50 years

HVDC

PART II

The semiconductor 'takeover'

Gunnar Asplund, Lennart Carlsson, Ove Tollerz

Mercury-arc valve based HVDC had come a long way in a short time, but it was a technology that still harbored some weaknesses. One was the difficulty in predicting the behavior of the valves themselves. As they could not always absorb the reverse voltage, arc-backs occurred. Also, mercury-arc valves require regular maintenance, during which absolute cleanliness is critical. A valve that avoided these drawbacks was needed.

The invention of the thyristor in 1957 had presented industry with a host of new opportunities, and HVDC transmission was now seen as a promising area of application. A new era was about to unfold.

All through the first half of the 1960s, as a result of the huge interest being shown in semiconductor applications, work had continued on development of high-voltage thyristor valves as an alternative to the mercury-arc type. In the spring of 1967, one of the mercury-arc valves used in the Gotland HVDC link was replaced with a thyristor valve. It was the first time anywhere that this kind of valve had been taken into commercial operation for HVDC transmission. After a trial of just one year, the Swedish State Power Board ordered a complete thyristor valve group for each converter station, at the same time increasing the transmission capacity by 50 percent.

Around the same time, tests were carried out on the Gotland submarine cable, which had been operating without any problems at 100 kV, to see if its voltage could be increased to 150 kV – the level needed to transmit the higher power. The tests showed that it could, and this cable was subsequently operated at an electrical stress of 28 kV/mm, which is still the worldwide benchmark for large HVDC cable projects today.

The scale and complexity of the Itaipu project presented a considerable challenge, and it can be considered as the start of the modern HVDC era.

The new valve groups were connected in series with the two existing mercury-arc valve groups, thereby increasing the transmission voltage from 100 to 150 kV. This higher-rated system was taken into service in the spring of 1970 – another world's 'first' for the Gotland transmission link.

With the advent of thyristor valves it became possible to simplify the con-

Gotland 1 extension, with the world's first HVDC thyristor valves

verter stations, and semiconductors have been used in all subsequent HVDC links. Other companies were now entering the field. Brown Boveri (BBC) – which later merged with ASEA to form ABB – teamed up with Siemens and AEG in the mid-1970s to build the 1920-MW Cahora Bassa HVDC link between Mozambique and South Africa. The same group then went on to build the 2000-MW Nelson River 2 link in Canada. This was the first project to employ water-cooled HVDC valves.

The late 1970s also saw the completion of new projects. These were the Skagerrak link between Norway and Denmark, Inga-Shaba in the Congo, and the CU Project in the USA.

The Pacific Intertie was also extended twice in the 1980s, each time with thyristor converters, to raise its capacity to 3100 MW at ±500 kV. (ABB is currently upgrading the Sylmar terminal with state-of-the-art technology.)

Itaipu – the new benchmark

The contract for the largest of all HVDC transmission schemes to date, the 6300-MW Itaipu HVDC link in Brazil, was awarded to the ASEA-PROMON consortium in 1979. This project was completed and put into operation in several stages between 1984 and 1987. It plays a key role in the Brazilian power scheme, supplying a large portion of the electricity for the city of São Paulo.

The scale and technical complexity of the Itaipu project presented a considerable challenge, and it can be considered as the start of the modern HVDC era. The experience gained in the course of its completion has been in no small way responsible for the many HVDC orders awarded to ABB in the years since.

After Itaipu, the most challenging HVDC project was undoubtedly the 2000-MW Québec – New England link. This was the first large multi-terminal HVDC transmission system to be built anywhere in the world.

HVDC cables have kept pace

As the converter station ratings increased, so too did the powers and voltage levels for which the HVDC cables had to be built.

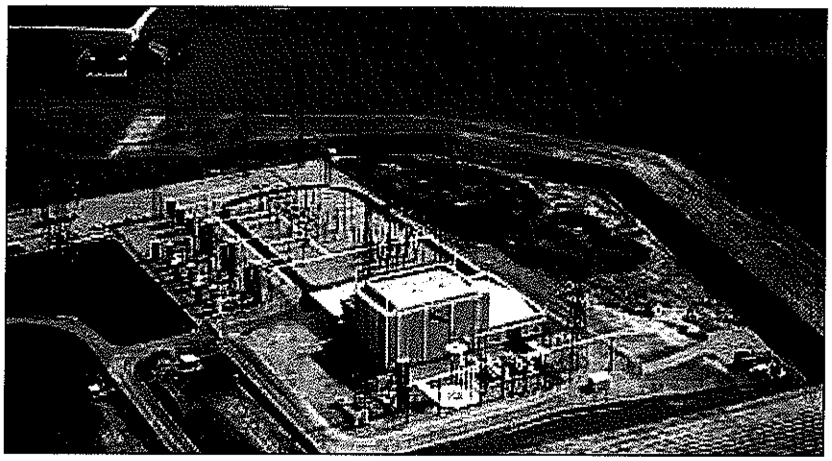
The most powerful HVDC submarine cables to date are rated 600 MW at 450 kV. The longest of these are the 230 km cable for the Baltic Cable link between Sweden and Germany, and the 260 km cable for the SwePol link between Sweden and Poland.

HVDC today

The majority of HVDC converter stations built today are still based on the principles that made the original Gotland link such a success back in 1954. Station design underwent its first big change with the introduction of thyristor valves in the early 1970s. The first of these were air-cooled and designed for indoor use, but soon outdoor oil-cooled, oil-insulated valves were also being used. Today, all HVDC valves are water-cooled [1].

Good examples of modern bulk power HVDC transmission are the links ABB

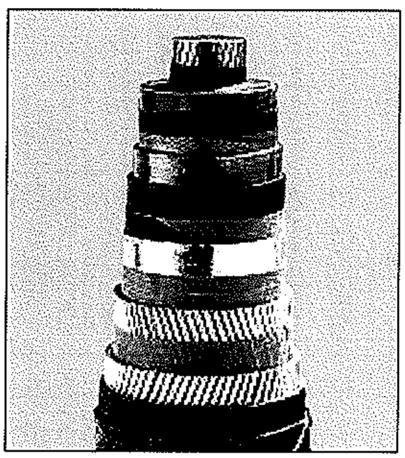
Foz do Iguaçu converter station with the Itaipu 12,600-MW power station in the background



Baltic Cable HVDC converter station

is installing for the Three Gorges hydroelectric power plant project in China. (An article on the Three Gorges project begins on page14 of this issue.)

In 1995 ABB presented a new generation of HVDC converter stations: 'HVDC 2000' [2]. HVDC 2000 was developed to meet stricter electrical disturbance requirements, to provide better dynamic stability where there was insufficient short-circuit capacity, to overcome space limitations, and to shorten delivery times.



Submarine cable for the 600-MW Baltic Cable HVDC link between Germany and Sweden

A key feature of HVDC 2000 was the introduction of capacitor commutated converters (CCC). This was, in fact, the first fundamental change to have been made to the basic HVDC system technology since 1954!

HVDC 2000 also includes other ABB innovations, such as continuously tuned AC filters (ConTune), active DC filters, outdoor air-insulated HVDC valves, and the fully digital MACH2™ control system.

The first project to employ HVDC 2000 with CCC and outdoor valves was the Garabi 2200-MW HVDC back-to-back station in the Brazil – Argentina HVDC Interconnection.

HVDC Light™

HVDC technology has become a mature technology over the past 50 years and reliably transmits power over long distances with very low losses. This begs the question: where is development work likely to go in the future?

It was conceived that HVDC development could, once again, take its cue from industrial drives. Here, thyristors were replaced a long time ago by voltage source converters (VSC), with semiconductors that can be switched off as well as on. These have brought many advantages to the control of industrial drive systems and it was realized that they could also apply to transmission systems. Adapting the technology of voltage source converters to HVDC, however, is no easy matter. The entire technology has to change, not just the valves.

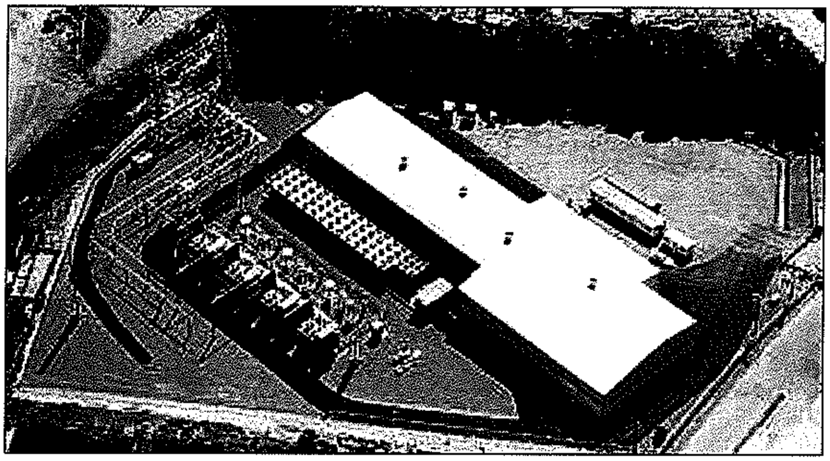
> Most of the HVDC converter stations built today are still based on the principles that made the original Gotland link such a success.

As development of its VSC converter got under way, ABB realized that the insulated gate bipolar transistor, or IGBT, held more promise than all the other available semiconductor components. Above all else, the IGBT needs only very little power for its control, making series connection possible. However, for HVDC a large number of IGBTs have to be connected in series, something industrial drives do not need.

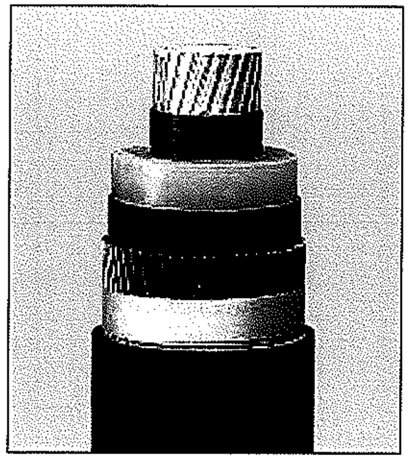
In 1994, ABB concentrated its development work on VSC converters in a project that aimed at putting two converters based on IGBTs into operation for small-scale HVDC. An existing 10-km-long AC line in central Sweden was made available for the project.

At the end of 1996, after comprehensive synthetic tests, the equipment was installed in the field for testing under service conditions. In 1997 the world's first VSC HVDC transmission system, HVDC Light™ [3], began transmitting power between Hellsjön and Grängesberg in Sweden.

In the meantime, seven such systems have been ordered, and six of them are now in commercial operation in Sweden, Denmark, the USA and Australia. HVDC Light is now available for ratings up to 350 MW, ±150 kV. ABB is to date the only company that has managed to develop and build VSC HVDC transmission systems [4].



Shoreham station, 330-MW HVDC Light™ Cross Sound Cable link, USA



HVDC Light land cable

One advantage of HVDC Light is that it allows an improvement in the stability and reactive power control at each end of the network. Also, it can operate at very low short-circuit power levels and even has blackstart capability. The HVDC Light cable is made of polymeric material and is therefore very strong and robust. This makes it possible to use HVDC cables where adverse laying conditions might otherwise cause damage. Extruded cable has also made very long HVDC cable transmission on land now economically viable. An example is the 180-km-long HVDC Light™ interconnection 'Murraylink' in Australia.

The introduction of capacitor commutated converters was the first fundamental change made to the basic HVDC technology since 1954!

And the next 50 years?

HVDC transmission has come a long way since that first Gotland link. But what does the future hold for it?

Bulk transmission is likely to rely on thyristor-based technology for many years since it is reliable and low in cost, plus losses are low. Increasing the voltage is one way to go here as it would allow much higher powers and very long distances for the links.

HVDC Light has the potential to be developed further. One direction might be toward higher voltages and powers, but low power and relatively high voltages are also conceivable for systems for smaller loads and generators.

The development of HVDC Light cable has made it possible to link up networks across very deep waters that have previously made such schemes unthinkable. The most interesting prospects for HVDC Light, however, lie in its potential for building multi-terminal systems. In the long term it might offer a genuine alternative to AC transmission, which today completely dominates this sector.

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[1] **B. Sheng, H. O. Bjarma:** Proof of performance – a synthetic test circuit for verifying HVDC thyristor valve design. ABB Review 3/2003, 25–29.

[2] **B. Aernlöv:** HVDC 2000 – a new generation of high-voltage DC converter stations. ABB Review 3/1996, 10–17.

[3] **G. Asplund, et al:** HVDC Light – DC transmission based on voltage sourced converters. ABB Review 1/1998, 4–9.

[4] **T. Nestli, et al:** Powering Troll with new technology. ABB Review 2/2003, 15–19.

