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South Dakota  
Department of Transportation  
Office of Research



U.S. Department  
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SD2001-08F



# Automated Road Closure Gate Needs Assessment and I-90, Exit 67 Electric Actuator Project

Study SD2001-08  
Final Report

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## ACKNOWLEDGEMENTS

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16. Abstract <p>Nearly all of South Dakota's road closure gates were installed in the early 1980's and few modifications have occurred to the gates since the original installations. This study examined possible changes to South Dakota road closure gates, including ways that automated features might be incorporated to make intended functionality more amenable. The ultimate goals of the project were to improve road closure gate operations and minimize the safety concerns for SDDOT maintenance personnel at road closure sites. The study required an overall assessment of road closure sites around the state to determine the performance issues surrounding existing gate configurations. The study then proceeded to relate what types of modifications might be warranted at each of the various sites, along with an assessment as to the extents that automation might be introduced.</p> <p>Reviews of literature focusing on state-of-the-art road closure equipment, various methodologies to perform road closures, and the dictates that frame the performance of road closures resulted in the accumulation of a variety of material on the subject. The research efforts to perform detailed assessments of road closure sites on a statewide basis were performed through in-depth surveys of maintenance personnel at SDDOT Area Offices. Other information was gathered through on-site visits to road closure locations both in- and out of the state. To facilitate the analysis efforts of the automated aspects, an actual installation of electrically actuated drop-arm style gates was performed for testing and evaluation purposes. The "test installation" was meant to evaluate the reliability of the design, mechanical, and operational characteristics of this type gate in comparison to similar characteristics found in South Dakota's existing swing-type gates.</p> <p>The investigations of South Dakota's existing road closure gate systems and their functional performance led to conclusions that the currently used gates do need to be replaced. However, the history collected on the existing gates frequency of use turned out to be a primary piece of evidence that indicated the gate replacement alternatives should not include very high costs, be greatly sophisticated, or include very extensive levels of automation. Study findings eventually led to conclusions that the implementation of basic, low cost equipment configurations at South Dakota road closure sites would be the best overall approach. Recommendations for alternative site treatments at the various road closure locations are based on criteria that strongly evidenced this strategy. However, research findings also indicated the SDDOT will need to ensure that applicable laws, policies, and procedural definitions for the performance of road closures in the state are closely adhered to during the implementation efforts.</p>			
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## 1.0 PROBLEM DESCRIPTION

Road closure gates in the State of South Dakota are primarily used to close roads to vehicular traffic during hazardous travel conditions brought on by inclement weather (e.g., snow storms, ice storms, etc). Since the gates are currently swing-type, hinged to posts, deployment often requires highway personnel to physically move the free end of the gate out across the roadway during dangerous road and weather situations. Potential hazards include slippery surfaces, poor visibility, and drifting snow that create extremely unsafe situations for highway personnel when road closure gates need to be deployed. Nearly all of South Dakota's road closure gates were installed in the early 1980's and few modifications or changes to any of the gates have occurred since that time. This study examines possible changes to the road closure gate design, including ways that automated features might be incorporated to make gate operations more amenable and acceptable. The ultimate goals of this project focus on the discovery of practical ways to reduce the labor intensity, as well as minimize the safety issues associated with road closure gate operations. An additional requirement of the study was defined to be an overall assessment of road closure sites around the state to eventually determine appropriate gate configurations, suitable levels of sophistication, and the extents of automation that might be warranted for each of the various sites.

To facilitate the research efforts of this project, it was determined that an actual installation of electrically actuated drop-arm style gates would be warranted. The "test installation" would evaluate the reliability of the design, mechanical, and operational characteristics of this type gate in comparison to the similar characteristics of South Dakota's existing swing-type gates. ThomTech Designs, Inc (hereinafter referred to as "ThomTech") was chosen to be the supplier of an actuator system that retrofits onto existing drop-arm style gates, and the Project's Technical Panel perceived this as a good system to test. The ThomTech electric linear actuator system readily attaches to pre-existing gate assemblies, thereby replacing the manual hand winch normally used to move the gate arm. The system also includes a wireless switch kit to activate advanced warning lights in flashing mode, as well as a handheld remote control device programmed to operate both the gates and the advance warning lights. Because drop-arm style gates were included in the plans for SDDOT Project IM-P-90-2(71)66 (scheduled for Fall '02 construction on Interstate 90, Exit 67 near Rapid City), installation of linear actuators was proposed on the gates designed for both the eastbound mainline, as well as the off-ramp at that interchange.

The research efforts to perform detailed assessments of existing road closure sites on a statewide basis entailed three primary points of focus: 1) siting suitability, 2) prevailing conditions of the road closure equipment, and 3) feasibility to instill improvements. It was

felt that focusing the information gathering and subsequent analysis on these three areas would lead to the most appropriate recommendations for gate configurations at all South Dakota road closure sites. Thereby, the critical information to be collected and analyzed was defined to include the following:

- Type of existing gate(s),
- Condition of existing gate(s),
- Availability of facilities in near proximity (including motels, restaurants, etc),
- Power/telecommunications accessibility,
- Frequency of use history,
- Aptness of gate locations, and
- Road closure performance needs.

Ensuing recommendations would need to identify site-specific road closure gate configurations suitably adapted to each location, and also assure that prevailing conditions would allow for the desired improvements.

Finally, it became apparent during the course of the study that some road closure sites might evidence the need to be abandoned, or else relocated. Such recommendations would need to be justified through comprehensive reviews of the following supplemental information:

- Any history of ongoing problems,
- Prevailing road closure policies, and
- The impacts of changing conditions at certain sites over extended timeframes.

The final report for this project will describe the research efforts undertaken to address the full scope of the problem, including the SDDOT's needs from a departmental standpoint, implementation feasibility, budgetary considerations, and institutional constraints.



## **2.0 RESEARCH OBJECTIVES**

### **2.1 PROJECT OBJECTIVES**

SDDOT Research Project SD2001-08, *Automated Road Closure Gate Needs Assessment and I-90, Exit 67 Electric Actuator Project*, was initiated to address the problems cited in the previous section of this report. The proposed effort entailed a needs assessment for all road closure sites in South Dakota whereby improvements to the performance and safety of road closure gate operations were paramount considerations. Based on these important concepts, the project was designed to address the following three key objectives:

1. Install electric actuators on drop-arm style road closure gates proposed on eastbound Interstate 90, Exit 67 project.
2. Evaluate the operational and mechanical functionality of the electric actuator and hand-held remote activator device.
3. Conduct a needs assessment of existing road closure gate locations to determine optimum gate configuration and applicability of future automated operation.

To successfully accomplish the project objectives, a comprehensive analysis including thorough testing of a drop-arm style gate was required for a new road closure installation at eastbound I-90, Exit 67 in South Dakota. A review of the historical performance of existing road closure gates then had to be related, as well as any problems encountered by SDDOT maintenance personnel when operating the gates. Finally, existing road closure policies, recent improvements to road closure operations in other northern-tier states, and the suitability of employing any new road closure methods in South Dakota had to be assessed and documented. Qualitative evaluations of South Dakota's current needs in relation to desired improvements at road closure sites could then be made.

### **2.2 PROJECT SCOPE**

Twelve specific tasks were performed to satisfy the research objectives of this project:

1. Conduct a review of literature pertaining to remote controlled road closure systems that meet FHWA standards.
2. Meet with the technical panel to review the project scope and work plan.

3. Develop a conceptual plan for actuator installation on Exit 67 gates and monitor installation of equipment for Exit 67 gate actuators and advanced warning signs to ensure that installation meets the project plans.
4. Develop an evaluation plan for the gate system that addresses costs, reliability and operational performance.
5. Develop an inventory of the existing road closure gate sites, including gate style, number of gates, and available infrastructure.
6. Interview and record observations from area engineers and maintenance supervisors regarding existing closure gate usage. Past operational issues, recommendations for improvements or additional closure gate needs within their area of responsibility should be discussed.
7. Briefly, summarize existing road closure policies. Discuss possible changes in policies or road closure procedures if automation is introduced to the road closure gate sites.
8. Develop a list of site criteria, required infrastructure, and costs for optimum gate configuration at existing closure gate sites to be reviewed and approved by the technical panel. Site criteria will include recommendations on equipment needed for various standard closure site configurations and a recommendation as to what level, if any, of automation is needed.
9. Prepare conceptual plans based on the literature review for various technically feasible closure gate system automation options, including hand held remotes, modem control, or website controlled system. The conceptual plan should include a statewide system with general recommendations based on the optimum gate configurations developed in Task 9.
10. Prepare a final report summarizing research methodology, findings, conclusions, and recommendations. The report shall also include various gate configurations drawings and schematic figures as well as basic costs of the various closure gate options.
11. Make an executive presentation to the South Dakota Department of Transportation Research Review Board at the conclusion of the project.

Tasks 1 and 2 were designed to review and summarize remote controlled road closure systems meeting FHWA standards that might then be employed at the SDDOT. Tasks 3 and 4 were designed for the installation, monitoring, and evaluation of drop-arm style gates and gate actuators on I-90, Exit 67 in South Dakota. Tasks 5 through 9 were designed to assess road closure sites, evaluate gate operations at those sites, and then formulate recommended strategies for improving road closure sites on a statewide basis based on

comparative analysis to the findings of previous tasks. The remaining project tasks were developed to allow SDDOT decision-makers to receive a formal presentation of the research findings, and also to have a documented report as reference.

## 3.0 TASK DESCRIPTION

### 3.1 LITERATURE REVIEW

*Task 1: Conduct a review of literature pertaining to remote controlled road closure systems that meet FHWA standards.*

Prior to initiating reviews of currently accepted, "state-of-the-art" road closure systems that could be correlated to the project requirements, it was deemed essential to carefully examine 2 reports arising from previous SDDOT research projects to gain a better historical perspective of how South Dakota's road closure gates have evolved. Therefore, reviews of SDDOT Research Project SD2000-11 "Automated Road Closure Gate" [Russell, S., A. Maxwell, and C. Weron, 2000] and SDDOT Research Project SD94-10 "Crash Testing of Standard South Dakota Road Closure Gates" [Holloway, J.C., B.T. Rosson, and R.K. Faller, 1995] were subsequently conducted.

SDDOT Research Project SD2000-11 was similar, but smaller in scope to this project effort. The researchers for SD2000-11 were not able to complete all of their project objectives due to time constraints and equipment delivery delays. The research effort comprising the matter of this report is essentially a continuation of SD2000-11, but with a greatly expanded scope and nature. Instead of merely assessing the worthiness of an automated road closure system, this project examines all road closure sites across the state to determine suitable treatments that might be accomplished at all South Dakota road closure locations.

SDDOT Research Project SD94-10 was performed as an assessment of the crash-worthiness of South Dakota's standard road closure gate, as designed and installed in the early- to mid-1980's, and that still remains as the State's standard road closure gate configuration to this day. The study found that the safety performance of South Dakota's existing gates was acceptable according to FHWA criteria for the crash-worthiness of the supporting structure installed with this type of gate.

Beyond the SDDOT reports, a few other pieces of literature concerning gate systems specifically designed for the closing of roads do exist. Appropriate reviews were conducted to assess the types of systems currently in use and the associated equipment that is also presently available. More specifically, the road closure gate currently used by the State of Wyoming was examined relative to this project through careful examination of "Testing and Evaluation of Wyoming Road Closure Gate – Final Report" prepared and published by the Texas Transportation Institute [Mak, S., K.K., R.P. Bligh, and D.C. Alberson, 1994]. Additionally, related site visits were performed around Gillette, WY and these activities are detailed more specifically in later sections of this report. The Minnesota Department of Transportation (MnDOT) - Office of Advanced Transportation Systems also has ongoing

research for a similar type gate operation at the intersection of I-90 & US 71 at Jackson, Minnesota. Information on the Jackson, MN system is summarized in a report entitled "I-90 Gate Operations System Research Report – I -90 & US 71 at Jackson, Minnesota" [ThomTech Design, Inc., and International Idea Institute Inc., 2001]. Finally, NCHRP ITS-IDEA Project 45 "Development and Trial Deployment of an ITS Avalanche Hazard Management System" has some relevant information on planned components for remote/automatically controlled snow gates. This is a project in progress and no final report became available during the course of this study.

Throughout the literature reviews for this research effort, one other primary document was continuously cited because of the standards contained therein that relate to crash testing compliance for roadside appurtenances such as road closure gates. The cited reference, National Cooperative Research Program (NCHRP) Report 350 [Ross, H.E., Jr., D.L. Sicking, R.A. Zimmer, and J.D. Michie, 1993] was subsequently located, acquired, and reviewed.

