and other shortages in several scenarios; therefore, it was included in this table for informational purposes.

Table 150: Industrial Shortage Summary
Alternative: ALTERNATIVE 8 – RURAL

	Existing Cargill Plant 1 Wahpeton	Potential New Industry Plant 2 Fargo	Potential New Industry Plant 3 Abercrombie	Potential New Industry Plant 4 Drayton	Potential New Industry Plant 5 Kindred
No. years with shortages:	0	0	0	0	0
Average annual shortage for 54-year simulation period (acre-feet):	0	0	0	0	0
Average annual shortage for years with shortages (acre-feet):	0	0	0	0	0
Largest annual shortage (acre-feet) and year:	0	0	0	0	0
Largest shortage percent of Total surface water demand (percent):	0	0	0	0	0

Table 151: River Flow Activity for Selected Flow Points[3]
Alternative: ALTERNATIVE 8 – RURAL

	Estimated Non-Damaging Channel Capacity[1,2] (cfs)	Number Of Months Above Channel Capacity	Average Monthly Flow (cfs)	Highest Simulated Monthly Flow (cfs)	Lowest Simulated Monthly Flow (cfs)
Sheyenne River Near Warwick	600	11	49	1418	0
Sheyenne River Below Baldhill Dam	4000	0	103	2400	1
Sheyenne River Near Valley City	2500	3	111	2885	1
Sheyenne River Near Lisbon	2250	5	130	3214	0
Sheyenne River Near Kindred	2800	1	177	3006	0
Red River Near Fargo	3000	19	579	9909	0
Red River Near Halstad	15000	4	1350	20605	23
Red River Near Grand Forks	21000	8	2697	36165	19
Red River Near Emerson	26000	11	3606	72435	43

1. Pat Foley, Corps of Engineers – St. Paul District, Personal Communication.
2. Raines, 1998.
3. Rounded to nearest whole cfs.

Table 152: Storage Activity Summary
Alternative: ALTERNATIVE 8 – RURAL

Storage Facility	Maximum Storage (acft)	Minimum Storage (acft)	Average Monthly Storage (acft)	Months below or at Minimum Storage	Maximum Outflow (cfs)	Minimum Outflow (cfs)	Average Outflow (cfs)
Lake Ashtabula Combined Storage	66600	28850	60420	0	2400	1	103
Lake Ashtabula Combined Elevation (feet)	1266	1257	1265				
Lake Ashtabula Combined Surface Area (Acres)	5300	3373	5222				

13. **Participant 2050 Demand Projections**.

During the Phase 1 process of identification of existing water supply demands, Reclamation was presented with water supply projections developed by several study area participants. These future water supply demands were based upon population growth and water use rate projections that could not be entirely supported by Reclamation. The future water supply demands ultimately used by Reclamation in the modeling scenario were developed from records of water diversions and delivery, combined with local and national trends in water use rates, and projections of population and industrial growth within the study area. The following table shows annual surface water demands for city, industry and rural water participant and Reclamation 2050 Projections.

	Participant 2050 Projections		**Reclamation 2050 Projections**	
	Population Estimate	**Annual Surface Water Demand [1] Ac-Ft**	**Population Estimate**	**Annual Surface Water Demand [1] Ac-Ft**
Fargo	243,072	67,122	192,600	36,610
West Fargo	28,050	4,919	33,300	5,703
Moorhead, MN	42,358	8,882	42,600	8,918
Valley City	10,923	1,824	6,570	1,255
Grand Forks	98,339	24,418	93,200	23,741
East Grand Forks	9,013	1,764	8,700	1,712
Grafton	7,416	1,588	5,100	1,242
Drayton [2]	1,380	4,137	900	758
Rural Water [3]	137,500	8,096	137,500	8,096
Existing Industry		6,000		6,000
Future Industry		24,000		24,000
TOTALS	578,051	152,750	520,470	118,035

1 Cities using ground water were maintained at the 1994 level of pumping withdrawals.
2 Drayton Participant estimate includes large industrial component.
3 Rural Water Systems estimated by Reclamation only and included in alternatives models.

