#44

DATA SUBMITTAL: GEOLOGY OF THE SOUTH RAMP - STATIONS 55+00 TO 65+00, EXPLORATORY STUDIES FACILITY, YUCCA MOUNTAIN PROJECT, YUCCA MOUNTAIN, NEVADA

MILESTONE SPG42BM3

Bureau of Reclamation and U.S. Geological Survey

Prepared in cooperation with the
NEVADA FIELD OFFICE,
U.S. DEPARTMENT OF ENERGY,
under Interagency Agreement DE-AI08-92NV10874

Denver, Colorado
1997

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PREFACE

These data are being submitted to the U.S. Department of Energy to fulfill Level 3 Milestone SPG42BM3: Letter Report: Geology of the South Ramp, Station 55+00 to 63+47. The Planning and Scheduling Account Number is 1.2.3.2.2.1.2 for the Summary Account titled: Geologic Mapping of the Exploratory Studies Facility. This submittal consists of two segments of detailed line surveys in tabulated format for Stations 55+00 to 60+00 and 60+00 to 65+00 and full periphery geotechnical maps for Stations 55+00 to 65+00 of the South Ramp. The data also include reports on rock mass quality ratings.

Table 1 of this summary is the PACS description/completion criteria of Milestone SPG42BM3 in outline form. The table is provided as a guide for DOE reviewers in verifying completion of the milestone. Documentation attached to this preface as part of the milestone requirements include copies of Technical Data Information Forms identifying acquired and developed data generated for this report (Attachment 1) and copies of the transmittal letters to the GENISES Administrator describing the data submitted for entry into the Technical Data Base (Attachment 2).

All the data submitted for completion of this milestone were collected and the data packages prepared in accordance with approved quality assurance procedures which implement requirements of the Quality Assurance Requirements Descriptions. Therefore, all data submitted have a Q status.

TABLE 1 - Description/completion criteria location summary for U.S. Department of Energy Level 3 Milestone: SPG42BM3 - Data Submittal: Geology of the South Ramp, Stations 55+00 to 65+00

CRITERIA	LOCATION/COMPLETION INFORMATION
TECHNICAL REQUIREMENTS	
1. This milestone data submittal will consist of a compilation of maps, graphical data treatments, and data collected in the Exploratory studies Facility (ESF) from Station 55+00 through Station 63+47.	Data consist of detailed line surveys, full periphery geotechnical maps and rock mass quality ratings reports for Stations 55+00 to 65+00.
2. Maps included with the report will be presented at a scale of 1:125.	All full periphery geotechnical maps (FPGMs) covering Stations 55+00 to 65+00 (Drawings OA-46-257 through OA-46-268) are presented at a scale of 1:125. See Section III.
3. These full-periphery geotechnical maps will show: A. Mapped geologic units and subunits, fractures, faults, and other important structural features (as appropriate), B. The location of all samples collected by the mapping group (or collected by the PIs and/or the ESF Technical Coordination Office), and C. As-constructed installed ground support and type.	The FPGMs incorporate Items A, B, and C of this criteria. See Section III.

TABLE 1 (Continued) - Description/completion criteria location summary for U.S. Department of Energy Level 3 Milestone: SPG42BM3 - Data Submittal: Geology of the South Ramp, Stations 55+00 to 65+00

CRITERIA	LOCATION/COMPLETION INFORMATION
4. The deliverable will supply first-order graphical fracture analysis in the form of tabulated data sets, stereo plots, and statistical treatment of fracture information (by stratigraphic unit, or some selected interval along the course of tunnel excavation) as necessary for illustrative purposes.	For illustrative purposes the FPGMs supply fracture analysis in the form of stereonets and cross sections (Section III). Detailed Line Surveys (DLS) provide tabulated data (See Sections IIA and IIB).
5. A cross section comparing the predicted geology of the south ramp through Station 63+47 and as-determined structural and stratigraphic interpretations will be presented.	The requested cross-section is in process but could not be included in this report because the pre-construction portion necessary for its completion cannot be released from Sandia Laboratories until their QA requirements are met. Sandia will be forwarding this information in the near future and the cross-section will be completed and submitted as part of Level 3 Milestone SPG42CM3, Geology of the South Ramp, due August 1997.
6. Results of the detailed line survey and appropriate graphical and tabular presentation of data will be included in the data submittal.	See the DLSs in tabulated format in Sections IIA and IIB.
7. Results of the RQD and Q&RMR analyses will also be provided and integrated into map or other graphical presentations of related data.	The FPGMs contain results of the RQD and Q&RMR analyses (Section III). See also the Rock Mass Ratings Report of this submittal, Sections IA and IB.
8. Simple statistical treatment or qualitative assessment of the results of the subject survey will be provided.	The FPGMs provide this information (Section III).

TABLE 1 (Continued) - Description/completion criteria location summary for U.S. Department of Energy Level 3 Milestone: SPG42BM3 - Data Submittal: Geology of the South Ramp, Stations 55+00 to 65+00

CRITERIA	LOCATION/COMPLETION INFORMATION
9. The following will be included in the report: A. Alcove maps (for additional constructed portions of Alcove 5, the thermal test facility, and Alcove 6, the north Ghost Dance Alcove) B. Line survey data C. Stereophotography D. Tabulations and assessment of structural data from alcove mapping investigations, and E. Statistical treatment of alcove fracture data.	The detailed line survey for Alcove 5 has been submitted earlier to the DOE Technical Data Base as part of the data package identified by the ATDT DTN GS960908314224.018. See Attachments 1 and 2 of the Preface for copies of the TDIF and the GENISES transmittal letter. The FPGM for Alcove 5 and the DLS and FPGM for Alcove 6 are in process but have not been completed because of inabilities to fully access the alcoves due to construction requirements. When completed, the data for the alcoves will be submitted as part of the South Ramp report due in August 1997 as Level 3 Milestone SPG42CM3.
10. Alcove borehole information will be incorporated for enhanced assessment of the geometry of stratigraphic units and structural features, as appropriate.	Alcove borehole information is not considered sufficient for incorporation in this milestone at this time.
REGULATORY REQUIREMENTS	
1. This deliverable shall be prepared in accordance with OCRWM approved quality assurance procedures implementing requirements of the Quality Assurance Requirements Description.	See the Preface.

