AN EMERGENCY RESPONSE PLAN FOR BRIDGE MANAGEMENT

WA-RD 289.1

Final Technical Report
December 1993

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16. ABSTRACT

The major objective of this project was to develop a post-earthquake emergency response plan for WSDOT bridge management. Three types of seismic events were considered in the development of the plan. Inspection forms were developed for the three-stage inspection process. For events other than minor earthquakes under favorable weather and lighting conditions, existing resources appear to be inadequate. Recommendations for improving the readiness of the WSDOT bridge management are provided.

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Final Technical Report

Research Project GC8719, Task 44
An Emergency Response Plan for Bridge Management

AN EMERGENCY RESPONSE PLAN FOR BRIDGE MANAGEMENT

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DISCLAIMER

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SUMMARY

In this project, researchers developed an emergency response plan for use by Washington State Department of Transportation (WSDOT) bridge management. This plan was formulated after the readiness of the bridge management was extensively examined. Inspection objectives relative to the three earthquake magnitudes that are possible in the Puget Sound region formed the basis for the plan development. CALTRANS documents and strategies were also reviewed to find procedures that would be relevant to the WSDOT bridge management. (1) Inspection forms for disaster assessment and a computer database based upon WSDOT's existing seismic database were developed for use in the plan.

The plan includes guidelines for Bridge and Structures, with checklists for the Bridge Management Engineer, the Bridge Condition Engineer, Team Leaders, and Team Members. A database consistent with these instructions was developed; it was based in part upon the existing seismic vulnerability database for bridges.

Implementation of the plan will not be effective unless certain related resources are made available to the bridge management. These resources include extensive radio communications, power generators and supplies for command centers, command center structural integrity (so they can remain operational after earthquakes), and volunteer recruitment and training. Workshops involving management from the Olympia Headquarters, the Mottman Office, and districts 1, 3 and 4 are recommended, as is crisis management training for inspectors by the Division of Emergency Management of the Department of Community Development. Further study of the manner in which forensic investigations are undertaken is also recommended.

INTRODUCTION AND RESEARCH APPROACH

THE PROBLEM

Earthquakes of various magnitudes are anticipated in the Puget Sound area. Following such events, WSDOT must continue to provide residents with functioning, albeit substantially curtailed, roadway transportation lifelines. An emergency response plan for inspection and structural damage assessment of bridges following earthquakes of various magnitudes would be beneficial to WSDOT in its efforts to continue to provide its services. WSDOT inspection teams and other structural engineers need a coordinated post-earthquake plan for effectively assessing structural damage to bridge components of critical roadway transportation networks.

RESEARCH OBJECTIVES

The major objective of the study was to develop a post-earthquake response plan for bridge management. To achieve this objective, the following tasks were accomplished:

1. assessment of the current resources and capabilities of the WSDOT for post-earthquake response to bridge damage;
2. establishment of consistent methods of structural damage assessment, data collection, and information communication;
3. modification of the WSDOT database for bridge information to establish methods for prioritizing bridges for post-earthquake inspection;
4. identification of the WSDOT command structure for crisis situations; and
5. formulation of an emergency response plan for bridge management that considers the technical issues of structural damage assessment, mobilization, coordination, and communication.

BACKGROUND

WSDOT bridge management has an effective response mechanism for predictable natural disasters that are limited geographically, such as regional flooding. As for earthquake preparedness beyond this limited response program, WSDOT has an extensive database of seismically vulnerable bridges. Resources for inspection teams are available in the most seismically vulnerable districts, 1, 3 and 4, as well as at the Mottman office for response efforts. However, these resources are inadequate for post-earthquake response. In developing the emergency response plan, the plans of the CALTRANS and other related agencies, as well as the responsibilities of the WSDOT, were considered. WSDOT's interaction with other state agencies, as well as with other organizations, was investigated. In this section, background material on the readiness of the state and the implications for the development of the emergency response plan for bridge management are considered. First, the responsibilities and the readiness of the state, in the context of transportation roadway lifelines, are briefly reviewed. Second, the readiness and the interaction of the state with other agencies are discussed. Third, the organization of volunteer efforts in Washington state is described.

The primary responsibilities of the WSDOT in a post-disaster scenario are

- to ensure the safety of the traveling public,
- to protect state highway facilities from additional damage,
- to restore traffic on state roads as quickly as possible, and
- to maintain a current assessment of the extent of the damage and operational status of the state highway system.

The roles and responsibilities of the WSDOT are detailed in the Emergency Management Plan. (2)

After any emergency, the primary responsibility of the state government is to make all critical public facilities, such as transportation roadways, functional within a 72-hour period, rather than responding to private needs. According to the emergency response plans described by the Federal Emergency Management Agency (FEMA), after the 72-hour period has expired, private citizens should then be able to turn to the state for assistance.

The Seismic Safety Advisory Committee (SSAC) was established in 1991 to develop a plan and make recommendations to the state legislature concerning the state's earthquake preparedness. This plan was sent to the Senate and House of Representatives' Committees on Energy and Utilities on November 27, 1991. It was later rewritten into legislation as House Bill 2791, but the legislation did not pass.

The SSAC reported that most organizations and individuals in the state are not prepared for an earthquake. The work of the Seismic Safety Advisory Committee was complementary to WSDOT's efforts in emergency response planning; however, it advocated increased funding for the retrofitting and rehabilitation of seismically vulnerable bridges, and coordination of planning with other agencies. (3) The "top priority" recommendations of the SSAC that are important to WSDOT are as follows:

(1) to establish by legislation an interagency seismic safety policy committee;

(2) to conduct a state-level review of emergency communication systems and implement the review recommendations;

(3) to clarify the liability law for volunteer emergency workers and implement a central registry of trained emergency worker and volunteer personnel;

(4) to provide standardized materials to help local jurisdictions more effectively train personnel; and

(5) to standardize planning guidelines for local jurisdictions as part of ongoing emergency planning.

Of particular interest to WSDOT bridge management were the following recommendations:

(1) to "continue the funding for the current WSDOT bridge retrofit program;

(2) [to] identify critical lifeline routes that include the state and local roads, bridges, transit routes and port facilities; and

(3) [to] develop a work program for seismic vulnerability assessments of local bridges."

Additionally, the SSAC recommended that standardized seismic safety guidelines be developed for lifeline emergency plans. The SSAC's review of the transportation lifelines caused it to recommend increased funding to strengthen all state-owned vulnerable bridges, not just those presently given highest priority, and vulnerability assessment of the approximately 2,000 city and county bridges in the state's transportation lifeline. These were not covered in the WSDOT vulnerability study.

The SSAC review found that earthquake preparedness at the local government level was uneven, and in general, most communities were inadequately prepared. This lack of preparation presents several problems for WSDOT bridge management. First, local bridges may affect critical state routes. Because the resources of local governments for bridge inspection and repair are very limited, WSDOT bridge management may have to assume these responsibilities. Second, coordination of WSDOT bridge management with the local communities varies. A workshop and established procedures would be useful for coordinating communication efforts for all bridge inspections in the most vulnerable areas of western Washington.

In studying the possible interaction between WSDOT and local agencies, such as King County Public Works and the City of Seattle, the researchers found that a coordinated plan for bridge inspection did not exist; each agency had its own (limited) resources. According to the vulnerability study conducted in 1990 by the City of Seattle, 238 bridges were located in the City of Seattle. The state owns 81 of these bridges. Coordination between the city and the state in terms of the seismic vulnerability assessment and post-earthquake inspection responsibilities of these bridges had not been undertaken. Thirty-nine bridges are owned privately or by other agencies. Of the remaining 118 bridges, 60 have been prioritized from "A" to "D". Bridges classified as "A" received a high traffic importance rating and a low structural capacity rating. The City of Seattle has a database of all its seismically vulnerable bridges, and a geographical information system (GIS) representation of its transportation network. Its post-earthquake response plan is under revision, and the bridges will most likely be inspected according to their vulnerability rating.

CALTRANS has successfully organized volunteers for emergency response efforts, and the SSAC and other agencies have encouraged the development of similar programs in Washington. Because liability is waived for trained volunteers in California under a declared state of emergency, CALTRANS has a large pool of volunteers. These volunteers are trained in workshops organized by CALTRANS, and they commit themselves to providing assistance well in advance of an emergency. To investigate volunteer efforts in the state of Washington, the researchers contacted ASCE and other engineering organizations. Contact with the local chapter of the American Society of Civil Engineers revealed that volunteer programs had not been a topic of serious discussion by the organization, but it would be receptive to such a program, if personal liability were waived. The Structural Engineers Association of Washington (SEAW) has discussed the emergency response efforts of engineers in great detail, both internally and with the state and local governments, and the organization has supported efforts to waive liability for volunteer engineers. Unless questions concerning liability are answered to the satisfaction of the membership, the organization will not be able to provide volunteers. Therefore, if WSDOT wishes to "draft" members for structural damage assessment in forensic investigations, or other duties to support its inspections and investigations, its legal affairs department must convince the SEAW membership that personal liability will be waived.

The responsibilities of the bridge management, beyond the general guidelines provided for the WSDOT to restore traffic flow, have not been formally stated, and their development formed the major portion of this project.

FINDINGS

RESPONSIBILITIES AND OBJECTIVES

Consistent with the general WSDOT responsibilities stated above, the specific responsibilities of the WSDOT Bridge and Structures Office were developed as follows:

1) Conduct a rapid survey of all bridges in the area(s) affected by the disaster to identify unsafe bridges.

2) Provide technical guidance to district personnel for emergency actions that need to be taken to ensure public safety and to prevent additional damage to the structures.

3) Conduct a detailed survey of all bridges in the affected area, identifying all damaged structures and recording the nature and extent of damage on each structure.

4) Recommend repairs to damaged bridges and provide the estimated cost of those plans, specifications, and repairs.

5) Maintain information files for all inspected bridges, to include operational status, general description of any damage repair activity, and rough cost of repairs.

6) Develop periodic summaries and reports for upper management and emergency operations centers.

The goal of the response plan was to ensure that these responsibilities were met.

The researchers established objectives consistent with the 72-hour response period, specifically for bridge inspection, for the three types of earthquakes that are anticipated in the Puget Sound. These inspection objectives for each type of earthquake event, rated by Richter magnitude, are shown in Table 1. For a minor earthquake, little or no damage is anticipated, as small earthquakes (e.g., Richter Magnitude = 3 - 4) have occurred in the Washington State with little effect. The emergency response efforts for this minor event are considered a subset of those required for the moderate event. Therefore, the minor event is not treated as a separate case. For a minor or moderate earthquake, inspection of all facilities within the 72-hour period is a reasonable goal. The moderate earthquake is one for which some damage is anticipated. However, for a great

Table 1. Objectives of WSDOT Bridge Management for Three Types of Earthquake Events. Suggested Post-Earthquake Time to Completion: 72 Hours

EVENT	MAGNITUDE	INSPECTION	FORENSIC INVESTIGATION
Minor or Moderate	Less than 5 5-6	Levels I-III	Priority established for investigations; team assignment for all investigations; initial field work conducted by teams; status report available through The Bridge and Structures Command Center in Olympia
Major	6-8	Level I to obtain overview. Routes prioritized; Level III inspection of highest ranking priority routes; assignment of Level II inspection for lower priority routes	Assignment of teams for conducting investigations; priority established; status report available through The Bridge and Structures Command Center in Olympia
Great	8 and above	Level III Inspection limited to critical priority routes that can be accessed; assignment of Level II inspection for less critical routes through Mottman Command Post	Listing established by The Bridge and Structures Command Center in Olympia for later assignment

event, only critical transportation lifelines would probably be inspected. All personnel probably would be directed towards the inspection, repair, and maintenance of these facilities within this period, and all other tasks would have lower priority. A review of the CALTRANS procedures following the Loma Prieta earthquake of 1989 revealed that over 2,000 bridges were inspected in a three stage process within the 72-hour period. This guideline was adopted for WSDOT's use in a comparable earthquake affecting the Puget Sound region. The philosophy of the inspection process is to eliminate safe bridges as rapidly as possible from further consideration so that resources may be applied to evaluating and repairing the damaged structures. In this manner, critical roadways will be opened for travel as quickly as possible following the earthquake.

GUIDELINES FOR INSPECTION

The emergency response plan was based on WSDOT's existing procedures, the bridge seismic vulnerability database, and consideration of the CALTRANS plan. This plan is based upon the allocation of resources in accordance with Table 1. The full text of the response procedures is provided in Appendix A. An outline of the inspection plan follows.

Figure 1 shows an overview of the inspection process, which includes three inspection stages, or levels, beginning with the event and ending with all inspections completed. A Level I or "drive-by" inspection is the first stage of the process. This cursory inspection is used to eliminate the collapsed or obviously unsafe bridges from inspection consideration. Information regarding the collapse or closure of these bridges is critical in planning routes for the inspection teams to travel to other bridges. As shown in Figure 1, priorities for the Level II inspection are established using information from the news media on the extent of the damage, reports from affected districts, and the existing bridge database. The priority index is used to rank bridges for inspection. (4) As defined in (4), the priority index is defined by the equation

$$PI = A \times C \tag{1}$$

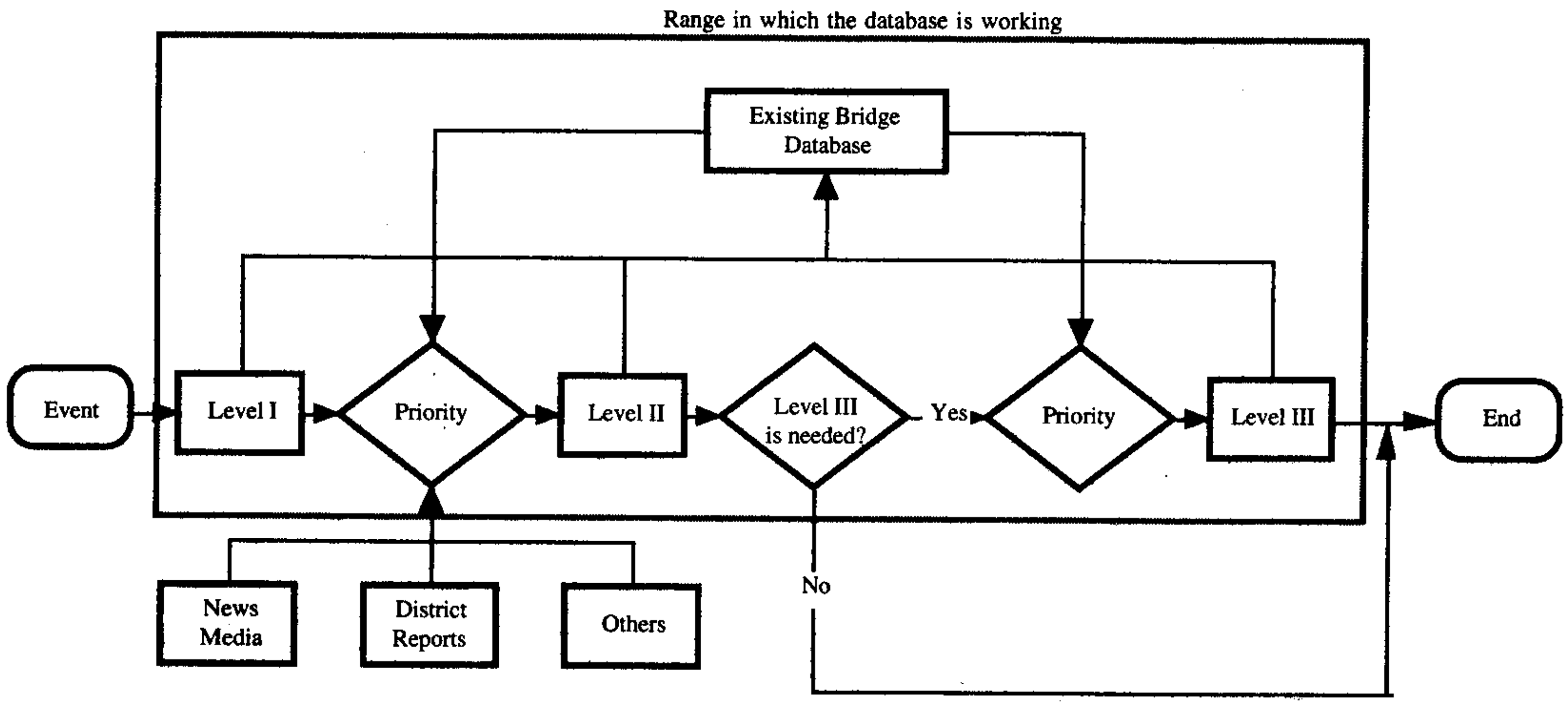


Figure 1. Overview of the Emergency Response Inspection Process

where "A" is a factor representing the criticality of the route carried by the bridge, criticality of the utility lines carried by the bridge, criticality of the route crossed by the bridge, and criticality of the bridge as a structure. "A" increases as criticality increases. "A" is calculated as follows:

$$A = [(RN_{carry})(DL_{carry} \times N_{carry})] + [UT_{carry}] + \frac{2}{3}[(RN_{cross})(DL_{cross} \times N_{cross})] + \frac{1}{4}\left[\frac{ADT_{carry}}{30{,}000\ (L)}\right]^{0.25} \qquad (2)$$

where RN_{carry} is a factor representing the nature of the route carried by the bridge; RN_{carry} equals 1.0 for an interstate route, principal artery, or confirmed emergency route; and 0.8 for all other routes. DL_{carry} is a factor representing the criticality of detour length for the route carried by the bridge; DL_{carry} is 1.00 when the detour length is greater than 10 miles, 0.80 when the detour length is 3 to 10 miles, and 0.75 when the detour length is less than 3 miles. N_{carry} is a factor representing the criticality of detour for the route carried by the bridge because of traffic congestion. N_{carry} is calculated as follows:

$$N_{carry} = \left[\frac{ADT_{carry}}{30{,}000}\right]^{0.25} \qquad (3)$$

where ADT_{carry} is the average daily traffic carried by the bridge. UT_{carry} is a factor representing the utility lines carried by the bridge; it has a value of 1 for a bridge carrying a confirmed essential utility line, and a value of 0 for all other bridges. RN_{cross} is a factor representing the nature of the route crossed by the bridge; it is 1.0 for a confirmed emergency route, 0.8 for all other routes, and 0.0 for no route under the bridge. DL_{cross} is a factor representing the criticality of detour length for the route crossed by the bridge; it is 1.0 when the detour length is greater than 10 miles, 0.80 when the detour length is 3 to 10 miles, and 0.75 when the detour length is less than 3 miles. N_{cross} is a factor representing the criticality of the detour for the route crossed by the bridge because of traffic congestion. It is calculated as follows:

$$N_{cross} = \left[\frac{ADT_{cross}}{30,000}\right]^{0.25} \tag{4}$$

where ADT_{cross} is the average daily traffic of the route crossed by the bridge. L is the length of the bridge in feet.

"C" is a factor representing the vulnerability of the bridge to seismic failure; "C" increases as the vulnerability of the bridge increases. "C" is calculated as follows:

$$C = 0.17\,[(a)\,(K)\,(SV)] \tag{5}$$

where (a) is the velocity-based peak ground acceleration coefficient. The coefficient (a) has a 10 percent probability of being exceeded in 50 years. K is a factor that adjusts (a) to the remaining service period of the bridge. SV is a factor representing the structural vulnerability. It increases as the seismic structural vulnerability increases. It is zero for the bridges that meet the current design standard criteria.

The WSDOT database includes the priority, importance, and vulnerability index values of the seismically vulnerable bridges in the state. The structural vulnerability factor is also included.

Priorities for the more detailed Level III inspection are established with both the Level II results and the bridge's vulnerability index C assigned by the database prior to the earthquake.

Figure 2 contains a more detailed view of this decision-making process. The inspection of bridges was modeled to take place in stages analogous to those used by CALTRANS. Table 2 contains specific definitions for each stage, or level, of inspection. The Level I inspection is used merely to remove from consideration bridges that have collapsed or are so heavily damaged that they must be closed. The reasoning behind this decision is that the major objective is to inspect as many bridges as possible. Collapsed bridges should be subject to detailed investigation to determine the cause(s) of failure; however, the more important immediate objective is to return the transportation lifelines

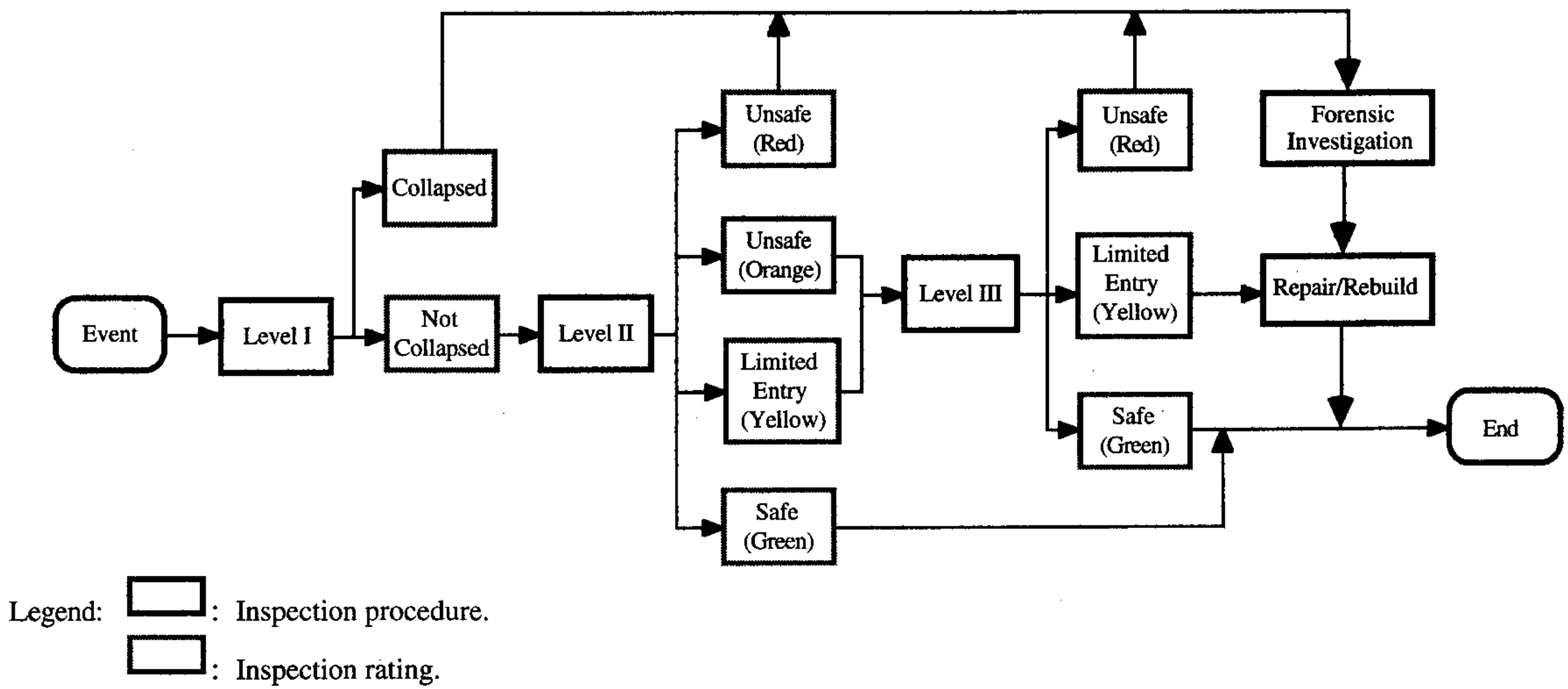


Figure 2. Overview of the Emergency Response Inspection Procedures

Table 2. Description of Inspection Levels for Emergency Response.

	Level I	Level II	Level III
Application Range	All bridges within the area affected by the earthquake	All bridges in affected area except those that collapsed or suffered partial collapse	All bridges recommended for further inspection by Level II teams
Means of Inspection	Aerial View (Helicopter) or Drive through or Traffic video-camera	For great event: helicopter. For other events, probably regular van-type transportation will be needed	For great event: helicopter. For other events, probably regular van-type transportation will be needed
Personnel	To be designated	Team of WSDOT personnel or volunteers led by an experienced WSDOT inspection engineer	"Regular" inspection teams
Objectives	(1)To close all unsafe bridges (2)To identify routes that cannot be traversed (3)To identify the geographical extent of damage/ affected area	(1)To close all unsafe bridges (2)To identify routes that cannot be traversed (3)To assess the structural and geotechnical post-earthquake vulnerability of the bridge	(1)To close all unsafe bridges (2)To assess the structural and geotechnical post-earthquake vulnerability of the bridge, and make recommendations for repair (3)To limit access to or close damaged bridges (4)To identify routes that should not be traversed
Resources	Helicopter(s), back-up power and casings for traffic video installations	"regular"/ existing inspection team equipment in addition to radios and cellular phones for communications; mountaineering equipment for access under unusual conditions; water, food and supplies for 72 hours per person	"regular"/ existing inspection team equipment in addition to radios and cellular phones for communications; mountaineering equipment for access under unusual conditions; water, food and supplies for 72 hours per person

to normal operation. Therefore, the decision to close bridges at Level I is based on a drive-by, reports from the field or news media, and aerial views if weather conditions permit.

A Level II inspection is undertaken by a team of engineers led by an experienced inspection engineer. Because the team members may not possess the expertise equivalent to a "regular" team, the bridge condition is ranked according to criteria on an assessment form, shown in Figure 3, as follows: safe (green), limited access (yellow), unsafe or close (orange-low confidence), and unsafe or close (red-high confidence). All "red" bridges are placed on a list for forensic investigation. Safe, "green" bridges are eliminated from further consideration, unless significant aftershocks occur. Bridges ranked "yellow" or "orange" are subject to a third inspection, called the Level III inspection. These color codes are useful not only in terms of reporting the conditions from the field, but also for maps to be placed in prominent positions at the command centers.

The Level III teams are composed of experienced bridge inspectors. The form for this assessment is shown in Figure 4. The Level III teams recommend repair or closure, followed by forensic investigation.

Finally, at some time after the 72-hour emergency response period, it is recommended that all bridges undergo a typical inspection. This inspection would be useful in identifying whether aftershocks had significantly changed earlier inspection rankings and in providing greater control over the records of bridges that were eliminated earlier from consideration (i.e., the "green" bridges). Because the priority and vulnerability indices are used to rank bridges for retrofit and other considerations, inspections of all bridges to confirm the values of these indices as a long-term objective are important.

The inspection forms for the Level II and III inspections have been created in Microsoft Excel and are based upon the WSDOT's seismic database. Structural considerations specific to expected earthquake damage are included in these forms. A

BRIDGE DESCRIPTION:

Number: ______________________________

Name: ______________________________

Route: ______________________________

Intersecting: ______________________________

Location: ______________________________

OVERALL RATING: (Check one)

- **SAFE** (Green) ☐
- **LIMITED ENTRY** (Yellow) ☐
- **UNSAFE** (Orange-low confidence) ☐
- (Red-high confidence) ☐

INSPECTOR:

Signature ______________________________

Title __________ Certification No ______________

Signature ______________________________

Title __________ Certification No ______________

INSPECTION DATE:

Mo/day/year ______________________________

Instructions: Review the bridge for the conditions listed below. A "yes" answer to 1, 2, 3, 4 or 5 is grounds for an **UNSAFE** rating for the entire bridge. If more review is needed, check **LIMITED ENTRY**. A "yes" answer to 6 or 7 requires barricades around the hazard.

Condition	**Yes**	**No**	**More Review Needed**
1 Collapse, partial collapse	☐	☐	☐
2 Superstructure damage (movement, buckling, cracking or failure)	☐	☐	☐
3 Substructure damage (tilting, settlement, sliding, cracking)	☐	☐	☐
4 Bearing device damage (failure, shearing or pull-out of bolts)	☐	☐	☐
5 Geotechnical hazard (soil liquefaction, slope failure, ground movement, fissures)	☐	☐	☐
6 Appurtenant structure damage (settlement and sliding of wingwalls, separation of wing wall from abutments, failure of parapet walls)	☐	☐	☐
7 Other hazard present	☐	☐	☐

Recommendations:

- ☐ No further action required
- ☐ Detailed inspection required (circle element(s)) *Superstructure* *Substructure* *Bearing* *Geotechnical* *Other* ________
- ☐ Repair required (circle element(s)) *Superstructure* *Substructure* *Bearing* *Geotechnical* *Other* ________
- ☐ Barricades needed in the following areas: ______________________________

  ____
- ☐ Other: ______________________________

  ____

Figure 3. WSDOT *LEVEL II* Post-Earthquake Bridge Inspection Form

Comments:

Sketch:

Figure 3. WSDOT *LEVEL II* Post-Earthquake Bridge Inspection Form (continued)

BRIDGE DESCRIPTION:

Number: ______________________________

Name: ______________________________

Route: ______________________________

Intersecting: ______________________________

Location: ______________________________

Structure type: ______________________________

Substructure type: ______________________________

Foundation type: ______________________________

No. of spans: ______________________________

OVERALL RATING: (Check one)

SAFE (Green) ☐

LIMITED ENTRY (Yellow) ☐

UNSAFE (Red) ☐

INSPECTOR:

Signature ______________________________

Title __________ Certification No __________________

Signature ______________________________

Title __________ Certification No __________________

INSPECTION DATE:

Mo/day/year ______________________________

Instructions: Complete inspection and checklist on reverse side and then summarize results below.

Status:	Level II	Level III	
Safe (Green)	☐	☐	
Limited Entry (Yellow)*	☐	☐	*How limited:
Unsafe (Orange)	☐		______________________
(Red)	☐	☐	______________________

Recommendations:

☐ No further action required

☐ Repair required (circle element(s)) *Superstructure* *Substructure* *Bearing* *Geotechnical* *Other* ____________

☐ Barricades needed in the following areas: ______________________________

____

☐ Other: ______________________________

Comments:

____

____

____

____

____

____

____

____

____

____

____

Figure 4. WSDOT *LEVEL III* *Post-Earthquake* Bridge Inspection Form

Instruction: Examine the bridge to determine if any hazardous conditions exist, and if necessary, determine the extent of limited entry. Inspector(s) should use judgment and prior experience in selecting a proper bridge rating.