Most of the literature relevant to this project was obtained from related project files at the SDDOT - Office of Research and the in-house Research Library at the SDDOT. Other literature was obtained via the Internet where computerized database searches were employed that cross-referenced "road closure gates" to the highway transportation sector as a whole. The in-house literature was reviewed initially, and the Internet searches were then performed to investigate the availability of any additional, newer material that might have been published since the previous SDDOT research efforts.

Reviews were performed with the intention of analyzing material thought to have the most direct relevance to South Dakota and the unique situations that are presented when road closures need to be performed in the state. Some of the primary review points considered unique to South Dakota conditions included:

- Rather large geographic area where many road closure sites are often considered too remote from SDDOT maintenance units to properly operate, maintain, and monitor.
- Limited resources to perform road closures adequately, and when necessary.
- A diversity of conditions, operational needs, and road closure frequency rates associated with the various sites around the state.
- State laws and departmental policies distinctive to the State of South Dakota in regard to the performance of road closures.



- Aspects of the highway network that ultimately impact road closure needs (i.e., Coordination with a neighboring state's road closings, higher-traffic interstate vs. lower-traffic rural secondary, etc.)
- Lack of standardized, well-defined criteria for siting road closure locations.

Some of these review items became apparent only during later research efforts when interviews, questionnaires, and gate inventories were gathered. As these later findings came into better focus, it allowed the information collected during the literature reviews to be re-examined, and then essentially refined, to include only the material most pertinent to SDDOT needs.

Finally, there were some interesting findings that accrued during the literature reviews that bear careful consideration when weighed against the matters surrounding road closures in South Dakota. The essential items of interest were found during literature reviews of transportation agencies overall, and these items are listed as follows:

- Crash testing of road closure gates and their supporting structures have been minimal.
- Intelligent Transportation Systems (ITS) initiatives are strongly suggesting more, and better integration of various transportation safety aspects including automated road closure gates, but the primary focus is in, and around urban areas.
- Laws, regulations, and policies governing road closures tend to vary greatly from state-to-state, and also significantly impact road closure practices.
- The means and mechanisms used to physically perform road closures also vary widely across states.

Taken collectively, these findings tend to indicate why a standardized approach to road closures is so difficult to achieve on a national basis. Therefore, the SDDOT needs to understand that some "groundbreaking" may be necessary in order to keep the focus keenly attuned to the state's own road closure needs.

### 3.2 MEET WITH THE PROJECT'S TECHNICAL PANEL

*Task 2: Meet with the technical panel to review the project scope and work plan.*

A kick-off meeting was held with the project's Technical Panel on September 27, 2002 to review the project scope and work plan for SDDOT Research Project SD2001-08, *Automated Road Closure Gate Needs Assessment and I-90, Exit 67 Electric Actuator Project*. A general overview of the planned research approach was provided in a PowerPoint presentation by Dennis Johnson, the project's Principal Investigator. The panel subsequently provided feedback and input that enhanced the project work plan very positively. The panel also provided valuable insights related to their own individual involvement with previous efforts concerning road closure gate research, as well as other topical insights based on their own background and experiences.

### 3.3 PLAN & MONITOR INSTALLATION OF EXIT 67 ROAD CLOSURE EQUIPMENT

*Task 3: Develop a conceptual plan for actuator installation on Exit 67 gates and monitor installation of equipment for Exit 67 gate actuators and advanced warning signs to ensure that installation meets the project plans.*

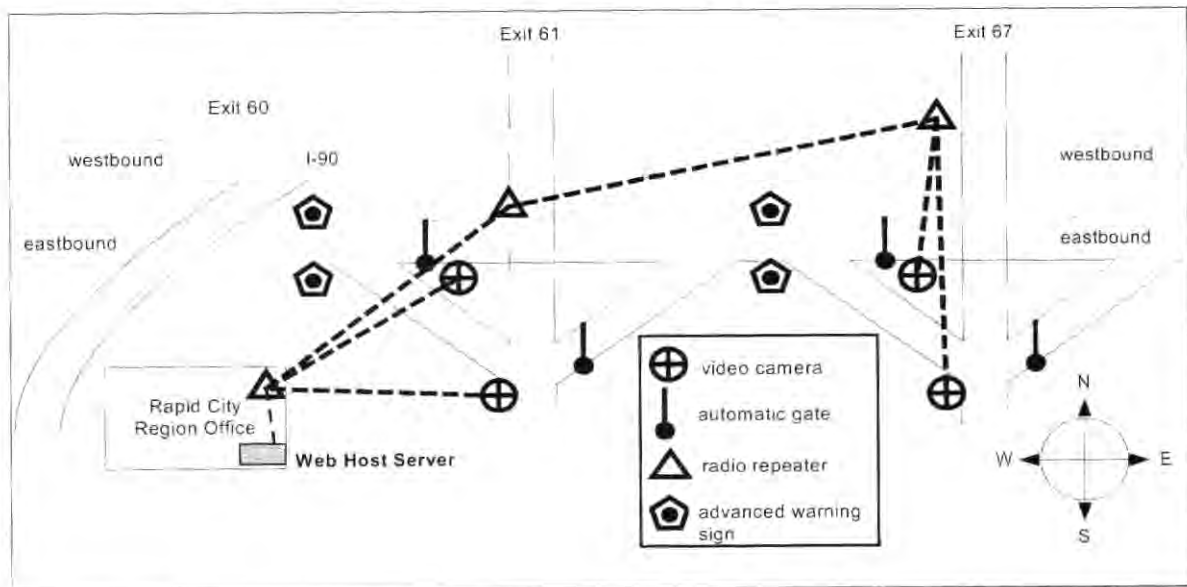
The originally conceived evaluation plan for an automated road closure gate system sought to combine Exits 61 and 67 on I-90 near Rapid City, SD and included a highly advanced technological system with very robust capabilities. The plan was basically regarded as a continuation of SDDOT Research Project SD2000-11, with a general awareness that the pilot project involving a fully automated road closure system near Jackson, MN had significant ramifications when related to South Dakota's research needs. As a result, actions were initiated to pursue a South Dakota test plan and the Jackson, MN pilot project consultant, ThomTech, was drawn upon by the SDDOT in attempts to find a "pre-conceived" system that could be installed on I-90, Exits 61 & 67 in South Dakota. The primary ThomTech system components were overviewed for the SDDOT Research Project SD2000-11 Technical Panel, as well as staff from the SDDOT - Office of Research, during an on-site demonstration given by ThomTech on June 19, 2002 in Pierre, SD. Following the demonstration, Mr. Greg Thompson of ThomTech and Mr. Dennis Johnson of the SDDOT Office of Research met on July 2, 2002 at the proposed test installation site near Rapid City to perform a feasibility analysis. The analysis identified primary system components for a road closure site at Exits 61 & 67, detailed as follows:

- Road closure gates at each interchange with gate arms, actuators, control boxes for automated operation, poles, bases, augers, LED lights, and remote control devices.

- Video cameras with motion sensing, broadband radio, antennas, control boxes, and pan/tilt for remote monitoring of the interchanges.
- Advanced warning signs with LED lights and communications kits for synchronized power-up when gates are operated.
- A Web-site system, including application software, server, router, database, master radios, and antennas for site monitoring and control.
- Repeaters to connect the Exit 61 & 67 sites to an in-office Web server.

In addition, a rough site diagram was prepared from the field sketches that were recorded during the inspections performed by Mr. Thompson and Mr. Johnson. The site diagram is furnished in Figure 3-1, below:

**Figure 3-1. Original Plan for I-90, Exits 61 & 67 Road Closure Site**



The primary concepts formulated during development of the road closure site plan called for incorporation of all components necessary to fully address perceived road closure needs at the SDDOT. Brief overviews of the system schema, along with the expected benefits to be derived from each component, are provided as follows:

- Automated drop-arm gates that could be operated remotely to provide safer, more reliable operations for SDDOT personnel.
- Video cameras that would allow SDDOT personnel to monitor weather conditions, road conditions, and site traffic from a convenient office location.

- Appropriate power and radio communications enabling gates, lights, and advance warning lights to be operated remotely, and in a synchronized fashion.
- A Web host server with preprogrammed software to provide a means for in-office monitoring, control, and operations of all facets of the road closure system.
- A database to allow images and other site information to be maintained as records (i.e., An image of a vehicle and the day/time the vehicle drove around a closed gate).

The conceptual plan comprises a vastly improved methodology for operating road closure sites in South Dakota, yet there was no way to know at this early stage of the research efforts whether the estimated cost for such a system would be duly proportionate to the perceived benefits. ThomTech provided a preliminary cost estimate of \$197,699 for the installation of the road closure test equipment as planned at Exits 61 & 67 of I-90, and as based on the details outlined above. Table 3.1 that follows provides the detailed preliminary cost estimates.

**Table 3-1. Preliminary Cost Estimates for SD Road Closure Test Site**

#	Item	Qty	Price	Cost
1	Gate kit for existing SD/DOT gate, includes actuator, control box, radio, antenna	4	\$8,060	\$32,239
2	Handheld, programmed for four gates & six advanced warning signs	1	\$3,746	\$3,746
3	Video kit with motion sensing, broadband radio, antenna, control box	4	\$9,645	\$38,580
4	Gate, pole, base, auger, gate arm, LED lights,	2	\$12,134	\$24,268
5	Advanced warning signs communications & switch kit to interface with existing SD/DOT signs	4	\$2,363	\$9,450
6	Web site control kit, includes application software, server, router, database, master radios, antennas	1	\$49,707	\$49,707
7	Repeater to connect remote gates (exit 67) to web server via the site at exit 61.	2	\$4,200	\$8,400
8	Pan tilt kit for video camera and sensing unit, includes mount	2	\$3,452	\$6,904
9	Engineering to customize system for SD/DOT, hours	64	\$95	\$6,080
10	Implementation & Training, each day	3	\$775	\$2,325
11	Installation costs for SD/DOT approved electrician	1	\$8,500	\$8,500
12	Travel costs, three people, two weeks, shipping	1	\$7,500	\$7,500
<b>Total</b>				<b>\$197,699</b>

Beyond the rather high cost, there were several other issues surrounding the technology that became quite troublesome. Most of the issues related to the difficulties of integrating the ThomTech system technology with the existing systems environment at the SDDOT. Some of the primary concerns are cited as follows:

- A separate Internet Protocol (IP) address would be required for each device (video camera, radio transmitter, etc.) at a road closure site, thereby proliferating the total number in the SDDOT system IP address pool significantly.
- The software is programmed to require one Web host site per road closure location, thereby pointing to a proliferation of Web host servers and disallowing a central host server with several Web pages to serve all road closure sites.
- Compatibility with the token-ring networks that are found at most SDDOT field offices was questionable as opposed to the more common Ethernet networks, which are compatible.
- The database software did not fully conform to South Dakota BIT standards and each site would require a separate database thereby creating support concerns.
- Web host servers need to be in close proximity to a road closure site, so unless a SDDOT server (office, shop, building, etc.) is nearby, a "free-standing" server would need to be installed outside the security and firewalls of the SDDOT network.

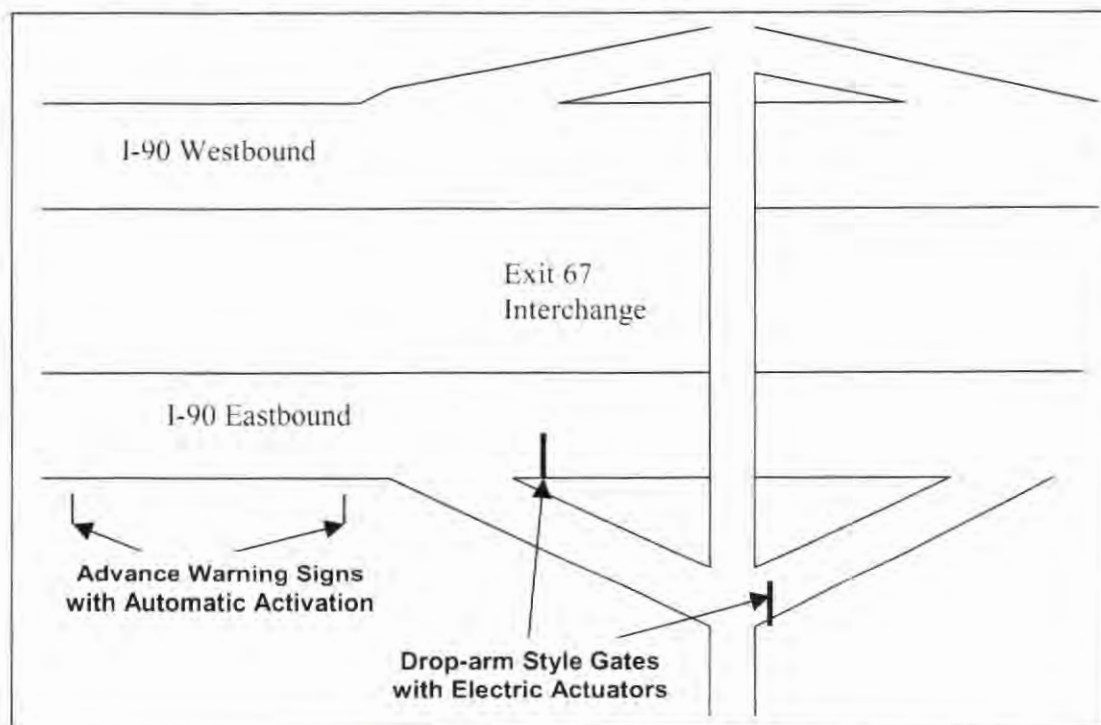
Other concerns related to certain components' tolerances in extreme environmental conditions (i.e., Wireless communications in heavy snow, hail, or across longer distances). Given the breadth and scope of the system concerns, it became highly questionable whether South Dakota BIT would be capable of supporting and maintaining all of the technological aspects.