In an effort to provide some information for comparisons, several water supply alternatives have been modeled using the participant demand estimated at Fargo. This particular demand is the largest in the study area and has the greatest potential impact on supply alternatives. These model runs do provide an indication of the water supply impacts resulting from a change (increase) in the demand needs.

a. Alternative 1 (No Action) - Model Run ALT1P (without Rural Demands):

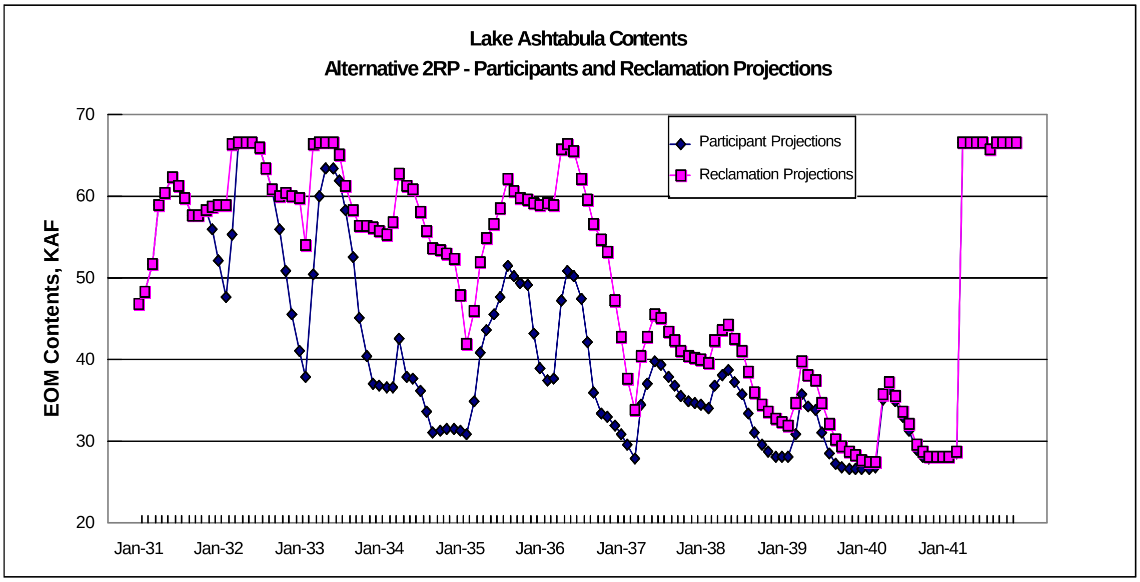
Water supply shortages for the year 1934 (year of greatest shortages) for these two demand scenarios under the No Action Alternative are:

“1934" Shortages	**Municipal Shortage, Ac-Ft**	**Industrial Shortage, Ac-Ft**	**Total Annual Shortage , Ac-Ft**
Participant Demand	57,220	23,690	80,910
Reclamation Demand	31,030	22,160	53,190
Rural Water Systems	8,096		8,096

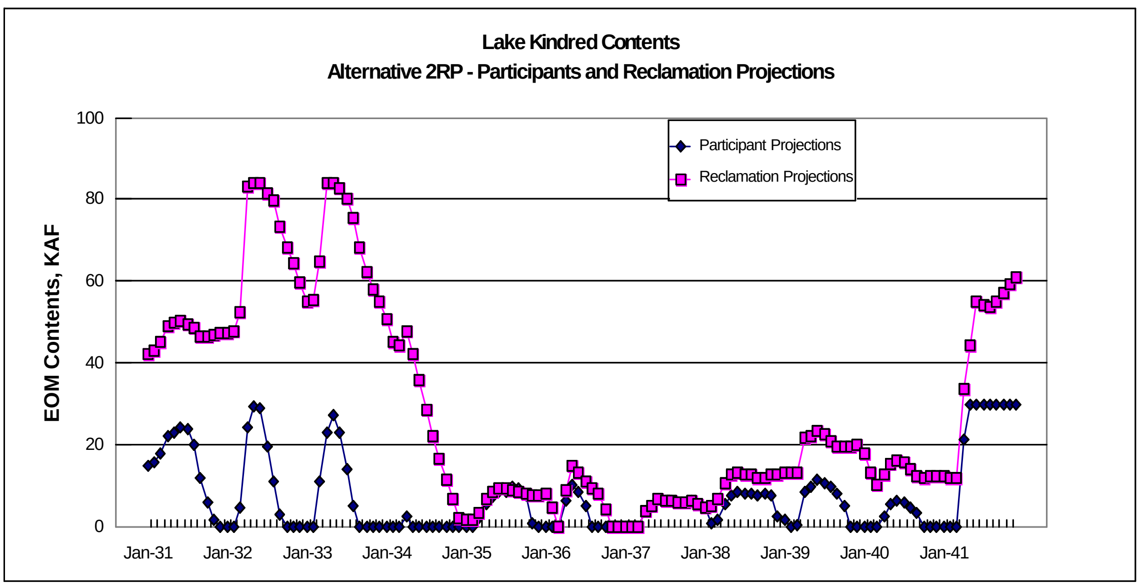
For comparisons of these alternatives, two “In-Basin” alternatives and two “Import” alternatives were modeled using the participant demand projections at Fargo with Reclamation demand projections at other cities, industries, and rural water systems. HYDROSS model runs for Alternative 2, Kindred Reservoir; Alternative 3, Enlarged Lake Ashtabula; Alternative 5, Bismarck to Fargo Pipeline; and Alternative 7, Import Using the GDU Facilities; have been completed for the year 2050 using the Fargo participant demand, and the Reclamation demand in all other places. These model runs are presented in an abbreviated form and are for information purposes only. The model runs are not as refined and are considered to be “provisional” due to the lack of more extensive review and error checking. Evaluations are not presented for these participant demand scenarios, however the financial ramifications were previously discussed.
.