Condition	Hazardous Condition Exists: Yes	No	Unknown	Measurement or Comments
1 *Structure Hazardous Overall*	☐	☐	☐	________
Collapse	☐	☐	☐	________
Partial collapse	☐	☐	☐	________
Other ________	☐	☐	☐	________
2 *Superstructure*				
Deck	☐	☐	☐	________
Stringers	☐	☐	☐	________
Floor beams	☐	☐	☐	________
Beams	☐	☐	☐	________
Trusses	☐	☐	☐	________
Arches	☐	☐	☐	________
Girders	☐	☐	☐	________
Joints	☐	☐	☐	________
Other ________	☐	☐	☐	________
3 *Substructure*				
Columns	☐	☐	☐	________
Piers	☐	☐	☐	________
Abutments	☐	☐	☐	________
Other ________	☐	☐	☐	________
4 *Bearing Devices*				
Failure	☐	☐	☐	________
Shearing or pull-out of anchor bolts	☐	☐	☐	________
Other ________	☐	☐	☐	________
5 *Geotechnical Hazards*				
Soil liquefaction	☐	☐	☐	________
Slope failure	☐	☐	☐	________
Ground movement, fissures	☐	☐	☐	________
Other ________	☐	☐	☐	________
________	☐	☐	☐	________

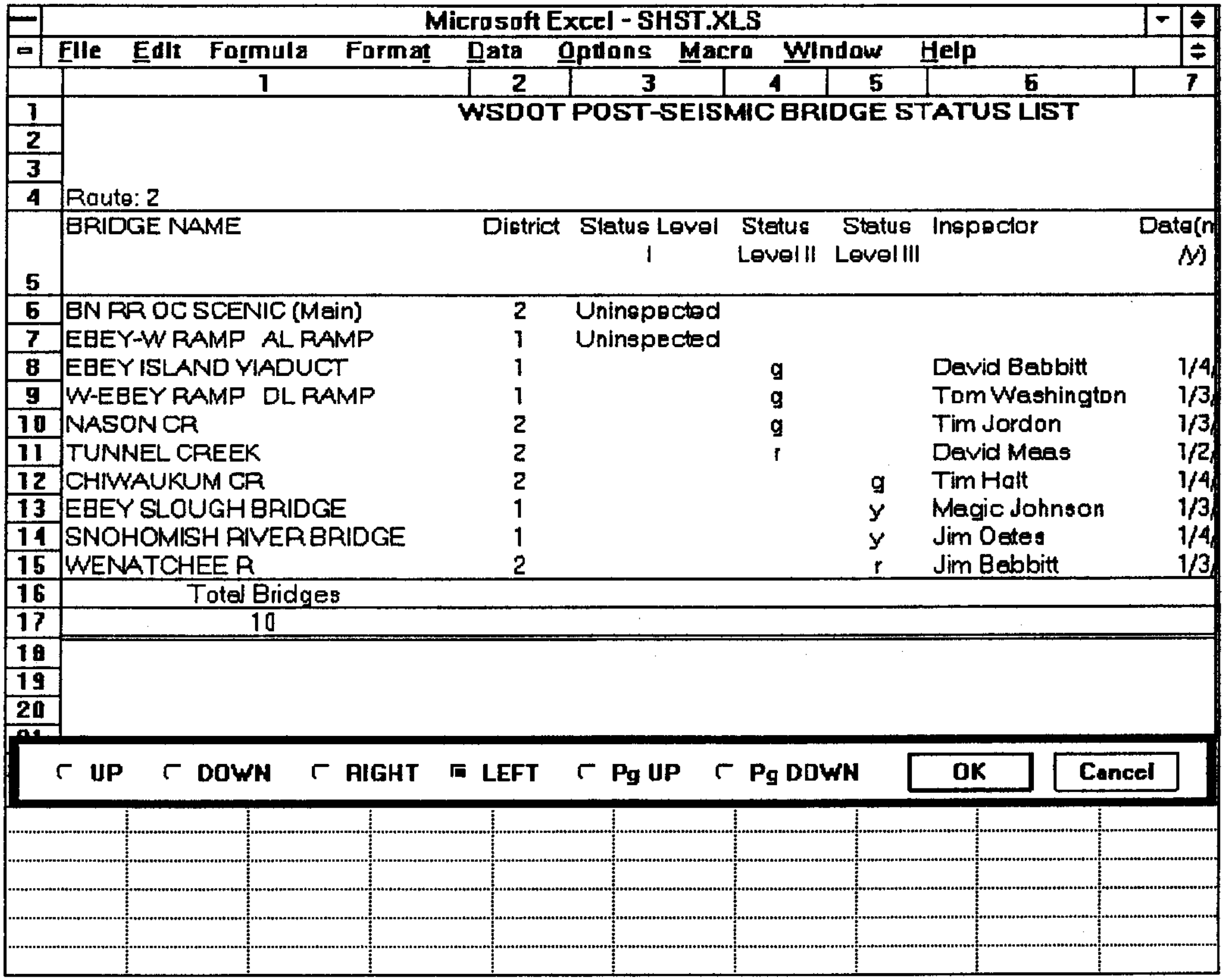
Figure 4. WSDOT <u>*LEVEL III*</u> *Post-Earthquake* Bridge Inspection Form (continued)

sample database ranking of bridges following inspection is given in Figure 5. This figure shows the database screen for a status summary of the bridges along the selected Route 2. The bridges show a letter rating for damage condition. For example, in the figure, "g" is green or safe. Details of the database are provided in Appendix B.

The organization of the post-disaster management is shown in Figure 6. Duties and responsibilities of all personnel are given in the guidelines provided in Appendix A. Figure 6 identifies the most important duties and the chain of command. First, the inspection command post has been designated to be the Mottman office. The Bridge and Structures office in Olympia will serve as the forensic investigations command center and will provide a link to the Mottman efforts. The Mottman role will likely diminish with time following the earthquake (i.e., as more of the bridges have been inspected). Repair efforts and investigation teams will become more important in the later hours after the earthquake. All affected districts should establish command centers immediately after an earthquake occurs. The districts most likely to be affected by an earthquake, such as 1, 3, and 4, should have compatible, detailed emergency response plans.

RESOURCES

Because the personnel requirements for emergency response cannot be precisely calculated, only approximate personnel requirements were estimated. First, the number of team leaders required for Level II and Level III inspections within a total 72-hour time period for the three types of events was estimated. The researchers considered estimates of the time required for travel and for bridge inspection under typical circumstances and introduced modifying factors for poor weather and light conditions. The calculations of required team leaders is given in Table 3 and 4 for all events for the Level II and Level III inspection analyses. The analyses for these calculations are described separately for the three types of earthquakes, moderate, major, and great, in the following paragraphs and in detail in Appendix C.



Microsoft Excel - SHST.XLS

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WSDOT POST-SEISMIC BRIDGE STATUS LIST

Route: 2

BRIDGE NAME	District	Status Level I	Status Level II	Status Level III	Inspector	Date(m/y)
BN RR OC SCENIC (Main)	2	Uninspected				
EBEY-W RAMP AL RAMP	1	Uninspected				
EBEY ISLAND VIADUCT	1		g		David Babbitt	1/4
W-EBEY RAMP DL RAMP	1		g		Tom Washington	1/3
NASON CR	2		g		Tim Jordon	1/3
TUNNEL CREEK	2		r		David Maas	1/2
CHIWAUKUM CR	2			g	Tim Holt	1/4
EBEY SLOUGH BRIDGE	1			y	Magic Johnson	1/3
SNOHOMISH RIVER BRIDGE	1			y	Jim Oates	1/4
WENATCHEE R	2			r	Jim Babbitt	1/3
Total Bridges						
10						

UP DOWN RIGHT LEFT Pg UP Pg DOWN OK Cancel

Figure 5. Sample Data Base Summary

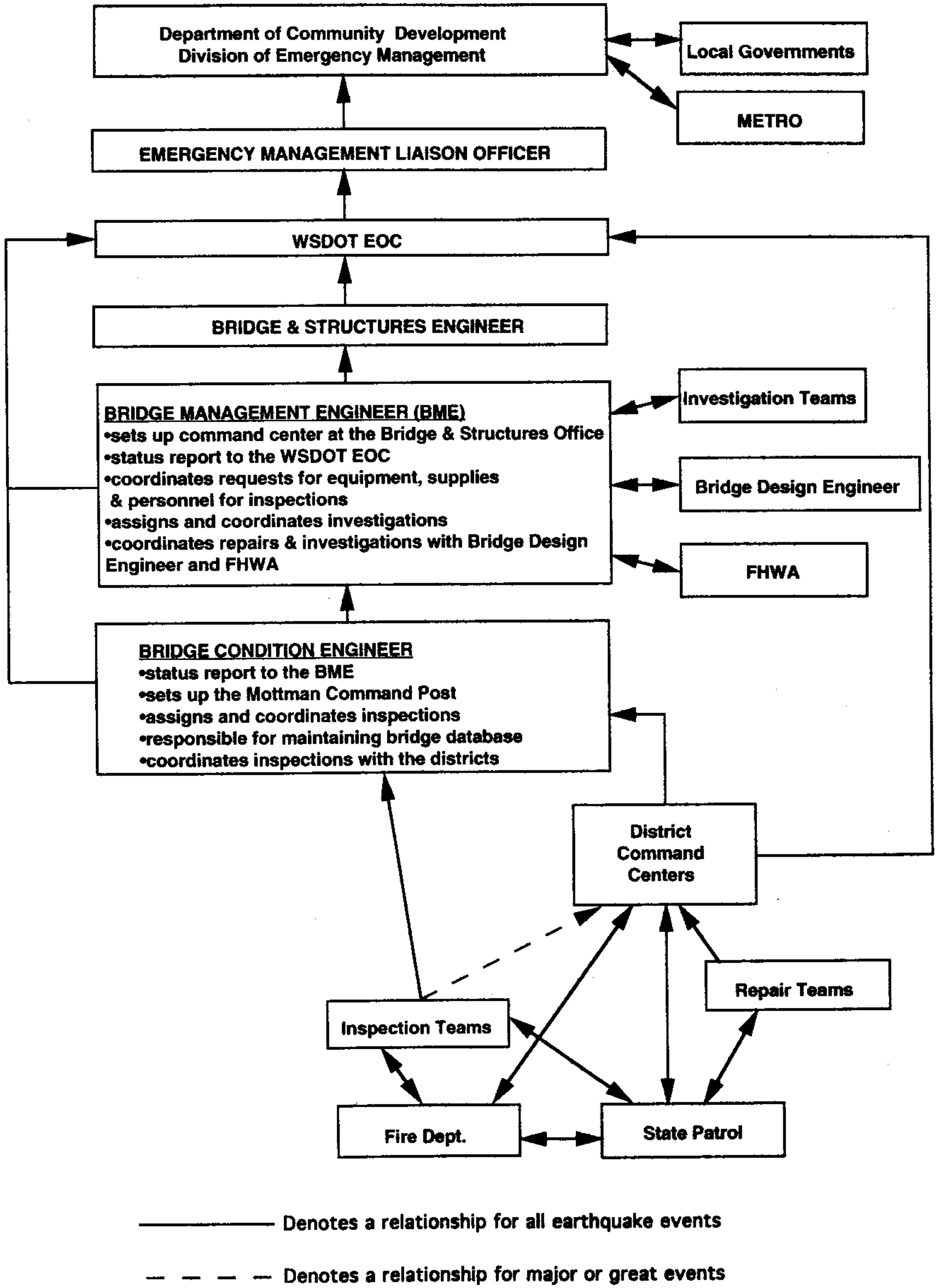

Figure 6. Emergency Response Communications for Bridge Management

Table 3. LEVEL II Inspection Calculations.

A total 48-hr inspection period is assumed.

Event	Rationale/ Source	Number of Bridges Used to Calculate Team Leaders	Number of Team Leaders Required
Moderate	All bridges with Structural Vulnerability Rate SV > 0	789	53-87
Major	Based upon Modified Mercalli Map [USGS]	1129	76-124
Great—assume only districts 1,3 and 4 affected	All bridges in districts 1, 3 and 4	1418	95-156
Great—assume all districts affected	All bridges in the database (districts 1-5)	1635	110-181

Table 4. Level III Inspection Calculations

A total 24-hr inspection period is assumed.

Event	Rationale	Number of Bridges	Number of Team Leaders Required
Moderate—Method 1	All bridges with Priority Index ≥ 35, corresponds approximately to Structural Vulnerability Rate ≥ 250	11	2-3
Moderate—Method 2	All bridges with Priority Index ≥ 25, corresponds approximately to Structural Vulnerability Rate ≥ 150	45	7-10
Major	Half of the bridges estimated for Level II based on MMI analysis (1189) were assumed to be affected.	698	94-154
Great—assume only districts 1,3 and 4 affected	Half of the total number of bridges in districts 1, 3, and 4 in the database (1418) were assumed to be affected.	709	94-156
Great—assume all districts affected	Half of the total number of bridges in the database (1635) were assumed to be affected.	820	109-180

The researchers used the priority index of the seismically vulnerable bridges contained in the WSDOT database to calculate the impact of a moderate event. For a moderate event, the total number of seismically vulnerable bridges is 789. That is, out of 1,418 bridges in districts 1, 3 and 4, 629 have priority index values of zero. This means that either the vulnerability index or the importance factor is equal to zero. Of the remaining 789, the priority index values range from slightly above zero to 54.7. The distribution of bridges in each district is as follows: 557 for District 1, 180 for District 3, and 52 for District 4. The larger the value of the priority index is (defined in equation (1)), the more important or the more vulnerable is the bridge. Two approaches were taken for the Level III analysis. First, only the bridges with priority indices of greater than 35, corresponding to structural vulnerability rates of greater than or equal to 250, were estimated to require the Level III inspection. For districts 1, 3 and 4, this number is 11. Second, all bridges with priority index values of greater than or equal to 25, corresponding to structural vulnerability rates of greater than or equal to 150, were estimated to require the Level III inspection. For districts 1, 3 and 4, this number is 45.

The major event calculations were undertaken in a different manner. Because the 1949 and 1965 earthquakes are considered major earthquakes, more information is available regarding the damage potential of earthquakes in this category. Using the estimates of damage from the USGS report for an earthquake in the Puget Sound region of Richter magnitude 7.5 (5, 6), the total number of damaged bridges was estimated to be 1,126. Of these, the total number of bridges requiring a Level III inspection was estimated to be 698. These numbers are consistent with the estimates for the moderate event based only on the priority index.

The great earthquake is the most difficult event for which to provide damage estimates. Therefore, to be conservative, two approaches were taken. First, for the Level II analysis, all of the 1,418 bridges located in the most vulnerable districts 1, 3 and 4 were assumed to require inspection. Second, all bridges in the WSDOT database (i.e., 1,635), were assumed to require Level II inspection. Some of these bridges would probably fail; because a detailed study would be required to estimate the number of failed bridges, it was assumed that no information would be available to eliminate bridges from consideration immediately. It was also assumed that approximately half of the bridges undergoing the Level II inspection would require Level III inspections. These estimates are consistent with those of the major and moderate events. Again, the estimates were assumed to provide conservative calculations of the personnel required for post-earthquake emergency response.

The number of team leaders required for Level II inspection given in Table 3 was calculated for 12-hour working shifts to ensure that all bridges would be inspected within the first 48 hours after the event and that all inspections, including Level III, would take place within the 72-hour emergency response period. According to the results, for the moderate event, under good conditions, 53 team leaders would suffice; under difficult conditions of poor weather and no daylight, 87 team leaders would be required to meet the demands. For the major earthquake, 76 team leaders would be able to complete the Level II inspections; 124 would be necessary under adverse conditions. For the great earthquake, if only districts 1, 3 and 4 were affected, 95 team leaders would be required under good conditions; under adverse conditions, 156 team leaders might be necessary. For the great earthquake, if all districts were affected, 110 team leaders would be required under good conditions; under adverse conditions, 181 team leaders might be necessary.

The number of Level III inspections can never be more than the number of Level II inspections; the worst case would be that all Level II inspected bridges would require Level III inspections. The results shown in Table 4 for Level III inspections suggest that under good conditions, only two or three team leaders would be required for the moderate event if it is assumed that only bridges with priority index values of greater than or equal to 35 would require Level III inspection. If bridges with priority index values of greater than or equal to 25 are considered for Level III analysis, then seven team leaders would be required for favorable conditions and 10 for adverse conditions. For the major event, if all 698 bridges were inspected within the emergency response period, the range of team leaders would be between 94 and 156. For the great event, the number of team leaders required to complete the Level III inspections within the emergency response period would be between 95 and 156 if only districts 1, 3 and 4 bridges were affected; if all districts are included, then the range would be 109 and 180. Because the critical emergency roadways for the state have not been formally designated, further refinement of the number of bridges that would have to undergo the Level III inspections following the great event during the 72-hour period cannot be made.

To assess the resources available, the researchers informally counted all trained personnel available in the Olympia office. Because the inspection resources are located at the Mottman office, rather than at the districts, the resources from the WSDOT headquarters in Olympia were considered in identifying team leaders. A breakdown by WSDOT job title of the number of employees in WSDOT headquarters in Olympia who could serve as Level II team leaders is shown in Table 5. Of the 68 employees listed, a minimum of five will be required for command center management. Attrition due to sickness, vacation, or disruption because of the earthquake itself, will decrease the pool to at most 60 employees available for team leadership at the Level II inspection level. However, even if 60 employees are available for inspection duties, 60 equipped vehicles are not available for use. Therefore, either substantial reductions in communications between the inspection teams and the command centers, or transportation of several teams in one vehicle, will be necessary if other fully equipped vehicles are not obtained from other sources.