TABLE 1 (Continued) - Description/completion criteria location summary for U.S. Department of Energy Level 3 Milestone: SPG42BM3 - Data Submittal: Geology of the South Ramp, Stations 55+00 to 65+00

CRITERIA	LOCATION/COMPLETION INFORMATION
2. The product shall be developed on the basis of the best technical data, including both Q and non-Q data. The Q status of the data used and cited in the report shall be appropriately noted.	See the Preface. All data are Q.
3. Stratigraphic nomenclature used shall be consistent with the Reference Information Base section 1.12(a): Stratigraphy-Geologic Lithologic Stratigraphy.	Stratigraphic nomenclature is consistent with the RIB section 1.12(a).
4. Within the report's Reference Section, references to data used in the report shall include record Accession Numbers or Data Tracking Numbers when available.	There is no reference section in this report. All data used and submitted for this milestone are reported on the following TDIFs: Data Tracking Numbers GS961108314224.023 (DLS) GS970108314224.002 (FPGM) GS970208314224.003 (DLS) GS970208314224.004 (FPGM)
5. Technical data contained within the deliverable and not already incorporated in the Geographic Nodal Information Study and Evaluation System (GENISES) shall be submitted for incorporation into the GENISES in accordance with YAP-SIII.3Q.	See Attachment 2 of the Preface.
6. Verification of technical data submittal compliance shall be demonstrated by including as part of the deliverable:	
1. A copy of the Technical Data Information Form generated identifying the data in the Automated Technical Data Tracking system, and	See Attachment 1 of the Preface.

TABLE 1 (Continued) - Description/completion criteria location summary for U.S. Department of Energy Level 3 Milestone: SPG42BM3 - Data Submittal: Geology of the South Ramp, Stations 55+00 to 65+00

CRITERIA	LOCATION/COMPLETION INFORMATION
2. A copy of the transmittal letter attached to the technical data transmittal to the GENISES Administrator.	See Attachment 2 of the Preface.
7. This deliverable shall be processed in accordance with YAP-5.1Q.	See attached YAR.

PREFACE

ATTACHMENT 1

Technical Data Information Forms

305969

YMP-023-R4
05/06/96

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION

(Check one): ☐ ACQUIRED DATA *(complete Parts I and II)*
Data Tracking Number (DTN): _____

☒ DEVELOPED DATA *(complete Parts I, II and III)*
Data Tracking Number (DTN): GS961108314224.023

PART I Identification of Data

Title/Description of Data: PROVISIONAL RESULTS: MAIN DRIFT AND SOUTH RAMP OF THE ESF, STATION 55+00 TO 60+00: DETAILED LINE SURVEY DATA

Principal Investigator (PI): BEASON, S C
Last Name — First and Middle Initials

PI Organization: U.S. BUREAU OF RECLAMATION

Are Data Qualified?: ☒ Yes ☐ No Governing Plan: SCP

SCPB Activity Number(s): 8.3.1.4.2.2.4

WBS Number(s): 1.2.3.2.2.1.2

PART II Data Acquisition/Development Information

Method: DATA WERE DEVELOPED USING TECHNICAL PROCEDURE NWM-USGS GP-32,R0, UNDERGROUND GEOLOGICAL MAPPING, AND SCIENTIFIC NOTEBOOK SN-0084, COLLECTION OF SITE CHARACTERIZATION DATA

Location(s): ESF - MAIN DRIFT AND SOUTH RAMP, RIGHT RIB

Period(s): 6/4/96 to 7/2/96
From: MM/DD/YY — To: MM/DD/YY

Sample ID Number(s): _____

PART III Source Data DTN(s)

MO960000000005.013

Comments

DATA WERE COLLECTED BY: GARY TURLINGTON, JIM ROGERS, DONNA SINKS, TOM MOYER, ALTON ALBIN, JIM BOWEN, ARTHUR LEE, AND DAWN GONZALEZ. SUBJECT TO REVISION

Checked by: Patricia G. Sheaffer FOR S.C. Beason — 1/27/97
Signature — Date

305981

YMP-023-R4
05/06/96

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION

(Check one): ☐ ACQUIRED DATA *(complete Parts I and II)*
Data Tracking Number (DTN): _____

☒ DEVELOPED DATA *(complete Parts I, II and III)*
Data Tracking Number (DTN): GS970108314224.002

PART I Identification of Data

Title/Description of Data: PROVISIONAL RESULTS: GEOTECHNICAL DATA FOR STATION 55+00 TO STATION 60+00, MAIN DRIFT OF THE ESF, FULL PERIPHERY GEOTECHNICAL MAPS (DRAWINGS OA-46-258 THROUGH OA-46-262) AND ROCK MASS QUALITY RATINGS REPORT

Principal Investigator (PI): BEASON, S C
Last Name First and Middle Initials

PI Organization: U.S. BUREAU OF RECLAMATION

Are Data Qualified?: ☒ Yes ☐ No Governing Plan: SCP

SCPB Activity Number(s): 8.3.1.4.2.2.4

WBS Number(s): 1.2.3.2.2.1.2

PART II Data Acquisition/Development Information

Method: DATA WERE DEVELOPED USING TECHNICAL PROCEDURE NWM-USGS GP-32, R0, UNDERGROUND GEOLOGIC MAPPING, AND SCIENTIFIC NOTEBOOKS SN-0083, COLLECTION AND PROCESSING OF GEOTECHNICAL DATA, AND SN-0084, COLLECTION OF UNDERGROUND SITE CHARACTERIZATION DATA.

Location(s): ESF - MAIN DRIFT AND SOUTH RAMP

Period(s): 6/5/96 to 11/20/96
From: MM/DD/YY To: MM/DD/YY

Sample ID Number(s): _____

PART III Source Data DTN(s)

GS961108314224.023	SNF32070996001.003	
SNF32020196001.012		
SNF32020196001.014		

Comments

DATA WERE COLLECTED BY: R. LUNG, R. BURT, G. EATMAN, D. BARR, A. LEE, D. BENNETT, A. LOCKHART, A. ALBIN, AND G. MONGANO.