The issues surrounding the costs and the technological aspects gave cause to re-examine the entire scope of the conceptual road closure test system. As a consequence, the project's Technical Panel met on August 12, 2002 to weigh the findings and seek a more suitable project approach. Inevitably, the panel felt that a statewide assessment of all road closure sites would be in order whereby the breadth of need for sophisticated and complex road closure systems might be identified more effectively. Discussions at the ensuing Research Review Board (RRB) meeting on August 15, 2002 reinforced the decision to re-direct the research efforts and a revised Project Statement was subsequently issued on September 16<sup>th</sup>. The fundamental changes to the project description included deferring the Internet, video, and all associated technological evaluations until applicability to all road closure sites on a statewide basis could be analyzed more effectively. It was also deemed more



relevant to simply test the typical, and more basic components of a road closure system, which included the drop-arm style gates, electric gate actuators, automated activation of advance warning lights, and remote operating devices. The estimated total cost for the revised test plan was \$34,393. A simple layout showing the final configuration for evaluating the more basic site configuration at Exit 67 on I-90 is provided in the following diagram, Figure 3-2:

**Figure 3-2. Final Plan for I-90, Exit 67 Road Closure Site**



Equipment specifications for the final configuration, including descriptions of the desired operability for major components, can be found in Appendix A of this report. Preliminary cost estimates for the revised (final) site configuration are provided in Table 3-2 on the following page.

**Table 3-2. Preliminary Cost Estimates for SD Road Closure Test Site - Revised**

#	Item	Qty	Price	Cost
1	Gate kit for existing SD/DOT gate, includes actuator, control box, radio, antenna	2	\$8,060	\$16,120
2	Handheld, programmed for four gates & six advanced warning signs	1	\$3,746	\$3,746
3	Advanced warning signs communications & switch kit to interface with existing SD/DOT signs	1	\$2,363	\$2,363
4	Engineering to customize system for SD/DOT, hours	32	\$95	\$3,040
5	Implementation & Training, each day	3	\$775	\$2,325
6	Installation costs for SD/DOT approved electrician	1	\$3,500	\$3,500
7	Travel costs, three people, three days, shipping	1	\$3,300	\$3,300
	<b>Total</b>			<b>\$34,393</b>

The final test plan did not imply that more sophisticated systems involving video aspects and Internet would be entirely excluded from consideration at the SDDOT. Instead, it was felt that the needs assessment portion of the research efforts would be a better venue to identify the levels of automation that might be appropriate for individual road closure sites throughout the state.

Due to the unanticipated revisions to the project scope, delays in receiving project materials from suppliers, and coordinating efforts that burgeoned as deadlines became compressed, the actual installation of the road closure test system at Exit 67 did not begin until late November, 2002. The system installation was essentially monitored throughout by project engineering staff from the Rapid City Area Office of the SDDOT and was continued through project completion in March 2003. SDDOT – Office of Research personnel involved with the project were able to observe critical initial installations on December 17 & 18, 2002, and also attend final installations complete with system testing on March 25, 2003. The operational functionality was deemed the most important aspect of the project efforts and Research personnel were particularly interested in observing the following:

- Accessibility, functionality, and sturdiness of the actuator and actuator appurtenant features, including control box and mountings.
- Operations, functionality, and sturdiness of gate-arm assemblies and gate-arm bracket guides.
- Suitability of all required manual operations of the equipment should power become unavailable.

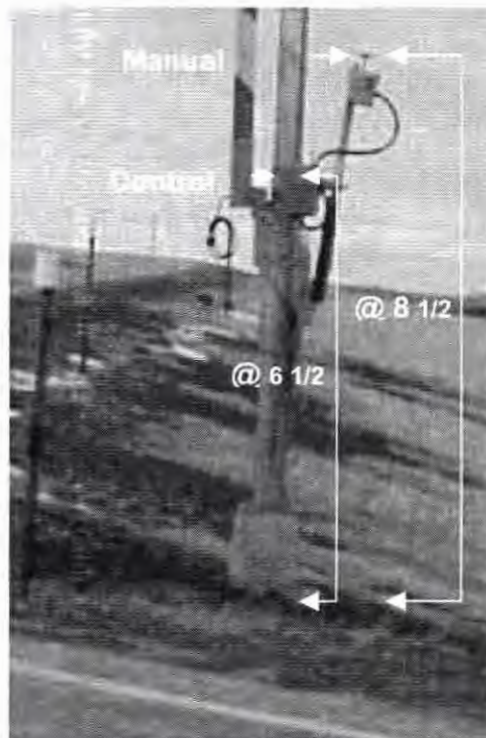
- Suitability, functionality, and location of signs and lighting, including automatic activation of all warning lights.
- Programming, communications, and range of the handheld remote device.

Monitoring of the installation and testing led the Office of Research to note several system characteristics where uncertainties prevailed. Some of these were minor and easily corrected prior to finalizing the installation of the test system. Others were more difficult and could not be fully treated, especially during this first-time installation at a South Dakota site.

The primary system aspects that had questionable characteristics are detailed below, complete with explanations of why these components were troublesome:

*Control box and actuator mountings* – were not easily accessible. The manufacture of the actuator itself did not lend itself well to ease of accessibility to the control box for push button power controls, or manual operations using a rotating flywheel once installed. The control boxes for the actuators are fixed to the actuator-mounting bracket, but if the base of the supporting light pole is significantly below the grade of the road these devices need to be installed quite high up on the supporting pole. This positioning is illustrated in Figure 3-3, below.

**Figure 3-3. Positioning of Gate-arm Operating Equipment, Exit 67**





*Gate-arm assemblies* – were somewhat questionable in regard to sturdiness and functionality. The arms are in two sections, manufactured of fiberglass and designed to breakaway in the event of an impact. The gate arms themselves received some minor damage merely through shipment to the site. Also, the telescoping, drop-down support of the gate arm was very lightweight, narrow, and not very effectual. Finally, the upper gate-arm brackets were too short to facilitate proper seating of the gate arm when locked in the upright position during windy conditions.

*Manual equipment operations* – were not tested as of the writing of this report. The primary reason was inaccessibility because (as cited above) push button controls are located inside the control box to be used in lieu of the remote. Again, the control box was mounted too high on the light pole to be accessible from ground level so an extensible platform would have been necessary to perform these operations.

*Signs and lighting* – generally appeared good during testing. However, the flashing lights on the gate arms were not exceptionally visible, but testing did occur during broad daylight hours.

*Handheld remote device* – operated as intended at the trial site. Again however, weather and other conditions were generally ideal during the day of tests.

Since the road closure site at Exit 67 was essentially conceived as a pilot project, the primary purposes were to test and observe the performance of system components. Any noted deficiencies have the possibility of being treated by a variety of means at a later time, such as performing modifications to system components, replacing unsuitable components with better equipment from other suppliers, or changing certain system configurations. Any improvements to gain desired operability when performing modifications would be dependent on factors like cost, installation difficulty, or equipment availability.

### **3.4 DEVELOP I-90, EXIT 67 ROAD CLOSURE GATE EVALUATION PLAN**

*Task 4: Develop an evaluation plan for the gate system that addresses costs, reliability and operational performance.*

As stated previously, road closure gates in the State of South Dakota are primarily used to close roads to vehicular traffic during wintertime travel conditions. However, there are certain occasions when the gates are closed for other reasons, such as hazardous materials spills, severe accidents, sudden accumulation of debris on the highway, etc. To adhere closely to project objectives, an evaluation plan of the test equipment based primarily on the reliability and operational performance during extreme wintertime weather conditions

was developed. The plan was entirely dependent on evaluations that would occur during actual road closings at Exit 67 during extreme wintertime weather conditions. The critical items included in the evaluation plan are detailed as follows:

- 1) A follow-up questionnaire would be utilized for each road closure occurrence. (The questionnaire conceived for the evaluation efforts can be found in Appendix B.)
- 2) The questionnaire was to be completed as soon as feasible after a road closure.
- 3) Appropriate Rapid City Area Office personnel involved with the road closure would need to provide the necessary information.
- 4) The information was to be gathered through personal interviews, either on site, via phone, Email, or any other means that was deemed most expedient and appropriate.
- 5) The information gathered was to be continuously assimilated in a logical manner through utilization of charts, spreadsheets, or other available means to facilitate the subsequent evaluation efforts.
- 6) Objective analysis performed at the end of the 2002-2003 winter season scrutinizing costs, benefits, drawbacks, performance characteristics, and other pertinent criteria deemed necessary would conclude the evaluation effort.

Since installation of the road closure equipment at Exit 67 was not completed until late March, there was no opportunity to perform an actual wintertime road closure and, therefore, the evaluation plan was never put into effect. Regardless, the winter of 2002-2003 was mild anyway and it was doubtful if any road closures would have occurred at Exit 67 during this season.

The evaluation performed during system testing when equipment installation concluded was a one-time incidence. Reasons include severe disturbances to traffic when a lane has to be shut down for trial gate closings. The limited testing did not allow the time necessary for thorough analysis or follow-up testing of components that might require it, nor did it allow for complete analysis of the system aspects under review. It was originally anticipated that the evaluation performed on gate operations during winter conditions would greatly supplement the installation testing. Since no equipment evaluation occurred over the winter months, potential deficiencies noted during installation testing could not be verified against actual working conditions.



### 3.5 DEVELOP INVENTORY OF EXISTING ROAD CLOSURE GATE SITES

*Task 5: Develop an inventory of the existing road closure gate sites, including gate style, number of gates, and available infrastructure.*

The SDDOT Office of Operations Support in the Division of Operations maintains a map of all road closure sites around the state. The "Road Closure Gate Locations" map (found in Appendix C of this report) was obtained and reviewed in early phases of this project to assess road closure coverage on a statewide basis. As seen on the map, most of the road closure sites in South Dakota can be found on the Interstate system (I-29 and I-90) with coverage tending to vary greatly among SDDOT Areas. Seventy-one road closure sites were identified overall with the actual number of sites contained in each SDDOT Area, and Region, broken down accordingly in Table 3-3 as follows:

**Table 3-3. Number of Road Closure Sites in Each SDDOT Region, and Area**

Aberdeen Region (10 Sites)	Mitchell Region (26 Sites)
Aberdeen Area – 2	Mitchell Area – 9
Watertown Area – 8	Sioux Falls Area – 14
Huron Area – 0	Yankton Area – 3
Pierre Region (12 Sites)	Rapid City Region (23 Sites)
Mobridge Area – 0	Belle Fourche Area – 7
Pierre Area – 3	Custer Area – 2
Winner Area – 9	Rapid City Area – 14

To facilitate the inventory collection process of existing equipment at road closure sites for this project, hardcopies of the "Road Closure Gate Locations" map were forwarded to each SDDOT Area Office. Along with copies of the map, a questionnaire requesting essential information for each road closure gate was enclosed. The questionnaires included standardized site sketches to allow identification of the specific gate placements at Rural Interstate, Urban Interstate, and Rural/2-Lane Highway locations. These were designed to be easily cross-referenced to the actual sites as numbered on the "Road Closure Gate Locations" map. Each SDDOT Area Engineer received a packet along with a cover memo explaining the project and the purposes behind the request for information. A sample questionnaire that underscores the requested information is furnished in Figure 3-4 on the following page.