In Table 6, calculations of possible team members for Level II inspections are given. Because the employees with the background and training in bridge inspection are located at Mottman and WSDOT headquarters in Olympia, these employees were considered for this emergency response investigation. Employees of the affected districts

Table 5. Employees located in Olympia who are qualified to serve as team leaders

	Job Title									
BRANCH	TPE2	TPE1	TSE	BES2	BES1	TE5	BE5	BE4	BE3	SUBTOTAL
Construction Support					1			4		5
Bridge Construction Office		1	3							4
Bridge Design	1			4	4		6	19	6	40
Bridge Management		1	1	1	1	3	1	7	3	18
Consultant Liaison						1				1
Subtotal	1	2	4	5	6	4	7	30	9	68

Table 6. Employees located in Olympia who are qualified to serve as team members

	Job Title							
BRANCH	BE2	BE1	MT3	TT3	TE2	TT2	TE3	SUBTOTAL
Bridge Design	5	3		2	6	2	1	19
Bridge Management	4	1	3	1	1	1		11
Subtotal	9	4	3	3	7	3	1	30

may be qualified to serve as team members for the Level II inspections, but they lack the training required for the Level III inspections. In addition, because the district management may assign duties to these employees for other emergency response tasks as outlined in (2), these employees have not been considered in the "head count" here. In the Recommendations section, a workshop to coordinate the emergency response plans is suggested, and this coordinated effort may reveal that a much larger pool of team members is available. A total of 30 employees from Olympia were assumed to be available under the present analysis; attrition as described above will decrease the pool to about 25 employees. These employees may assist the leaders as indicated in Table 5.

Therefore, approximately 50 teams consisting of two employees, at least one of whom is drawn from the team leader category, is assumed to be available for inspection. For a moderate event with good weather conditions, this number will suffice for Level II inspections. For a moderate event, this number will also be sufficient for Level III inspections. Although uncertainties are associated with the estimates for the major and great events, particularly for the Level III calculations, it appears that resources to provide these teams adequate transportation, support, and communications capabilities are not presently available for the major or great events.

INTERPRETATION, APPRAISAL AND APPLICATION

Presently, even with this plan, the WSDOT is very limited in its ability to effectively respond to any event other than a minor or moderate earthquake that incurs limited damage, with no other complicating factors such as inclement weather or rush-hour traffic. Steps to remedy this situation are provided in the recommendations section.

RECOMMENDATIONS

For the plan to be successfully implemented, resource limitations must be considered. Recommendations are discussed in the following paragraphs.

1. WSDOT management should be aware that sufficient personnel to undertake the inspections under all conditions are not presently available, as discussed in the Resources section. Decisions must be made regarding the means to overcome this shortage through volunteer efforts or partnership agreements with other agencies.

2. Radio communications systems for the Olympia and Mottman inspection teams should be installed in all vehicles. These systems must be the same as, or at least compatible with those of the districts. A radio communications center must be established at Mottman, or its capability to serve as a command post will be severely limited. Without this communications system, the plan will not be reliable under any circumstances. Reliance on phones following any natural disaster is unwise, as historically, the telephone system does not function after an earthquake at its full, pre-earthquake capacity for days or even weeks.

3. The buildings designated as command centers should be rendered operationally earthquake resistant. That is, the buildings should remain functional after an earthquake, but they do not have to be "unscathed" by an earthquake. For example, factors such as whether the load bearing walls are bolted to the foundation should be considered; all deficiencies should be corrected. Additionally, the interior contents of all command center buildings should be made as earthquake resistant as possible. For example, computers should be attached with velcro or other fasteners to desks; cabinets should be bolted to walls; and fire extinguishers should be

available. Power generators and supplies for personnel (to last 72 hours at a minimum) must be provided at all command centers. Again, the Mottman command post must have first priority for power generation, particularly for the gasoline pumps near the equipment shed, to operate. Although the policy is to fill the gasoline tanks of vehicles every afternoon before parking for the night, gasoline pumps may be required after the earthquake occurs. For example, an earthquake may strike in the afternoon before the gasoline tanks are routinely filled. In addition, in a great event, commercial gasoline stations will likely not be operating for days afterward.

4. Staging and storage areas in the Puget Sound region, particularly near the heavily populated Seattle-Tacoma area, should be identified and implemented. Implementation in this context means that emergency equipment or supplies should be stored at these sites now in preparation. The transport of heavy or large equipment after an earthquake is not advisable. Also, these areas are important for recovery communications and coordination of Olympia and district tasks.

5. Recruitment and training of a volunteer force for undertaking as many tasks as possible is critical to enable the greatest number of WSDOT engineers to be involved in the inspection process. Because inspection expertise is not something volunteer engineers could attain at a one-day seminar, these people should be used for the investigation of collapsed bridges, investigation of structural facilities for damage outside of the bridge area, or any other tasks that might support the progress of the inspections.

6. Better resolution of the critical roadway lifelines is needed. Presently, the seismic bridge database uses the priority and vulnerability indices to rank

the bridges in order of inspection importance. Although the priority index does take into account the importance of the bridge (4), and in moderate and major events this ranking may suffice, during a great event better resolution is imperative. Immediately following a great event, all inspection resources must be applied to the most critical lifeline without hesitation. For this reason, a study to identify these routes should be undertaken.

7. Participation in post-disaster response exercises on a regular basis is required to prepare for the real event. These exercises may be undertaken within WSDOT, or in conjunction with those staged by local agencies.

8. As shown in Figure 2, all bridges that have been heavily damaged or have collapsed and have been closed to traffic will be ranked for forensic investigation. The ranking will be undertaken by the Bridge Management engineer on the basis of the priority index or the vulnerability index and available resources. Pre-established teams of volunteers will probably be called upon to undertake most of this work. However, the rapid conduct and organization of this type of investigation under less-than-ideal conditions warrants further study.

9. Workshops for all inspectors by the Department of Community Development would provide training and guidance in decision making and duties during emergency life-or-death situations. Workshops for Olympia and district management on coordinating efforts would be useful.

10. Implementation of geographical information system (GIS) capability with the bridge database would be useful in providing immediate visual representation and routing when some bridges in the system have failed or are partially closed to traffic.

11. A better network of reporting and recording equipment may be useful. A system comprising seismic monitoring equipment, earthquake proof traffic assessment video cameras for daytime visual checks, and real-time computer checks on traffic to monitor traffic flow may prove to be useful in Level I inspection efforts and communication.

IMPLEMENTATION

The Instructions for Emergency Response may be distributed immediately. The document should be updated annually so that methods for contacting other districts or agencies will remain current. Complete implementation of the emergency response plan will not be possible unless resources are made available, as discussed in the Recommendations section of this report.

ACKNOWLEDGMENTS

The writers would like to extend their sincere appreciation to O.R. George and Willis Whitney for their technical guidance during this project. Ed Henley and Steve Tonks had many useful suggestions. WSDOT personnel in Districts 1 and 3, particularly Daryl Rush and Chris Keegan, contributed in gathering and supplying information that was important to the study.

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APPENDIX A

WSDOT BRIDGE AND STRUCTURES OFFICE PROCEDURES FOR EMERGENCY RESPONSE

WSDOT BRIDGE AND STRUCTURES OFFICE PROCEDURES FOR EMERGENCY RESPONSE

PURPOSE

The purpose of this document is to provide a list of actions for WSDOT bridge management to take after a catastrophic event involving bridges on the state highway system occurs. (Roles and responsibilities of the WSDOT are given in the Emergency Response Plan.)

Locations and phone numbers of the WSDOT Headquarters Emergency Operations Centers (WSDOT EOC), Mottman Command Post, and district command centers are in Table A.1. Table A.2 contains an alphabetical listing of organizations to contact for resources. In this document, a minor earthquake is defined to be one in which the Richter magnitude is in the range of 5 to 6; a major earthquake is in the range of 6 to 8; and a great earthquake registers at 8 and above.

No one can predict the occurrence or nature of a disaster. It is important that management personnel be familiar with the emergency procedures so that plans can be quickly implemented and adapted to the specific situation.

RESPONSIBILITIES

The primary objectives of the WSDOT in a post-disaster scenario are as follows:

- to ensure the safety of the traveling public,
- to protect state highway facilities from additional damage,
- to restore traffic on state roads as quickly as possible,
- to maintain a current assessment of the extent of the damage and operational status of the state highway system, and
- to effect ongoing communication with other responding agencies and public communication centers.

The specific responsibilities of the WSDOT Bridge and Structures Office are as follows:

Table A.1. Communications (July 1993)

Location	Phone Number(s)
STATE EOC Department of Community Development Emergency Management Division P.O. Box 48346 4220 E. Martin Way Olympia, WA 98504-8346	(206)459-9191/SCAN 585-9191
WSDOT EOC "HEADQUARTERS" Transportation Building P.O. Box 7358 Olympia, WA 98504-7358 Director: John Conrad, Chief Maintenance Engr.	(206)705-7851/SCAN 705-7851
Bridge & Structures Command Center Maple Park & Jefferson Street P.O. Box 47340 Olympia, WA 98504-7340 Contact: Bob George	(206)705-7208/ SCAN 705-7200
Mottman Command Post 2680 Mottman Road P.O. Box 47341 Olympia, WA 98504-7341 Contact: Jackie Jabara	(206)586-2802/SCAN 321-2802
District 1 Command Center -Seattle 15700 Dayton Ave. N. P.O. Box 330310 Seattle, WA 98133-9710	(206)440-4000/SCAN 440-4000
District 2 Command Center -Wenatchee 1551 North Wenatchee Avenue P.O. Box 98807 Wenatchee, WA 98801-1156	(509)663-9641/ SCAN 565-1641
District 3 Command Center -Tumwater 5720 Capital Blvd., Tumwater P.O. Box 47440 Olympia, WA 98504-7440	(206)357-2605/SCAN 357-2605 Fax: (206) 357-2601
District 4 Command Center -Vancouver 4200 Main Street, S-15 P.O. Box 1709 Vancouver, WA 98668-1709	(206)696-6621/ SCAN 476-6621
District 5 Command Center -Yakima 2809 Rudkin Road Union Gap P.O. Box 12560 Yakima, WA 98909-2560	(509)575-2516/SCAN 558-2516
District 6 Command Center -Spokane North 2714 Mayfair Street Spokane, WA 99207-0290	(509)456-3000/SCAN 545-3030
Corps of Engineers Emergency Operations Center 4735 E. Marginal Way S. Seattle, WA 98124	(206)764-3406
FHWA Barry Brecto Tom Johnson	 (206)753-9482 (206)753-9486

Table A.2. Alphabetical Listing of Resources (July 1993)

	Equipment & Supplies	Information	Personnel
American Red Cross Seattle-King County Chapter (206) 323-2345 FAX (206) 325-8211		X	
CALTRANS[1] •Bridge Management (916) 227-8840	X		X
Corps of Engineers[2] Emergency Operations Center (206) 764-3406	X	X	X
District 1-Seattle Command Center 440-4000/SCAN440-4000 Equipment: (206)768-5826/SCAN493-5826 Radio 105	X	X	X
District 2-Wenatchee Command Center(206)663-9641/SCAN 565-1641		X	
District 3-Tumwater Command Center(206)357-2605/SCAN 357-2605 Equipment:(206)357-2640/SCAN357-2640 Radio 305	X	X	X
District 4-Vancouver Command Center(206)696-6621/ SCAN 476-6621 Equipment:(206)696-6643/SCAN476-6643 Radio 405	X	X	X
District 5-Yakima Command Center(509)575-2516/ SCAN 558-2516 Equipment:(509)575-2574/SCAN558-2574 Radio 505	X	X	X
District 6-Spokane Command Center(509)456-3030/ SCAN 545-3030 Equipment:(509)456-3022/SCAN545-3022 Radio 605	X	X	
FEMA Federal Emergency Management Agency 130 228th St SW, Bothell, WA 98021 (206)487-4604,-4600,-4400		X	
FHWA •Barry Brecto 753-9482 •Tom Johnson 753-9486	X	X	X
Idaho State DOT •(208)334-8204			X

[1] These agencies may be busy inspecting their own damage if a subduction zone earthquake occurs. In some scenarios, the coastal region from Vancouver, B.C. to Northern California will be damaged.

[2] If a state of disaster is declared.

Table A.2. Alphabetical Listing of Resources (July 1993) (continued)

	Equipment & Supplies	Information	Personnel
KING COUNTY: •King County Emergency Management Room EA46, King County Courthouse Seattle, WA 98104 Lavon McCord (Supervisor) (206) 296-3830, 296-3311 •King County Public Works (206) 296-8100 Wallace Ip (206)296-3711/SCAN 667-3711, FAX (206) 296-8198	X	X	X
METRO •Emergency Planning (206) 684-1534, FAX 684-1741		X	
Military Go through WSDOT EOC			X
Natural Resources, Dept. of Ken Hoover, 902-1300 Heavy Equipment for Fire Control Only	X		
Newspapers News Desk [Puget Sound Region] •Seattle P-I/ Times (206) 448-8303 •Journal American (206) 453-4230		X	
Oregon State DOT[1] •Director: (503) 378-6388			X
SEATTLE: •City of Seattle Emergency Management Laura Clark (Director) (206) 233-5076 •Seattle Engineering Dept. Richard Miller/Timothy Lane (206) 684-5301	X	X	X
Television Stations •KCTS [Channel 9] (206) 728-6463 •KCTW [Channel 11] (206) 572-5789 •KING [Channel 5] (206) 448-5555 •KIRO [Channel 7] (206) 728-7777 •KOMO [Channel 4] (206) 443-4000		X	
Traffic System Management Center (TSMC) •Pete Briglia (206) 464-7592 (Videocamera for traffic control)		X	
Washington State Patrol • 911 or • Business office (206) 464-6610 [Seattle]		X	
WSDOT EOC("Headquarters") •Command Center: RM 1C4 Transportation Building (206)705-7851/ SCAN 705-7851 •Equipment Administrator (206)586-6141/SCAN321-6141 •Transportation Equipment Manager (206)753-6012/SCAN234-6012 Radio 5	X	X	X

1) Conduct a rapid survey of all bridges in the area(s) affected by the disaster to identify unsafe bridges. This type of inspection is called a Level I Inspection. A flow chart showing the four levels of inspection is given in Figure A.1. Table A.3 describes the inspection levels.

2) Provide technical guidance to district personnel for emergency actions that must be taken to ensure public safety and to prevent additional damage to the structures.

3) Conduct a detailed survey of all bridges in the affected area, identifying all damaged structures and recording the nature and extent of damage of each structure (Level II Inspection, and Level III Inspection if needed, see Figure A.1 and Table A.3).

4) Recommend repairs to be done to damaged bridges and provide plans, specifications, and estimated cost of those repairs.

5) Maintain information files for all inspected bridges, recording information regarding operational status, general description of any damage repair activity, and rough cost of repairs.

6) Develop periodic summaries and reports for upper management and emergency operations centers.

The Mottman Command Post will be responsible for directing the initial inspection efforts, including maintenance of the bridge status database file(s). The Bridge and Structures Command Center in Olympia will be responsible for developing and issuing status reports, preparing capacity calculations for damaged bridges, and preparing plans for investigation and repair. The Bridge and Structures Command Center in Olympia will coordinate the design effort for major repairs and any necessary coordination with the FHWA.

The district command center will frequently communicate detailed information (called in, if possible) to the Mottman Command Post in the first 24 to 48 hours and at least twice a day until the urgency subsides. For critical bridges, such as viaducts, major interchanges, and waterway crossings, reports should be communicated immediately.

The supervisor of the Mottman Command Post will be responsible for developing and maintaining the information file. He will also prepare inspection progress and damage assessment reports for the Bridge Management Engineer and others, as required.