Checked by: Patricia G. Sheaffer 2/20/97
Signature Date

306017

YMP-023-R4
05/06/96

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION

(Check one): ☐ ACQUIRED DATA *(complete Parts I and II)*
Data Tracking Number (DTN): _____

☒ DEVELOPED DATA *(complete Parts I, II and III)*
Data Tracking Number (DTN): GS970208314224.003

PART I Identification of Data

Title/Description of Data: PROVISIONAL RESULTS: GEOTECHNICAL DATA FOR STATION 60+00 TO STATION 65+00, SOUTH RAMP OF THE ESF; DETAILED LINE SURVEY DATA

Principal Investigator (PI): BEASON, S C
Last Name First and Middle Initials

PI Organization: U.S. BUREAU OF RECLAMATION

Are Data Qualified?: ☒ Yes ☐ No Governing Plan: SCP

SCPB Activity Number(s): 8.3.1.4.2.2.4

WBS Number(s): 1.2.3.2.2.1.2

PART II Data Acquisition/Development Information

Method: DATA WERE DEVELOPED USING TECHNICAL PROCEDURE NWM-USGS GP-32,R0, UNDERGROUND GEOLOGIC MAPPING, AND SCIENTIFIC NOTEBOOK SN-0084, COLLECTION OF UNDERGROUND SITE CHARACTERIZATION DATA

Location(s): ESF - SOUTH RAMP

Period(s): 7/16/96 to 8/26/96
From: MM/DD/YY To: MM/DD/YY

Sample ID Number(s): _____

PART III Source Data DTN(s)

MO960000000005.015

Comments

DATA WERE COLLECTED BY G. TURLINGTON, D. CHURCHILL, J. ROGERS, D. SINKS, R. BURT, D. GONZALES, A. LEE, K. DOW, T. MOYER, D. BARR, A. ALBIN, AND G. MONGANO

Checked by: Patricia G. Sheaffer 2/20/97
Signature Date

306018

YMP-023-R4
05/06/96

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION

(Check one): ☐ ACQUIRED DATA (complete Parts I and II)
Data Tracking Number (DTN): _____

☒ DEVELOPED DATA (complete Parts I, II and III)
Data Tracking Number (DTN): GS970208314224.004

PART I Identification of Data

Title/Description of Data: PROVISIONAL RESULTS: GEOTECHNICAL DATA FOR STATION 60+00 TO STATION 65+00, SOUTH RAMP OF THE ESF, FULL PERIPHERY GEOTECHNICAL MAPS (DRAWINGS OA-46-263 THROUGH OA-46-268) AND ROCK MASS QUALITY RATINGS REPORT

Principal Investigator (PI): BEASON, S C
Last Name — First and Middle Initials

PI Organization: U.S. BUREAU OF RECLAMATION

Are Data Qualified?: ☒ Yes ☐ No Governing Plan: SCP

SCPB Activity Number(s): 8.3.1.4.2.2.4

WBS Number(s): 1.2.3.2.2.1.2

PART II Data Acquisition/Development Information

Method: DATA WERE DEVELOPED USING TECHNICAL PROCEDURE NWM-USGS GP-32,R0, UNDERGROUND GEOLOGIC MAPPING, AND SCIENTIFIC NOTEBOOK SN-0084, COLLECTION OF UNDERGROUND SITE CHARACTERIZATION DATA, AND SCIENTIFIC NOTEBOOK SN-0083, COLLECTION AND PROCESSING OF GEOTECHNICAL DATA.

Location(s): ESF - SOUTH RAMP

Period(s): 8/1/96 to 11/25/96
From: MM/DD/YY — To: MM/DD/YY

Sample ID Number(s): _____

PART III Source Data DTN(s)

SNF32070996001.003
SNF32070996001.004
SNF32070996001.005

Comments

DATA WERE COLLECTED BY G. TURLINGTON, D. CHURCHILL, J. ROGERS, D. SINKS, R. BURT, D. GONZALES, A. LEE, K. DOW, T. MOYER, D. BARR, A. ALBIN, G. MONGANO, G. EATMAN, R. LUNG, D. BENNETT, AND A. LOCKHART

Checked by: Patricia G. Sheaffer (Signature) 2/21/97 (Date)

PREFACE

ATTACHMENT 2

Transmittal Letters to the GENISES Administrator

United States Department of the Interior

U. S. GEOLOGICAL SURVEY
Box 25046 M.S. 425
Denver Federal Center
Denver, Colorado 80225

IN REPLY REFER TO:

February 26, 1997

QA: N
WBS:1.2.5.3.5

Joanna L. Wiggins
Technical Data Base Administrator
M&O/TRW
Yucca Mountain Project Office
1180 Town Center Drive
Las Vegas, NV 89134

SUBJECT: Yucca Mountain Site Characterization Project (YMP) Technical Data Base (TDB) Data Transmittal - **Provisional Results: Main Drift and South Ramp of the ESF, Station 55+00 to 60+00: Detailed Line Survey Data**

DTN: GS961108314224.023 TDIF: 305969

The subject Data Transmittal Package is being submitted to the YMP TDB in accordance with YMP Administrative Procedure (YAP)-SIII.3Q, Revision 1, ICN 0. All data have been technically reviewed as required. This TDB partially fulfills **Milestone SPG42BM3**. The following items are enclosed:

1. Technical Data Information Form (1), 1p.
2. Example of the submitted data annotated with parameters and attributes, 1p.
3. Hard Copy of Subject Data, 98p.
4. Abbreviations for the detailed line survey data, 1p.
5. YMP-USGS Surrogate Record, 2p.
6. One 3½" diskette containing the subject data in ASCII format.

Please capture the annotated supporting information and the abbreviations page in the TDB.

If you have any questions, please contact me at (303) 236-0516, X271, or Craig R. Walker at X278.