Further information on HVDC can be found at www.abb.com/hvdc

50 years

HVDC

PART I

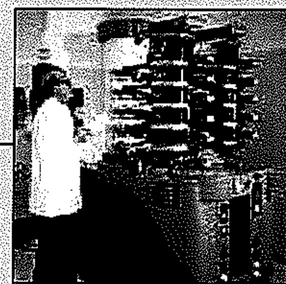


ABB – from pioneer to world leader

Gunnar Asplund, Lennart Carlsson, Ove Tollerz

In 1954, at a time when much of Europe was busy expanding its electricity supply infrastructure to keep pace with surging demand, an event was quietly taking place on the shores of the Baltic Sea that would have a lasting effect on long-distance power transmission. Four years earlier, the Swedish State Power Board had placed an order for the world's first commercial high-voltage direct current (HVDC) transmission link, to be built between the Swedish mainland and the island of Gotland. Now, in 1954, it was being commissioned.

50 years on, ABB proudly looks back at its many contributions to HVDC technology. Since the laying of that early 90 kilometers long, 100-kV, 20-MW submarine cable, our company has gone on to become the undisputed world leader in HVDC transmission. Of the 70,000 MW of HVDC transmission capacity currently installed all over the world, more than half was supplied by ABB.

With the arrival of the electric light bulb in the homes and factories of late 19th century Europe and the USA, demand for electricity grew rapidly and engineers and entrepreneurs alike were soon busily searching for efficient ways to generate and transmit it. The pioneers of this new technology had already made some progress – just being able to transmit power a few kilometers was regarded as something fantastic – when an answer to growing demand was found: hydroelectric power. Almost immediately, interest turned to finding ways of transmitting this 'cheap' electricity to consumers over longer distances.

First direct, then alternating current

The first power stations in Europe and the USA supplied low-voltage, direct current (DC) electricity, but the transmission systems they used were inefficient. This was because much of the generated power was lost in the cables. Alternating current (AC) offered much better efficiency, since it could easily be transformed to higher voltages, with far less loss of power. The stage was thus set for long-distance high-voltage AC (HVAC) transmission.

In 1893, HVAC got another boost with the introduction of three-phase transmission. Now it was possible to ensure a smooth, non-pulsating flow of power.

Although direct current had been beaten at the starting gate in the race to develop an efficient transmission system, engineers had never completely given up the idea of using DC. Attempts were still being made to build a high-voltage transmission system with series-con-

Analog simulator used in the design of the early HVDC transmission systems

nected DC generators and, at the receiving end, series-connected DC motors – all on the same shaft. This worked, but it was not commercially successful.

AC dominates

As the AC systems grew and power increasingly was being generated far from where most of its consumers lived and worked, long overhead lines were built, over which AC at ever-higher voltages flowed. To bridge expanses of water, submarine cable was developed.

> Even when HVDC transmission finally proved technically feasible, it was doubted for a long time whether it could compete with HVAC in the marketplace.

Neither of these transmission media was without its problems, however. Specifically, they were caused by the reactive power that oscillates between the capacitances and inductances in the systems. As a result, power system planners began once again to look at the possibility of transmitting direct current.

Back to DC

What had held up high-voltage direct current transmission in the past was, first and foremost, the lack of reliable and economic valves that could convert HVAC into HVDC, and vice versa.

The mercury-arc valve offered, for a long time, the most promising line of development. Ever since the end of the 1920s, when the Swedish ASEA – a founding company of ABB – began making static converters and mercury-arc valves for voltages up to about 1000 V, the possibility of developing valves for even higher voltages had been continually investigated.

This necessitated the study of new fields in which only a limited amount of existent technical experience could be applied. In fact, for some years it was debated whether it would be possible at all to find solutions to all the various problems. When HVDC transmission finally proved to be technically feasible there still remained uncertainty as to whether it could successfully compete with HVAC in the marketplace.

Whereas rotating electrical machines and transformers can be designed very precisely with the aid of mathematically formulated physical laws, mercury-arc valve design depends to a large degree on knowledge acquired empirically. As a result, attempts to increase the voltage in the mercury-vapor-filled tube by enlarging the gap between the anode and cathode invariably failed.

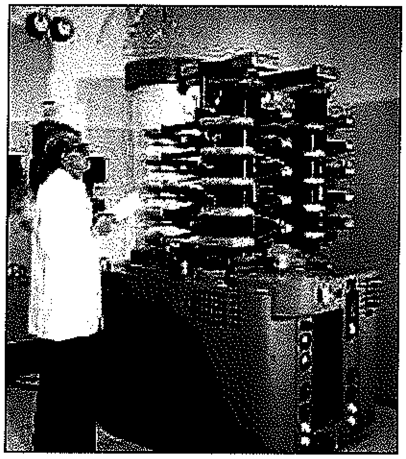
The problem was solved in 1929 by a proposal to insert grading electrodes between the anode and cathode. Subsequently patented, this innovative solution can in some ways be considered as the cornerstone of all later development work on the high-voltage mercury-arc valve. It was during this time that Dr. Uno Lamm, who led the work, earned his reputation as 'the father of HVDC'.

The Gotland link

The time was now ripe for service trials at higher powers. Together with the Swedish State Power Board, the company set up, in 1945, a test station at Trollhättan, where there was a major power plant that could provide energy. A 50-km power line was also made available.

Trials carried out over the following years led to the Swedish State Power Board placing, in 1950, an order for equipment for the world's first HVDC transmission link. This was to be built between the island of Gotland in the Baltic Sea and the Swedish mainland.

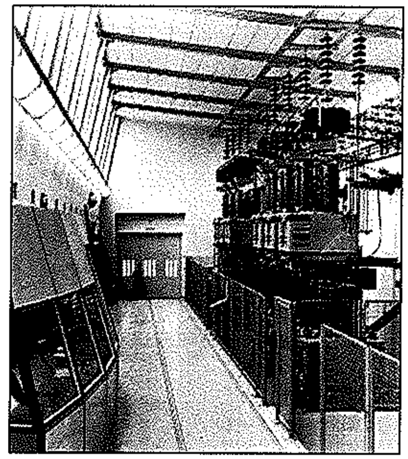
Following on this order, the company intensified its development of the mercury-arc valve and high-voltage DC cable, while also initiating design work on other components for the converter stations. Among the equipment that benefited from the increased efforts were transformers, reactors, switchgear and the protection and control equipment.



Early mercury-arc valve for HVDC transmission

Finally, in 1954, after four years of innovative endeavor, the Gotland HVDC transmission link, with a rating of 20 MW, 200 A and 100 kV, went into operation. A new era of power transmission had begun.

The original Gotland link was to see 28 years of successful service before being finally decommissioned in 1986. Two new links for higher powers have meanwhile been built between the island and the Swedish mainland, one in 1983 and the other in 1987.



Mercury-arc valves in the first Gotland link, 1954

Only some of the existing AC system technology could be applied to the new DC system. Completely new technology was therefore necessary. Specialists in Ludvika, led by Dr. Erich Uhlmann and Dr. Harry Forsell, set about solving the many very complex problems involved. Subsequently, a concept was developed for the Gotland system. This proved to be so successful that it has remained basically unchanged right down to the present time!

Continual development of the mercury-arc valve secured a level of reliability that has resulted in some HVDC projects with these valves still being in operation after 35 years.

Since Gotland is an island and the power link was across water, it was also necessary to manufacture a submarine cable that could carry DC. It was seen that the 'classic' cable with mass impregnated paper insulation that had been in use since 1895 for operation at 10 kV AC had potential for further development. Soon, this cable was being developed for 100 kV DC!

Early HVDC projects

The early 1950s also saw the British and French power administrations planning a power transmission link across the English Channel. High-voltage DC transmission was chosen, and the company won its second HVDC order – this time a link for 160 MW.

The success of these early projects generated considerable worldwide interest. During the 1960s several HVDC links were built: Konti-Skan between Sweden and Denmark, Sakuma in Japan (with 50/60 Hz frequency converters), the New Zealand link between the South and the North Islands, the Italy – Sardinia link and the Vancouver Island link in Canada.

The largest mercury-arc valve HVDC transmission link to be built by the company was the Pacific Intertie [1] in the USA. Originally commissioned for 1440 MW and later uprated to 1600 MW at ±400 kV, its northern terminal is sited in The Dalles, Oregon, and its southern terminal at Sylmar, in the northern tip of the Los Angeles basin. This project was undertaken together with General Electric, and started operating in 1970.

In all, the company installed eight mercury-arc valve based HVDC systems for a total power rating of 3400 MW. Although many of these projects have since been replaced or upgraded with thyristor valves, some are still in operation today, after 30 to 35 years of service!

Part II: 50 years of HVDC transmission – the semiconductor 'takeover' ➠ page 10

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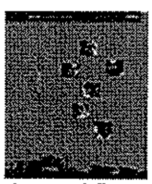
[1] **L. Engström:** More power with HVDC to Los Angeles. ABB Review 1/88, 3–10.



News

Black Hills Power Partners with Basin Electric Power Cooperative to Build Electric Sy:

East Meets West

RELEASE DATE: August 2, 2002

For Information Contact: **Barbara Thirstrup**, Manager Governmental & Public Affairs

Rapid City, SD — "East Meets West" was the theme of today's groundbreaking ceremony for a Black Hills Power and Basin Electric Power Cooperative of Bismarck, ND. Dignitaries joined rep both companies this morning at 10:30 at the Rushmore Plaza Holiday Inn to kick off the constru the 200 MW converter.

Together, Basin Electric and Black Hills Power are building an electric system inter-tie to conne and western power grids at a site southeast of Rapid City. Basin will own 65% of the $70 million Hills will own 35%.

"There are only about six of these facilities connecting the eastern and western transmission sy: Landguth, CEO of Black Hills Corporation. "We're fortunate to have this one in Rapid City. This infrastructure provides tremendous reliability and support for electric suppliers and customers. I 200 MW generator right at our back door."

Rapid City Mayor Jerry Munson said, "This inter-tie is a valuable tool to allow forward motion in City. It's an incredible investment of private industry for public investment, and Rapid City is pro site."

Pennington County Commissioner Jim Kjerstad said, "Thank you for locating this project in Pen It's good news for the County, and also for the taxpayers."

South Dakota Public Utilities Commission Executive Director Deb Elofson said, "Siting facilities : be difficult, but this process went very smoothly. The inter-tie project is a wise decision for all co

Ron Harper, CEO of Basin Electric Power Cooperative, said, "We're proud of the great working have with Black Hills Power. In all of our joint projects, customers have won in the end because duplicated facilities. This project represents the coming together of many entities." Harper gave you to Sharon Norman, the fourth-generation rancher who sold a portion of her land so that the sited.

Jack Dwyer, of ABB, the global Zurich-based company which designed the inter-tie, compared t capacity of the facility to "three-and-a-half-million light bulbs" of power. He explained the functio back converter station." The facility converts alternating current to direct current and back to alte so that electricity can be transferred between the eastern and western power grids, which are sl "sync."

"We've always been proud to bring new technology to our customers," said Landguth, "whether cooled condensing in power plants in the Western Hemisphere or bringing broadband services t We are committed to economic development and the quality of life in our communities, just as B project benefits all of our customers."

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HVDC PROJECTS LISTING

Prepared for the
DC and Flexible AC Transmission Subcommittee
of the
IEEE Transmission and Distribution Committee
by the
Working Group on HVDC and FACTS Bibliography and Records