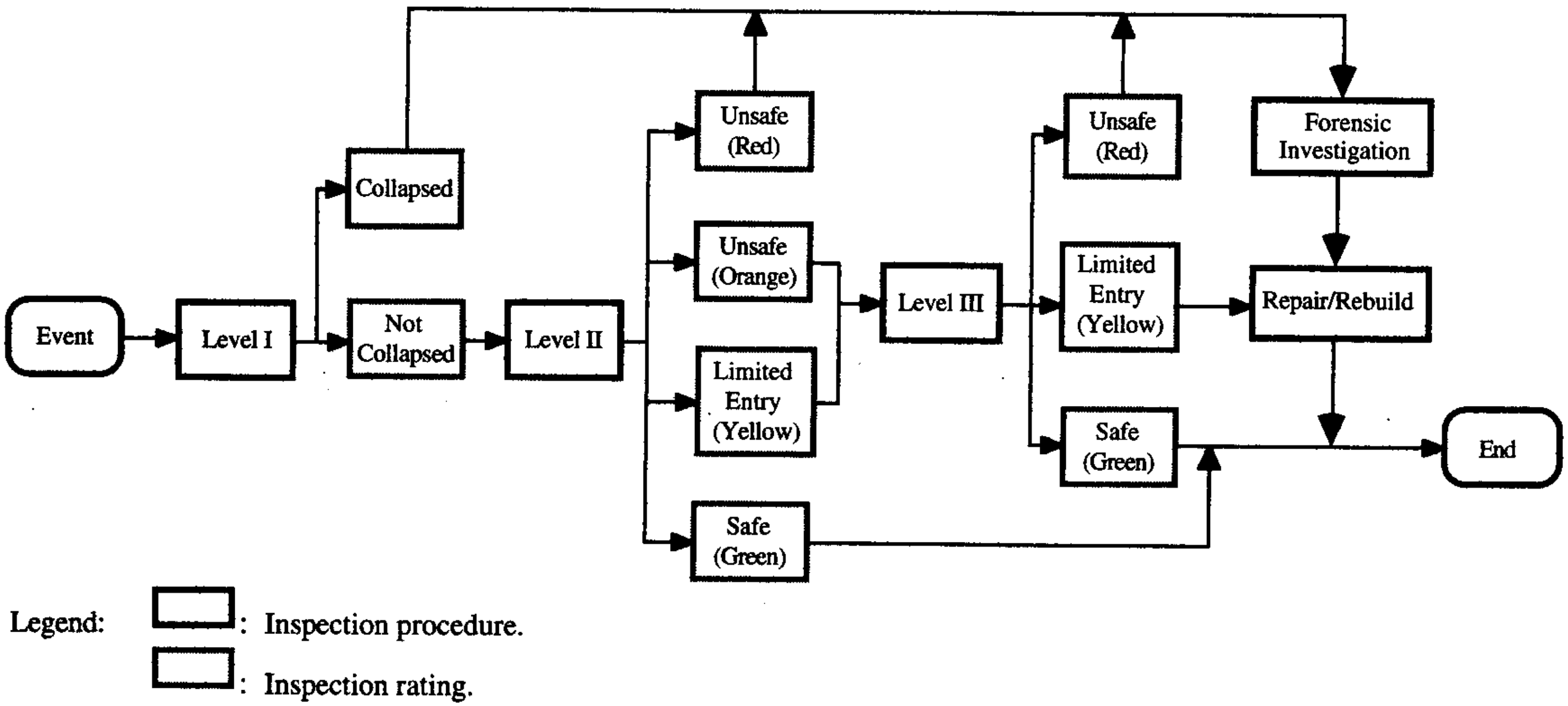


Figure A.1. Overview of the Emergency Response Inspection Procedures

Table A.3. Description of Inspection Levels

	Level I	Level II	Level III
Application Range	All bridges within the area affected by the earthquake	All bridges in affected area except those that collapsed or suffered partial collapse	All bridges recommended for further inspection by Level II teams
Method of Inspection	Aerial View (Helicopter) or Drive through or Traffic video-camera	For great event: helicopter. For other events, probably regular van-type transportation will be needed	For great event: helicopter. For other events, probably regular van-type transportation will be needed
Personnel	To be designated	Team of WSDOT personnel or volunteers led by an experienced WSDOT inspection engineer	"Regular" inspection teams
Objectives	(1) To close all unsafe bridges (2) To identify routes that cannot be traversed (3) To identify the geographical extent of damage/ affected area	(1)To close all unsafe bridges (2) To identify routes that cannot be traversed (3) To assess the structural and geotechnical post-earthquake vulnerability of the bridge	(1)To close all unsafe bridges (2) To assess the structural and geotechnical post-earthquake vulnerability of the bridge and to make recommendations for repair (3) To limit access to or close damaged bridges (4) To identify routes that should not be traversed
Resources	Helicopter(s), back-up power and casings for traffic video installations	"regular"/ existing inspection team equipment in addition to radios and cellular phones for communications; mountaineering equipment for access under unusual conditions; water, food and supplies for 72 hours per person	"regular"/ existing inspection team equipment in addition to radios and cellular phones for communications; mountaineering equipment for access under unusual conditions; water, food and supplies for 72 hours per person

A copy of these reports will be transmitted daily to the applicable district command center.

To assist the limited staff in the district(s), inspection and support personnel will be sent from the Mottman Command Post as needed. For each district, the administrator should make an early assessment of his needs (Level I Inspection) and request the number of personnel and skills required.

On the basis of the reports from the field personnel, the Bridge Condition Engineer will assess the need for special equipment and transmit a request to the unaffected districts, as well as to the Bridge Management Engineer or the WSDOT EOC.

ACTIONS

Inspection Supervisors

Any earthquake within the state that causes damage to the state highway system will be considered a disaster. When a disaster occurs, the Bridge Management Engineer or the Bridge Condition Engineer will be contacted by at least one of the following: the district maintenance staff, the Mottman office, or the WSDOT EOC. The first person reached should establish contact with the WSDOT EOC, or the Chief Maintenance Engineer or alternate, and the Bridge and Structures Engineer. He should then contact other Bridge Office supervisors to apprise them of the situation to mobilize staff.

Each employee of the Bridge and Structures Division should keep a copy of the inspection call-out alert list and home phone list at his residence.

The inspection team leaders will be contacted by a Regional Inspection Engineer or the Special Structures Engineer. The team leaders will contact and assemble their team members.

Staff-General

After the occurrence of a major disaster, phone lines may be out of service or heavily congested. If employees have not been contacted, and it seems possible that their services will be needed, they should call the office or report to the nearest contact office for instructions. For the district staff, contact offices are the district command center or the communications center. Employees should advise these offices of their location and availability.

Bridge Inspection personnel on a field assignment should call the Mottman office for instructions or proceed directly to the district command center in the damaged area.

Overview

Figure A.2 provides an overview of the actions to be taken during the post-earthquake emergency response process. The actions of bridge management are outlined in this figure, and described in detail in the next sections. Checklists for the Bridge Management Engineer, Bridge Condition Engineer, team leaders, and team members are provided at the end of this appendix.

OFFICE ACTIVITIES

Responsibilities of the Bridge Management Engineer

1) Ensure that the Mottman Command Post is set up, operational and adequately staffed.

   - Advise the Bridge Condition Engineer to set up the bridge inspection command post in the Mottman office. If the Bridge Condition Engineer cannot be reached, either establish the Mottman Command Post, or designate an acting chief to do so. Provide the telephone number of the command post to all staff members and to headquarters and district command centers.

2) Establish, or designate an acting chief to establish, a command center at the Bridge and Structures Office for the coordination of requests from Mottman and the districts for Level II and III inspections. Subtasks include the following:

   - Identify personnel available for inspection teams or other tasks.
   - Respond to requests for engineering information for structural assessments from the field.
   - Establish a 24-hour staffing schedule for the command center.
   - Post maps of the damaged areas.

3) Contact the WSDOT EOC to inform them of your activities. Contact them for additional communication needs, such as cellular phones, extra battery packs and re-chargers, additional phone lines, etc.

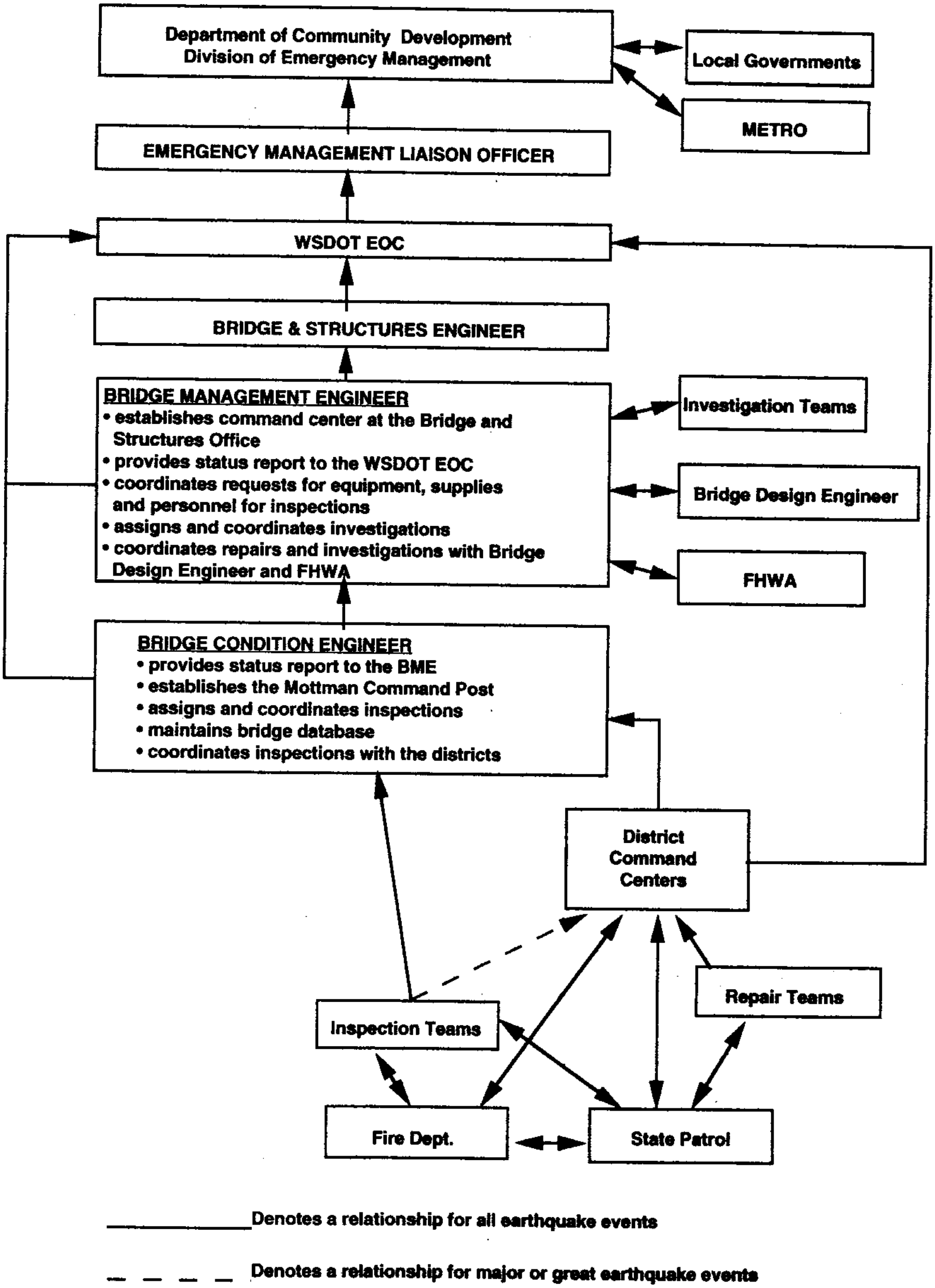


Figure A.2. Emergency Response Communications for Bridge Management

4) Initiate and coordinate assignment of WSDOT team members to FHWA-WSDOT Damage Assessment Teams.

5) Designate a staff member to collect and record information on all repair projects. There may be a large number of damaged structures and numerous emergency repair projects. Repairs will be done by maintenance forces, emergency contracts, regular contracts, or by change orders for bridges within the limits of on-going construction contracts. Depending on the size and complexity of the repair project, design of the repairs may be handled by field personnel or by the Bridge Design Branch. To avoid confusion, duplication of assignments, false starts, etc., a staff member should be assigned to collect and record information on all repair projects. This person should be the central source and clearing house for information regarding repair projects. Copies of the bridge reports related to damage inspection in a district will be sent to the district administrator.

6) Conduct daily staff meetings to provide a brief summary of important events, decisions, agreements, and assignments.

7) Assign and coordinate investigation teams as reports are received from the field.

8) Prepare and distribute a daily summary report to the Bridge and Structures Engineer and the WSDOT EOC. The summary should consist of short remarks to keep those involved informed.

Responsibilities of the Bridge Condition Engineer

1) Contact the Bridge Management Engineer to advise on the location of the event and activities. If the Bridge Management Engineer cannot be reached, contact the WSDOT EOC or the Chief Maintenance Engineer.

2) Establish, staff, and operate the Mottman Command Post. Subtasks of establishing the Mottman Command Post include the following:

- Assign an Inspection Engineer to accompany any initial reconnaissance flight.
- Assign a staff member to create a computer data file to record damage reports as they are called in. Diskettes for producing the reports and managing the information database are kept by both the Bridge Condition Information Engineer and the Bridge Deck Program Engineer.
- Assign a staff member to receive and redirect noncritical phone calls to minimize key manager involvement. Calls from the media should be directed to the Public Affairs Office.
- Assign a staff member to receive, record, and forward offers from other agencies and the private sector to provide equipment, material, special services, advice, etc., to the WSDOT EOC and appropriate district command centers.
- Post maps of the damaged areas to provide a visual display of damage sites.

- Establish a 24-hour staffing schedule for the Mottman Command Post as needed.

- Assign a staff member to coordinate lodging requirements for all out-of-town Mottman personnel involved in disaster-related activities.

3) Identify inspection needs for and coordinate inspection efforts with affected districts.

    - For a minor event, assign inspection team leaders and teams, coordinating efforts with district personnel and send to the affected district(s).

    - For a major or great event, delegate the coordination of teams and inspection team leaders to Bridge Inspection Supervisors who will travel to the affected district command center(s) to coordinate local efforts. These engineers should report to the Bridge Condition Engineer every 2 hours during the first 24 hours after the event, or as often as necessary.

4) Request additional supplies, equipment, and personnel through the Bridge Management Engineer or the WSDOT EOC.

5) Inform the Bridge Management Engineer of collapsed or severely damaged bridges to which a forensic investigation team should be sent.

6) Prepare summary reports for the Bridge Management Engineer.

Responsibilities of the District Administrator

For a major or great event, the affected District Administrators will set up command centers in their district offices.

They should implement other office activities as listed under the responsibilities of the Management Supervisors in the WSDOT Emergency Response Guide or request assistance from the WSDOT EOC in Olympia. These activities will include a monetary estimate of the repairs required, based on Level I inspections, i.e., reports from field personnel and other sources. This estimate is crucial because the subsequent actions the Governor takes will be greatly influenced by this estimate. Formal assistance from FEMA and other federal government agencies, such as the military, will be provided only if the region is declared a "disaster area."

The District Administrator will not be responsible for assembling the Inspection (Damage Assessment) Teams. However, a staff member should be designated to obtain blocks of rooms at commercial lodging facilities for incoming inspection teams and out-of-town personnel.

District office activities should be coordinated with those of the Mottman Command Post and the Bridge and Structures Command Center in Olympia to avoid duplication of effort and ensure that all necessary activities are undertaken.

FIELD ACTIVITIES

Responsibilities of Inspection Engineers

In a major or great event, the Bridge Condition Engineer or the Bridge Management Engineer will dispatch an Inspection Supervisor to establish immediate bridge inspection coordination at the district command centers. The Inspection Supervisor will direct the bridge damage assessment effort and prioritize and coordinate emergency bridge repair activities within the district. The Inspection Supervisor will coordinate the Inspection Team's efforts with district maintenance crews. Level II inspections may be made with a Bridge Inspection team leader and crews of maintenance personnel. Level III inspections will require additional bridge inspection engineers to assist the team leader. Maintenance personnel should accompany the Level III teams to initiate repairs. The Inspection Supervisor will coordinate efforts for the repair or shoring of damaged structures with the Bridge and Structures Office Command Post in Olympia.

Field Inspections

All field personnel should apprise the Mottman Command Post and the appropriate district command center of where they will be spending the night. Affected districts should request blocks of rooms at commercial lodging facilities for inspection teams and out-of-town personnel. This will greatly facilitate the recovery management efforts.