Sincerely,

Patrick W. McKinley

Patrick W. McKinley
Data Management Coordinator
Yucca Mountain Project Branch
U.S. Geological Survey

PWM:CRW
Enclosures
Copy w/o enc. to: C.M. Newbury, DOE/YMP, Las Vegas
S.J. Bodnar, M&O/TRW, Las Vegas
R.W. Craig, USGS, Las Vegas
S.C. Beason, USGS, Mercury
R. Arnold, USGS, Denver
P.G. Sheaffer, PWT, Denver
Copy w/ enc. to: Records Processing Center, Las Vegas, Items 2 & 5
305969

United States Department of the Interior

U. S. GEOLOGICAL SURVEY
Box 25046 M.S. 425
Denver Federal Center
Denver, Colorado 80225

IN REPLY REFER TO.

February 26, 1997

QA: N
WBS:1.2.5.3.5
Page 1 of 1

Joanna L. Wiggins
Technical Data Base Administrator
M&O/TRW
Yucca Mountain Project Office
1180 Town Center Drive
Las Vegas, NV 89134

SUBJECT: Yucca Mountain Site Characterization Project (YMP) Technical Data Base (TDB) Data Transmittal - Provisional Results: Geotechnical Data for Station 60+00 to Station 65+00, South Ramp of the ESF; Detailed Line Survey Data

DTN: GS970208314224.003 TDIF: 306017

The subject Data Transmittal Package is being submitted to the YMP TDB in accordance with YMP Administrative Procedure (YAP)-SIII.3Q, Revision 1, ICN 0. All data have been technically reviewed as required. This TDB partially fulfills Milestone SPG42BM3. The following items are enclosed:

1. Technical Data Information Form (1), 1p.
2. Example of the submitted data annotated with parameters and attributes, 1p.
3. Hard Copy of Subject Data, 100p.
4. Abbreviations for the detailed line survey data, 1p.
5. YMP-USGS Surrogate Record, 2p.
6. One 3½" diskette containing the subject data in ASCII and Excel format.

In agreement with Steve Bodner, Steve Beason's group has supplied the subject data in Excel format for distribution purposes.

Please note that the hard copies are titled Main Drift and South Ramp. These data are only from the South Ramp. The Main Drift is a mislabeling and does not affect the data.

Please capture the annotated supporting information and the abbreviations page in the TDB.

If you have any questions, please contact me at (303) 236-0516, X271, or Craig R. Walker at X278.

Sincerely,

Patrick W. McKinley

Patrick W. McKinley
Data Management Coordinator
Yucca Mountain Project Branch
U.S. Geological Survey

PWM:CRW
Enclosures
Copy w/o enc. to: C.M. Newbury, DOE/YMP, Las Vegas
S.J. Bodnar, M&O/TRW, Las Vegas
R.W. Craig, USGS, Las Vegas
S.C. Beason, USGS, Mercury
R. Arnold, USGS, Denver
P.G. Sheaffer, PWT, Denver
Copy w/ enc. to: Records Processing Center, Las Vegas, Items 2 & 5
306017

United States Department of the Interior

U. S. GEOLOGICAL SURVEY
Box 25046 M.S. 425
Denver Federal Center
Denver, Colorado 80225

IN REPLY REFER TO

February 26, 1997

QA: N
WBS: 1.2.5.3.5

Joanna L. Wiggins
Technical Data Base Administrator
M&O/TRW
Yucca Mountain Project Office
1180 Town Center Drive
Las Vegas, NV 89134

SUBJECT: Yucca Mountain Site Characterization Project (YMP) Technical Data Base (TDB) Data Transmittal - GEOTECHNICAL DATA FOR STATION 55+00 TO 60+00, MAIN DRIFT OF THE ESF, FULL PERIPHERY GEOTECHNICAL MAPS (DRAWINGS OA-46-257 THROUGH OA-46-262) AND FOR STATION 60+00 TO 65+00, SOUTH RAMP OF THE ESF, FULL PERIPHERY GEOTECHNICAL MAPS (DRAWINGS OA-46-263 THROUGH OA-46-268) AND ROCK MASS QUALITY RATINGS FOR STATION 55+00 TO 65+00.

DTNs:	TDIFs:	STATIONs:
GS970108314224.002	305981	55+00 to 60+00
GS970208314224.004	306018	60+00 to 65+00

The subject Data Transmittal Package is being submitted to the YMP TDB in accordance with YMP Administrative Procedure (YAP)-SIII.3Q, Revision 1, ICN 0. All data have been technically reviewed as required. This TDB submittal partially fulfills Milestone SPG43BM3. The following items are enclosed:

1. Technical Data Information Forms, (2) 2p.

2. Hard copy of the Full Periphery Geotechnical Maps, Drawings OA-46-257 through OA-46-268), 12 Drawings. Note that the Scanline Q and RMR data acquired by J.T.F. Agapito Associates along with the EXCAVATION RATE AND SUPPORT data reported on the map headers are not being submitted with this TDB submittal (see annotated Maps OA-46-263 and OA-46-264). This is a GIS submittal associated with parameter P113-Rock Quality Designation.

3. Annotated copy of the USGS/USBR Minimum Rock Mass Classification, 1p. Note that the submitted data, RQD, Rated Q, and Rated RMR, are highlighted on this page. The remaining columns are supporting information, used in determining the submitted data, and therefore not submitted.

4. Hard copy of the data USGS/USBR Minimum Rock Mass Classification, 8p.

5. "Abbreviations," 1p.

6. "Stratigraphic Unit" descriptions, 1p.

7. "Introduction," 6p. Note that this section includes the Q Rating numerical value descriptions, RMR numerical value descriptions, and RQD index. This section also includes disclaimers and limitations on the data that have been highlighted for TDB inclusion.

Please capture the annotated supporting information in the TDB.

If you have any questions, please contact me at (303) 236-0516, X271, or Ann Lezark at X229.