Figure 3-4. Inventory Questionnaire for SDDOT Area Offices

### SDDOT ROAD CLOSURE GATE INVENTORY

Please identify the road closure site number from the state "Road Closure Gate Locations" map provided, as it pertains to this particular questionnaire sheet: \_\_\_\_\_

#### GATE INFORMATION:

Gate Number (from "Standard Road Closure Site Sketches"): \_\_\_\_\_

Gate Type:

Gate Dimensions:

Gate Mount:

Break-away Base? ☐ Yes ☐ No

Distance from roadway centerline to footing of gate mount:

(For Interstate ramps, distance from far edge of pavement to footing of gate mount)

Gate Operation:

Gate Stabilization:

Gate Age:

Gate Condition/Maintenance Required:

Gate Painting/Reflectivity:

Sign Type:

Sign Lettering:

Warning Lights:

#### ADVANCE WARNING SIGN INFORMATION:

(If no advance warning signs are present and/or portable signs are used during road closure situations, please skip this section.)

Sign Number (from "Standard Road Closure Site Sketches"): \_\_\_\_\_

Type:

Dimensions:

Colors:

Message:

Post(s):

Age:

Condition/Maintenance Required:

Warning Lights:

Nearly all SDDOT Area Offices returned inventory questionnaires complete with the desired information on road closure sites within their jurisdictions. All of the completed questionnaires are maintained by the SDDOT – Office of Research in the file for Project SD2001-08. The information received comprises a detailed inventory of the equipment at South Dakota road closure sites, as well as the specific locations and working conditions of that equipment. It was discovered during the process of collecting inventory information that several gate locations had been abandoned, moved, or otherwise added as compared to the original “Road Closure Gate Locations” map that was distributed. As a result, an updated version of the map was subsequently generated and a copy of this “Updated Road Closure Gate Locations Map” can also be found in Appendix D of this report.

The inventory particulars also contained other information that was felt to be essential to subsequent project tasks where site-specific questions relating to relevancy, adequacy, and operability were deemed fundamental. Finally, it was recognized that information from the inventory would be highly complementary to the observations of Area Office personnel regarding existing road closure gate usage, as well as road closure policies as defined and described under the work efforts for Tasks 6 & 7 of this project. Key information from: 1) inventory responses, 2) recorded observations, and 3) SDDOT policies has again been combined into the spreadsheet appearing as Table 3-6, in Section 3.8 of this report.

### **3.6 RECORD INFORMATION ON EXISTING ROAD CLOSURE GATE USAGE**

*Task 6: Interview and record observations from area engineers and maintenance supervisors regarding existing gate closure usage. Past operational issues, recommendations for improvements or additional closure gate needs within their area of responsibility should be discussed.*

To facilitate the information gathering of the observations noted by SDDOT Area Office personnel on existing closure gate usage, a survey questionnaire was again employed. The questionnaire was included with the packet sent to SDDOT Area Offices as previously described in Section 3.5 of this report. Again recognizing the time constraints imposed on SDDOT maintenance personnel in responding to surveys, the questions were minimized, yet structured to gain the primary information deemed most relevant to the study needs. It was also anticipated that follow-up phone conversations and impromptu interviews might need to be conducted with Area Office personnel upon receipt of the completed forms. This process would allow noteworthy observations to be developed further, or additional information to be requested afterwards. An example of the 10-question form used to collect the opinions and observations of Area Office personnel can be found in Figure 3-5 on the following page.

Figure 3-5. Road Closure Gate Questionnaire for SDDOT Area Offices

## ROAD CLOSURE GATE QUESTIONNAIRE FOR SDDOT AREA OFFICES

(Feel free to use additional sheets if not enough space is provided to answer any of the following questions in complete detail.)

Please identify the road closure site number from the state "Road Closure Gate Locations" map provided, as it pertains to this particular questionnaire sheet: \_\_\_\_\_

1. Is the primary purpose of this road closure site related to severe winter weather conditions?  
\_\_\_ Yes \_\_\_ No
2. Is it also closed for purposes other than described in 1, above? \_\_\_ Yes \_\_\_ No  
(If 'Yes', please describe)
3. When was the last time the road was closed at this site?
4. Recognizing that records are not usually kept, could you at least approximate how many times per year (over the past 10 years) the road been closed at this site? \_\_\_\_\_  
(If the road was closed at this site for more than one purpose, please cite the average number of closures/year for each of the purposes it was closed.)
5. Who actually performs the road closure when it needs to be performed? (i.e., SDDOT Highway Maintenance personnel, Highway Patrolman, etc.)  
(If conditions, situation, timing, etc, dictate who actually performs the road closure, please provide details.)
6. Is the road closure site monitored after the road is closed at this location?  
(If so, please identify the monitoring party, frequency, lengths of time, purpose(s), etc.)
7. Have there been problems encountered during the actual operations of closing the road at this site?  
\_\_\_ Yes \_\_\_ No  
(If 'Yes', please identify the problem(s) and include the frequency rate that the problems occur.)
8. Have there been problems encountered after the road has been closed at this site? \_\_\_ Yes \_\_\_ No  
(Again, if 'Yes' please explain.)
9. Do you feel the gate(s) are located properly at this road closure site? \_\_\_ Yes \_\_\_ No  
(If 'No', please explain.)
10. Please identify any improvements to this road closure site, if you indeed feel there are problems here that could be relieved:



All SDDOT Area Offices participated in the questionnaire process, phone interviews, or both. Once again, the completed questionnaires and interview notes are maintained by the SDDOT – Office of Research in the SD2001-08 project file. The observations and opinions of Area Office personnel entail a fairly comprehensive historical perspective concerning the use and maintenance of the existing SDDOT road closure equipment. Although a general consensus is that the present systems have performed adequately over the past several years, most feel that the time has come for key improvements to be instigated. Respondents to the study concurred overall on the primary shortcomings that need to be addressed, and these can be identified as follows:

- Ground anchors for cabling the gates in place across the roadway are not easily accessible when snow cover is present, are often damaged or removed by snowplows, and cannot be readily adjusted when cable lengths require adjustment.
- Gates are often difficult to swing out onto the roadway during severe winter weather conditions that may include heavy winds, icy conditions, or deep snow, and some injuries have occurred in the past during these operations.
- Battery-operated portable lights that need to be placed in gate bracket mountings during a road closure are often unreliable, particularly if the batteries are run down after long periods of storage or the brackets are filled with snow and ice.
- "Flip-up" advance warning signs are often difficult to open during severe winter weather conditions that include heavy winds and many of these signs are too high to be readily accessible.
- Gates are often not highly visible, or lighting is felt to be insufficient enough to cause numerous reports of vehicles colliding with gates.
- Site monitoring is difficult, particularly for the more remote road closure sites, and many reports of vehicles driving around road closure gates were evidenced.

Although other problems were reported by study respondents, the above were considered the main items to be noted.

Many Area Offices have modified equipment, procedures, or operations at road closure sites over the years in efforts to overcome many of the deficiencies noted above. Most of these efforts have been performed on an ad hoc basis and have generally been considered as temporary modifications, at least until more permanent and reliable solutions could be found. The more notable "workarounds" include the following:



- Parking manned, or unmanned maintenance vehicles with mounted flashing lights either behind, or near the ends of road closure gates to increase visibility, help prevent vehicles driving around gates, and give the sense that the site is being monitored full-time.
- Piling snow around the gates to help prevent vehicle collisions with gates, stabilize the gates when cabling or cable anchors are deficient, or help prevent vehicles from driving around closed gates.
- Not replacing gates and/or advance warning signs at certain road closure sites when new construction requires their removal, and then simply taking portable barricades and signs to that site when a road closure needs to be performed.
- Taking portable barricades, signs, or maintenance vehicles with flashing lights to a site when a road closure needs to be performed because the existing road closure site has been abandoned, or existing equipment is not in good working order.

The workarounds reported may not be considered too drastic if there are indicators are that road closures at a particular location only happen very rarely and the countermeasures instilled tend to alleviate stresses for SDDOT maintenance personnel. However, if the workarounds leave ambiguity where conformance to appropriate laws or policies are concerned, then a more difficult set of problems may arise.

Probably the most important finding of this project task was the number of times that road closures are actually performed. A primary question on the survey form asked Area Offices to approximate how many times per year (over the past 10 years) roads were actually closed at each existing site within their jurisdiction. The responses to this question were assimilated, average numbers of road closures were compiled, and results were then tabulated as follows in Table 3.4.

**Table 3-4. Average Number of Road Closings per Site for SDDOT Regions**

SDDOT Region	Average Number of Annual Road Closings/Site
Aberdeen (8 Sites)	Once Every 2 Years
Mitchell (21 Sites)	Once Every 2½ Years
Pierre (13 Sites)	Once Every 3 Years
Rapid City (24 Sites)	Once Every 2 Years
Statewide (66 Sites)	Once Every 2½ Years

The highest number of road closings at any one site (averaged over 10 years) was twice per year, and the least number of closings included several gates that had never been closed over a ten year period. Also, many reports indicated that not all road closures were for

severe winter weather conditions, which would then tend to lower the average yearly closing, for wintertime considerations. Finally, it should be noted that the total number of road closure sites on Table 3-4 is less than the total number shown on Table 3.6 appearing later in this report. This is due to the fact that the information returned from Area Offices via the survey questionnaires indicated some sites were abandoned, or will soon be abandoned.

During the analysis phase of this project effort, it became readily apparent that the task findings could not be suitably correlated with the usage of any other existing, or newly implemented road closure systems anywhere else. The Task 1 Literature Reviews were pertinent as far as correlating previous South Dakota research efforts, detailing the crash-worthiness of the Wyoming drop-arm style gate, and relating the concepts of the Minnesota pilot project. However, literature that described the desired operational and functional aspects of road closure systems was not readily apparent within the reviews performed for Task 1. Also, the Task 4 research efforts to perform an evaluation of road closure gate equipment including limited automated features at a South Dakota site could not be fully accomplished for reasons as cited previously in Section 3.4 of this report. Taking all these facts into consideration, the Project Technical Panel felt that a thorough review of the Wyoming drop-arm style gate system would be appropriate, particularly at this juncture of the research efforts. The Wyoming DOT (WYDOT) has nearly 300 drop-arm style gates deployed statewide and most of these have been in service for several years. Since the I90, Exit 67 equipment evaluation of Task 4 eliminated most of the automated aspects for a conceptual road closure system, the panel decided that the Wyoming road closure gate configuration had enough similar mechanical aspects to provide a fairly solid base for relative comparisons on functional usage.

On May 20, 2003, a meeting was held at WYDOT – District 4 offices in Gillette, WY. Attending the meeting were Mr. Barry Bowersox – WYDOT Area Maintenance Supervisor, Mr. Josh Jundt – WYDOT Resident Engineer, Mr. Daniel Staton – SDDOT Rapid City Region Traffic Engineer, and Mr. Dennis Johnson SDDOT Office of Research. On the days before and after this meeting, several Wyoming road closure sites were also visited for information gathering purposes. The meeting, coupled with the site investigations, provided venues to gather pertinent notes, plans, and other documentation relative to the equipment comparisons. The focus of the investigations was to compare Wyoming's configuration to the newly installed South Dakota equipment at Exit 67 on I-90, as well as to compare the operational aspects of Wyoming's gates to the functionality of South Dakota's existing swing-type gates. Table 3.5 on the following page cites the primary deficiencies that became apparent during comparisons of South Dakota's existing swing-type gates to the Wyoming drop-arm gate system.

Table 3-5. Comparison of SD Swing-type Gates to WY Drop-arm Gates

Apparent Deficiencies – SD Gates	WY Gate Review Findings
• Inaccessible ground anchors for cabling	• Stabilizing cables already fixed to drop-arm and light pole
• Gates difficult to swing open against wind	• Gates “drop” under own weight, counter-balanced, and are operated by winch
• Gates and warning lights are not highly visible	• Gates fixed to luminaire on pole; also have brighter, LED warning lights
• Desired “barricade” appearance not highly effectual	• 2 gates, staggered, across both Interstate lanes (give the effect roadway is barricaded all the way across, yet snow-plows can drive between gates)
• “Drive-arounds” difficult to control	• WY state laws, DOT policies provide more effective controlling measures at sites
• Flip-up advance warning signs difficult to operate, also rely on battery powered warning lights	• Permanent, “non-folding” signs read: “ROAD CLOSED WHEN FLASHING”, with warning lights being solar powered

Copies of the plans for a standard WYDOT road closure gate system, copies of Wyoming road closure laws, meeting notes, and other documentation related to the road closure gate reviews conducted in Wyoming are maintained in the file for this project at the SDDOT – Office of Research.