SYSTEM / PROJECT	HVDC SUPPLIER	YEAR COMMISSIONED	POWER RATING (MW)	DC VOLTAGE (kV)	LINE/ CABLE (km)	MERCURY/ THYRISTOR/ TRANSISTOR	LOCATION
MOSOW-KASHIRA (retired from service)	RUSSIAN	1951 ( )	30	±100	100	MERC	RUSSIA
GOTLAND I (retired from service)	ASEA	1954 (1986)	20	±100	96	MERC	SWEDEN
GOTLAND EXTENSION (retired from service)	ASEA	1970 (1986)	30	±150	96	THY	SWEDEN
GOTLAND II	ASEA	1983	130	150	100	THY	SWEDEN
GOTLAND III	ASEA	1987	260	±150	103	THY	SWEDEN
GOTLAND HVDC LIGHT	ABB	1999	50	±60	70	TRA	SWEDEN
ENGLISH CHANNEL (retired from service)	ASEA	1961 ( )	160	±100	64	MERC	ENGLAND-FRANCE
VOLGOGRAD-DONBASS	MINISTRY FOR ELECTROTECHNICAL INDUSTRY OF USSR	1962/65	720	±400	473	MERC/THY	RUSSIA
NEW ZEALAND HYBRID INTER ISLAND LINK	ASEA	1965	600	±250	609	MERC	NEW ZEALAND
NEW ZEALAND HYBRID INTER ISLAND LINK	ABB	1992	1240	+270/-350	612	THY	NEW ZEALAND
NEW ZEALAND HYBRID INTER ISLAND LINK		PLANNED				THY	NEW ZEALAND
KONTI-SKAN 1	ASEA	1965	250	±250	180	MERC	DENMARK-SWEDEN
KONTI-SKAN 1	AREVA	2005	250	±250	180	THY	DENMARK-SWEDEN
KONTI-SKAN 2	ASEA	1988	300	285	150	THY	DENMARK-SWEDEN
SAKUMA (retired from service)	ASEA	1965 ( )	300	2x125	B-B	MERC	JAPAN
SARDINIA (retired from service)	ENGLISH ELECTRIC	1967 ( )	200	200	413	MERC	ITALY
VANCOUVER I	ASEA	1968/69	312	±260	74	MERC	CANADA
VANCOUVER II	GENERAL ELECTRIC	1977/79	370	±280	74	THY	CANADA
PACIFIC INTERTIE	ASEA/GE	1970	1440	±400	1362	MERC	U.S.A
PACIFIC INTERTIE	ASEA/GE	1982	1600	±400	1362	MERC	U.S.A
PAC INTERTIE UPGRADE	ASEA	1985	2000	±500	1362	THY	U.S.A
PACIFIC INTERTIE EXPANSION	BROWN BOVERI	1989	3100	±500	1362	THY	U.S.A
KINGSNORTH (retired from service)	ENGLISH ELECTRIC	1972 (1987)	640	±268	82	THY	UNITED KINGDOM
EEL RIVER	GENERAL ELECTRIC	1972	320	±80	B-B	THY	CANADA
NELSON RIVER 1	ENGLISH ELECTRIC/GEC ALSTHOM	1973	1854	±463	890	MERC	CANADA
NELSON RIVER 1	GEC ALSTHOM	1992/93	1854	±463	890	MERC/THY	CANADA
NELSON RIVER 1	SIEMENS	2001/02	1854	±463	890	THY	CANADA
NELSON RIVER 2	AEG/BBC/SIEMENS	1978	900	±250	940	THY	CANADA
NELSON RIVER 2	AEG/BBC/SIEMENS	1985	2000	±500	940	THY	CANADA
SKAGERRAK I	ASEA	1976	275	±250	240	THY	NORWAY-DENMARK
SKAGERRAK II	ASEA	1977	275	±250	240	THY	NORWAY-DENMARK
SKAGERRAK III	ABB	1993	500	±350	240	THY	NORWAY-DENMARK
SHIN-SHINANO 1	HITACHI/TOSHIBA/NISSHIN	1977	300	125	B-B	THY	JAPAN
SHIN-SHINANO 2	HITACHI/TOSHIBA/NISSHIN	1992	300	125	B-B	THY	JAPAN
SQUARE BUTTE	GENERAL ELECTRIC	1977	500	±250	749	THY	U.S.A.
DAVID A. HAMIL	GENERAL ELECTRIC	1977	100	±50	B-B	THY	U.S.A
CAHORA-BASSA	AEG/BBC/SIEMENS	1977/78/79	1920	±533	1420	THY	SOUTH AFRICA
C.U.	ASEA	1979	1000	±400	701	THY	U.S.A
HOKKAIDO-HONSHU	ASEA	1979	150	125	167	THY	JAPAN
HOKKAIDO-HONSHU	HITACHI/TOSHIBA	1980	300	250	167	THY	JAPAN
HOKKAIDO-HONSHU	HITACHI/TOSHIBA	1993	600	±250	167	THY	JAPAN
ACARAY	SIEMENS	1981	50	±25.6	B-B	THY	PARAGUAY-BRAZIL
VYBORG	MINISTRY FOR ELECTROTECHNICAL INDUSTRY OF USSR	1981	355	1X170(±85)	B-B	THY	RUSSIA-FINLAND
VYBORG	MINISTRY FOR ELECTROTECHNICAL INDUSTRY OF USSR	1982	710	2x170	B-B	THY	RUSSIA-FINLAND
VYBORG	MINISTRY FOR ELECTROTECHNICAL INDUSTRY OF USSR	1984	1065	3x170	B-B	THY	RUSSIA-FINLAND
VYBORG	MINISTRY FOR ELECTROTECHNICAL INDUSTRY OF USSR	1999	4x405	±85	B-B	THY	RUSSIA-FINLAND
ZHOU SHAN PROJECT		1982	50	100	42	THY	CHINA
INGA-SHABA	ASEA/GE	1982/83	560	±500	1700	THY	ZAIRE
DUERNROHR 1 (retired from service)	AEG/BBC/SIEMENS	1983 (1997)	550	145	B-B	THY	AUSTRIA
EDDY COUNTY	GENERAL ELECTRIC	1983	200	82	B-B	THY	U.S.A.
CHATEAUGUAY	BBC/SIEMENS	1984	2x500	2x140.6	B-B	THY	CANADA-U.S.A.
OKLAUNION	GENERAL ELECTRIC	1984	200	82	B-B	THY	U.S.A
ITAIPU 1	ASEA	1984	1575	±300	807	THY	BRAZIL
ITAIPU 1	ASEA	1985	2383	±300	807	THY	BRAZIL
ITAIPU 1	ASEA	1986	3150	±600	807	THY	BRAZIL
ITAIPU 2	ASEA	1987	3150	±600	818	THY	BRAZIL
BLACKWATER	BBC	1985	200	57	B-B	THY	U.S.A.
SACOI	CGEE/ALSTHOM	1985	200	200	415	THY	ITALY-CORSICA-SARDINIA
SACOI THREE TERMINAL	CGEE/ALSTHOM	1993	300	±200	385	THY	ITALY-CORSICA-SARDINIA
HIGHGATE	ASEA	1985	200	±56	B-B	THY	U.S.A.
MADAWASKA	GENERAL ELECTRIC	1985	350	130.5	B-B	THY	CANADA
MILES CITY HVDC SYSTEM (MCCS)	GENERAL ELECTRIC	1985	200	82	B-B	THY	U.S.A
BROKEN HILL	ASEA	1986	40	2x17 (±8.33)	B-B	THY	AUSTRALIA
INTERMOUNTAIN POWER PROJECT (I.P.P.)	ASEA	1986	1920	±500	785	THY	U.S.A.
CROSS CHANNEL BP 1+2	CGEE-ALSTHOM/GEC-ALSTHOM	1985/86	2000	±270	70	THY	FRANCE-U.K.
DES CANTONS-COMFERFORD	GENERAL ELECTRIC	1986	690	±450	172	THY	CANADA-U.S.A.
QUEBEC-NEW ENGLAND	GE/ABB	1986/92	2250	±450	1500	THY	CANADA-U.S.A.
VIRGINIA SMITH	SIEMENS	1987	200	50	B-B	THY	U.S.A
GESHA (GEZHOUBA-SHANGHAI)	ABB/SIEMENS	1989	600	500	1000	THY	CHINA
GESHA (GEZHOUBA-SHANGHAI)	ABB/SIEMENS	1990	1200	±500	1046	THY	CHINA
VINDHYACHAL	ASEA	1989	500	2x69.7	B-B	THY	INDIA
McNEILL	GEC ALSTHOM	1989	150	42	B-B	THY	CANADA
FENNO-SKAN	ABB/ALCATEL	1989/98	572	±400	233	THY	FINLAND-SWEDEN
FENNO-SKAN 2		PLANNED 2010	800	500	233	THY	FINLAND-SWEDEN
BARSOOR LOWER SILERU	BHEL	1989/91	100	±200	196	THY	INDIA
BARSOOR LOWER SILERU	BHEL	FUTURE	400			THY	INDIA
RIHAND-DELHI	ABB/BHEL	1991	750	500	814	THY	INDIA
RIHAND-DELHI	ABB/BHEL	1992	1500	±500	814	THY	INDIA
NICOLET TAP	ASEA	1992	2000				CANADA
SAKUMA	HITACHI/TOSHIBA/MITSUBISHI/NISSHIN	1993	300	±125	B-B	THY	JAPAN
ETZENRICHT (retired from service)	SIEMENS	1993 (1997)	600	160	B-B	THY	GERMANY-CZECH REPUBLIC
VIENNA SOUTH-EAST (retired from service)	SIEMENS	1993 (1997)	600	145	B-B	THY	AUSTRIA-HUNGARY
URUGUAIANA	TOSHIBA	1994	50	15	B-B	THY	BRAZIL-ARGENTINA
BALTIC CABLE	ABB	1994	600	±450	261	THY	SWEDEN-GERMANY
WELSH	SIEMENS	1995	600	162	B-B	THY	U.S.A
KONTEK	ABB/NKT CABLES	1995	600	400	171	THY	DENMARK-GERMANY
HAENAM-CHEJU	GEC ALSTHOM	1997	300	±180	101	THY	SOUTH KOREA
CHANDRAPUR-RAMAGUNDUM	GEC ALSTHOM	1997/98	1000	2x205	B-B	THY	INDIA
CHANDRAPUR-PADGHE	ABB	1998	1500	±500	736	THY	INDIA
LEYTE-LUZON	ABB/MARUBENI	1998	440	350	455	THY	PHILIPPINES
VISAKHAPATNAM	GEC ALSTHOM	1998	500	205	B-B	THY	INDIA
MINAMI-FUKUMITZU	HITACHI/TOSHIBA	1999	300	125	B-B	THY	JAPAN
VIZAG 1	GEC ALSTHOM	1999	500	205	B-B	THY	INDIA
VIZAG 2	ABB	2005	500	±88	B-B	THY	INDIA
KAALAMO		PLANNED 1999	40	20	B-B	THY	FINLAND
NORTH-SOUTHEAST		PLANNED 1999	1000			THY	BRAZIL
SWEPOL LINK	ABB	2000	600	±450	254	THY	SWEDEN-POLAND
DIRECTLINK	ABB	2000	3 x 60	±80	59	TRA	AUSTRALIA
KII CHANNEL	HITACHI/TOSHIBA/MITSUBISHI	2000	1400	±250	102	THY	JAPAN
KII CHANNEL		FUTURE	2800	±500	102	THY	JAPAN
GARABI 1	ABB	2000	1100	±70	B-B	THY	ARGENTINA-BRAZIL
GARABI 2	ABB	2002	2000	±70	B-B	THY	ARGENTINA-BRAZIL
RIVERA	GEC ALSTHOM	2000	70	20	B-B	THY	URUGUAY-BRAZIL
GRITA	PIRELLI/ABB	2001	500	400	316	THY	GREECE-ITALY
TIAN-GUANG	SIEMENS	2001	1800	±500	960	THY	CHINA
HIGASHI-SHIMIZU	HITACHI/TOSHIBA	2001	300	125	B-B	THY	JAPAN
MOYLE INTERCONNECTOR	SIEMENS	2001	2x250	2x250	64	THY	UNITED KINGDOM
THAILAND-MALAYSIA	SIEMENS	2001	300	±300	110	THY	THAILAND-MALAYSIA
MANTARO-SOCABAYA		PLANNED 2001	300	±190	840	THY	PERU
CROSS SOUND	ABB	2002	330	±150	40	TRA	U.S.A
MURRAYLINK	ABB	2002	200	±150	176	TRA	AUSTRALIA
SASARAM	GEC ALSTHOM	2002	500	205	B-B	THY	INDIA
IB VALLEY-JAIPUR		PLANNED 2002	3000			THY	INDIA
EUROCABLE		PLANNED 2002	600	500	600	THY	NORWAY-GERMANY
RAPID CITY TIE	ABB	2003	2 x 100	±13	B-B	THY	U.S.A.
EAST-SOUTH INTERCONNECTOR	SIEMENS	2003	2000	±500	1400	THY	INDIA
BAKUN			2130	3x±500	1335	THY	MALAYSIA
THREE GORGES-CHANGZHOU	ABB/SIEMENS	2003	3000	±500	860	THY	CHINA
THREE GORGES-GUANGDONG	ABB	2004	3000	±500	940	THY	CHINA

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HVDC PROJECTS LISTING

Prepared for the
DC and Flexible AC Transmission Subcommittee
of the
IEEE Transmission and Distribution Committee
by the
Working Group on HVDC and FACTS Bibliography and Records