Sincerely,

Patrick W. McKinley

Patrick W. McKinley
Data Management Coordinator
Yucca Mountain Project Branch
U.S. Geological Survey

Enclosures
Copy w/o enc. to: C.M. Newbury, DOE/YMP, Las Vegas
S.J. Bodnar, M&O/TRW, Las Vegas
R.W. Craig, USGS, Las Vegas
S.C. Beason, USBR, Denver
Raye Arnold, USGS, Denver
P.G. Sheaffer, PWT, Denver
Copy w/ enc. to: Records Processing Center, Las Vegas, Item 3

305961

U.S. Geological Survey
U.S. Bureau of Reclamation
Underground Mapping Team

Yucca Mountain Project

Geotechnical Report
Rock Mass Quality Ratings

Main Drift
of the
Exploratory Studies Facility (ESF)

Station 55 +00 to 60 + 00

FINAL COPY

Prepared By:
John Steighner
Bill Singleton
Jeanne Major

U.S. Geological Survey
U.S. Bureau of Reclamation
Yucca Mountain Project

TABLE OF CONTENTS

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Abbreviations I
Introduction III

Section 1

USBR Rock Mass Classification 1.1
This section contains a summary of Q and RMR rating values, along with reference drawings. This report is submitted to the Technical Database.

Sections 2 thru 4
These sections not included in this report. They are included in the Supplemental and Supporting Information volume.

Section 2

Abbreviations 2.1

Q and RMR Spreadsheets 2.2
This section contains a summary of Q and RMR rating values in a Microsoft EXCEL spreadsheet format. These data will be submitted to the Technical Database in electronic format only.

Section 3

Q System and Rock Mass Rating Field Forms 3.1
This section contains the field forms utilized in the tunnel to record raw data. These forms will be submitted to the Project Records Center as supporting information.

Section 4

Rock Quality Designation Field Forms and Spreadsheet 4.1
This section contains RQD scanline field forms used in the tunnel to record the raw data. These forms were submitted to the Project Records Center as supporting information. An EXCEL spreadsheet used to calculate RQD will be submitted to the Technical Database in electronic format only.

Abbreviations

AJO	rating adjustment for joint orientation - RMR
BFZ	begin fault zone
BW	begin wedge
C	strength index - RMR
Cdl	condition of discontinuity, length - RMR
CDS	condition of discontinuity, separation - RMR
Cdr	condition of discontinuity, roughness - RMR
Cdf	condition of discontinuity, filling - RMR
Cdw	condition of discontinuity, weathering - RMR
dw	deep wedge
EZ	end zone
EW	end wedge
ESF	exploratory studies facility
fw	fracture wedge
fz	fracture zone
Gnd	ground
Jn	joint set number - Q
Ja	joint alteration number - Q
Jn	joint number set number - Q
Jr	joint roughness number - Q
JwQ	joint water reduction factor - Q
Jcd	joint discontinuity description - RMR
Jr/Ja	shear Strength ratio
Js	joint spacing index - RMR
JwR	joint groundwater index - RMR & Q
lith	lithophysae
NR	not rated
PI	principal investigator
pf	parallel fracture
Q	quality of rock mass
Rev	revision
RMR	rock mass rating
RQC	rock quality classification
RQD	rock quality designation
RQD/Jn	block size ratio
S over L	springline
SRF	stress reduction factor - Q
SS	steel set
sw	shallow wedge

Stratigraphic Units

Tmr	Rainier Mesa
Tpki	tuff unit "x"
Tpc	Tiva Canyon Tuff
Tpbt4	pre-Tiva Canyon bedded tuff
Tpy	Yucca Mountain Tuff
Tpbt3	pre-Yucca Mountain bedded tuff
Tpp	Pah Canyon Tuff
Tpbt2	pre-Pah Canyon bedded tuff
Tpt	Topopah Spring Tuff
Tptrv	Topopah Spring crystal rich vitric zone
Tptrn	Topopah Spring crystal-rich nonlithophysal zone
Tptrl	Topopah Spring crystal-rich lithophysal zone
Tptpul	Topopah Spring crystal-poor upper lithophysal zone
Tptpmn	Topopah Spring crystal-poor middle nonlithophysal zone
Tptpll	Topopah Spring crystal-poor lower lithophysal zone

INTRODUCTION

Norwegian Geotechnical Institute Q System Procedures

The Norwegian Geotechnical Institute Q rock mass classification system was selected by the underground designers for use in the North Ramp Tunnel of the Exploratory Studies Facility. The Q system establishes a numerical value for the quality of the rock for engineering purposes. A Q rating is calculated as the product of six parameters according to the following equation:

$$Q = (RQD/Jn) * (Jr/Ja) * (JwQ/SRF)$$

where:

- RQD is an integer number equal to the RQD percentage. In the equation above the numerical value of 90 is used for an RQD of 90%. See section 4.
- Jn is an index number based on assessment of the number of joint sets in the rating length considered.
- Jr is an index number representing the roughness of the joint set.
- Ja is an index number based on the alteration or filling of a given joint set.
- JwQ is an index number based on groundwater conditions. The "Q" is used to distinguish this index from the RMR system groundwater rating.
- SRF is an index number based on in-situ conditions which influence the stability of the excavation.

The rock quality can range from Q = 0.001 to Q = 1000 as shown in the following table:

Table 1: Q system Qualitative Rock Description

Q value	.001-.01	.01-.1	.1 - 1	1 - 4	4 - 10	10 - 40	40 - 100	100 - 400	400 - 1000
Rock Quality Description	Exceptionally Poor	Extremely Poor	Very Poor	Poor	Fair	Good	Very Good	Extremely Good	Exceptionally Good

The values of the six parameters along with the assigned minimum Q rating are reported in this data package. The minimum Q rating is used to represent the most conservative and safest rating of each section of tunnel. The supplemental section additionally provides a calculated maximum Q value which was determined as a result of the most favorable joint set characteristics.