As stated earlier, the South Dakota-Wyoming gate comparisons also allowed the questionable aspects of the equipment installed at Exit 67, I90 in South Dakota to be scrutinized more closely. Most notably:

- 1) The WYDOT gate arms and drop-down leg supports apparently adhere to sturdier specifications than the equipment installed at Exit 67.
- 2) The crank-handles for the winch used in raising and lowering the WYDOT gates are at, or below the low end of the gate arms, thus allowing easier access as opposed to the flywheel installations at Exit 67 which are seated above the actuator, and therefore very high above ground level.
- 3) The uppermost gate-arm brackets are constructed with a deeper seat to facilitate proper locking of the gate arm when standing in the upright position during windy conditions.

Since there are no “automated” features associated with the WYDOT gate design, qualitative assessments of the perceived advantages or disadvantages of these aspects could not be performed.

Upon completing reviews comparing South Dakota and Wyoming road closure gate equipment, there was strong evidence that the siting of road closure gates played a significant part in the actual number of road closures performed at a site. As an example, several remotely located road closure gates in South Dakota were reported to have very



infrequent use, or else not used at all. For this reason, conclusions were drawn whereby follow-up information from SDDOT Region Engineers (as primary decision-makers for the siting of road closure gates) was considered essential to gain a fuller perspective about siting and usage of road closure gates. On May 22, 2003, Mr. Dave Huft and Mr. Dennis Johnson of the Office of Research attended a regularly scheduled meeting of SDDOT Region Engineers to discuss the locations of road closure gates around the state, as well as the criteria used to determine the siting of gates. The SDDOT Region Engineers were presented with the questions at hand, considered the issues upon returning to their home offices, and then replied back to the Office of Research by June 20, 2003 with some recommended strategies for each of their Regions. The primary recommendations from Region Engineers included elimination of most road closure sites currently existing "off-Interstate" and the addition of only a few new sites at key locations on Interstate routes. The following site numbers (as related to the "Road Closure Gate Locations" map in Appendix D) were recommended for removal:

- Site #20 on I90 at Chamberlain
- Site #46 on Highway 10 near Sisseton
- Site #53 at the Intersection of Highways 73 & 212 near Faith
- Site #54 on Highway 79 near Reva
- Site #55 on Highway 85 near Buffalo
- Site #58 on Highway 79 near Newell
- Site #59 on Highway 212 near Newell
- Site #62 at the Intersection of Highways 18 & 79 near Hot Springs
- Site #61 on Highway 79 near Rapid City
- Site #73 on I90 at Rapid City

The following are newly proposed road closure sites as recommended by SDDOT Region Offices:

- I29 Interchange at MRM 26, connecting Highway 50 near Vermillion
- I29 Interchange at MRM 180, connecting Highway 81 near Watertown

Beyond the above recommendations, Region Offices suggested various modifications to many of the existing sites, such as: more signage, additional gates at certain on/off ramps, scaling back on the number of gates at some locations, additional warning lights, and various equipment retro-fitting. Also, there were recommendations to install warning signs with flashing lights at many interchanges where state highway routes intersect with the Interstate system, which could then be activated as necessary when long stretches of the Interstate become closed.

### **3.7 SUMMARIZE EXISTING ROAD CLOSURE POLICIES**



*Task 7: Briefly, summarize existing road closure policies. Discuss possible changes in policies or road closure procedures if automation is introduced to the road closure gate sites.*

Current South Dakota Codified Laws (SDCL) ultimately provide the authoritative guidelines for temporarily restricting or closing highways in South Dakota due to inclement weather. The applicable laws are SDCL 31-4-14.1, SDCL 31-4-14.2, and SDCL 31-4-14.3. SDDOT policy for temporarily restricting or closing highways in South Dakota due to inclement weather complements the SDCL content, but adds specificity and procedural doctrine as would be expected of a state agency that has lead responsibilities. In particular, the Office of Maintenance/Construction Management in the Division of Operations maintains SDDOT Policy Number OM-1996-01, providing the essential departmental directives for performing wintertime road closures. This policy is reproduced in Figure 3-6 on the following page along with subsequent brief discussions on the sections considered relevant to the research needs for this study.

Figure 3-6. SDDOT Policy Statement OM-1996-01

The Region Engineers and the Highway Patrol captain are granted the authority by their respective Department Secretaries to restrict traffic on a section of highway pursuant to SDCL 31-4-14.1 and with the approval of the Governor, when inclement weather causes conditions which are dangerous to the safety of the traveling public.

The Region Engineer, in consultation with the local Highway Patrol Captain, will determine when weather and driving conditions are such that traffic should be restricted on a section of highway and for the safety of the traveling public. The Highway Patrol captain will consult with the Sheriff of each county within the proposed closure. This may be accomplished using the teletype and sending each sheriff's office a message worded as follows:

Due to current inclement weather conditions (Section of Highway) will be closed to traffic in approximately one hour. Should you have comments or care to discuss this closure call Highway Patrol Captain \_\_\_\_\_ at \_\_\_\_\_.

The Highway Patrol Captain will notify the Superintendent of the Highway Patrol who in turn will notify the Governor of the intended closure. The Region Engineer will advise the Director of Operations who will notify appropriate FHWA and Department of Transportation officials.

Upon agreement to restrict travel on a section of highway, the Region Engineer will immediately take one or more of the following actions to notify the traveling public of the restricted traffic conditions:

- A. Erect suitable barriers upon the highway to restrict or prohibit travel;
- B. Post warnings and notice of the condition of such highway for travel;
- C. Post signs for direction of traffic upon the highway relative to use or non-use of such highways;
- D. Place warning devices on the highway;
- E. Close installed snow gates.

Points of travel restriction will be established and will be clearly identified at locations such that the traveling public will be able to use an alternate route to by-pass the restricted area or will be afforded nearby access to basic accommodations during the period of restriction.

The Highway Patrol captain will inform State Radio and local broadcasting media of the travel restrictions. The media shall be advised of the closure limits, that snow removal operations have been discontinued and motorists who travel in the closed highway are subject to a Class 2 misdemeanor.

Once the points of travel restriction have been established, a trip will be made through the restricted area, if necessary and possible, to assist any stranded motorists.

Flagpersons will be used to warn, detour and direct traffic at traffic restriction points for at least 2 hours after the closure, except when weather conditions make this practice inadvisable. Region Engineers shall arrange to have variable message boards placed in advance of the closure points and outside of the storm area to advise the traveling public of the closure. The Maintenance Engineer shall arrange to have Tourism announce the closure on the lighted billboard at the Minnesota Line Rest Area.

All travel restrictions are to be coordinated with adjacent instate and out-of-state maintenance areas. Highway patrol captains will law enforcement officials and Region Engineers will advise transportation and highway officials. Captains and Region Engineers will obtain and keep current names and telephone numbers of neighboring state officials.

When the emergency is over and the highway is safe for traffic, the Region Engineer will remove the restriction and allow traffic to proceed. He will immediately inform the Highway patrol Captain to contact State Radio and the local broadcasting media regarding the lifting of the restrictions.

There are a few main items contained in Policy OM-1996-01 that bear careful scrutiny relative to the research efforts of this study. Probably the most notable point is that a Region Engineer apparently only needs to take one (as a minimum), out of five possible courses of action in order to close a highway during severe weather conditions. Without a formal policy analysis, it appears that to restrict travel on a state roadway a Region Engineer only needs to perform one of the following actions:

- (1) Erect suitable barriers on the highway.
- (2) Post warning and notice of highway conditions.
- (3) Post directional signs on the highway.
- (4) Place warning devices on the highway, or
- (5) Close installed snow gates.

Although more than one of the above actions may be taken (and usually several are taken by the SDDOT), it certainly leaves open to question whether the minimal efforts to close a road are truly acceptable, particularly when certain road closure equipment is often considered unusable. The SDDOT policy wording is generally taken from SDCL 31-4-14.2, so SDDOT Policy OM-1996-01 merely appears to reiterate South Dakota law. However, a distinguishable exception relates to (5), whereby the SDDOT refers to performance of a road closure using "...installed snow gates." In contrast, the corresponding road closure option in SDCL 31-4-14.2(5) reads: "Place flagmen to warn, detour, or direct traffic on the highway...", and says nothing about the use of road closure gates. The SDDOT policy does later include a statement apparently meant to counterbalance any discrepancies with SDCL by stating that road closure sites will be manned for at least 2 hours after the road is closed, "except when weather conditions make this practice inadvisable." Based on the survey responses from SDDOT Area Offices for this study, this practice is evidently very hard to maintain, and particularly for the more remote road closure sites where it appears to be nearly impossible to keep sites manned.

Another notable item in SDDOT policy is that travel restrictions on a road will be performed "such that the traveling public will be able to use an alternate route to bypass the restricted area", or else basic accommodations will need to be afforded nearby. In essence, there are several road closure sites in remote areas of South Dakota where it is questionable whether either of these 2 criteria can truly be satisfied.

SDCL 31-4-14.3 is a law enacted within recent years that is not referenced in SDDOT Policy OM-1996-01. Basically, the law states that it is a civil misdemeanor for a motorist to drive around any barriers, warning devices, or flagmen when travel has become restricted on a highway, or the highway has become closed pursuant to subdivision SDCL 31-4-14.2(1), (4), or (5). Penalties are encompassed in declarations that violators will be liable



for all rescue and recovery costs, but not to exceed ten thousand dollars. Again, it should be noted that SDCL 31-4-14.2(5) is not worded like SDDOT Policy OM-1996-01, item (5).

As stated early on in this report, laws and policies governing travel restrictions on highways vary greatly among states. South Dakota laws that deal with road closures during adverse weather conditions appear to be somewhat loosely structured as compared to similar laws of other states. For most states, prevailing law will clearly dictate how a state DOT will address the needs at road closure sites. As a relative example, the Jackson, MN pilot project involving the use of video cameras to monitor, record, and provide evidence of any vehicles driving around a closed gate during winter conditions could represent an action the Minnesota DOT is considering due to the prevailing laws of that state.

### **3.8 DEVELOP OPTIMUM GATE CONFIGURATIONS AT ROAD CLOSURE SITES**

*Task 8: Develop a list of site criteria, required infrastructure, and costs for optimum gate configuration at existing road closure gate sites to be reviewed and approved by the technical panel. Site criteria will include recommendations on equipment needed for various standard closure site configurations and a recommendation as to what level, if any, of automation is needed.*

Most of the criteria to develop optimized gate configurations at South Dakota road closure sites were derived in preceding tasks of this study. The literature reviews of Task 1, and the South Dakota test site reviews of Task 4 both provided vital insights on the merits, or drawbacks of various road closure equipment. The prevailing conditions at each road closure site in South Dakota were considered highly relevant, and the questionnaires returned from Area Offices as part of Task 5 were considered invaluable in providing detailed information on the current state of road closure equipment at each location. The observations submitted by Area and Region Offices were also very important to the information gathering of Task 6 on maintenance and operational issues, and also proved very useful in developing further criteria. Finally, the policy reviews of Task 7 provided relative distinctions for planning acceptable road closure equipment configurations, site placements, and procedural strategies. Basically, the information gathering of the project task efforts described in the previous sections of this report effectively advanced a set of decision factors whereby road closure site configurations might be optimally treated.