1) By the time the Inspection Teams arrive at their assigned area, district maintenance crews will usually have already checked for damage (Level I inspection). Unless given other instructions by Bridge Management in Olympia or Mottman, the team should check with the district personnel to discover which structures have been damaged. These structures should be

inspected first (Level II and III Inspections), so that emergency actions to shore or repair these structures can begin as soon as possible.

2) If the members of the Inspection Team are not familiar with an area, they should request the assistance of at least one district maintenance staff member. These individuals can guide the team through alternate routes if heavy damage has occurred.

3) All damage assessment teams should have local maps and a copy of the Bridge List with them.

4) After the severely damaged bridges have been initially inspected and actions have been taken to ensure their safety, a more detailed inspection or investigation should be undertaken. Inspection Engineers should ask the districts to provide equipment and personnel to help in this effort.

5) Hinges in box girders, footings, and piles are structural elements that are sometimes difficult to inspect. These elements may suffer great damage under seismic motion. Good indicators of possible damage are spalling of the concrete at deck expansion joints, barrier rails and bearing seats, and large cracks or ground settlement over the footings.

6) Aftershocks, traffic, or simply gravity loading may extend damage in an already damaged structure. Inspection teams should mark all the termination points and width of large cracks and provide references on the structure itself to facilitate the detection of condition changes in the bridge's members.

7) Collapsed and severely damaged bridges should be investigated by forensic investigation teams assigned by the Bridge Management Engineer. The Bridge Management Engineer will also coordinate the activities of the investigative forensic teams, as well as their interactions with the FHWA.

Closures, Repairs and Shoring

1) At the beginning of any inspection, first consider the following:

   a) Is the structure in imminent danger of collapse? If so,

      i. Coordinate with the State Patrol to stop traffic from crossing the bridge.

      ii. Radio for district assistance to provide temporary barricades.

      iii. Inform the District Command Center of the closing.

   b) What needs to be done to ensure public safety and prevent further damage?

      i. Traffic restrictions on the bridge will be implemented by the districts based on the recommendations of the inspection teams.

ii. Shoring or repair requests should be sent to the appropriate district command center.

2) The district command centers will make decisions concerning repair implementation.

3) The district command centers will inform the Mottman Command Post of closings and repairs.

Reports

The first reports to be submitted will be verbal ones sent to the Mottman Command Post as soon as possible following a disaster.

Every 2 hours, or as requested, more refined and detailed reports should be submitted to the Mottman Command Post. These reports should define affected areas and identify closed roads and highways.

Communications

The Mottman Command Post will notify the involved districts of Inspection Teams or Inspection Engineers coming to their area.

Team Leaders will maintain regular contact with the Mottman Command Post or district command centers via vehicle-mounted and hand-held highway radios or telephones.

Teams will communicate with each other with hand-held highway radios if necessary. The teams will communicate with the district maintenance personnel by face-to-face contact in the field, highway radio, and telephone. The District 1 Communications Center may relay messages between the two groups.

The Bridge Management Engineer will inform the Bridge and Structures Engineer and the WSDOT EOC of the status of the inspections.

Other means of communication between the Olympia Bridge and Structures office, the Mottman office, and the district command centers include FAX machines and cellular phones. These phone numbers should be made available to all EOCs.

During the hours immediately following an earthquake, it may be necessary for all radio networks to be controlled at one of the following levels:

- Code GREEN: Normal use of radios.
- Code YELLOW: Use only by field personnel for emergency purposes.
- Code RED: No use unless requested by the WSDOT EOC, or if there is a life and death situation.

CHECKLIST FOR THE BRIDGE MANAGEMENT ENGINEER

#	ITEM	
1.	Advise the Bridge Condition Engineer to establish the bridge inspection command post in the Mottman office. If the Bridge Condition Engineer cannot be reached, either set up the Mottman Command Post, or designate an acting chief to do so.	
2.	Establish, or designate an acting chief to establish, a command center at the Bridge and Structures Office for the coordination of requests from Mottman and the districts. • Identify personnel available for inspection teams or other tasks. • Respond to requests for engineering information and structural assessment requests from the field. • Establish a 24-hour staffing schedule for the command center. • Post maps of damaged areas.	
3.	Contact the WSDOT EOC to inform them of your activities. Contact them for additional communication needs, such as cellular phones, extra battery packs and re-chargers, additional phone lines, etc.	
4.	Initiate and coordinate assignment of WSDOT inspection team members to the FHWA-WSDOT Damage Assessment Teams.	
5.	Coordinate with the Bridge Design Engineer on needed assistance in repair design and on the need for design personnel to assist on inspections or damage assessments.	
6.	Repair Project Information: • For a minor event, designate a staff member to collect and record information on all repair projects. • For a major or great event, designate staff member(s) as necessary for each affected district to coordinate the collection and recording of information on all repair projects.	
7.	Conduct daily staff meetings to provide a brief summary of important events, decisions, agreements, and assignments.	
8.	Assign and coordinate investigation teams as reports are received from the field.	
9.	Prepare and distribute daily a summary report to the Bridge and Structures Engineer and the WSDOT EOC.	

CHECKLIST FOR THE BRIDGE CONDITION ENGINEER

#	ITEM	
1.	Contact the Bridge Management Engineer to advise on the whereabouts of the event and activities. If the Bridge Management Engineer cannot be reached, contact the WSDOT EOC.	
2.	Establish, staff and operate the Mottman Command Post, or designate an acting chief to carry out these functions[1]. • Assign an Inspection Engineer to accompany any initial reconnaissance flight. • Assign a staff member to create a computer data file to record damage reports as they are called in. Diskettes for producing the reports and managing the information database are kept by both the Bridge Condition Information Engineer and the Bridge Deck Program Engineer. • Assign a staff member to receive and redirect noncritical phone calls to minimize key managers involvement. Calls from the media should be directed to the Public Affairs Office. • Assign a staff member to receive, record and forward offers from other agencies and the private sector to provide equipment, material, special services, advice, etc., to the WSDOT EOC and appropriate district command centers. • Post maps of the damaged areas to provide a visual display of damage sites. • Establish a 24-hour staffing schedule for the Mottman Command Post, as needed. • Assign a staff member to coordinate lodging requirements for all out-of-town Mottman personnel involved in disaster-related activities.	
3.	Identify inspection needs for and coordinate inspection efforts with affected districts. • For a minor event, assign inspection team leaders and teams, coordinating efforts with district personnel, and send to the affected district(s). • For a major event, delegate the coordination of teams and inspection team leaders to Bridge Inspection Supervisor(s) who will travel to the district command center(s) to coordinate efforts. These Engineer(s) should report to you every 2 hours during the first 24 hours after the event, or as you request. • For a great event, identify available personnel for inspection. Contact the Bridge Management Engineer or the WSDOT EOC for further instructions.	
4.	Request additional supplies, equipment and personnel from the Bridge Management Engineer or the WSDOT EOC.	
5.	Inform the Bridge Management Engineer of collapsed or severely damaged bridges to which an investigation team should be sent.	
6.	Prepare summary reports for the Bridge Management Engineer.	

[1]All of these items are based on the assumption that power or a power generator will be available at Mottman. Otherwise, the WSDOT EOC will have to provide facilities.

CHECKLIST FOR TEAM LEADERS

1.	Assemble team after receiving directions from the Bridge Condition Engineer.	
2.	Check the personal equipment of each team member.	
3.	Check the van and communications equipment before leaving Mottman or other location.	
4.	Notify the district command center of the team's location when you enter or leave a district. • In a minor earthquake, all inspections will be coordinated directly from the Mottman Command Post. • If a major or great event occurs in which more than one district is affected, the Mottman Command Post will delegate the coordination of inspections in each district to an Inspection Supervisor who will be located at the district command center. In this instance, you will report directly to the district command center instead of to Mottman.	
5.	Provide inspection results to the Mottman Command Post (or district command center in a major or great earthquake) every 2 hours when contacted, unless told otherwise by The Bridge Condition Engineer (BCE). • If it is necessary to keep the lines of communication open, the BCE will contact you at specified times. • Contact the Mottman Command Post (or district command center in a major or great earthquake) for equipment, supplies, or personnel requests.	
6.	Take photographs of every bridge inspected that shows signs of damage. Keep a photograph log.	
7.	Get the names and addresses of persons who may have taken photographs before you arrived.	
8.	Coordinate with other emergency departments, such as the State Patrol or Fire Department. (In any situation on the highway involving several agencies, the State Patrol is always in charge.)	
9.	In any unexpected situation, make decisions based on the objectives of ensuring the safety of the traveling public and protecting state property, and contact the Mottman Command Post (or district command center in a major or great earthquake) ASAP.	
10.	When finished with your shift, provide the Mottman Command Post (or district command center in a major or great earthquake) with your motel name, location, and phone number.	
11.	Inspection Focus - The following items should be checked in any post-earthquake inspection: • Bearings, • joints, • primary structural elements, and • alignment of rails, members and joints.	

CHECKLIST FOR TEAM MEMBERS

1.	Assemble your personal equipment.	
2.	Coordinate with your team leader. If you do not know who your team leader is, ask The Bridge Condition Engineer to identify him/her.	
3.	Take photos of all inspected bridges showing damage.	
4.	Get the names and addresses of persons who may have taken photos before you arrived.	
5.	Be sure to identify any markings made on the bridge, such as the ends of significant cracks with the date, the time, and your initials. Because of aftershocks, someone may have to return to inspect the bridge soon after you leave.	

APPENDIX B

DATA BASE USER'S GUIDE

DATABASE USER'S GUIDE

This guide provides a brief description of an example of an emergency response inspection database. This database was developed using the existing WSDOT seismically vulnerable bridge database. This guide provides an example of the type of database procedures that would be useful for emergency response management. This section is written as a user's guide to the database and explains the types of commands implemented.

A command macro has been written so that you, the computer user, can run the macro to perform the basic operations of the database. You can enter bridge inspection information at different inspection levels and obtain bridge status reports. The inspection data are entered in forms provided so that you can quickly find a single bridge inspection result for the corresponding level of inspection. With a bridge status report, you can identify the latest inspection level and the priority for the ongoing inspection level if it is needed. District numbers, route numbers, inspectors, and dates of inspection are also shown in the status report. You may print, browse, or save the status report within the macro. If you would like to edit a status report in your own format, you must save the status report, exit the macro, then open the report in an Excel worksheet and edit it as you would any other Excel worksheet.

Dialog boxes were designed to guide you in making choices. Running the macro is easy and only requires selecting dialog boxes with the mouse.

This guide describes the features of the macro and gives procedures for using it to complete the tasks designed. The database file and the macro file were developed using Microsoft Excel 3.0 for Windows.

INSTALLATION OF THE FILES

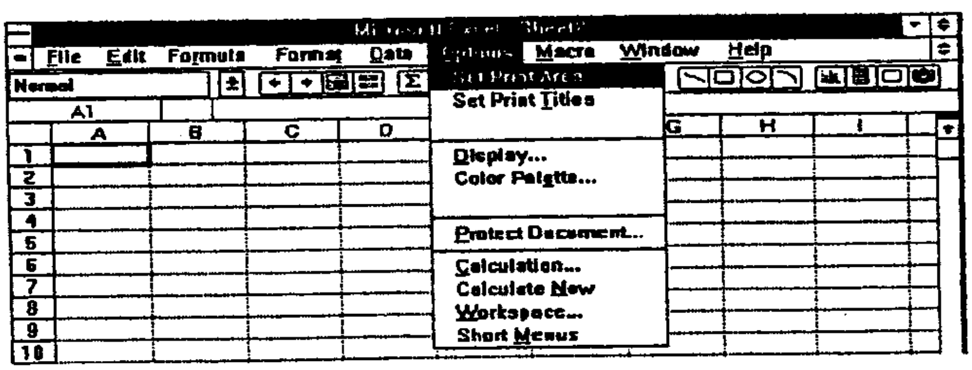
For the most efficient use of the database, install the database file and the macro file in your computer's hard disk drive. To do this, at the DOS prompt, copy the files from the floppy disk of your computer to the hard disk drive. The files are: PRO2.XLM, DBA.XLS, SHST.XLS, and SHST1.XLS.

Note You should avoid opening files in the floppy disk with Excel, and then later, saving them to the hard disk drive. Since the macro file PRO2.XLM refers to the database file DBA.XLS of the same directory, using two drives may cause the macro file to refer to the database file in another directory. Consequently, the macro may not run correctly.

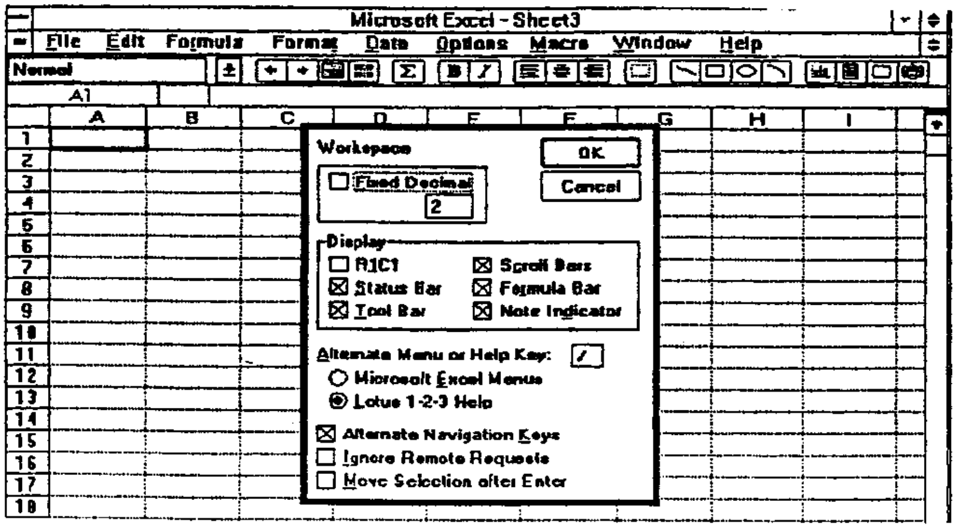
RUNNING THE MACRO

The macro and database files were developed in the R1C1 reference style. Before opening the files, you must change the worksheet to R1C1 style if it is in the A1 style. To do this, select "Workspace..." under the "Options" menu of Excel, as shown in the figures below. A dialog box will appear. Use the mouse to click the "R1C1" style name, and then click on the "OK" button to change the style. The macro was designed to run automatically every time you open the file DBA.XLS. To start the macro, open the file DBA.XLS in Excel. On the other hand, if you choose "Exit" in the main menu dialog box of the macro, the macro automatically closes the file DBA.XLS and saves the changes you have made, i.e., the bridge inspection results. The last thing you do is close the file PRO2.XLM.

- **Options Menu** appears when "Options" is selected:

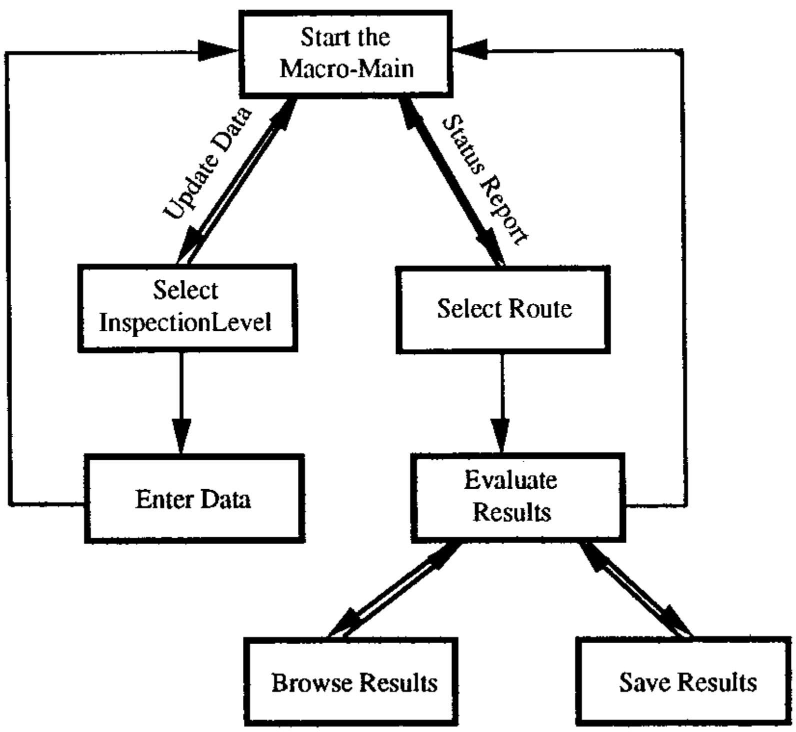


- **Workspace dialog box** appears when "Workspace" under the "Options" menu is selected:



Summary of Operations

The figure below identifies the operations available in the macro. Each selection is described separately in the sections below.