SYSTEM / PROJECT	HVDC SUPPLIER	YEAR COMMISSIONED	POWER RATING (MW)	DC VOLTAGE (kV)	LINE/ CABLE (km)	MERCURY/ THYRISTOR/ TRANSISTOR	LOCATION
GUI-GUANG	SIEMENS	2004	3000	±500	936	THY	CHINA
TROLL A	ABB	2004	2x40	±60	70	TRA	NORWAY
LEYTE-MINDANAO		PLANNED 2004	400			THY	PHILIPPINES
VIKING CABLE		PLANNED 2004	600	450	600	THY	NORWAY-GERMANY
LAMAR	SIEMENS	2005	211	±63	B-B	THY	U.S.A.
EAST-WEST ENERGY BRIDGE		PLANNED 2005	500	600	1800	THY	GERMANY-POLAND-RUSSIA
EAST-WEST ENERGY BRIDGE		PLANNED 2010	1000			THY	GERMANY-POLAND-RUSSIA
ICELAND-SCOTLAND LINK		PLANNED 2005	550	400	950	THY	ICELAND-SCOTLAND
ICELAND-SCOTLAND LINK		FUTURE	1100	±400	950	THY	ICELAND-SCOTLAND
NORWAY-UK		PLANNED 2005	800		700	THY	NORWAY-UK
MEPANDA UNCUA		PLANNED 2006	500			THY	MOZAMBIQUE
BASSLINK	SIEMENS	2006	500	400	360	THY	AUSTRALIA
ESTLINK	ABB	UNDER CONSTRUCTION 2006	350	150	106	TRA	ESTONIA-FINLAND
LEWIS DE-ICER	AREVA	UNDER CONSTRUCTION 2006	250	±17.4	242	THY	CANADA
LONG ISLAND CABLE PROJECT		2007	600	±450	40	THY	USA
RUSSIA-CHINA		PLANNED 2007	2500		2000	THY	RUSSIA-CHINA
NORNED		UNDER CONSTRUCTION 2007	600	500	580	THY	NORWAY-NETHERLANDS
THREE GORGES-SHANGHAI		UNDER CONSTRUCTION 2007	3000	±500	900	THY	CHINA
NEPTUNE	SIEMENS	UNDER CONSTRUCTION		±500		THY	CANADA-U.S.A.
SAPEI		PLANNED 2008	500	±500	440	THY	ITALY MAINLAND-SARDINIA
CHINA-RUSSIA (HEIHE)		PLANNED 2008	750		B-B	THY	CHINA-RUSSIA
NORTHEAST-NORTH (GOALING)		PLANNED 2008	1500		B-B	THY	CHINA
OUTAOUAIS	ABB	2009	2x625	315	B-B	THY	CANADA
YUNNAN-GUANGDONG		PLANNED 2009	5000	800		THY	CHINA
LINGBAO EXPANSION		PLANNED 2009	750		B-B	THY	CHINA
AL FADHILI	AREVA	UNDER CONSTRUCTION 2009	3 x 600	3 x 222	B-B	THY	SAUDI ARABIA
STOREBAELT		PLANNED 2010	600	400	58	THY	DENMARK
FAREAST (RUSSIA) - NE CHINA		PLANNED 2010	3000			THY	CHINA-RUSSIA
HULUNBEIR (INNER MONGOLIA) - SHENYANG		PLANNED 2010	3000			THY	CHINA
NINGXIA-TIANJING		PLANNED 2010	3000			THY	CHINA
NW-SICHUAN (BAOJI-DEYANG)		PLANNED 2011	3000			THY	CHINA
NORTH SHAANXI-SHANDONG		PLANNED 2011	3000			THY	CHINA
SHANDONG-EAST		PLANNED 2011	1200		B-B	THY	CHINA
GEZHOUBA-SHANGHAI EXPANSION		PLANNED 2011	3000			THY	CHINA
XIANJIABA-SHANGHAI		PLANNED 2011	6400	800		THY	CHINA
JINGPING-EAST CHINA		PLANNED 2012	6400	800		THY	CHINA
NORTH-CENTRAL		PLANNED 2012	1000		B-B	THY	CHINA
JINGHONG-THAILAND		PLANNED 2013	3000		900	THY	CHINA-THAILAND
XILUODU-HUNAN		PLANNED 2014	6400	800		THY	CHINA
LABRADOR-NEWFOUNDLAND (LOWER CHURCHILL PROJECT)		PLANNED 2015				THY	
IRKUTSK (RUSSIA) - BEIJING		PLANNED 2015	6400	800		THY	RUSSIA-CHINA
XILUODU-HANZHOU		PLANNED 2015	6400	800		THY	CHINA
NUOZHADU-GUANGDONG		PLANNED 2015	6400	800		THY	CHINA
HUMENG-SHANDONG		PLANNED 2015	6400	800		THY	CHINA
JINSHA RIVER II - EAST CHINA		PLANNED 2016	6400	800		THY	CHINA
HUMENG-TIANJING		PLANNED 2016	6400	800		THY	CHINA
GOUPITAN-GUANGDONG		PLANNED 2016	3000			THY	CHINA
HUMENG-LIAONING		PLANNED 2018	6400	800		THY	CHINA
JINSHA RIVER II - FUJIAN		PLANNED 2018	6400	800		THY	CHINA
HAMI-C.CHINA		PLANNED 2018	6400	800		THY	CHINA
JINSHA RIVER II - EAST CHINA		PLANNED 2019	6400	800		THY	CHINA
TALCHER-BANGALORE	SIEMENS	FUTURE	2000	±500	1400	THY	INDIA
CEPA (RASPIER-RAJASTHAN)		FUTURE	2000	500		THY	INDIA
ISACCEA		FUTURE	600		B-B	THY	RUMANIA
POLAND-LITHUANIA		FUTURE			B-B	THY	
UK-NETHERLANDS		FUTURE				THY	UK-NETHERLANDS

The above HVDC List was based on the 2005 version of the CIGRE Compendium of HVDC Schemes Throughout the World.
Initial changes to the CIGRE list were made by incorporating changes from:
- Mike Bahrman, ABB - January 2006
- Neil Kirby, AREVA - April 2006
- Robyn Taylor, Teshmont - modifications based on the detailed descriptions from the 2005 version of CIGRE AG B4.04, COMPENDIUM OF HVDC SCHEMES THROUGHOUT THE WORLD text
- Robyn Taylor, Teshmont - modifications based on the IEEE HVDC Projects Listing, January 2000 issue

Further changes have been made by persons listed in the "comments" column

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Transmission

- Ancillary services
- Control areas
- North American Electric Reliability Council
- Power grid

Ancillary services

What types of ancillary services does Western provide?
Ancillary services support the transmission of capacity and energy from resources to loads to help maintain a reliable operation. Western offers ancillary services as part of its control area services.

The Federal Energy Regulatory Commission defines ancillary services as:

- **Scheduling, System Control and Dispatch** —scheduling the amount of energy to be delivered, assigning load and ensuring operational security;
- **Reactive Supply and Voltage Control** —maintaining correct voltage through adjustments to generator output;
- **Regulation and Frequency Response** —following the moment-to-moment variations in the demand or supply in the control area;
- **Energy Imbalance** —providing energy correction for any hourly mismatch between a transmission customer's energy supply and demand served.
- **Spinning Reserves** —providing immediate backup service from a reserve unit to serve load in case of a system contingency. (When the reserve unit is operating, it is spinning, thus the name spinning reserve.)
- **Supplemental Reserves** —serving loads when a contingency exists; not available immediately to serve load but can be available within a short time.

Control areas

Does Western operate any control areas?

Western operates four of 150 control areas within the three power grids in the United States and Canada. Western operates three of 30 control areas within the Western Interconnection. These three control areas are called the WAUM-West, or Western Area Upper Missouri-West, operated by our Upper Great Plains Region; the WALC, or Western Area Lower Colorado, which our Desert Southwest Region operates; and WACM, or Western Area Colorado Missouri, which our Rocky Mountain Region operates. Western's Sierra Nevada Region operates as a contract-based, sub-control area within the Sacramento Municipal Utility District control area.

Western's Upper Great Plains Region also operates a control area in the Eastern Interconnection, or eastern grid, called the Western Area Upper Missouri-East, or the WAUM-East.

How do dispatchers at control areas balance supply and demand?
Dispatchers must match resources (generation) to demand and delivery schedules. They must monitor and maintain system voltage. On an hourly basis, real-time dispatchers validate delivery schedules with each of the other scheduling entities. They also validate these schedules at the end of the day. In addition, they work to verify that delivery schedules for customers are balanced. They manage real-time e-tags—which document the scheduling of energy from an energy supplier and the reservation to transmit that energy—and they assist Automatic Generation Control dispatchers with energy purchases and sales for Area Control Error requirements.

They must also follow procedures and protocols for the regional reliability councils, the North American Electric Reliability Council and Western Electricity Coordinating Council.

How do dispatchers prevent service interruptions?
Supply and demand must be perfectly in balance. Even small imbalances can cause voltage levels to swing significantly. To prevent damage, the grid is designed so that whenever unacceptable fluctuations in voltage levels or frequencies begin to occur at any point in the system (due to lines de-energizing), the generation in the area will immediately shut down. When shutdowns occur at the powerplants, the connections to adjoining areas are designed to automatically isolate the area where the imbalance occurs from the rest of the grid. So power that had been flowing over the line that failed automatically shifts to other, adjacent lines, reducing the risk of interrupting service to end-use customers or overloading lines.

How does Western fit into the North American Electric Reliability Council?
Western is a member of the Western Electricity Coordinating Council and the Mid-Continent Area Power Pool, two of 10 reliability councils of the North American Electric Reliability Council. Western dispatchers also operate Western's system under NERC Operating Criteria. Each system dispatcher must pass a test to become NERC certified. Dispatchers within the Western Interconnection must also be WECC Certified.

Power grid

How does Western fit into the grid?

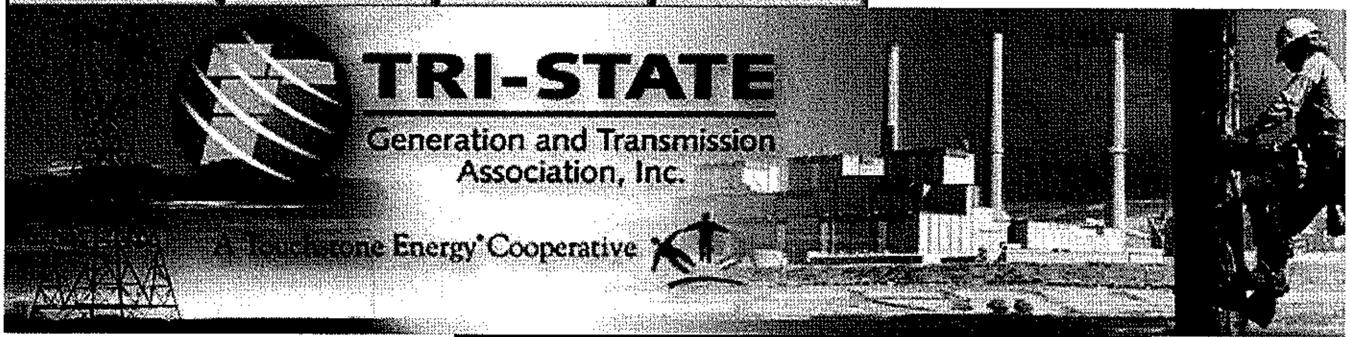
The United States does not have one national power grid, but rather three separate grids—a Western grid, an Eastern grid and one in Texas, managed by the Electric Reliability Council of Texas. The electric system in the western United States —called the Western Interconnection—operates independently from the electric system in the eastern United States. Western operates primarily in the Western grid and owns and maintains more than 10 percent of the transmission lines in the Western Electricity Coordinating Council area.

Western also operates a control area (Western Area-Upper Missouri East) in the eastern grid, which is called the Eastern Interconnection. Western owns and maintains more than 30 percent of the transmission line mileage in the Mid-Continent Area Power Pool area within the Eastern Interconnection.

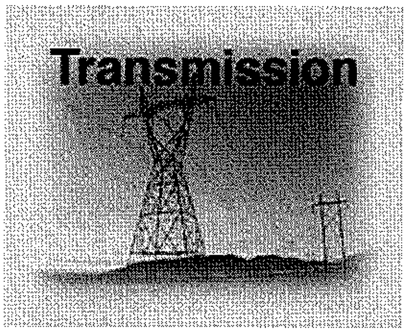
How many Direct Current ties are there and does Western operate any?
There are six DC ties connecting the Western Interconnection and the Eastern Interconnection in the United States and one additional DC tie in Canada. Western is associated with four of them. Western owns and operates the Virginia

Smith (Sidney, Neb.) DC tie; owns 60 percent of the Miles City DC (Mont.) tie and operates it; and operates the David A. Hamil DC Tie Stegall (Neb.) DC tie (owned by Tri-State Generation and Transmission Cooperative.) Western also operates the back-to-back DC Converter Station project in Rapid City, S.D., owned by Basin Electric Power Cooperative and Black Hills Power and Light. The station can transfer up to 200 MW or power between the Western Electricity Coordinating Council in the Western Interconnection and the Mid-Continent Area Power Pool in the Eastern Interconnection. The other two U.S. ties are Public Service Company of New Mexico 's Blackwater N.M., DC tie and the El Paso Electric and Texas-New Mexico Power Company's Artesia, N.M., DC tie. Xcel Energy is building another DC tie in Lamar, Colo.

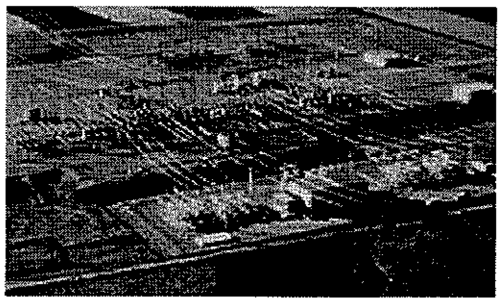
Does Western interconnect with other entities?
Western is connected with nearly every utility in the Upper Midwest, Rocky Mountain, and Desert Southwest regions and also has extensive transmission resources in California. Use of this transmission, the transmission available to Western under wheeling contracts with other utilities, and access to the DC ties, allows Western to reach resources and transmit power where needed over most of the western United States. Western also interconnects with merchant generators, such as Calpine's Sutter powerplant.



Consumer-Owned Power Supplier to the West



DC Tie



Tri-State is one of the few utilities supplies electricity on both sides national electric system separatio 1977, the G&T has owned and op the David A. Hamil DC Tie at Ste Neb., which joins the eastern and power grids. It was the first such built in the United States.