Rock Mass Rating (RMR) Procedures

The RMR system, also known as the Geomechanics Classification, is an empirical rating system based on the sum of six rockmass parameters. Bieniawski developed the system in 1973 and, with the addition of case histories, revised it to the present form (Bieniawski, 1989). The numerical rock mass rating, RMR, is calculated according to the following equation:

$$RMR = C + RQD + Js + Jcd + JwR + AJO$$

where

C	is a numerical value associated with the intact rock compressive strength
RQD	is a numerical value associated with the rock mass RQD (the rating is not equal to the RQD value)
Js	is a numerical value associated with the fracture spacing of a given joint set
Jcd	is a numerical value associated with the condition of discontinuities
JwR	is a numerical value dependent on groundwater or inflow conditions. The "R" is used to distinguish this rating from the Q system joint water rating.
AJO	is a numerical value associated with the orientation of discontinuities

Compressive strength, joint spacing, joint condition, groundwater and joint orientation parameters are divided into five ranges of values. The rating numbers reflect the importance of each parameter. In this procedure the joint set with the lowest total rating for spacing, joint condition and orientation is used to calculate the RMR.

Table 2 RMR Rock Mass Classification

Rock Mass Rating	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100
Rock Quality Description	Very Poor	Poor	Fair	Good	Very Good

The values of the six parameters along with the assigned RMR rating are reported in this data package.

Rock Quality Designation (RQD) Procedures

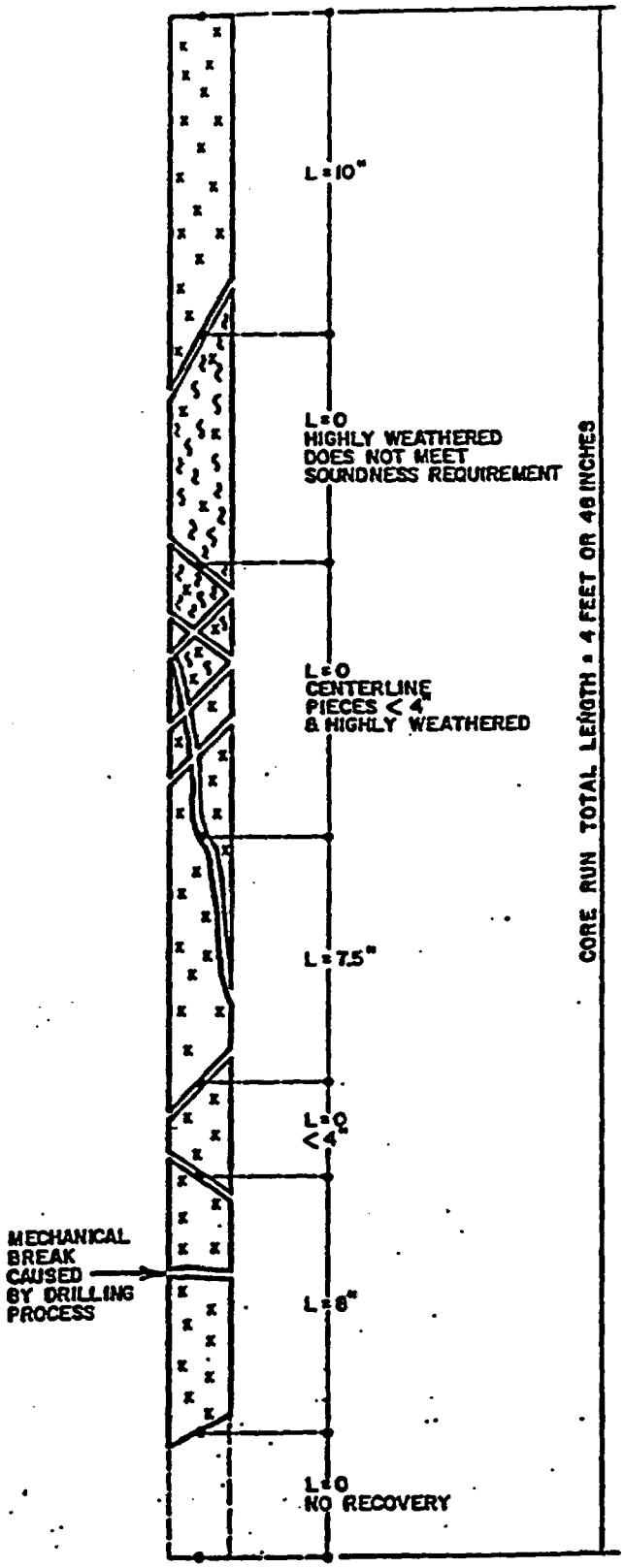
The rock quality designation (RQD) was developed as an index of rock quality for design and construction. At that time rock quality information was usually available only from geologic descriptions and the percentage of core recovery. D.U. Deere developed this index in 1964, published the concept in 1967 (Deere et al., 1967), and he revisited it 20 years later (Deere, 1989). RQD has been employed extensively in the United States and in Europe to identify low quality rock zones and to estimate tunnel support. RQD is a simple, inexpensive, and reproducible quantitative index. Problematic rock that is highly weathered, soft, fractured, sheared, and jointed is counted against the rock mass. Thus, it is simply a measurement of the percentage of "good" rock recovered from an interval of a borehole. The total length of core pieces which are 4 inches (about 100 mm) and longer, is divided by the length of the core run. The correct procedure for measuring RQD is illustrated in Figure 1. Rock mass classification based on RQD alone proved to be ineffective; however, RQD remains an important parameter. Both the RMR and Q systems use RQD as one rock mass rating factor. RQD is calculated using the following equation:

$$\text{RQD \%} = \frac{\sum \text{Length of sound core pieces} > 100\text{ mm (4 in)}}{\text{Total core run length}} * 100\%$$

To calculate RQD from observation of the tunnel wall, lengths of intact rock along the DLS survey tape are estimated or calculated as the percentage of core pieces 100 mm or longer which would be recovered in an imaginary horizontal drill hole along the right wall of the excavation. The same piece of core could be measured three ways: along the centerline, from tip to tip, or along the fully circular barrel section (Fig. 2). The recommended procedure is to measure the core length along the centerline (Fig. 1). The reasons that the center-line measurement is preferred are that 1) it results in a standardized RQD that is not dependent on the core diameter, and 2) it avoids unduly penalizing the quality of the rock mass for cases where fractures parallel the borehole and are cut by a second set.

Two methods are used to estimate the RQD. RQD is first determined by visual observation of the tunnel wall. This visual estimate is recorded on data forms. The second method uses line survey data to calculate an RQD. Both the visual observation and the line survey data collection require procedures to describe fractures which occur in molds of wedges removed from the tunnel wall.