START THE MACRO - MAIN MENU

1 Start Excel.

2 Change worksheet reference style to R1C1 if it is in the A1 style.

3 Open the file DBA.XLS.

4 Click "Continue" button on the first screen. (The main menu dialog box appears.)

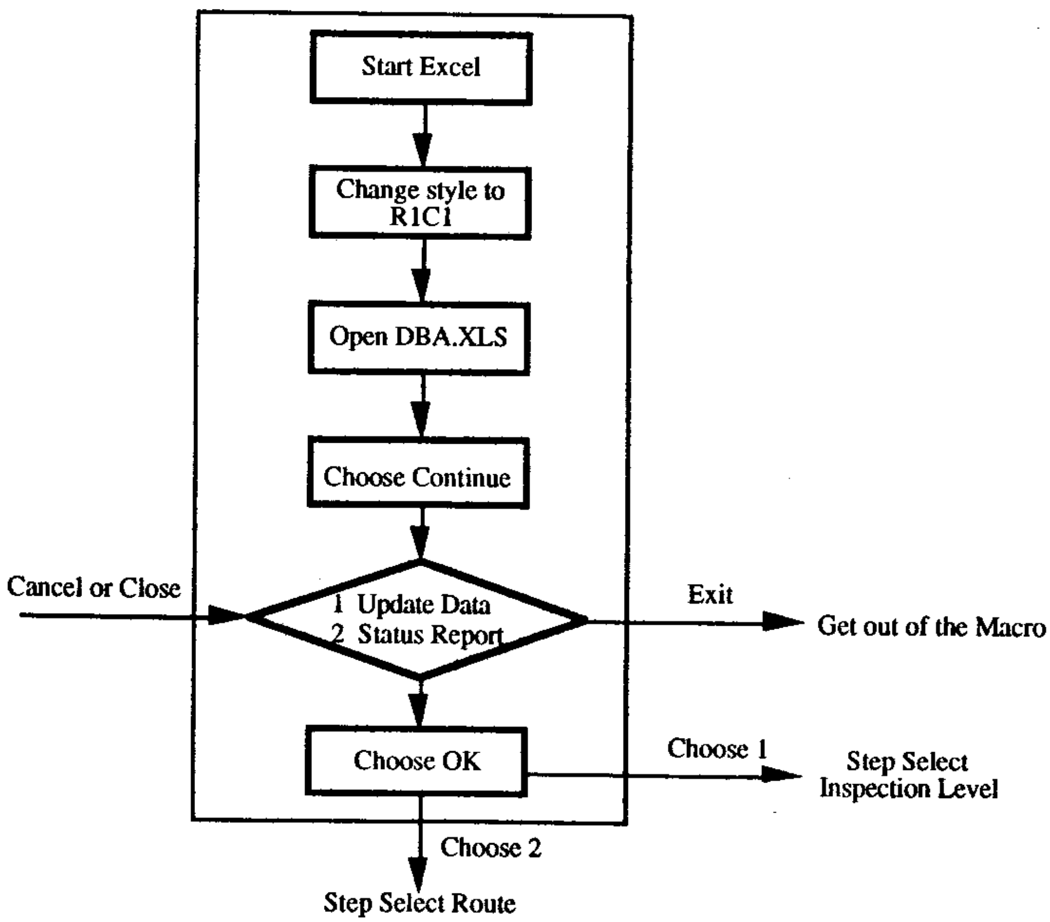
5 Choose "Update Data" to enter inspection results or "Status Report" to view the inspection result and/or priority for ongoing inspections.

6 Choose "OK" to proceed.

If you have chosen "Update Data," go to "Select Inspection Level." If you have chosen "Status Report," go to "Select Route."

Choosing "Exit" will let you quit the macro, and return to the Excel worksheet. The file DBA.XLS is saved automatically with the changes you have made. **Before you leave Excel, close the file PRO2.XLM and do not save any changes.**

Summary of Operations



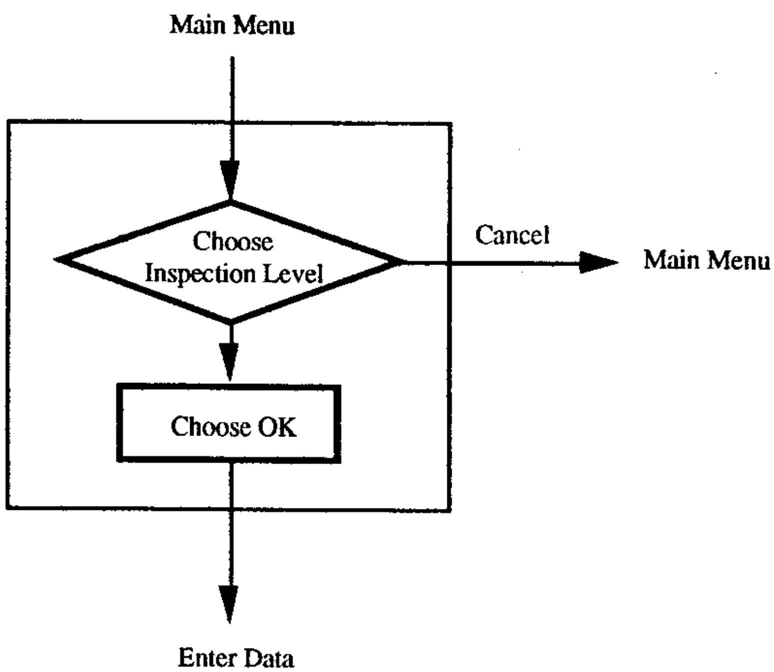
SELECT INSPECTION LEVEL

1 Choose the inspection level you want.

2 Choose "OK."

The "Cancel" button returns the control to the Main Menu.

Summary of Operations



ENTER DATA

There are three data forms corresponding to Level I through Level III inspections. On the right side of data forms, there are a "Record Number" indicator and six command buttons. Their functions are as follows:

- **Record Number indicator/Criteria**—Indicates which record is displayed and how many records are in the database. When you choose the "Criteria" button, it changes to the word "Criteria."

- **New**—Adds a new blank record to the bottom of the database.

- **Delete/Clear**—The "Delete" button deletes the displayed record permanently. If you choose the "Criteria" button, it changes to the "Clear" button, which clears all existing criteria.

- **Restore** —Cancels the changes you have made and restores the record to its original contents, as long as you do so before moving to a different record.

- **Find Prev**—Goes to the previous record or searches backward through the database and displays the previous record that matches the specified criterion.

- **Find Next**—Goes to the next record or searches forward through the database and displays the first record that matches the specified criterion.

- **Criteria/Form**—Switches between the regular data form and the criteria form. When you choose the "Criteria" button, the record number indicator changes to the word "Criteria," the "Criteria" button changes to the "Form" button, and the "Delete" button to the "Clear" button.

The operations of entering data are listed step by step as follows:

1 Choose the "Criteria" button.

2 Choose the "Clear" button if you want to clear the existing criteria.

3 In the boxes next to the field names, type the criteria you want Excel to use when searching the database.

4 Choose the "Find Next" button or "Find Prev" button to search through the database until the record (bridge) you want is found.

5 Type the inspection results in the corresponding boxes. After entering this record, press "ENTER."

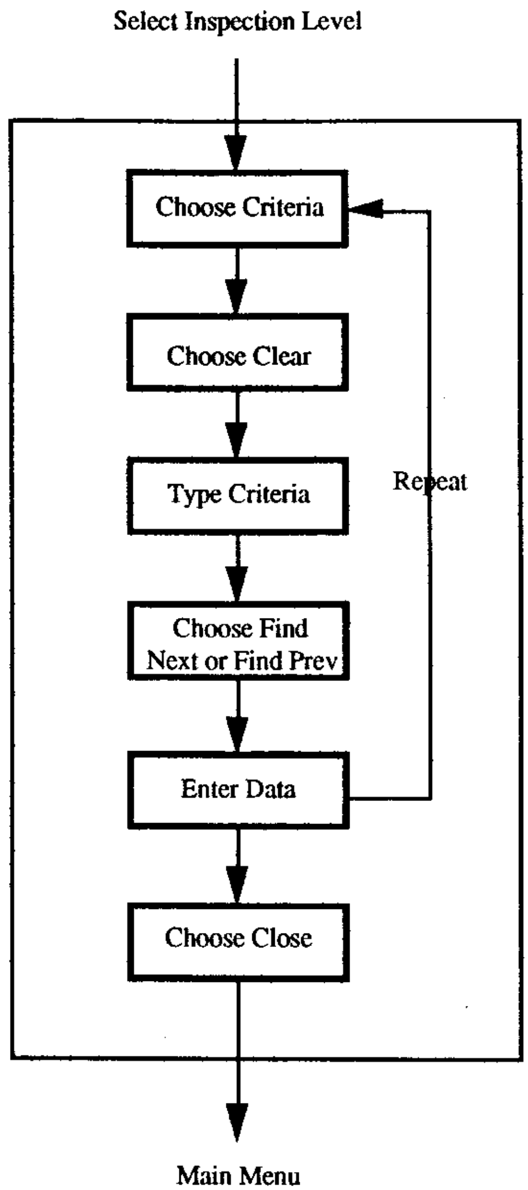
6 Repeat steps 1 through 5 until you finish entering the data.

7 Choose the "Close" button.

Important When you finish entering the inspection results of a bridge, press "ENTER." If you do not press the "ENTER" key, the inspection results you typed will not be saved.

Tips ***Specifying a criterion*** —To locate the record wanted, you can type the first several letters of the bridge name and the route number on which the bridge is located. You can use wild card characters in the criterion. For more information, see the "Microsoft Excel User's Guide," pages 360-361.

Summary of Operations



SELECT ROUTE

1 Choose the route you want.

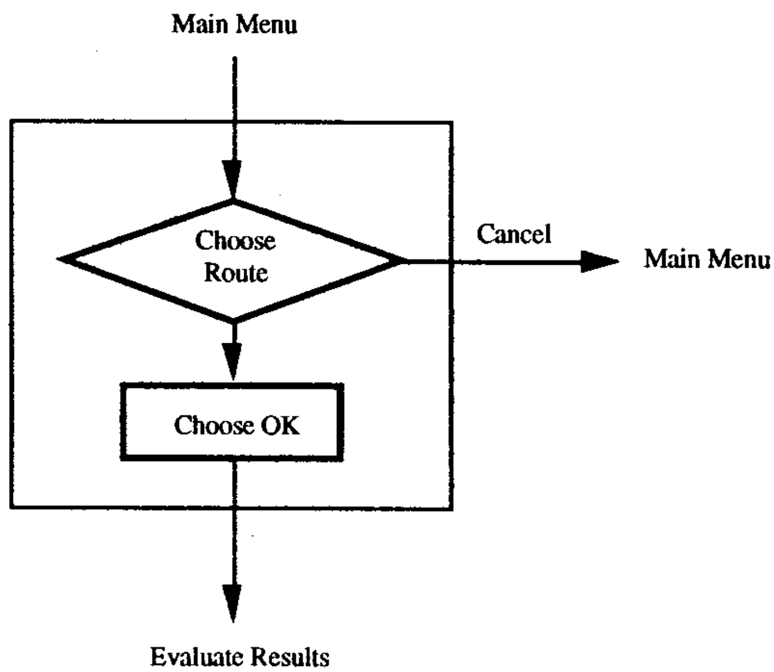
2 Choose "OK."

The "Cancel" button returns the control to the Main Menu.

Note Available routes in the database are as follows:

2	3	4	5	6	7	8	9	10	11	12	14	16	17	18
20	26	28	82	90	97	99	101	104	105	107	109	112	121	123
140	141	153	160	161	162	165	167	169	181	202	203	204	205	207
209	237	240	281	285	302	303	305	308	403	405	407	409	410	411
432	433	500	501	503	504	505	506	507	508	509	510	512	513	514
516	518	520	522	524	525	526	527	529	530	532	534	536	539	542
543	547	599	603	821	823	900	906	908	970					

Summary of Operations



EVALUATE RESULTS

Following the "Select Route" step, the macro automatically extracts the bridge status and relevant information, such as district numbers, inspectors, and inspection dates of the latest inspection level by the route you select, and organizes this information in the form of tables. You can print, browse, or save the report so that you can edit it or use it later.

- **Print**—Prints one copy of the status report in a pre-designed format.

- **Browse**—Allows you to view the report using the dialog box located at the bottom of the screen for scrolling.

- **Save**—Saves the report with the file name you give it in the following dialog box as long as you stay in the macro. The designated directory for saving files is directory C. If you want to change the report format, print more than one copy of the report, or save it in a directory other than directory C, you must save the file and exit the macro first.

The operations of evaluating results are listed step by step as follows:

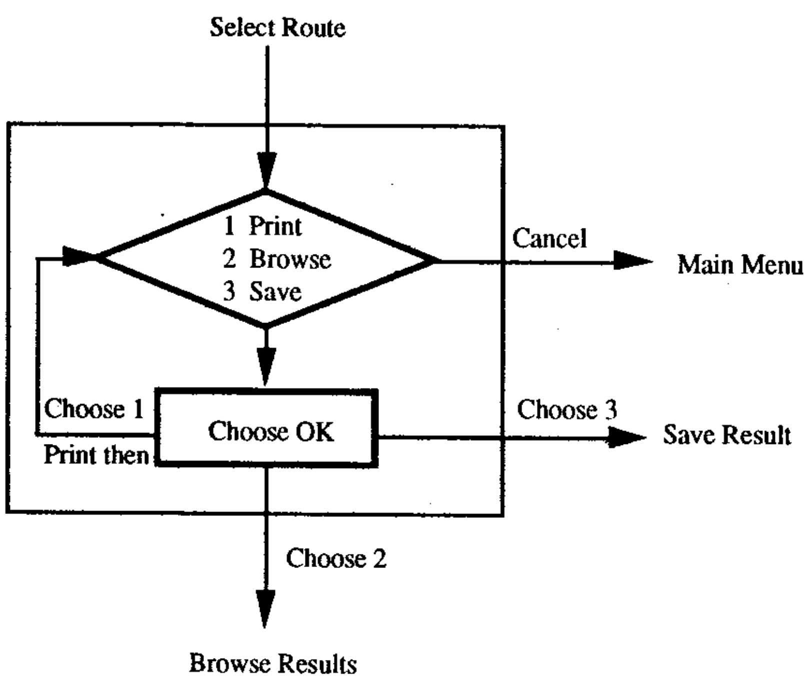
1 Choose "Print," "Browse," or "Save."

If you choose "Browse," go to "Browse Results." If you choose "Save," go to "Save Results."

2 Choose "OK."

The "Cancel" button returns the control to the Main Menu.

<u>**Summary of Operations**</u>



BROWSE RESULTS

- **Up** — Move to previous row.
- **Down** — Move to next row.
- **Right** — Move to next column.
- **Left** — Move to previous column.
- **Page Up** — Move to previous screen page (18 rows back).
- **Page Down** — Move to next screen page (18 rows forward).