Direct current (DC) ties bridge the electric separation between the eastern and western power grids by converti alternating current to direct current, and then converting it back to alternating That conversion is necessary so that the energy is in sync with the alternatin on the other side of the system separation.

Tri-State Generation and Transmission Association, Inc. 1100 W. 116th Avenue Westminster, CO 80234 (303) 45

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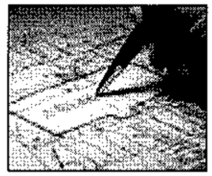
BUILDING & ZONING

Building & Zoning 308.254.5300 E-mail: Building & Zoning



Ordinance and Zoning Regulations

ND, with a net capacity of 222 MW. Leland Olds Unit 2 was placed in service on December 15, 1975 with a net capacity of 447 MW.

b) WAPA Peaking Capacity: In 1968, Basin Electric executed a long-term contract with the federal government for USBR (now WAPA) hydro peaking from the dams in the Missouri River Basin. This contract currently provides Basin Electric with 280 MW of winter peaking capacity.

c) Spirit Mound Station: Basin Electric placed in service on June 30, 1978, two oil-fired combustion turbines. The combined winter rating of the two units is 120 MW (net) and the summer rating is 104 MW (net). The capacity is intended to be used primarily as reserves or replacement during initial outages of base load units or during peak load periods when existing base load units cannot meet the demand. The Spirit Mound Station is located near Vermillion, SD.

d) Neal IV: Basin Electric and Northwest Iowa Power Cooperative (NIPCO), one of Basin Electric's member cooperatives negotiated a new power supply contract which provides that NIPCO will sell to Basin Electric NIPCO's 33 MW of uncommitted capacity and associated energy from Unit No. 4 of the George Neal Generating Station (Neal IV). In return NIPCO entered into a wholesale power contract with Basin Electric whereby Basin Electric will sell and deliver to NIPCO all of NIPCO's capacity and energy requirements in excess of the power and energy available to NIPCO from the Western Area Power Administration.

e) Laramie River Station: Basin Electric, together with five other consumer-owned power supply entities, began construction in July 1976 on the Laramie River Station near Wheatland, in southeast Wyoming. The station's three 550 MW (net) units became fully operational in November 1982. As project manager and operating agent for the Missouri Basin Power Project (MBPP), Basin Electric was assigned overall responsibility for the design, construction and operation of the power plant and related transmission. Units 2 and 3 of the Laramie River Station are electrically connected to the western system; Unit 1 is electrically connected to the eastern system. During 2000 the maximum output rating of each of these units was increased by 18-20 MW. This increased output capability will be used in emergency situations to maintain system reliability. The amount of power that Basin Electric receives from the east side unit is 46 MW (net).

f) Antelope Valley Station: Basin Electric operates two 450 MW (net) thermal-generating units near Beulah, ND. Approximately 110+ MW of electric power for the Dakota Gasification Company Synfuels Plant facilities are supplied by the Antelope Valley Station. Basin Electric has sold 66 MW of participation power from AVS Unit 2 to Montana-Dakota

Utilities Co. The contract terminates on November 1, 2006. Basin Electric has also sold 98 MW of participation power from AVS #1 and #2 to the Montana Power Company. This sale is for the November through April periods through 2010. The remaining AVS power is available for use by Basin Electric to serve its member cooperatives' increasing loads. Unit 1 began commercial operation on July 1, 1984 and Unit 2 began partial commercial operation on June 1, 1986.

g) Prairie Winds Chamberlain Project: Basin Electric, in partnership with East River Electric Power Cooperative, has constructed a wind energy project near Chamberlain, South Dakota. The 2.6 megawatt capacity turbines were placed into commercial service in January 2002. The energy is delivered to members as part of Basin Electric's overall power supply.

h) Other Short Term Resources: Basin Electric has also entered into a number of short-term purchase agreements to meet contractual power supply obligations. Due to the relatively short-term duration of these arrangements no specifics are provided.

i) Future Power Supply: None

The resources available to Basin Electric to serve its members west-side requirements are as follows:

a) Laramie River Station: The Laramie River Station capacity that Basin Electric will receive from the two west-side units is 678 MW (net).

b) Miles City DC Tie: Basin Electric and WAPA have jointly constructed a 200 MW back-to-back, AC-DC-AC tie at Miles City, MT. This tie enables Basin Electric to serve Central Montana Electric Power Cooperative Inc., a Class A member with electrical loads located primarily west of the east-west ties, using capacity from east-side resources such as Antelope Valley Station.

c) Rapid City DC Tie: Basin Electric and Black Hills Power and Light are proposing a 200 MW asynchronous tie at Rapid City, SD. This tie will enable Basin Electric to serve new coalbed methane load growth in northeastern Wyoming located west of the east-west ties, using capacity from east side resources such as Antelope Valley Station.

The projected load values contained in Exhibits 1 through 4 were obtained from the econometric based PRS completed in 1999. These loads have been adjusted to an at-generator system coincident basis by allowing for reserves, on-peak losses, and system diversity as outlined in Exhibits 5 and 6.

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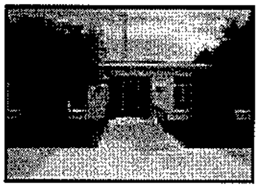


The City Office houses the City Manager, Public Services, C Clerk, Human Resources, Inspections, Accounts Payable C Cashier/Receptionist and Handi Bus. The office handles ut customers, connection and disconnection services, utility p: for handicap, business occupation licenses, cemetery lot pu accounts payable, human resources, inspections and codes

City of Sidney Business Office 308-254-5300 City Manager 308-254-4444 Human Resou

Administration

City Manager - Gary Person	garyperson@c
Human Resources - Jo Houser	jhouser@cityo1
Public Service Director - John Hehnke	publicservices(
Building & Zoning Administrator - Jim Pelster	jimpelster@cityofsidney.org

Administration Office

City Clerk - Geri Anthony	gerianthony@(
Deputy Clerk - Cynthia Heilbrun	cheilbrun@city
Account Clerk (Accounts Payable) - Lori Borchert	lborchert@city
Account Clerk (Utilities) - Kim Phillips	kphillips@cityc
Account Clerk (Cashier/Receptionist) - Katie Rogers	krogers@cityo
Public Transportation - Les Larsen	308-254-7070

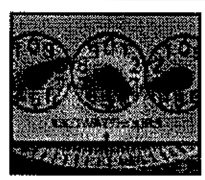
PUBLIC SERVICES

Click on City Depa more information i

Cemetery 308.254.2337 E-mail: park

Located at 2 Greenwood Road.

Electric Department 308.254.6345 E-mai



Located at 1034 Forrest Street.

Landfill 308.254.6071 E-mail: solid waste

Park 308.254.3307 Pool 308.254.0956 E-

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- Services
- Calendar of Events
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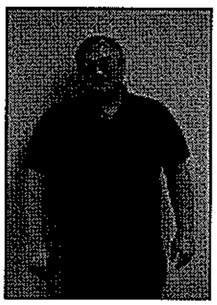
Beulah, North Dakota
701-873-2110

City Government

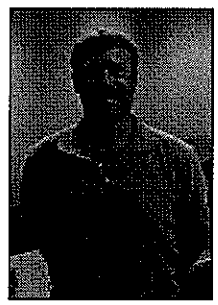
- ***Mayor / City Council***
- ***City Hall***
- ***Police Department***
- ***Public Works***
- ***Water Plant***

MAYOR/CITY COUNCIL

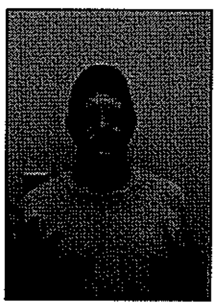
Darrell Bjerke, Mayor- (Budget & Finance, County, State & Fed
Liaison, City Hall, Community Promotion & Economic Developm
PO Box 276
Beulah ND 58523
701-873-5367
bjerke@westriv.com



Roger Gazur - (City Partnerships Liaison (Airport & Schools), Employee Relations & Safety, CHR)
PO Box 967
Beulah ND 58523
701-873-2421
machine25a@yahoo.com



Robert Moos - (P
Commissioner, Planning & Zoning Associate Employe Relations)
PO Box 358
Beulah ND 58523
701-873-5289
rlmoos@westriv.c



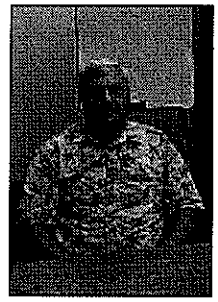
Larry Walker - (City Properties, Civic Center, City Tranportation, Library)
236 Riviera Drive
Beulah ND 58523
701-873-5880
lkwalker@btigate.com

Albert Aanderud -
(Beulah Chamber Liaison, City Clean Beautification, Emergency Servic Fire Dept., Flood, Ambulance, etc.)
PO Box 122
Beulah ND 58523
701-873-5183

Robert Schutt -
(Sidewalks, Bike Paths, & Bridges, Forestry, Cemetery)
207 10th St. NE
Beulah ND 58523
701-873-5672
schuttr@beu.midco.net

Herb Dittus - (Soli
Waste & Re-cycle, Public Works Equipment - Chair Golf Course Liaiso Associate Employe Relations)
PO Box 93
Beulah ND 58523
701-873-5743
hdittusb@westriv.c

Darwin Reinhardt -
(Water & Sewer, Public Works Equipment)
225 Sheila Drive
Beulah ND 58523
701-873-2186
city427nd@lycos.com



Clyde Schulz -
(Streets (Liaison P
Board), Public Wo
Equipment,
Assessments)
PO Box 57
Beulah ND 58523
701-873-5601
cdschulz@westriv.

CITY HALL

Char Henke
Receptionist
873-4637

Cindy Johnson
Deputy Auditor
Utility Billing
Supervisor
873-4637
chbeulah@westriv

Linda Wiedrich
Auditor
873-4637
lwbeulah@westriv.com

John Phillips
City Planner, Build
Inspector
Development Dire
City Assessor
873-2110
jpbeulah@westriv.

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Kennie Voegele
Chief of Police
873-5252
pd1740@westriv.com

Linda Hilz
Receptionist -- Cle
Court
873-5252
beulahpd@westriv

Paul Martin
Sergeant

Eric Ahrens
Patrolman

Frank Senn
Patrolman

Ray Becker
Patrolman

Home
House Number Info
Pictures of Our Town
Municipal Code
NM Blue Book
Council Meeting
Mayor & Council
City Departments
City Directory
Job Listings
Public Hearings & Notices
Map of Artesia
Report Street Light Out
City of Artesia Services
Artesia NM City Guides
Government Office Listing
Rent Car- Airport
Other Links

Mayor Manuel Madrid Mayor

Mayor Secretary Lisa Johnson
511 W Texas Ave Mayor Secretary

Human Resource Director Bill Thalman HR Director

Public Utilities Director Neil Knott Public Utilities Director 505-746-0069

City Hall
Clerk-Treasurer Aubrey Hobson City Clerk-Treasurer
Assistant Clerk Lisa Johnston Asst. Clerk
Assistant Clerk-Treasurer Jan Briggs Asst. Treasurer

City Hall (Utility Department)
Supervisor Jan Briggs
After Hour Water Emergency

Planning Department 505-746-2122

Building Inspector/Permits Danny Jones Inspector
Code Enforcement Cheryl Hinkle Code Enforcement

Municipal Judge Kay Kiper Judge
Courts Web Page

Airport Jimmy Joseph Airport

Artesia Center Recreation - Artesia Center Luis Reyes

Commission on Aging Dora Fierro

Museum Nancy Dunn Museum Web Page	
Library Library Web Page Pam Castle	
Police Department Police Web Page Director of Public Safety Chief Donald Raley	
Fire Department Fire Dept Home Page Chief J. D. Hummingbird Captain Richard Zuniga	
Warehouse Street Alanzo Acosta Streets Park Karl Reeve Parks Water Jamey Schwiger Water Garage Robert Thompson Garage IT Tech Barry Goldstrom IT Tech	
Waste Water Michael E Stroud Michael E Stroud	
Woodbine Cemetery Sexton: Isaac Aguilar Cemetery	
Transfer Station & Solid Waste Jimmy Bustamante Transfer Station Web Site Jimmy Bustamante	
Purchasing Mary Josselyn Purchasing	

Send mail to jbriggs@artesianm.com with questions or comments about this web site.
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Last modified: 09/20/07

City of Clovis, New Mexico — A City On The Move - Come Grow

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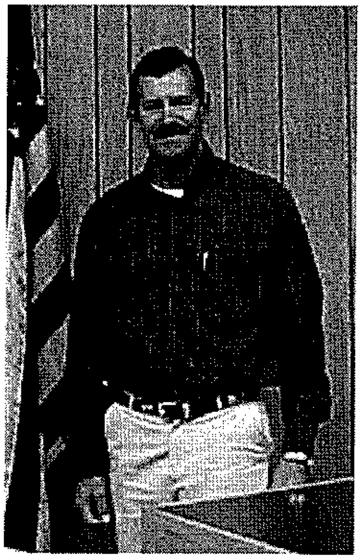
Building Safety



Director: Pete Wilt

Location: Bert Cabiness City Government Center
321 Connelly
Clovis, NM 88101

Phone: 505-763-9609

Fax: 505-763-9316

Hours: 8:00 am - Noon
1:00 - 5:00 pm
Monday - Friday

E-mail: inspections@cityofclovis.org

Farmers Electric 800 445 8541

DC Tie -
XCel energy - 505 769 4250

For the Code Enforcement division - click here.