Visual RQD Procedure. The length of core not recovered (or recovered in lengths less than 10 cm) is estimated by visually scanning the DLS tape. For a five-meter reach, one technique is to count the number of 10 cm lengths not recovered. That number doubled and subtracted from 100 gives the RQD. For example, through a five-meter reach, if three lengths (10 cm each) of rock are estimated to be short pieces the visual RQD is 94%.



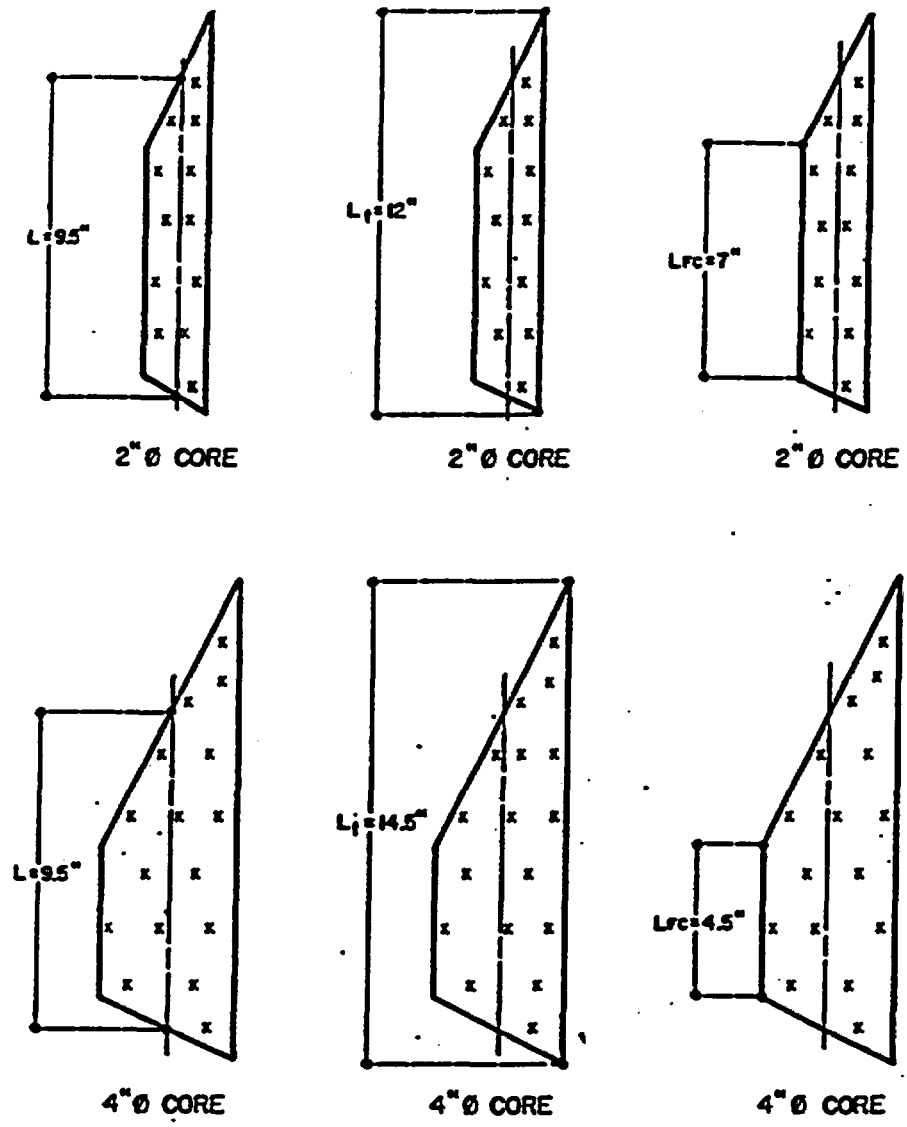
$$RQD = \frac{\sum \text{LENGTH OF SOUND CORE PIECES} > 4 \text{ INCHES (100mm)}}{\text{TOTAL CORE RUN LENGTH}}$$

$$RQD = \frac{10 + 7.5 + 8}{48} \times 100\%$$

RQD = 53% (FAIR)

RQD (ROCK QUALITY DESIGNATION)	DESCRIPTION OF ROCK QUALITY
0-25 %	VERY POOR
25-50 %	POOR
50-75 %	FAIR
75-90 %	GOOD
90-100%	EXCELLENT

FIG. 1 – RQD LOGGING



CENTERLINE

A. CORRECT METHOD FOR CORE LENGTH MEASUREMENT – LENGTH OF CORE INDEPENDENT OF CORE DIA.

TIP TO TIP

B. INCORRECT METHOD FOR CORE LENGTH MEASUREMENT – LENGTH DEPENDENT ON CORE DIA.

FULLY CIRCULAR

C. INCORRECT METHOD FOR CORE LENGTH MEASUREMENT – LENGTH DEPENDENT ON CORE DIA.

FIG. 2 – LENGTH MEASUREMENT OF CORE FOR RQD.

Fracture zones, wedge molds, subparallel fractures, fractures behind steel sets, and lithophysao zones are estimated as described below in the section titled line survey RQD Procedures. Experience indicates that the two independent visual estimates of RQD will usually fall within a five percentage point range.

Line Survey RQD Procedures. USBR/USGS collects fracture data along a line established on the right rib of the tunnel parallel to the tunnel axis and approximately one meter below the springline. A metric survey tape is attached to the tunnel rib or steel sets. The tape is used by mapping team Geologists to locate fractures exceeding a given length for the Detailed Line Survey (DLS), procedure GP-32. The same tape is used to determine RQD. For RQD all natural fractures are considered, thus ignoring mechanical breaks as a result of drilling or blasting. The station of each individual fracture is recorded or the beginning and ending stations of zones of zero RQD are recorded.

The fundamental assumption for calculation of RQD using the scanline data is that length of rock between recorded fractures is intact rock. From that assumption, the total of intact rock pieces which are longer than 10 cm are determined from the fracture spacing. That length, expressed as a percentage of the total length, is the line survey RQD. Note this technique does not depend on an assumed fracture spacing distribution. In fact, the fracture-spacing distribution may be reduced from the RQD data collected in this procedure. The directional bias associated with a line survey in one direction is not eliminated.