b. Alternative 2RP; Kindred Reservoir with Participant Demands - Model Run ALT2RP

Using the participant demand projections results in a much greater draw on the Sheyenne and Red River systems. This increased draw on the rivers does not allow water to be captured and stored in Lake Ashtabula or Kindred Reservoir at the same rate as Alternative 2 using Reclamation projections. With the limited inflows during the 1930's drought cycle, the new Kindred Reservoir can only fill to 30,000 acre-feet. Beginning reservoir contents are one-half of the active storage, which is same criteria used in the previous alternative 2. The end-of-month reservoir contents for the 1930's drought event are shown on the following graphs.



Lake Ashtabula Contents
Alternative 2RP - Participants and Reclamation Projections
EOM Contents, KAF
70
60
50
40
30
20
Jan-31
Jan-32
Jan-33
Jan-34
Jan-35
Jan-36
Jan-37
Jan-38
Jan-39
Jan-40
Jan-41
Participant Projections
Reclamation Projections

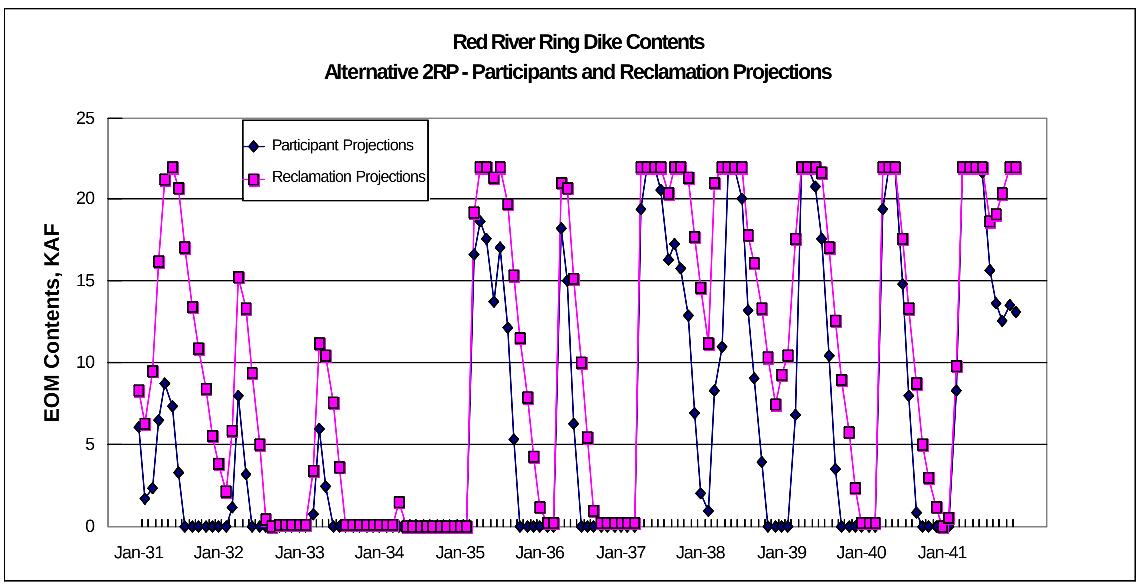


Lake Kindred Contents
Alternative 2RP - Participants and Reclamation Projections
EOM Contents, KAF
100
80
60
40
20
0
Jan-31
Jan-32
Jan-33
Jan-34
Jan-35
Jan-36
Jan-37
Jan-38
Jan-39
Jan-40
Jan-41
Participant Projections
Reclamation Projections

Shortages still remain in the study area due to the smaller active storage size of Kindred Reservoir. A summary of the remaining shortages is also presented in the following table.