City of Clovis, New Mexico
Inspections /Planning & Zoning / Code Enforcement

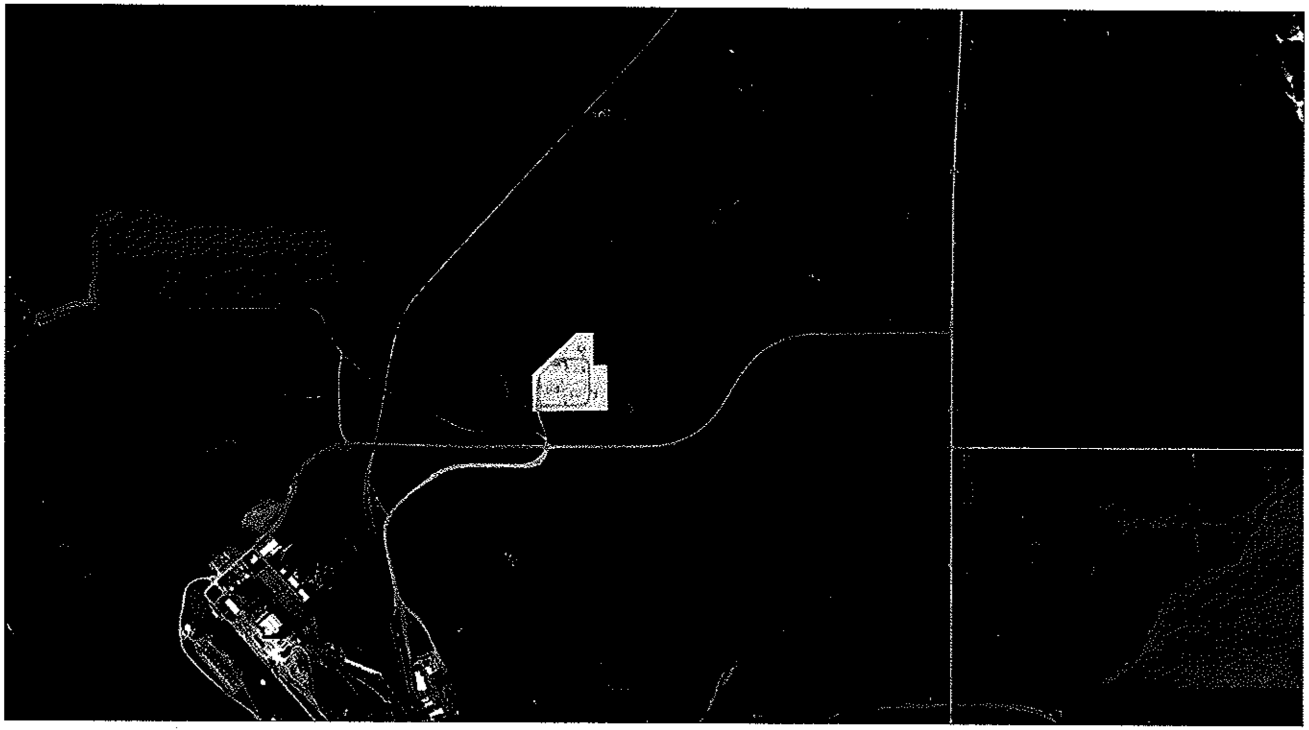
The City of Clovis Inspections Department is responsible for all Building, Plumbing and Mechanic Permitting for the City of Clovis.

NOTE: The State of New Mexico inspectors handle all the Electrical Permits, and Manufactured I Inspections.

Are you interested in obtaining a building permit to remodel your house, build a swimming pool or your home? How about obtaining specific construction standards and fees for commercial building activities? 7829) or come visit us (located in the east office area of City Hall) and allow our courteous staff assist y obtaining valuable information pertaining to all aspects of the permitting, construction and inspection pr

You can also download Applications and Procedural Information.
Visit our Online Document Library - click here.

Google Maps Address **Beulah, ND**



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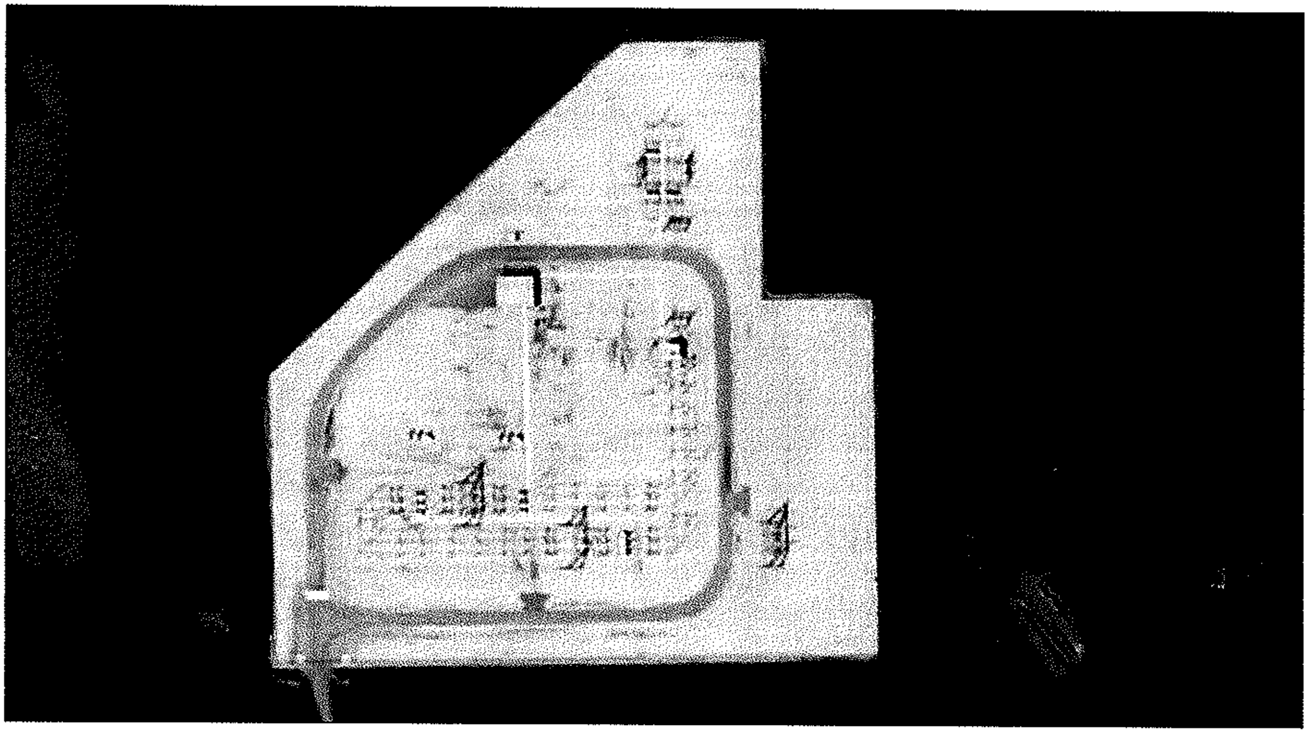

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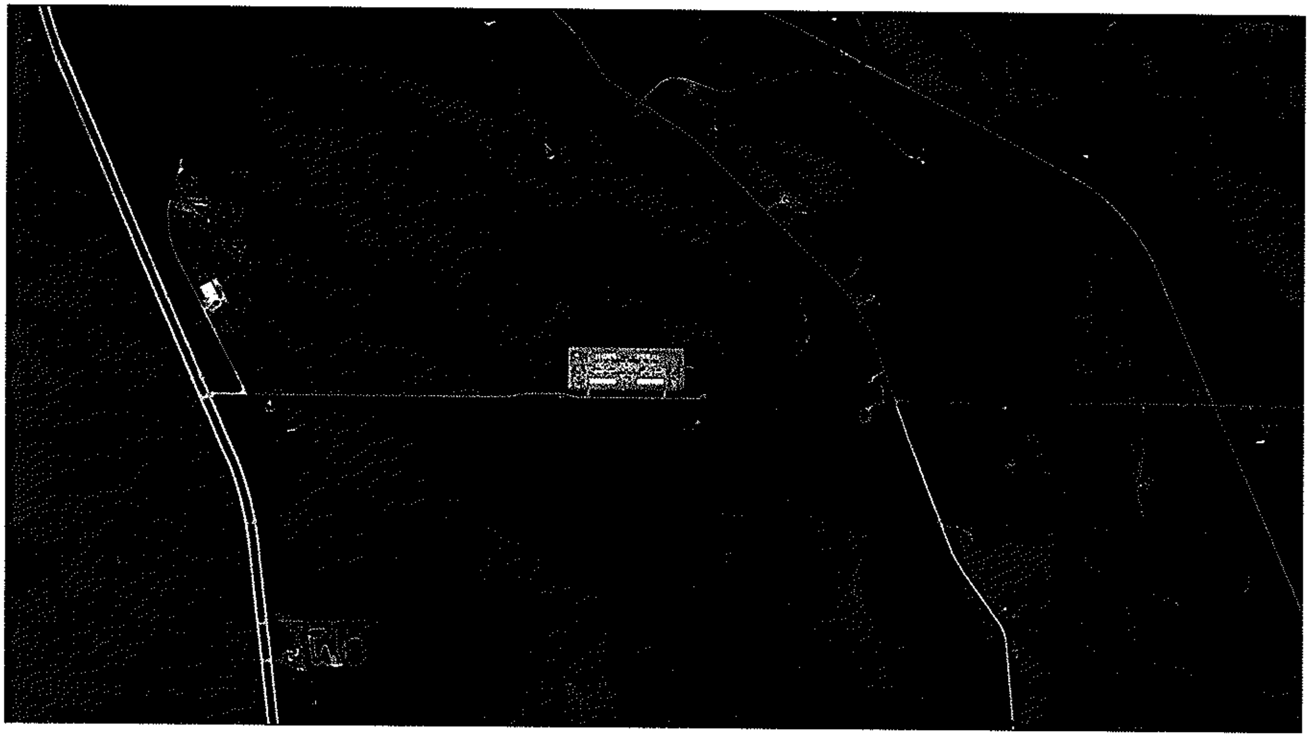