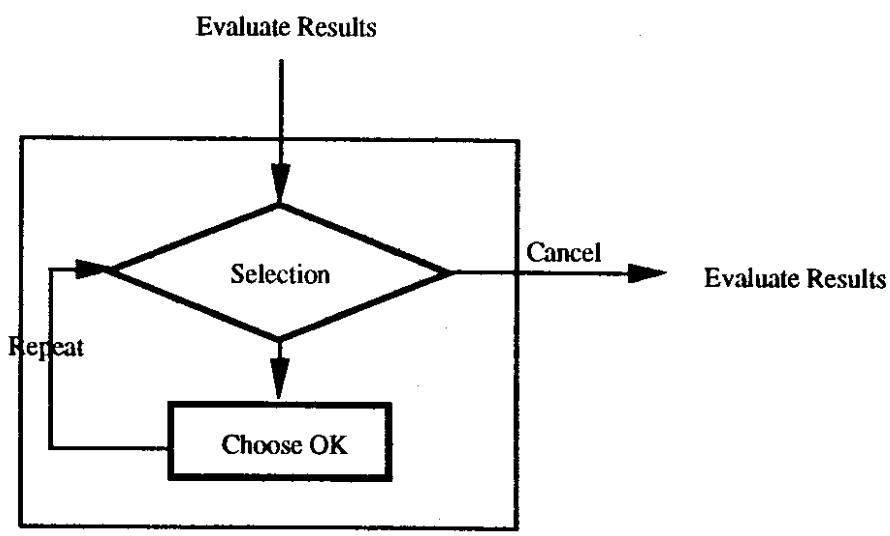
The operations of browsing results are listed step by step as follows:

1 Make a selection.

2 Choose "OK."

The "Cancel" button returns the control to "Evaluate Results."

Summary of Operations



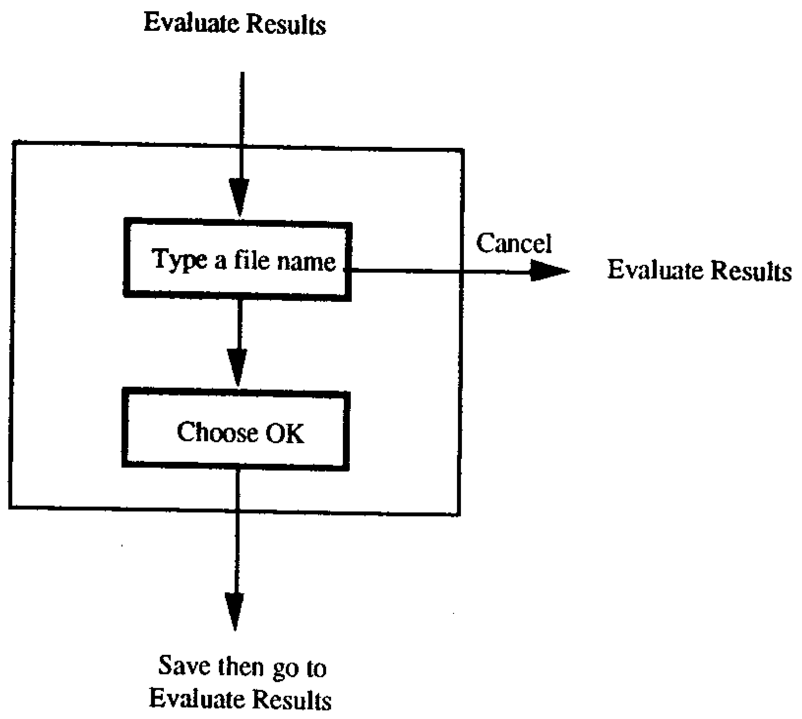
SAVE RESULTS

1 Type the file name without its extension. The default Excel worksheet file extension is ".xls."

2 Choose "OK."

The "Cancel" button returns the control to "Evaluate Results."

Summary of Operations



TROUBLESHOOTING

The Macro File PRO2.XLM Cannot Be Opened — If you start the macro by opening the file DBA.XLS and the greeting screen does not appear, it is probably because the macro file cannot be opened. Check the path of the "auto_open" function.

a Make the file "DBA.XLS" the active file if it is not.

b Choose "Formula Define."

c Select the name "AUTO_OPEN" in the "Names in Sheet" box.

d In the "Refers To" box, check if the path (drive, directory, and/or subdirectory) of the macro file matches your setting. If the path does not match your setting, correct the path.

e Choose "OK."

f Close the file "DBA.XLS" and save the changes.

g Restart the macro.

If at any time there is a problem, close all active files (DBA.XLS, PRO2.XLM, SHST.XLS , and SHST1.XLS), save only changes to the file "DBA.XLS" if you have entered inspection results, and then, restart the macro.

APPENDIX C

CALCULATIONS OF RESOURCE REQUIREMENTS

CALCULATIONS OF RESOURCE REQUIREMENTS

The estimated number of team leaders required for three types of earthquakes was calculated. These calculations are described below for the Level II and Level III inspections, respectively. Both sets of calculations were based upon the number of bridges that are expected to sustain structural damage. Because the expected seismic damage data for the Puget Sound and Washington state are limited, several approximate methods were used to provide estimates of the number of bridges that would require inspection. These methods are described in the following section, before the Level II and Level III inspection resource requirements are presented.

BRIDGE DAMAGE ESTIMATES

The bridge damage estimates were based upon the priority index (PI) values. The priority index is defined as (repeated from the main text)

$$PI = A \times C \quad (C.1)$$

where "A" is a factor representing the criticality of the route carried by the bridge, criticality of the utility lines carried by the bridge, criticality of the route crossed by the bridge, and criticality of the bridge as a structure. "A" increases as criticality increases. "C" is a factor representing the vulnerability of the bridge to seismic failure; "C" increases as the vulnerability of the bridge increases. "C" is calculated as follows:

$$C = 0.17\,[(a)\,(K)\,(SV)] \quad (C.2)$$

where (a) is the velocity-based peak ground acceleration coefficient. The coefficient (a) has a 10 percent probability of being exceeded in 50 years. K is a factor that adjusts (a) to the remaining service period of the bridge. SV is called the structural vulnerability rate. It increases as the seismic structural vulnerability increases. It is zero for the bridges that meet the current design standard criteria.

Because the priority index incorporates more information than the vulnerability or structural vulnerability rate, it was assumed to provide a better measure for damage estimates. However, estimates for districts 1,3 and 4 based upon the priority index were also checked to identify the corresponding vulnerability index C and structural vulnerability rate SV values to ensure that the most vulnerable bridges were included in the estimates. Table C.1 identifies the number of bridges in each priority index grouping according to the vulnerability index value C, and Table C.2 identifies the number of bridges in each priority index grouping according to the structural vulnerability rate SV values. All numbers were obtained using the WSDOT bridge seismic vulnerability database. For both tables, the following information concerning parameter ranges and notation is provided:

Range of values for the entire database;

Priority Index: $0 \leq PI \leq 54.7$

Vulnerability Index C: $0 \leq C \leq 15.3$

Structural Vulnerability Rate: $0 \leq SV \leq 360$

Notation used in Tables C.1 and C.2:

(0,100) represents all numbers in the range that are > 0 and < 100;

(0,100] represents all numbers in the range that are > 0 and ≤ 100;

[100, 150) represents all numbers in the range that are ≥ 100 and < 150.

Tables C.1 and C.2 show that the number of bridges in the ranges of C, SV, and PI values overlap considerably. Therefore, because the priority index contained information on both the vulnerability and importance of the bridge, it was used in the resource requirement calculations whenever more accurate expected seismic damage information was not available.

Table C.1 Vulnerability and Priority Index Database Analysis.

Priority Index PI	Vulnerability Index C	District 1	District 3	District 4	Totals	Sub-Totals
0	0	228	177	224	629	629
(0,15)	(0,2)	26	11	4	41	
	[2,4)	71	33	34	138	
	[4,6)	222	60	13	295	
	[6,8)	110	43	3	156	
	[8,10)	5	4	0	9	
	[10,12.44]	3	0	0	3	642
[15,25)	(4.48,6)	6	1	0	7	
	[6,8)	48	16	0	64	
	[8,10)	8	6	0	14	
	[10,12)	8	1	0	9	
	[12,14.3]	8	1	0	9	103
[25,35)	(6,10)	1	0	0	1	
	[10,12)	14	0	0	14	
	[12,14.7]	16	1	0	17	32
[35,54.7]	(10,12)	3	0	0	3	
	[12,14)	6	1	0	7	
	[14,15.3]	2	0	0	2	12
Totals PI>0		557	178	54	789	
Totals all		785	355	278	1418	1418

Table C.2. Structural Vulnerability Rate and Priority Index Database Analysis.

Priority Index, PI	Structural Vulnerability Rate, SV	District 1	District 3	District 4	Totals	Sub-totals
0	0	228	177	224	629	629
(0,15)	(0,100)	99	38	12	149	
	[100,150)	251	66	23	340	
	[150,200)	78	42	15	135	
	[200,250)	6	5	4	15	
	[250,300)	2	0	0	2	
	[300,325.8]	1	0	0	1	642
[15,25)	[100,150)	30	4	0	34	
	[150,200)	23	14	0	37	
	[200,250)	9	6	0	15	
	[250,300)	11	1	0	12	
	[300,360]	4	0	0	4	102
[25,35)	[150,200)	1	0	0	1	
	[200,250)	1	0	0	1	
	[250,300)	17	1	0	18	
	[300,360]	14	0	0	14	34
[35,54.7]	[250,300)	2	0	0	2	
	[300,360]	8	1	0	9	11
Totals P.I.>0		557	178	54	789	
Totals all		785	355	278	1418	

The Level II and Level III inspection team leader requirements were estimated with the priority index as the parameter for bridge damage selection. The Level II bridge estimates were undertaken first. For the moderate earthquake, only structurally vulnerable bridges located in districts 1, 3, and 4 were considered for Level II inspection. This is equivalent to stating that all bridges in districts 1, 3, and 4 with PI > 0, which corresponds to SV > 0, would require inspection. This number, according to the database, is 789. For the major earthquake, information was available to undertake an analysis using the Modified Mercalli Index [USGS], which yielded an estimate of 1,189 bridges for Level II inspection. For the great earthquake, there were two methods of analysis. First, all bridges located in districts 1, 3, and 4 would be subject to Level II inspection; this number is 1,418. Second, all bridges in the database, which would include districts 1 - 5, throughout the entire state, would be subject to Level II inspection; this number is 1,635. Table C.3 summarizes the rationale used for the Level II bridge estimates.

Table C.3. Rationale for bridges estimates for the Level II inspection analysis.

Rationale or Source of Information Used for Bridge Estimates	Number of Bridges Used to Calculate Team Leaders Required
All bridges in the WSDOT database with PI > O, which corresponds to SV > 0	789
Based upon Modified Mercalli Map [USGS]	1129
All bridges in the WSDOT database located in Districts 1, 3 and 4	1418
All bridges in the WSDOT database (includes Districts 1-5)	1635

For the Level III inspections, different methods were employed for the three earthquake events. For the moderate event, two approaches were employed. First, all bridges with priority index values of greater than or equal to 35 were assumed to sustain structural damage such that Level III inspection would be required; this number is 11. Second, all bridges with priority index values of greater than or equal to 25 were assumed to sustain structural damage such that Level III inspection would be required; this number is 45. For the major event, half of the bridges calculated for the Level II were assumed to require Level III inspection. For the great event, half of the bridges in each case considered for the Level II inspections were assumed to require Level III inspections. The rationale behind the Level III inspection estimates is summarized in Table C. 4.

Table C.4. Rationale for bridges estimates for the Level III inspection analysis.

Rationale	Number of Bridges
All bridges in the WSDOT database with Priority Index ≥ 35, corresponds approximately to Structural Vulnerability Rate ≥ 250	11
All bridges in the WSDOT database with Priority Index ≥ 25, corresponds approximately to Structural Vulnerability Rate ≥ 150	45
Half of the bridges calculated for the Level II based on MMI analysis (1189) were assumed to require Level III inspection.	698
Half of the total number of bridges in districts 1,3, and 4 in the database (1418) were assumed to require Level III inspection.	709
Half of the total number of bridges in the database (1635- this includes all districts) were assumed to require Level III inspection.	820 [rounded up from 817.2]

TEAM LEADER REQUIREMENTS FOR LEVEL II INSPECTIONS

The Level II general calculation is as follows:

The total number of bridges to be inspected x The time to inspect one bridge
divided by
48 hours total to complete the Level II inspections

This calculation yields the number of team leaders required per 12-hour shift. To obtain the total number of inspectors required for all four shifts during the 48-hour period, this value is multiplied by four. To account for poor weather and darkness or poor daylight conditions traveling to and inspecting the bridges, two modifying factors were used. The multiplicative factors of unity, 1.1, or 1.5 were used to modify the estimated time needed to inspect all bridges. An area factor of 0.8 was used to reduce the total number of teams to account for the fact that many of these bridges would be located in geographic "clusters," and once a team had reached its first destination, the other bridges would be close by. Table C.5 contains the numerical results for the three types of earthquake events. These estimates are not precise, but rather, indicate the general number of personnel required for best and worst case scenarios.

TEAM LEADER REQUIREMENTS FOR LEVEL III INSPECTIONS

The Level III general calculation is as follows:

The total number of bridges to be inspected x The time to inspect one bridge
divided by
24 hours to complete the Level III inspections.

This calculation yields the number of team leaders required per 12-hour shift. To obtain the total number of inspectors required for two shifts during the 24-hour period, this value is multiplied by two. As with the Level II calculations, two modifying factors were used to account for poor weather and darkness or poor daylight conditions traveling to and inspecting the bridges. The multiplicative factors of unity, 1.1, or 1.5 were used to modify the estimated time needed to inspect all bridges. An area factor of 0.8 was used to reduce the total number of teams to account for the fact that many of these bridges would be located in geographic "clusters," and once a team had reached its first destination, the other bridges would be close by. Table C.6 contains the numerical results for the three types of earthquake events. These estimates are not precise, but rather, indicate the general number of personnel required for best and worst case scenarios.

DISCUSSION

In both cases, these calculations are optimistic because they assume that Level I reports would be instantaneous. Level II inspections would occur for every bridge that was still operational after the event. Only a large number of collapses would reduce the number of bridges to be inspected at this level. The number of Level III bridges estimated for inspection would vary considerably from event to event because the estimate is based partially upon the vulnerability of the bridges.

Table C.5. Team Leader Calculations for the Level II Inspections.

Inspection Time/ Bridge [hr] "I"	$F_{weather}$ "Fw"	$F_{daylight}$ "Fd"	Time Total/ Bridge "T" = I*Fw*Fd	Number of Bridges "B"	F_{area} "F"	No. of Team Leaders per 12-hr shift =(T*B*F)/48 (rounded)	No.of Team Leaders for the entire 48 hour period=(T*B*F)/12 (rounded)
1	1	1	1	789	0.8	14	53
1	1	1	1	1126	0.8	19	76
1	1	1	1	1418	0.8	24	95
1	1	1	1	1635	0.8	28	110
1	1.1	1	1.1	789	0.8	15	58
1	1.1	1	1.1	1126	0.8	21	83
1	1.1	1	1.1	1418	0.8	26	104
1	1.1	1	1.1	1635	0.8	31	120
1	1.1	1.5	1.65	789	0.8	22	87
1	1.1	1.5	1.65	1126	0.8	31	124
1	1.1	1.5	1.65	1418	0.8	39	156
1	1.1	1.5	1.65	1635	0.8	46	181

Table C.6. Team Leaders Calculations for the Level III Inspections.

Inspection Time/ Bridge [hr] I	$F_{weather}$ Fw	$F_{daylight}$ Fd	Time Total/ Bridge "T" = I*Fw*Fd	Number of Bridges "B"	F_{area} "F"	No. of Team Leaders per 12-hr Shift =(T*B*F)/24 (rounded)	No.of Team Leaders for the entire 24-hr period =(T*B*F)/12 (rounded)
2	1	1	2	11	0.8	1	2
2	1	1	2	45	0.8	4	7
2	1	1	2	698	0.8	47	94
2	1	1	2	709	0.8	48	95
2	1	1	2	820	0.8	55	109
2	1.1	1	2.2	11	0.8	1	2
2	1.1	1	2.2	45	0.8	4	8
2	1.1	1	2.2	698	0.8	52	102
2	1.1	1	2.2	709	0.8	52	104
2	1.1	1	2.2	820	0.8	61	120
2	1.1	1.5	3.3	11	0.8	2	3
2	1.1	1.5	3.3	45	0.8	5	10
2	1.1	1.5	3.3	698	0.8	77	154
2	1.1	1.5	3.3	709	0.8	78	156
2	1.1	1.5	3.3	820	0.8	91	180