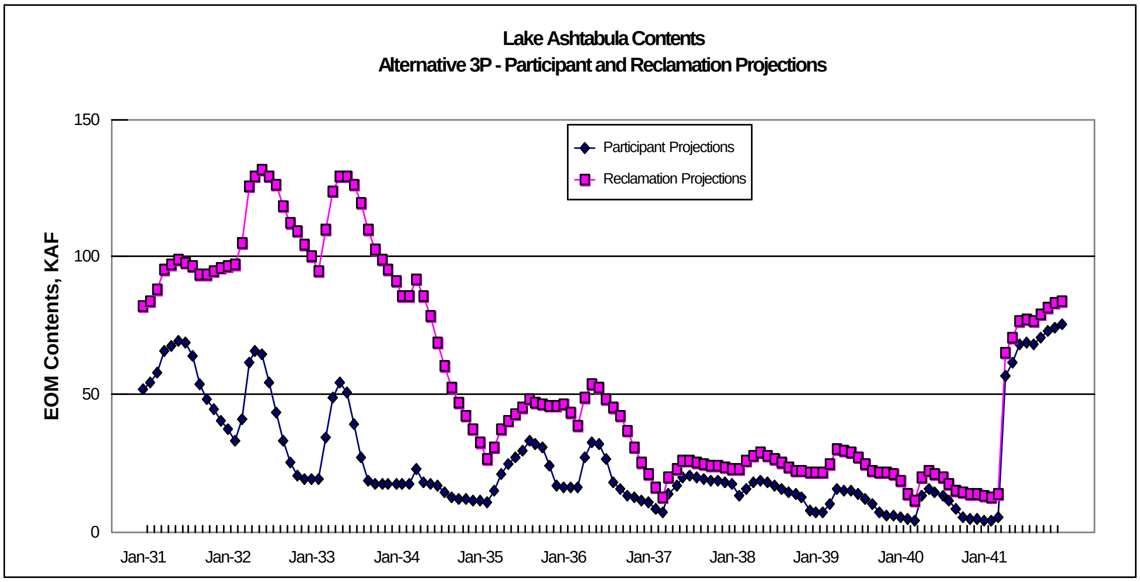
Municipal Shortages, Participant Demands	Largest Shortage, Ac-Ft per Year	Industrial Shortages	Largest Shortage, Ac-Ft per Year
City of Fargo	50,760 (1934)	**Existing Cargill**	4,230 (1934)
City of Moorhead	6,750 (1934)	**New Industry 2**	5,500 (1934)
City of West Fargo	1,030 (1934)	**New Industry 3**	4,480 (1934)
Valley City	390 (1940)	**New Industry 5**	220 (1940)
		Misc Industry	720 (1940)
Combined Municipal	58,740 (1934)	**Combined Industrial**	14,400(1934)
Northern Rural Water Systems	980 (1934)		
Southern Rural Water Systems	3,730 (1934)		