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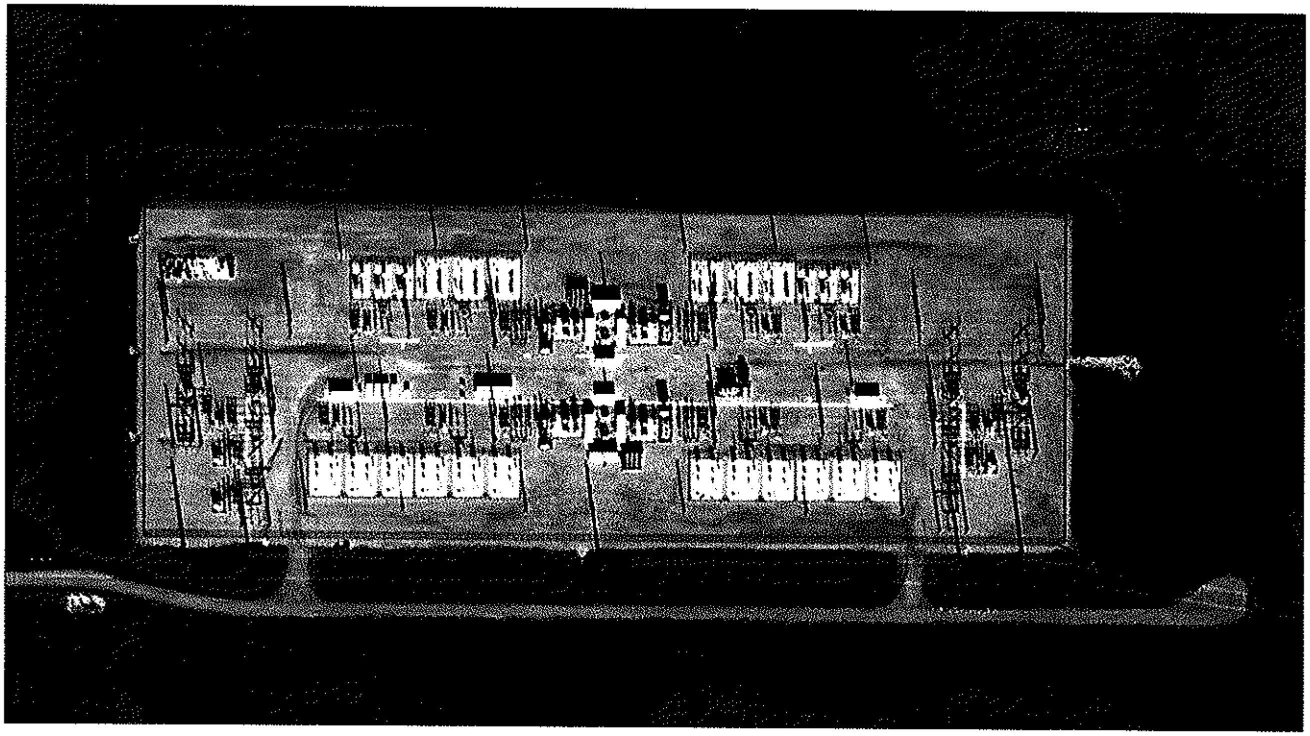
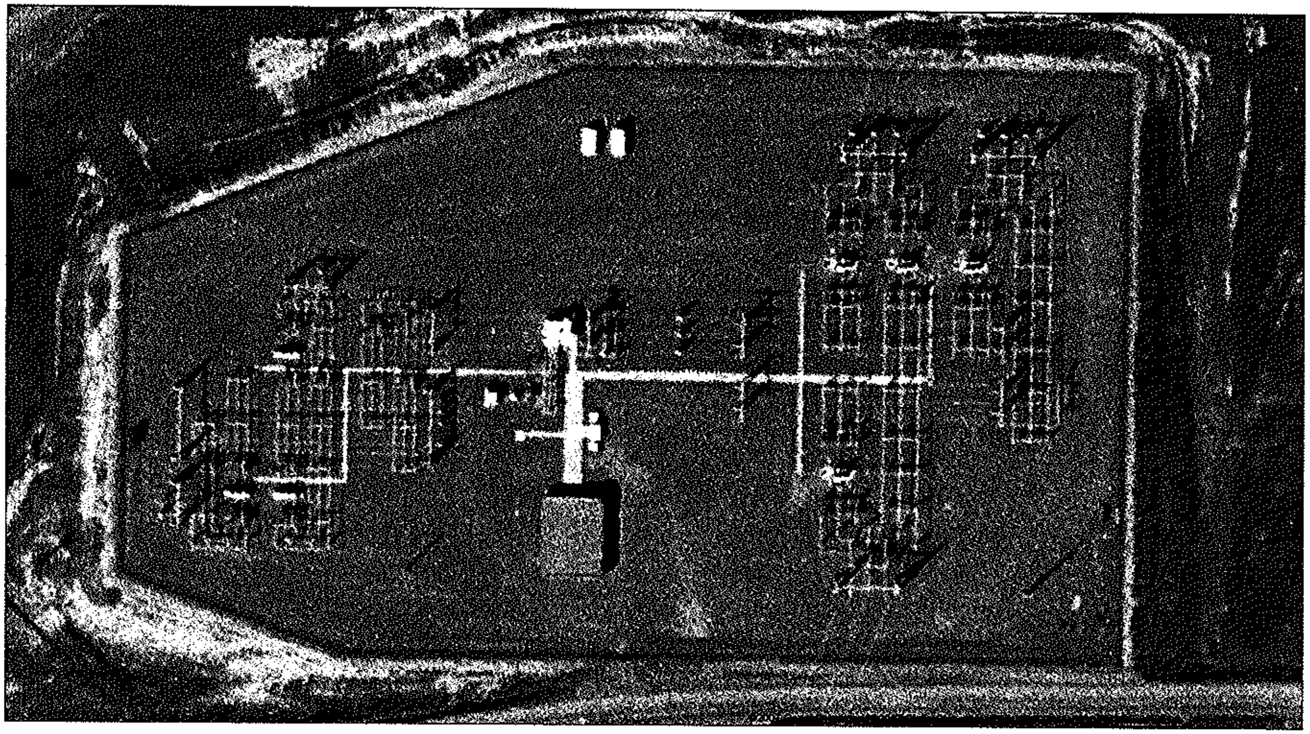