The primary assumption throughout most of the task descriptions for this project envisioned optimum gate configurations at the SDDOT that would generally include *some* degree of automation to alleviate many of the perceived problems at road closure sites. Therefore, during the research efforts of Tasks 5 & 6 where information about existing gate equipment and gate usage was being collected, the research efforts also sought to survey power and telecommunications companies in South Dakota to determine availability of



those utilities at each of the various road closure sites. All of the material from SDDOT Area & Region Offices, utility companies, and other sources was combined into a spreadsheet for subsequent analysis. It was felt the assimilated data would essentially provide the decision-making factors that could be used to weigh, score, and categorize road closure sites so that optimum site configurations could then be conceived. Eleven columns of data comprise the spreadsheet, which are itemized and described as follows:

1. **Site #** – The road closure site number that can be cross-referenced to the "Road Closure Gate Locations" map in Appendix C.
2. **Power** – Where proximity of an available power line to the road closure site is indicated by 1) within 300', 2) 300-1,500' away, or 3) greater than 1,500' away.
3. **Telecom** – Where proximity of an available telecommunications line to the road closure site is indicated by 1) within 300', 2) 300-1,500' away, or 3) greater than 1,500' away.
4. **Facilities** – Where facilities such as motels, restaurants, etc. are within reasonable proximity to road closure sites, and rated as 1) Good: greater than 500 lodging rooms available, 2) Fair: 100-500 lodging rooms available, or 3) less than 100 lodging rooms available.
5. **Probs?** – Where the survey questionnaires returned from the SDDOT Area Offices might point to any operational problems occurring at road closure sites within their jurisdiction, indicated by Y) yes, or N) no.
6. **Type** – The type of gate that currently exists at each road closure site, indicated by S) standard, D) drop-arm, or O) other.
7. **Siting** – Indicating whether SDDOT Area Offices felt that the siting of particular gates within their jurisdictions were either 1) good, 2) they're unsure, or 3) poor.
8. **Condition** – Indicating the condition of existing road closure equipment as either, 1) good, 2) needing maintenance, or 3) needing replacement.
9. **Freq./Use** – Where numbers indicate the average number of times per year that a road closure gate has actually been used. (Averages were computed based on the number of times SDDOT maintenance personnel could estimate actual road closures over a ten-year time span.)
10. **Improve?** – Indicating whether SDDOT Area Offices felt that the existing sites could be improved in any way, and so indicated by either 1) no, 2) maybe, or 3) yes.
11. **Recs?** – Represents any recommendations that may have been forwarded by SDDOT Region Engineers concerning particular road closure sites within their Regions.

The following pages lay out spreadsheet information included in the site evaluation criteria, otherwise referenced as Table 3-6, "Criteria Spreadsheet to Configure SDDOT Road Closure Sites."

Table 3-6. Criteria Spreadsheet to Configure SDDOT Road Closure Sites

Site #	Power	Telecom	Facilities	Probs?	Type	Siting	Condition	Freq./Use	Improve?	Recs?
1	3	3	1	Y	S	1	2	0.3	3	
2	1	1	1	Y	S	1	1	0.3	2	
3	1	1	1	Y	S	1	1/2	0.3	2	
4	1	1	1	Y	S	1	2	0.33	2	
5	1	2	1	Y	S	1	2	0.33	2	
6	1	1	1	Y	S	2	1	0.5	2	
7	1	1	1	Y	S/D	1	2	0.5	2	
8	1	1	1	Y	S	1	2	0.25	2	
9	1	1	1	Y	S	1	2	0.25	1	
10*	1	1	1	N/A	N/A	N/A	N/A	N/A	N/A	
11	2	3	2	Y	S	1	2	2	2	
12	1	2	2	Y	S	1	2	2	2	
13	2	1	2	Y	S	1	2	0.3	3	
14	2	1	2	Y	S	1	2	0.3	3	
15	2	2	2	Y	S	1	3	0.3	3	
16	2	1	2	Y	S	1	2	0.3	3	
17	1	1	3	Y	S	1	1/3	0.3	3	
18	1	1	3	Y	S	1	3	0.3	3	
19	1	1	1	Y	S	1	1	0.4	3	
20	1	1	1	N	S	3	1	0.4	3	Remove
21	1	1	1	Y	S	2	2	0.4	3	
22	2	2	2	Y	S	3	2	0.2	2	
23	2	1	2	Y	S	3	2	0.4	3	
24	1	1	1	Y	S	1	2	0.5	3	
25	1	1	1	Y	S	1	1	0.5	3	
26**	2	1	2	Y	S	3	2	0.1	3	
27*	3	3	2	N/A	N/A	N/A	N/A	N/A	N/A	
28(2)	2	2	1	Y	S	2	2	0.75	2	
29	1	2	1	Y	S	1	1	0.75	2	
30	1	1	1	Y	S	1	2	0.5	3	
31*	1	2	2	N/A	S	3	3	N/A	3	
32*	2	2	2	N/A	S	3	3	N/A	3	
33	2	1	2	Y	S	1	3	0.5	3	
34	2	3	2	Y	S	1	2	0.15	3	
35	1	1	1	Y	S	1	2	0.25	3	
36	1	1	1	Y	S	2	2	0.1	2	
37*	1	1	1	N/A	N/A	N/A	N/A	N/A	N/A	
38*	1	1	1	N/A	N/A	N/A	N/A	N/A	N/A	
39	2	2	1	Y	S	1	1	0.75	1	
40	2	3	2	N/A	S	3	1	0	3	
41	1	2	1	Y	S/O	1	2/3	0.75	3	
42	1	2	1	Y	S	1	2	0.75	3	
43	1	1	1	N	S	1	1	1.5	1	
44*	1	2	3	N/A	N/A	N/A	N/A	N/A	N/A	
45	1	1	2	N	S	1	1	0.5	3	
46	1	1	2	Y	S	2	2	0.5	3	Remove
47*	1	1	2	N/A	N/A	N/A	N/A	N/A	N/A	
48	1	1	2	N	S	1	1	0.3	1	

\* Road Closure Site Removed

\*\* Mainline Gate Removed



Table 3-3. Criteria Spreadsheet to Configure SDDOT Road Closure Sites (Cont'd)

[illegible]

\* Road Closure Site Removed

Several other factors besides those appearing in the above table had to be considered during the analysis efforts to formulate road closure site configurations, but these related more to South Dakota conditions, and the unique situations often faced by the SDDOT which are not necessarily “measurable” criteria. These factors were alluded to earlier in this report under Section 3.1, “Literature Review” where South Dakota’s road closure needs were measured using more assumptive bases’ because initial reviews of road closure methodologies employed by other states could not always be directly related to South Dakota conditions. As the study evolved, these factors were refined and brought into a

better focus for the analyses' leading to the conceptual site configurations. Following are South Dakota considerations that had to be taken into account beyond the criteria presented in Table 3-6:

- Rather large geographic area where many road closure sites are often considered too remote from SDDOT maintenance units to properly operate, maintain, and monitor.
- Limited resources to perform road closures with the degree of safety that would be desired during critical times of adverse weather conditions.
- Limited budgetary resources as compared to a majority of states that have larger, more urbanized populations.
- A diversity of weather, geographic, and other localized conditions that can be attributed to various groups of sites around the state.
- State laws and departmental policies ultimately shaping the performance of road closures that are exclusive to the State of South Dakota.
- Aspects of the highway network that ultimately impact road closure needs (i.e., Coordination with a neighboring state's road closings, higher-traffic interstate vs. lower-traffic rural secondary, etc.)

Essentially, study efforts recognized that the subjective criteria above would need to be incorporated with the objective criteria in Table 3-6 to aptly develop road closure site configurations well suited to South Dakota.

Based on reviews of the items above and the criteria in Table 3-6, the analysis efforts began with road closure site configurations that included 6 primary alternatives. At the same time, it was also assumed that various subsets could be developed from the 6 main configurations by either adding, or removing certain equipment components. To facilitate accuracy when comparing alternatives, the configurations are based on a road closure for one lane of traffic only. The 6 primary configurations are described as follows, along with estimated costs and a brief opinion about the implementation feasibility for each:

- 1) Basic, drop-arm style gate. This configuration would be very similar to the WYDOT gate system that includes a gate arm, light pole, base, raising-lowering mechanism, LED lights, and switch kit to interface lights with advance warning signs. **Estimated cost: \$15,000.** (Please note that this cost estimate does not include installation of power for the luminaire at the light pole also used for the gate mounting.)



*Feasibility statement: Costs are not excessive (although the estimate is only for equipment, and does not include installation or construction costs). This configuration seems to represent a significant improvement over the existing swing-type gates from an operational standpoint for SDDOT maintenance personnel.*

- 2) Drop-arm style gate with limited automated aspects. This configuration takes the basic equipment components from 1, above, and adds the automated aspects identical to the test equipment installed at the I90, Exit 67 pilot project initiated for this research study. **Estimated cost: \$34,000.** (This estimate of costs includes \$15,000 for the drop-arm gate configuration of 1, above, then adds \$19,000 which is based on the original estimate to install the I90, Exit 67 test equipment utilizing existing SDDOT drop-arm gates and signage, and thereby represents the costs to incorporate both types of equipment. Again, the estimate is based on automating 1 gate only, and does not include the costs associated with automating ramp, and other gates like at Exit 67.)

*Feasibility statement: This configuration represents an even greater improvement over the existing swing-type gates from an operational standpoint for SDDOT maintenance personnel. However, the costs increase quite dramatically as compared to 1, above.*

- 3) Drop-arm style gate with a full range of automated aspects – This configuration takes the basic equipment components of 1, above, and adds the full range of automation for a road closure site, and like the one originally specified and proposed for the Exit 67 test site. **Estimated cost: \$107,000.** (This estimate of costs includes \$15,000 for the drop-arm gate configuration of 1, above, then adds \$92,000 which is based on the original proposal to install the full range of automated aspects at the I90, Exit 67 test site whereby existing SDDOT drop-arm gates and signage would be utilized. The estimate is again based on automating 1 gate only, but does include a video camera, web host server, corresponding software, and appropriate radio communications equipment.)

*Feasibility statement: This configuration represents the ultimate in improvements over the existing swing-type gates from an operational standpoint for SDDOT maintenance personnel. However, the costs are extremely high when compared to any of the other configuration estimates.*

- 4) Portable barriers and message signs – This configuration represents an alternative that could be incorporated on an as-, and where needed basis at the SDDOT. Plastic, sectionalized, and interlocking barriers that meet NCHRP Report 350 recommendations can be filled with sand-, or water-ballast and would include reflective safety markings and battery operated warning lights. **Estimated cost: \$2,500.** (Estimate includes 3 interlocking barrier sections and metal flip-up signs

that are portable, but does not include any portable, digital message board type of advance warning devices.)

*Feasibility statement: This configuration represents the minimum requirement for performing a road closure, but also has to be perceived as a feasible alternative for certain situations, or else as an alternative that would be supplemental to other configurations.*

- 5) Road closure signage with warning lights, but no barriers – At the present time this configuration could only be considered at the juncture of 2 major highway routes falling on a stretch of road where 2 permanent road closure sites lie at either end. **Estimated cost: Minimal.** (Fully dependent on the type of signs and warning lights to meet minimum requirements for such functionality.)

*Feasibility statement: This alternative could only be used to supplement existing, permanent road closure sites unless applicable South Dakota codified laws and SDDOT policies were interpreted and/or modified in ways to make this more feasible as a "stand-alone" road closure option.*

- 6) Standard, SDDOT swing-type gate – This configuration represents what the SDDOT has been using since the early 1980's. However, most existing sites would require significant maintenance and/or modifications to be brought up to acceptable working standards. **Estimated cost: \$4,100 for a total gate replacement.** (Gate "upgrades" would be dependent on the costs associated with the maintenance and/or modifications needed at each individual site.)

*Feasibility statement: Essentially a "do nothing" alternative that carries no great risk.*

In analyzing the criteria to ultimately develop *optimum* gate configurations for road closure sites in South Dakota, the next logical course was to eliminate site configurations deemed unfeasible to implement. The initial focus centered on configurations that included automated aspects. Two conditions were quickly identified as the critical decision factors to use during the process of elimination. The decision factors were namely the average *frequency of use* for the existing South Dakota road closure sites, and the estimated *costs* to introduce automated aspects to a road closure site. Estimated costs were not included in the criteria spreadsheet of Table 3-6 because cost estimates for the 6 configurations cited above would need to be applied to each existing site in South Dakota, and this was felt to be an analysis methodology that would quickly become unmanageable. Instead, the cost estimates were applied only within tolerable ranges during the course of the site analyses, and thus the process was expedited.

The average *frequency of use* for existing sites on a Region-by-Region basis was formulated earlier in this study (Table 3-4, page 21 of this report.) A review of Table 3-6, above, reveals the absolute highest average for site frequency of use is a mere 2 times/year.

and this number was reported at only 3 sites. Average *frequency of use* rates for road closure sites drop significantly from this point with one site actually reporting 0 usage over the last 10 years.

Based on the low average usage rates for sites statewide combined with the high costs of Configuration 3 to fully automate a site, implementation of this alternative cannot be recommended anywhere in the state.

Applying a similar costs/benefits analysis using Configuration 2 that defines limited automation, implementation at most South Dakota road closure locations also cannot be fully justified. However, the SDDOT may want to consider this alternative at 4 vital Interstate locations near borders with other states where coordinated road closings are often more critical. Implementation of Configuration 2 might also be considered at 2-3 key points on Interstate routes around the outskirts of each of the Rapid City and Sioux Falls urban areas where necessary road closings have greater impacts. Taking these issues into account, road closure sites where implementation of Configuration 2 might be considered are as follows:

- On I90, Exit 10 near Spearfish (Wyoming border)
- On I90, Exit 406 near Brandon/Sioux Falls (Minnesota border)
- On I29, Exit 2 near North Sioux City/Sioux City, IA (Iowa border)
- On I29 at the North Dakota border (generally operated by the North Dakota DOT)
- On I90, Exit 55 on the west side of Rapid City (Deadwood Ave. interchange)
- On I90, Exit 67 on the east side of Rapid City (Ellsworth AFB interchange)
- At the I29/I229 interchange on the south side of Sioux Falls
- At the I29/I90 interchange on the NW side of Sioux Falls

More specifics on the analysis results and subsequent recommendations for Configuration 2 are provided in ensuing sections of this report.