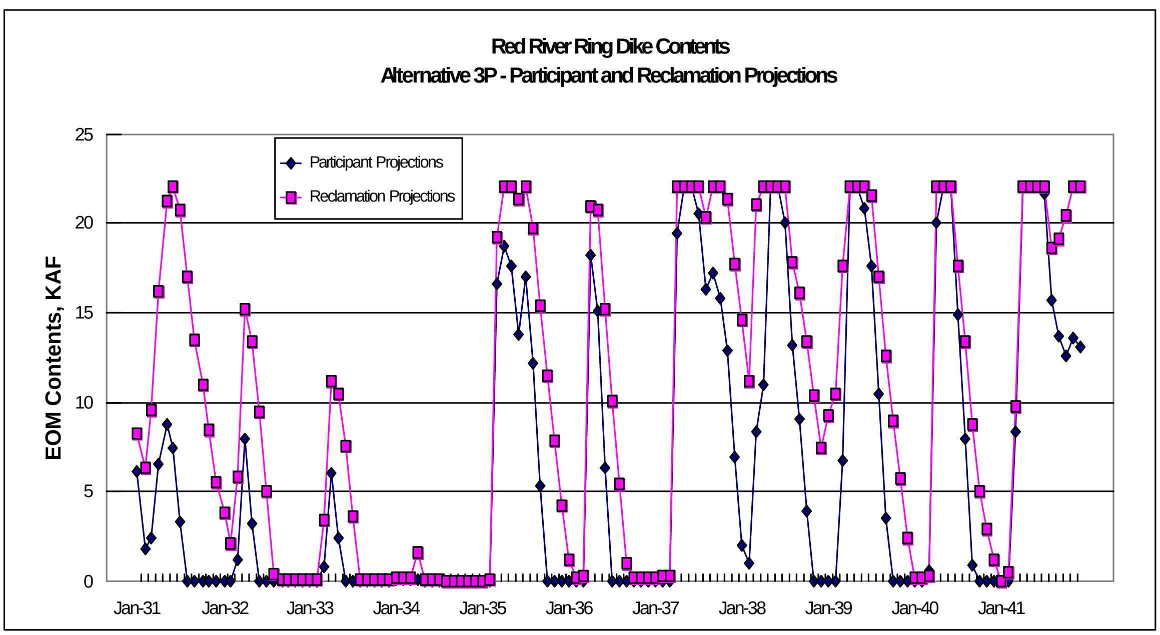
This alternative also includes a ring dike on the Red River near Fargo. The inflows to the ring dike are also more limited due to the increased demand on the Red River at Fargo. The following end-of-month contents of the ring dike illustrate the difference between the two demand projections.



c. Alternative 3P: Enlarged Lake Ashtabula with Participant Demands - Model Run ALT3P

The results of the increased demands on the Red and Sheyenne Rivers limits the amount of water that is available for storage in Lake Ashtabula. During the years 1931-1941, the largest size of Lake Ashtabula that can be produced is approximately 75,400 ac-ft, which is only slightly larger than the size of the existing reservoir. The comparison of the end-of-month contents for the Reclamation demand projections and Participant demand projections is shown in the following graph. Similarly, ring dike end-of-month content is limited by the amount of flow available for diversion and storage.





With the limited size increase of Lake Ashtabula, there are shortages remaining in this model scenario. The remaining shortages are the greatest for the year 1934 and are as follows:

Municipal Shortages, Participant Demands	Largest Shortage Ac-Ft per Year	Industrial Shortage	Largest Shortage Ac-Ft per Year
City of Fargo	51,100	**Existing Cargill**	4,190
		New Industry 2	4,830
City of Moorhead	6,400	**New Industry 3**	4,650
		Misc. Industry	720
Combined Municipal	57,500	**Combined Industrial**	13,860

These shortages do not include rural water systems. As with the previously presented Alternative 2, rural water systems shortages could be assumed to be an additional 4700 ac-ft in the worst case year.

d. Alternative 5A1P: Bismarck to Fargo Pipeline with Participant Demands Model Run ALT5A1P

Use of the participant demand in this import alternative has been modeled to determine the increased pipeline size needed to meet the increased demand. The pipeline import uses ring dikes at both Fargo and Wahpeton to re-regulate the import flows. Ring dike re-regulation is proposed to lower the peak demand flow and help control the pipeline size needed.

The import flow needed to offset shortages modeled using the participant demand projections is estimated to be 106 cfs. Flow capacity estimated using Reclamation projections was 65 cfs. There are no remaining shortages with this import scenario and rural water system shortages are included.

Reservoir end-of-month contents for the ring dikes and Lake Ashtabula are nearly identical to the Alternative 5A values using Reclamation demands.

e. Alternative 7abcP: Import Using Existing GDU Facilities - Model Run ALT7abcP

Import alternatives 7a, 7b, and 7c, use various portions of the existing GDU facilities. All of these imports are sized to meet shortages downstream on the Sheyenne River with some water transfer to the upper Red River for industrial shortages. Using the participant demand on the Sheyenne River at Fargo creates a larger import need. The import needed on the upper Sheyenne River system, using the participant demand, is estimated to be 122 cfs. The estimated import need using Reclamation projections is 72 cfs. End-of-month contents for Lake Ashtabula are nearly identical to the previous Alternative 7abc values with the Reclamation demand projections.