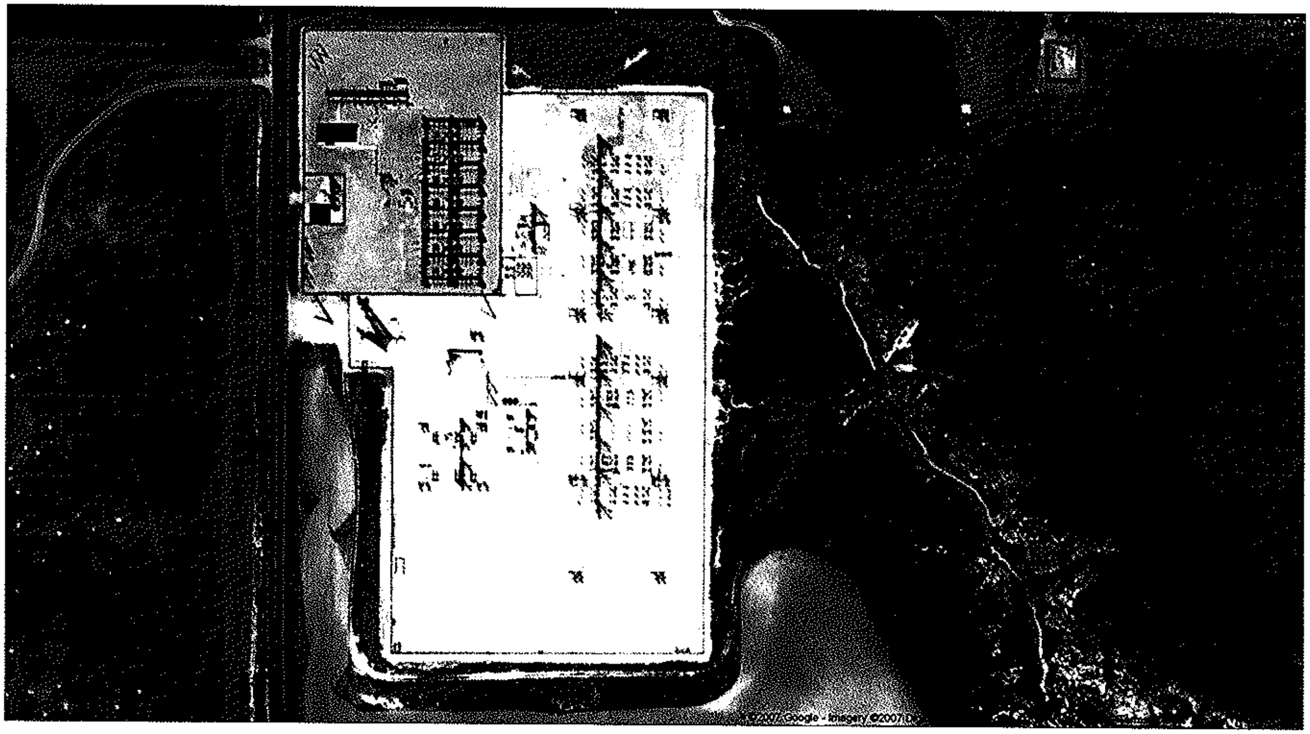
Google Maps Address **Miles City, MT**

Google Maps Address **Miles City, MT**

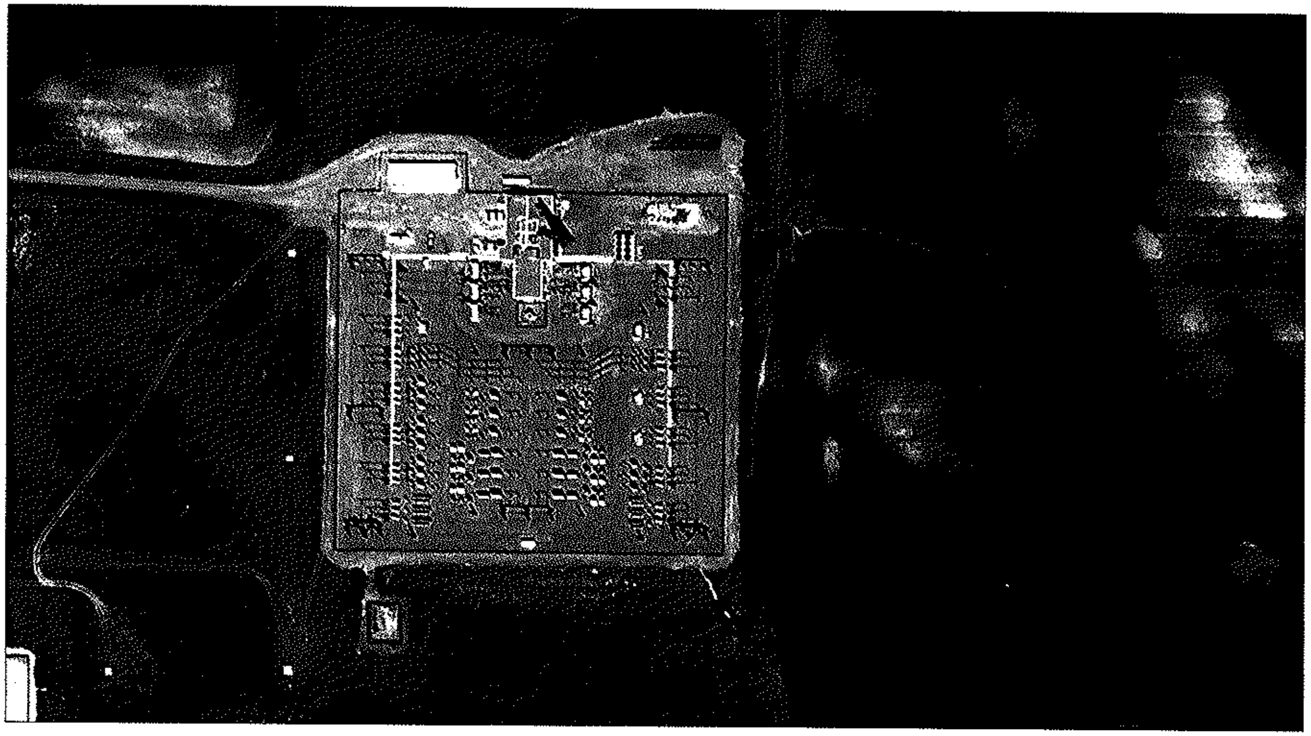


Google Maps Address **Miles City, MT**

Google Maps Address **Sidney, NE**



Google Maps Address **Sidney, NE**



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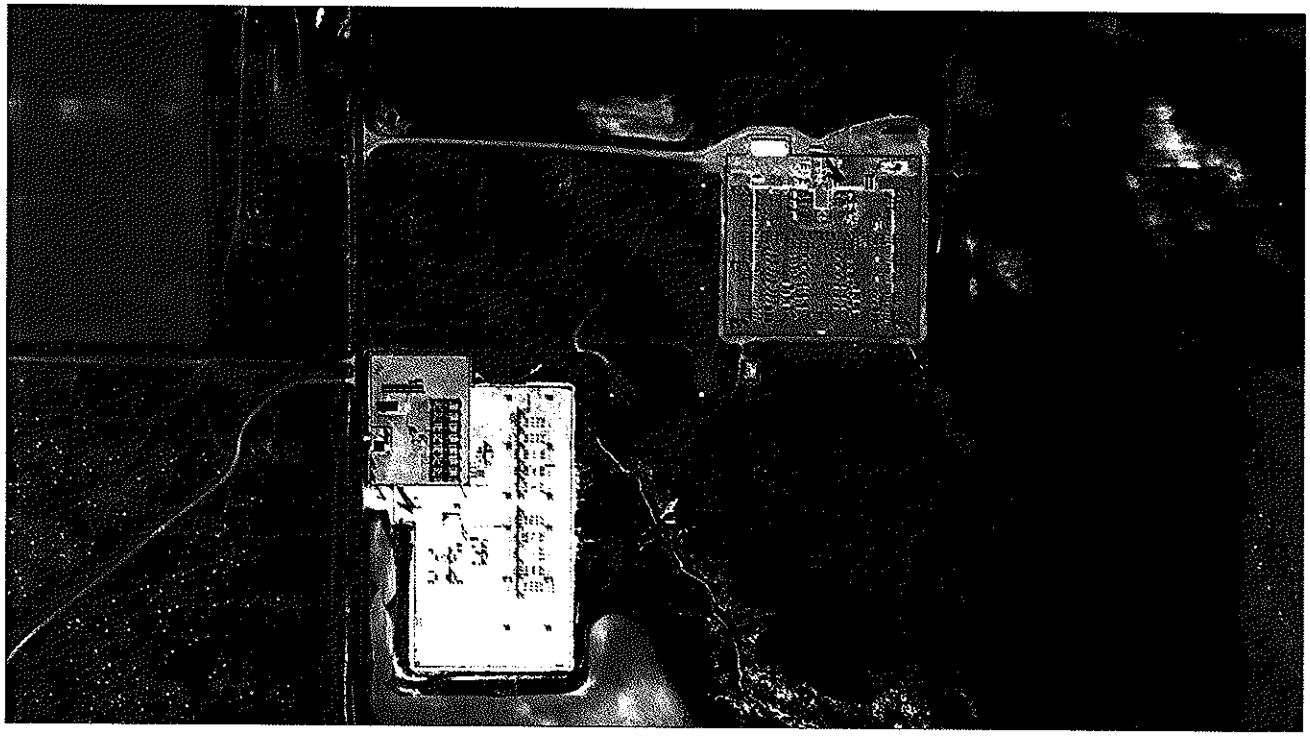
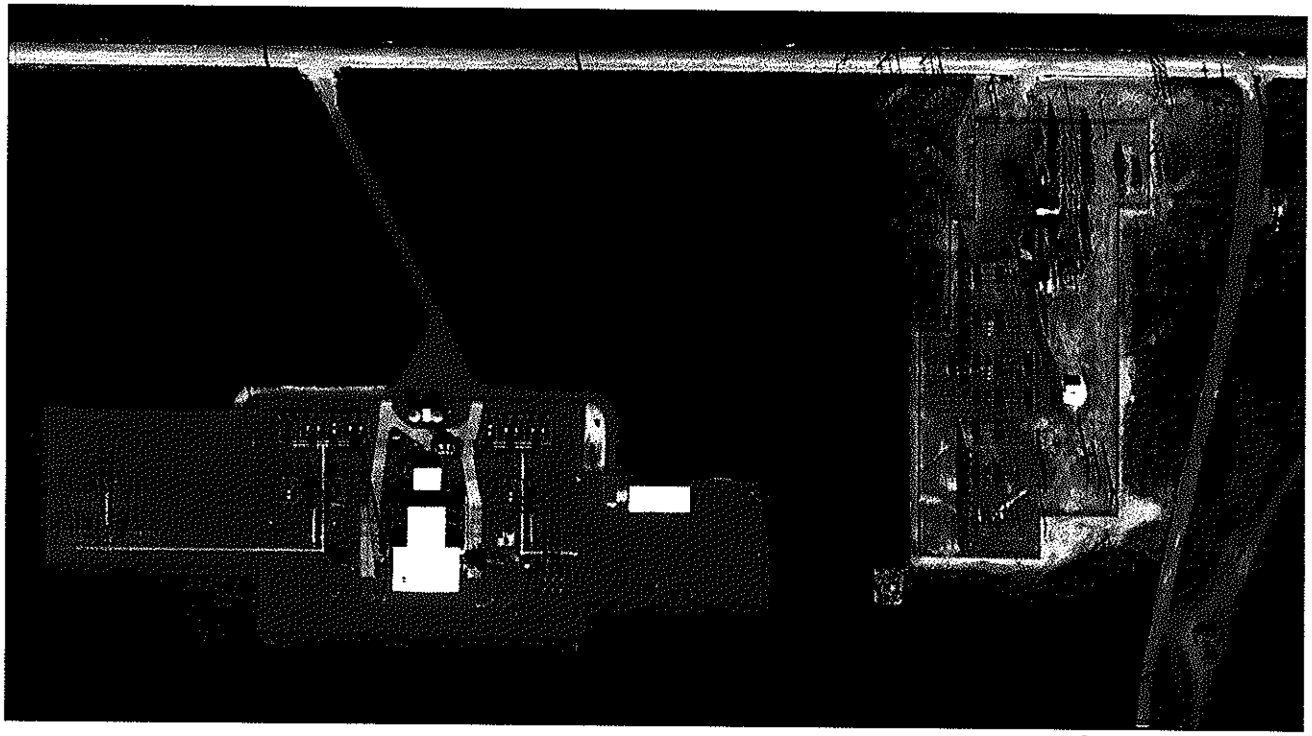


Google Maps Address **Sidney, NE**

Google Maps

Results **1** - **1** of about **1** for **"city of blackwater" nm**

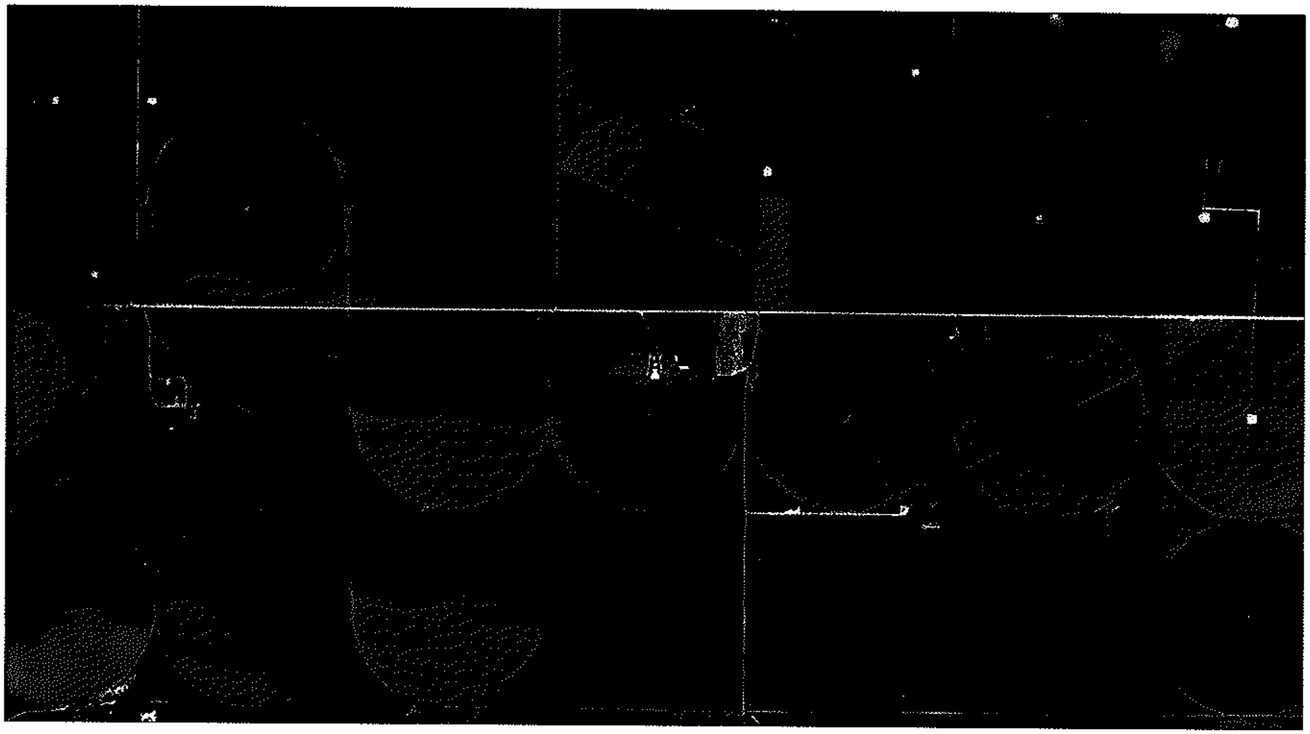


A. Back River Waste Water Trtmnt
8201 Eastern Blvd, Baltimore, MD
(410) 396-9800

Blackwater, NM DC Tie

Google Maps

Results **1** - **1** of about **1** for **"city of blackwater" nm**



A. Back River Waste Water Trtmnt
8201 Eastern Blvd, Baltimore, MD
(410) 396-9800

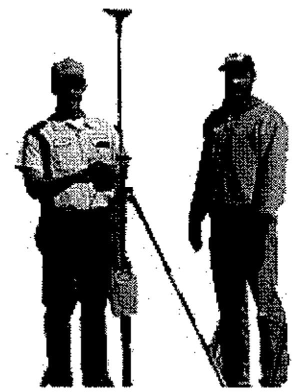
Blackwater, NM DC Tie

Engineering Dept. Overview

The Department has a total of two employees. The superintendent is a licensed professional land surveyor in the State of Colorado. His assistant has a degree in Civil Engineering Technology from the University of Southern Colorado. Together their combined experience totals 40+ years in a variety of land surveying and engineering tasks.

The Engineering Department exists to serve all other departments within the City with many concerns. These include map productions, designs of storm sewers, sanitary sewer and curb & gutter, as well as many issues involving the water department. In addition, questions arise concerning property boundary, plat conformity with current regulations and other matters with the building department, which also requires our attention. All municipal maps are updated with current changes, whether by computer or hard copy, for use by all departments and for sale to the public. Design of public infrastructure, plus right-of-way and easements issues for other government agencies including Light & Power are taken care of by the department. Permits for telephone excavations, lot stakes, and land survey plats, boundary concerns, drainage concerns and address issues are concerns addressed for the public.

Land Surveying Department
111 North 2nd Stree
Lamar, CO 81052t
(719) 336-2279



APPENDIX A

PHONE CALL NOTES

The following are notes taken from the various phone calls made by HDR staff in conjunction with researching the Intertie Facilities.

Date: **October 10th, 2007 Wednesday**
Attendees: Jim Keck, Black Hills Power 721-2612
Location: Phone Call 10:30 AM
Notes: I called Jim to ask if he had any information on the location of other intertie facilities in the United States. He said he would look into it and get us any info that he comes up with. I notified him that we are presenting the report at the Legal and Finance Committee over lunch and at the City Council meeting on Monday night. Jim later returned an email that identified seven intertie locations including Rapid City.

Date: **October 10th, 2007 Wednesday**
Attendees: Craig Jardine, HDR National Director for Power Delivery 406-656-8100
Location: Phone Call 3:50 PM
Notes: Craig returned my call and said the only other facility that he is aware of off the top of his head is in Miles City near the edge of town by a dairy farm. He said he doesn't know if any zoning issues would have arose and it's been there for 20 or 30 years. He said it is run by Western Area Power Administration and gave Doug Hanson as a contact, 720-962-7364.

Date: **October 11th, 2007 Thursday**
Attendees: Doug Hanson, WAPA 720-962-7364
Location: Phone Call 11:50 AM
Notes: Doug returned my call about the WAPA intertie stations. He was aware that they were operating two facilities - one at Virginia Smith, Nebraska and one at Miles City, Montana. He said it would be better to contact those local offices. Sam Miller of the Billings WAPA office would know about Miles City (406-247-7466). Jerry Jenison is in the Rocky Mountain region and would know about the Nebraska one (970-461-7252).

Date: **October 11th, 2007 Thursday**
Attendees: Sam Miller, WAPA 406-247-7466
Location: Phone Call 1:20 PM
Notes: Sam was familiar with the Miles City Converter Station that WAPA operates. He said that Miles City is smaller then Rapid with a population of about 10,000. It's in a hilly area "out in the middle of no place". He said that the station is approximately a mile out of town and is separated by the interstate. He is not aware of any noise issues that have ever came up at the station and there really isn't anything around it at this time. The station is not in city limits so any zoning and land use plans would be by the county.

Date: **October 11th, 2007 Thursday**
Attendees: Jerry Jenison, WAPA 970-461-7252
Location: Phone Call 1:20 PM
Notes: Jerry was familiar with the Virginia Smith intertie near Sydney Nebraska. He said that the facility has been there for over 20 years. It sits up on a bluff about 100 feet above the town approximately one half mile north of town. He wasn't sure how far it is from city limits but said that there is mostly farmland around it. Sydney has a population of about 6,400 and sits about 3 miles north of I-80 with railroad tracks through the center of the town. Jerry said that he didn't know about the zoning around the facility but there has never been a noise or vibration issue that he knows of.

PHONE CALL NOTES - CONTINUED

Date:	**October 11th, 2007**	**Thursday**
Attendees:	Jim Pelster, Sidney NE	308-254-5300
Location:	Phone Call	3:30 PM
Notes:	Jim is the building and zoning administrator for Sidney, NE. We attempted to contact Jim several times but did not receive any return phone calls.	

Date:	**October 12th, 2007**	**Friday**	
Attendees:	Kent Cardiff, Tri State	308-247-3190	303-254-3605
Location:	Phone Call	9:20 AM	
Notes:	Kent was familiar with the David A Hamil Tie near Stegall Nebraska. He said the facility has been there since 1977. It is located approximately 10 miles from Limon and 20 miles from Scottsbluff. The land surrounding the site is mostly farmland. Kent said there are no existing zoning restrictions on the site as it is well away from any town. The nearest residence is approximately half a mile from the site and Kent said that there has never been a noise or vibration issue that he knows of.		

Date:	**October 12th, 2007**	**Friday**
Attendees:	Artesia NM	505-746-0069
Location:	Phone Call 10:20 AM	
Notes:	Neil Knott is the former Public Utilities Director for Artesia, NM. He had recently retired and the city had not replaced him at the time we tried to contact them.	

Date:	**October 15th, 2007**	**Monday**
Attendees:	Pete Wilt, Clovis NM	505-763-9609
Location:	Phone Call	11:30 AM
Notes:	Pete is in charge of planning and zoning enforcement in Clovis, NM. He did not know anything about the DC Tie near Clovis and said he didn't know of any noise or vibration issues near there. He directed us to the Public Service Company of New Mexico.	

Date:	**October 16th, 2007**	**Tuesday**	
Attendees:	Blake Forbes, Public Service of NM		505-280-2704
Location:	Phone Call	3:30 PM	
Notes:	Blake was familiar with both the Blackwater and Artesia DC Tie Stations in New Mexico. He said that both facilities are located away from towns and have no specific zoning that he was aware of. Blake said that both the stations are surrounded by farmland and there have not been any noise or vibrations issues at either site.		