Configurations 1, 4, 5, and 6 did not contain automated aspects so reviews of these equipment configuration alternatives relied on different sets of criteria. Primary comments on the process of eliminating configurations from the remaining 4 alternatives are as follows:

- Configuration 6 is essentially a "do nothing" alternative and analysis results tend to indicate this is not a viable option.

*Primary reason(s):* A primary focus of this study centered on questions surrounding the functional performance of Configuration 6. The survey forms returned from SDDOT Area Offices, coupled with follow-up research, tended to verify that the age,



safety concerns, and operational problems of this road closure site configuration tends to reinforce the perceptions that these issues need to be addressed.

- Configuration 1 is a drop-arm style gate that includes road closure equipment only, without any automated aspects. Research analysis concludes this to be the most viable of all other options for most road closure sites in the state.

*Primary reason(s):* Costs are not excessive, safety concerns are reduced, and operational standards are improved for SDDOT maintenance personnel.

- Configurations 4 & 5 cannot be fully perceived as road closure alternatives that maintain solutions conforming to the original notions of this study. However, these configurations could be considered workable as standalone configurations with the correct supportive conditions, or otherwise considered to provide supplemental advantages when integrated with other configurations.

*Primary reason(s):* Costs would be minimal and potential benefits could be increased if necessary details were suitably addressed.

The preparation of specific plans and recommendations for the treatment of road closure sites in South Dakota did require further analysis during the efforts to accomplish the work objectives under those tasks. Therefore, more detailed discussions of all 6 site configurations are contained in this report under Section 3.9, "Prepare Conceptual Plans for Road Closure Sites", and Section 4.0, "Recommendations".

### **3.9 PREPARE CONCEPTUAL PLANS FOR ROAD CLOSURE SITES**

*Task 9: Prepare conceptual plans based on the literature review for various technically feasible closure gate system automation options, including hand held remotes, modem control, or website controlled system. The conceptual plan should include a statewide system with general recommendations based on the optimum gate configurations developed in Task 8.*

Since this project emphasized the possible incorporation of automated aspects to road closure sites in South Dakota, most of the research efforts were geared toward the ultimate formulation of plans that included technology components. As research progressed however, findings tended to scale back significantly the emphasis to implement configurations with automated features, and also to minimize the number of possible configurations that might be afforded. Also, based on the recommendations of this report there was a realization that final decisions might clearly necessitate the formulation of wholly new road closure configurations integrating components from 2 or more alternatives. Therefore, in lieu of furnishing any detailed plans under this task effort, specific road closure equipment is detailed along with suggested ways the equipment might be integrated to afford optimum site configurations. From these perspectives, the following



discussions treat each of the 6 "generalized" configurations as presented in the previous section of this report:

**Configuration 6: Standard SDDOT swing-type gate.** The operational and safety concerns of several aspects of the road closure gate equipment of this configuration were borne out through the research efforts of this project. In the survey questionnaire to SDDOT Area Offices, there were even some responses indicating that head injuries and other distresses (some involving subsequent hospital visits) had occurred during manual swing-out operations of the gate during high wind situations. Many responses indicated a variety of other operational problems associated with existing gates and only 7 sites reported to have no problems, as seen on the spreadsheet in Table 3-6. The recommendations in Section 4.0 of this report will clarify how this gate equipment should be "phased out" and upgrades to this existing gate equipment, or integration with other conceptual gate configurations is advised against.

**Configuration 3: Drop-arm style gate with a full range of automated aspects.** The high equipment costs tend to relegate nearly all equipment components of this configuration unfeasible to consider. If the cost of certain components could be rationalized, incorporation with equipment from other configurations would still be unfeasible at the present time due to the technology issues cited earlier in this report. (e.g., separate IP addresses for each component, requirements to have servers on site, separate software databases for each server, networking considerations, etc.) If technology issues were addressed, or usage of certain road closure sites became more critical thereby justifying costs, then particular components of this configuration might become more suitable. This research effort did not reveal anything to indicate this might happen in the foreseeable future, however.

**Configuration 2: Drop-arm style gate with limited automated aspects.** The automated equipment of this configuration represents minimized incorporation of technology components, but still identified as workable at a South Dakota road closure site. There remain several questions surrounding the equipment that could not be fully answered due to the time constraints imposed on the evaluation efforts planned at Exit 67 on I90. In particular:

- ✓ Is the handheld, remote-controlled device that essentially allows gate operations from a "line-of-sight" distance significantly advantageous? Also, does it operate reliably in severe weather conditions like heavy, blowing snow? If maintenance personnel can drive within a couple of miles of a gate, it would seem that driving all the way to the gate location would not be much different. If so, this item could be eliminated from equipment considerations for any configuration where it might otherwise be considered, thereby reducing costs by \$3,746.

- ✓ Is a powered gate arm essential? Or, would a non-powered gate arm that could be raised and lowered with a battery powered hand drill be nearly as effective? Elimination of the powered gate arm and hand-held device tend to make this configuration closely resemble Configuration 1, which is a basic, drop-arm style gate without automated aspects. For Configuration 1 it still needs to be remembered that power does need to be supplied at the gate location for the luminaire that lights the area around the road closure. (Unless decisions were made whereby the corresponding light pole would *not* serve as the gate mounting, but then conformance to crash test standards would come into question.)
- ✓ Are there places in South Dakota where severe winter weather conditions sometimes result in power outages on fairly regular basis, and particularly at more remote locations? If there are known areas like this, the purpose of installing powered gates would seem to be defeated more often than not, unless the SDDOT would ever consider using solar panels like WYDOT does at many of their sites.

There may well be sites where low frequency of use and higher equipment costs might be offset by extenuating circumstances. An example would be a road closure site on the outskirts of an urban area that is normally manned by a law enforcement officer. The officer may not necessarily be familiar with, or equipped to perform road closure gate operations. Under such circumstances, a powered gate complete with a remote control device might be strongly considered. The road closure locations appearing in the bullet list in the previous section of this report (on page 37) should be scrutinized as candidate sites for limited automated capabilities of this basic type.

**Configuration 1: Basic drop-arm style gate.** Final analysis results compiled under this study indicate that the equipment of this configuration represents the most logical alternative in regard to cost effectiveness, improving safety (for both SDDOT maintenance personnel and the travelling public), improving functional performance, and standards compliance. Equipment deliberations for this alternative primarily involve choices between the equipment specified for the I90, Exit 67 testing phase of this study and the equipment components making up a standard WYDOT drop-arm gate. The equipment options distinguished between the two types are noted as follows:

	<u>Exit 67 Equipment</u>	<u>WYDOT Equipment</u>
Non-powered gate operations	Auger-type. Manual flywheel or manual power-drill operations.	Winch with steel cable on gate arm. Crank handle to operate winch.

Gate configuration (across 2. same direction lanes of Interstate highway)	One gate installed on the primary lane.	One gate each lane (2 total), staggered, with primary gate towards on-coming traffic.
Capability to be upgraded for power operations	Readily upgraded.	Not as easily upgraded.

**Configuration 4: Portable barriers and message signs.** Some SDDOT Area Offices reported the use of portable barriers at road closure sites where existing gates were in a state of disrepair, or else removed altogether. There were also reports of portable signs taken to sites where gates remained useable, but corresponding signs were in disrepair or missing. For those road closure sites seeing very infrequent use, the utilization of portable road closure equipment might be considered as the most viable option. Portable barriers and signs would also give more flexibility by allowing better reactivity to certain road closure setup needs, timing, and location. There are wide selections of portable barriers and signs on the market, including a variety of setup and anchoring options. Figure 3-7, below, is a representative example illustrating 3 sections of portable barricade that are hollow, made of polyethylene, and that can be filled with water or sand ballast.

**Figure 3-7. Representative Example of Portable Barricade**



In addition to using portable equipment in a standalone road closure configuration, the equipment could also be used to supplement a mainline Interstate road closure gate where only one lane is normally closed. In this situation, a portable barrier could be set up on the other lane, set back to allow snow plows and other authorized vehicles passage much like the WYDOT configuration. Employing this type of a strategy might reduce some of the questionable workarounds involved with the piling of snow, or the parking of a lighted



vehicle at the end of a permanent gate as many SDDOT Area Offices did indeed report during the course of this study.

**Configuration 5: Road closure signage with warning lights, but no barriers.** As stated previously in this report, this configuration would only be considered in plans to supplement nearby road closure sites where additional notification to the travelling public is desired. However, if current legal and policy doctrines indicate this configuration has an acceptable rationale in a "standalone" configuration, or laws and policies are otherwise changed to allow it, then this type of equipment would represent a viable road closure alternative. The following figure, Figure 3-8, illustrates how notification to the travelling public can take the form of either a warning, or a declaration of the penalty imposed for non-compliance with the warning.

**Figure 3-8. Illustration of Road Closure Notifications**



Thereby, these 2 approaches indicate how message structure on the warning signs might dictate the necessity, or non-necessity to have a physical barrier on the roadway, depending on the structure of supporting laws.

### **3.10 PREPARE A FINAL REPORT**



*Task 10: Prepare a final report summarizing research methodology, findings, conclusions, and recommendations. The report shall also include various gate configurations drawings and schematic figures as well as basic costs of the various closure gate options.*

This document represents the Project Final Report as called for in the description for this task.

### **3.11 MAKE EXECUTIVE PRESENTATION TO THE RESEARCH REVIEW BOARD**

*Task 8: Make an executive presentation to the South Dakota Department of Transportation Research Review Board at the conclusion of the project.*

Task performance was scheduled for a regular meeting of the Research Review Board on August 19, 2003.

## 4.0 RECOMMENDATIONS

The reviews, analysis, and conclusions arising from the task definitions for this research study resulted in the following recommendations:

- 1) The SDDOT needs to ensure that ambiguities or discrepancies between departmental policies and SDCL relating to road closures on the state highway system are addressed through proper legal counsel. Reviews would need to compare and contrast SDDOT policies with SDCL to note any perceived irregularities. The project researcher would be made available to SDDOT legal counsel for further clarification of the reviews performed during this research project as needed. SDDOT Operations Support could then determine the impacts of finalized SDDOT policies to road closure equipment appropriateness, site layouts, signage types, and other considerations. This needs to be accomplished by November 1, 2003. If this action is not fulfilled, certain ambiguities will remain concerning the setup and operations of road closure sites.
- 2) The SDDOT Region Engineers need to meet with the project researcher to determine a final, standardized procedure for selecting road closure sites based on the "Criteria Spreadsheet to Configure SDDOT Road Closure Sites" furnished in the project Final Report by December 15, 2003. This could be accomplished as an agenda item at regularly scheduled meetings. The successful completion of Recommendation 1, above, may well produce results that will impact this process. If this action is not accomplished, the selection of road closure sites will continue to be performed on an ad hoc basis where important criteria have the possibility of being ignored, and equipment procurements could become very non-homogeneous.
- 3) The SDDOT needs to begin replacing the existing swing-type gates with new drop-arm gates under a phased implementation plan that considers replacement necessities resulting from construction activities or total replacement needs based on deteriorated conditions of existing gates. The age, operational issues, and safety concerns associated with the existing swing-type gates all point to the need to replace this equipment with drop-arm gates that have the desired operational upgrades and safety features. The replacement process should be a phased effort that minimizes impacts to budgets, and it also should not be perceived as a statewide construction effort with immediate intentions to get all existing gates replaced at once. Instead, existing gates can be phased out during highway construction projects that dictate their removal, or as the existing gates reach states of disrepair that do indeed require their replacement. If the existing gates are not replaced, SDDOT

maintenance personnel will continue to struggle with operational problems and safety will also continue to be an issue.

Based on the outcomes of Recommendations 1 & 2 above, there may well be sites where gates are felt to be unnecessary (i.e., Lack of nearby facilities, highly infrequent need to close the roadway, etc.) In these cases, portable barriers and signs, or else simply warning signs with proper notification to the public may be deemed adequate. In other cases, sites like those previously cited near state borders or at critical points around urban areas may need to include powered gate installations at the site. Considerations would include future ITS integration, under-equipped personnel manning the site more regularly (such as a SD Highway Patrol Officer), or other planned actions where future integration would require retrofitting of non-powered gate arms to be burdensome. Other than special attention to the equipment configurations at low-, and high priority sites, a basic drop-arm gate configuration is recommended for all other sites in South Dakota. Not recognizing the low-, and high priority sites at this time would most likely result in additional future expenditures.

- 4) **Each SDDOT Region should consider procurement of one road closure site configuration that is comprised of portable equipment.** The equipment configuration would consist of one set of portable barricades, signs, and warning lights that are all readily transportable to any road closure location of choice. Prior to any procurement, the use of portable equipment should be discussed with maintenance personnel at each Region. At the same time, compliance of the equipment with NCHRP Report 350 should be ensured. Maintenance personnel at each Region would be expected to test and verify the workability of this equipment in "standalone" configurations, and as supplemental equipment to pre-existing sites.

SDDOT personnel designated to respond to these recommendations should feel free to contact the SDDOT Office of Research for any clarifications or assistance regarding the above. Since this study was performed "in house", implementation of the recommendations contained herein can be presumed as inter-office continuation of the project efforts.

## 5.0 REFERENCES

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## **APPENDIX A**

### **TECHNICAL SPECIFICATIONS: AUTOMATED ROAD CLOSURE GATE SYSTEM**

## EXIT 67 ROAD CLOSURE GATE TECHNICAL SPECIFICATIONS

1. The gate arm actuators shall be designed to mount to existing gate arms and luminaire pole. Actuators shall include all necessary components and hardware necessary to open and close gate arm. The actuator shall be operated either using a local open/close switch or remotely via the handheld remote unit using a 900 MHz wireless connection.
2. Actuator shall include a manual hand wheel for opening or closing gate in the event power is not available. Hand wheel shall also have a hex nut accessible to allow the use of a cordless drill for turning the actuator mechanism.
3. Parts for each gate shall include 1-WG-B1142001 0 - cylinder rod attachment, 1-WG-B1143001 - cylinder attachment, 2-WG-B1144001 - u-bolts, 1 - WG-CY1 - cylinder-electrical linear actuator w/manual override (Andco), and WG-MGH - misc. gate hardware, lockable Thomtech control box and 900 MHz radio and antenna.
4. Miscellaneous conduit and wiring to connect actuator and control box to power in luminaire base. All electrical connections shall be made in accordance with applicable codes and accepted standards.

### Handheld Remote:

1. The handheld remote shall be programmed by ThomTech to operate each gate and the advanced warning lights switch independently from each other.
2. Include integrated 900 MHz spread spectrum modem with built in modem antenna.
3. Backlit LCD display for status and menu controls.
4. 4-button user interface for scrolling, selecting and entering.
5. Standard 12-volt automotive input and removable, 5-cell, NiMh battery pack. Built in battery charger, w/ cigarette lighter adapter.
6. Audio feedback
7. One-year warranty on parts and workmanship.
8. Safety Technologies VoiceCommander VC47B.

### Advanced Warning Light Switch:

1. All equipment and devices necessary to close circuit in flasher unit to activate advanced warning lights at signs and gates.
2. Enclosure shall house all necessary relays, radio modems and local switching.
3. Switch shall be operable using on/off switch at enclosure or via wireless communications with 900 MHz spread spectrum radio modem and handheld unit.
4. Enclosure shall be lockable using a pad lock.
5. Parts shall include 1 - WG-WSCB-warning sign control box. ThomTech control box and radio that integrates with 900 MHz spread spectrum communication s network to turn flasher on/off at the flasher unit.

## APPENDIX B

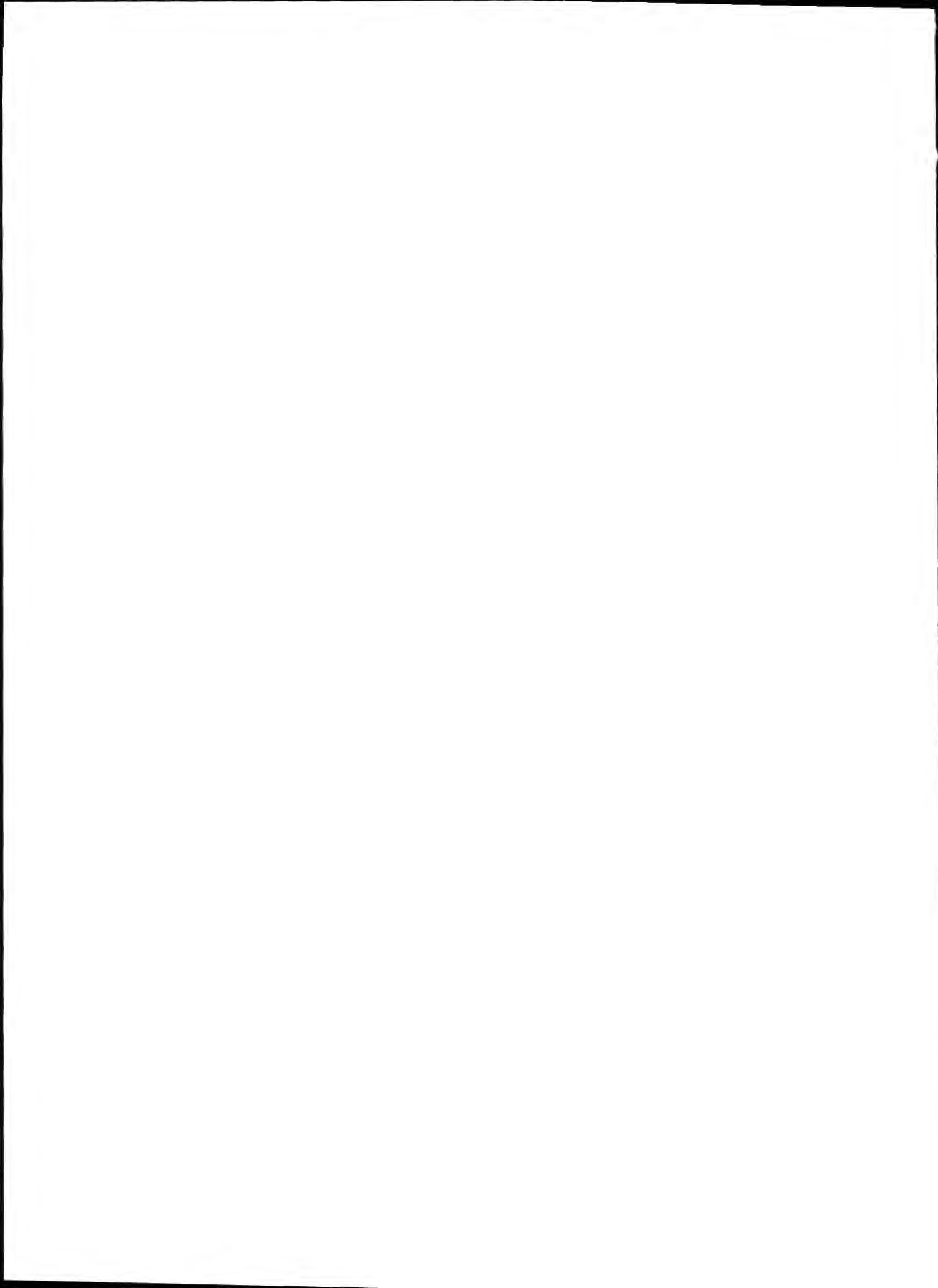
### EXIT 67 ROAD CLOSURE SITE EVALUATION QUESTIONNAIRE





### **Task 4 Follow-up Questionnaire**

1. What was the reason for the road closure?
2. Describe the prevailing weather conditions during the road closure. (Snow, sleet/ice, wind, temperature, etc)
3. How was the gate closed? (Remotely, at the gate, powered, manually, etc.)
4. Were any problems experienced during the road closure? (If so, describe.)
5. Compare the road closure operations with the new gate to previous operations using a "swing-type" gate. (i.e., Describe any benefits and/or drawbacks.)
6. After the road closure, did all components of the gate configuration perform as intended? (Gate, advanced warning signs, lights, etc.)
7. After the road closure, how was the site monitored? (By whom, frequency rate or continuously, necessary public interactions, necessary equipment attention, etc.)
8. Were any "gate drive-arounds" by the public noted? (and, How were these known? How many?, etc.)
9. How long was the road closed?
10. Describe anything else that occurred when the road was closed, during the time it was closed, and then when it was re-opened, that may be noteworthy.



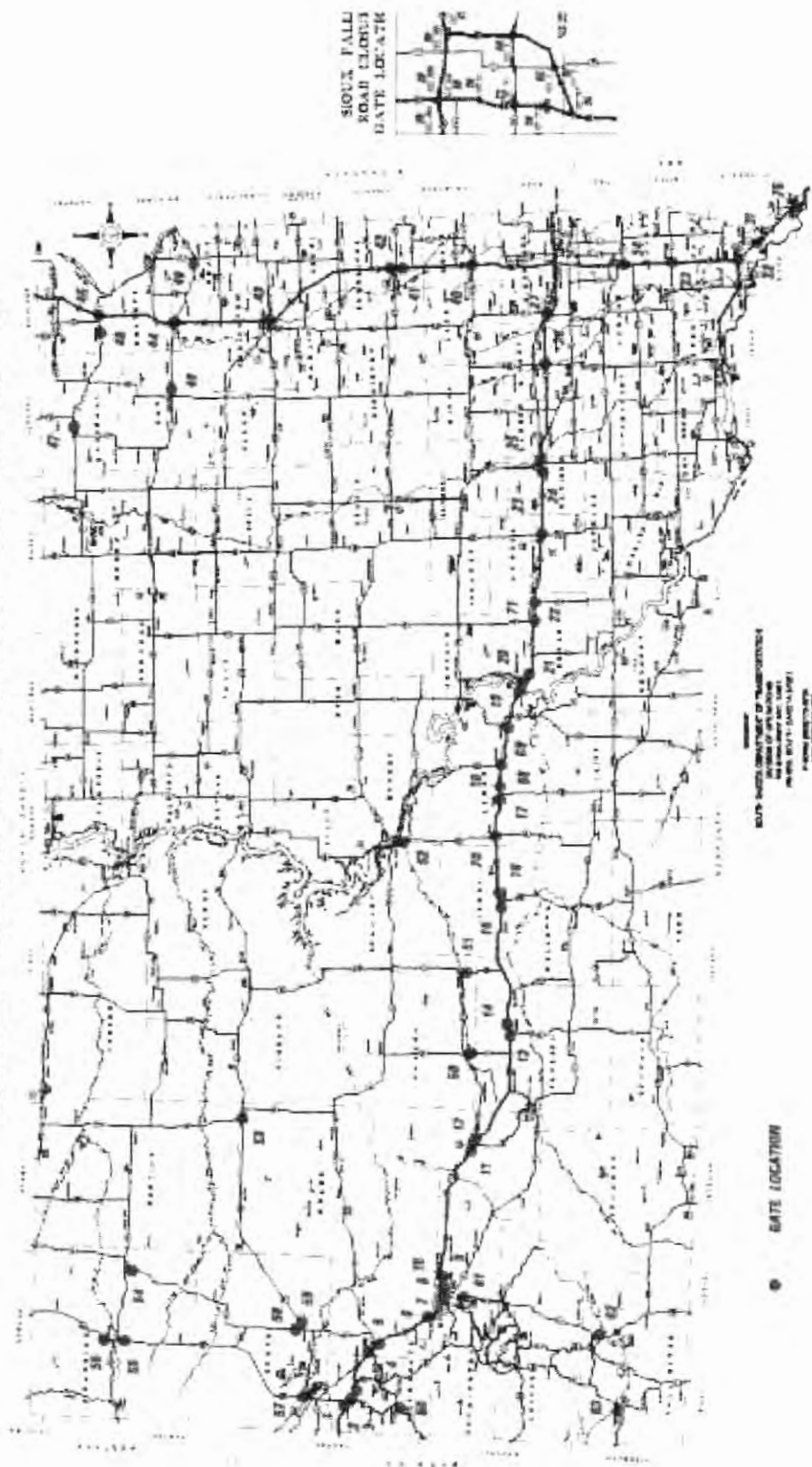
## APPENDIX C

### ROAD CLOSURE GATE LOCATIONS SITE MAP





# ROAD CLOSURE GATE LOCATIONS





## APPENDIX D

### UPDATED ROAD CLOSURE GATE LOCATIONS SITE MAP





# ROAD CLOSURE GATE LOCATIONS