The paragraphs below list several details applied to standardize the procedure.

Fracture Zones: An area of closely spaced fractures is described by noting the beginning and ending stations of the zone. Individual fractures are not recorded. The average fracture spacing is estimated. On the RQD Scanline Form, the notations fz and Ez are used to identify the beginning and ending stations of a fracture zone. The calculated length of intact rock is zero through these zones.

Shallow Wedge Molds: Generally, this mold will result from the intersection of two fractures subparallel to the scanline. This shallow mold appears to fracture the imaginary core so that the shortest side of the core is less than 100mm. The length between beginning and ending fractures is not counted as intact rock for calculation of the RQD. The beginning and ending stations of this zero RQD zone are identified on the scanline form as sw and EZ.

Fractured Wedge Molds: Fractures through a wedge zone are projected along strike to the DLS tape. The fracture stations are recorded and the RQD is calculated normally using only the fracture stations. The notation fw for fractured wedge or dw for deep wedge are optionally noted on the RQD scanline form. Fracture stations do not necessarily project to the DLS tape in numerical order; so data is sorted and entered into the spreadsheet in increasing station order.

Subparallel Fractures: Fractures which strike nearly parallel to the imaginary drill hole, or low angle fractures produce a theoretical longitudinal fracture of the core. For this condition, the length of fracturing is assigned a zero RQD value. The beginning station is recorded and identified with the notation pf. The ending station is recorded and identified with the notation EZ. This value represents the most conservative approach. This procedure differs slightly from Deere's procedure which states that subparallel fractures should be treated the same way as any other fracture, by determining where it intersects the centerline of the core (Fig. 1).

Fractures Behind Steel Sets: In areas supported by steel sets, an accurate station for fractures behind the sets cannot be recorded. Where fracturing on either side of the steel sets suggests fracturing behind the steel sets an estimated station for the inferred fractures is recorded and RQD is calculated using these fractures.

Lithophysal: Lithophysae encountered in core drilling would produce a length of drill hole with no core recovery. For reaches through lithophysae zones cavities larger than about 50mm are excluded from the theoretical length of intact rock. The notation lith and EZ are used on the scanline forms either to identify the location of lithophysae cavities or to estimate an overall length reduction due to the cavities. This procedure of "zeroing out" lithophysae zones produces a more conservative or lower value. Lithophysae voids might not produce sliding planes, which affect stability. This particular issue is not addressed by Deere or in any other current publications.

Fracture stations and notations on the Scanline RQD field form are entered into the Excel spreadsheet to calculate a line survey RQD.

SECTION 1 - USBR Rock Mass Classification

Page

USBR Rock Mass Classification
Q Rock Quality and Rock Mass Ratings 1.1

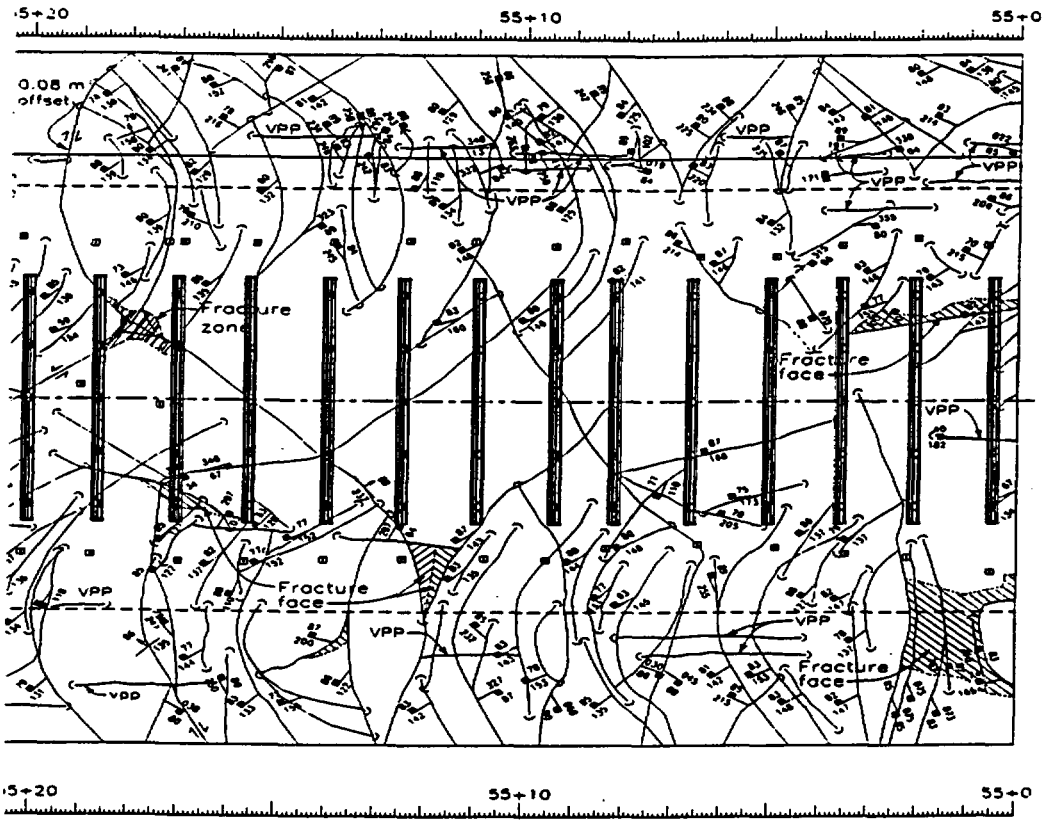
Notes:

1. The full periphery tunnel maps shown in this section are for reference only. See the final QA approved maps for geologic details.

2. The Rated by line on the following pages lists person(s) who gathered the information by analyzing the tunnel's wall.

USGS/USBR Rock Mass Classification

Begin Station: 5500 **End Station:** 5520 **Date:** 17 Jun 96
Rated by: Jeanne Major



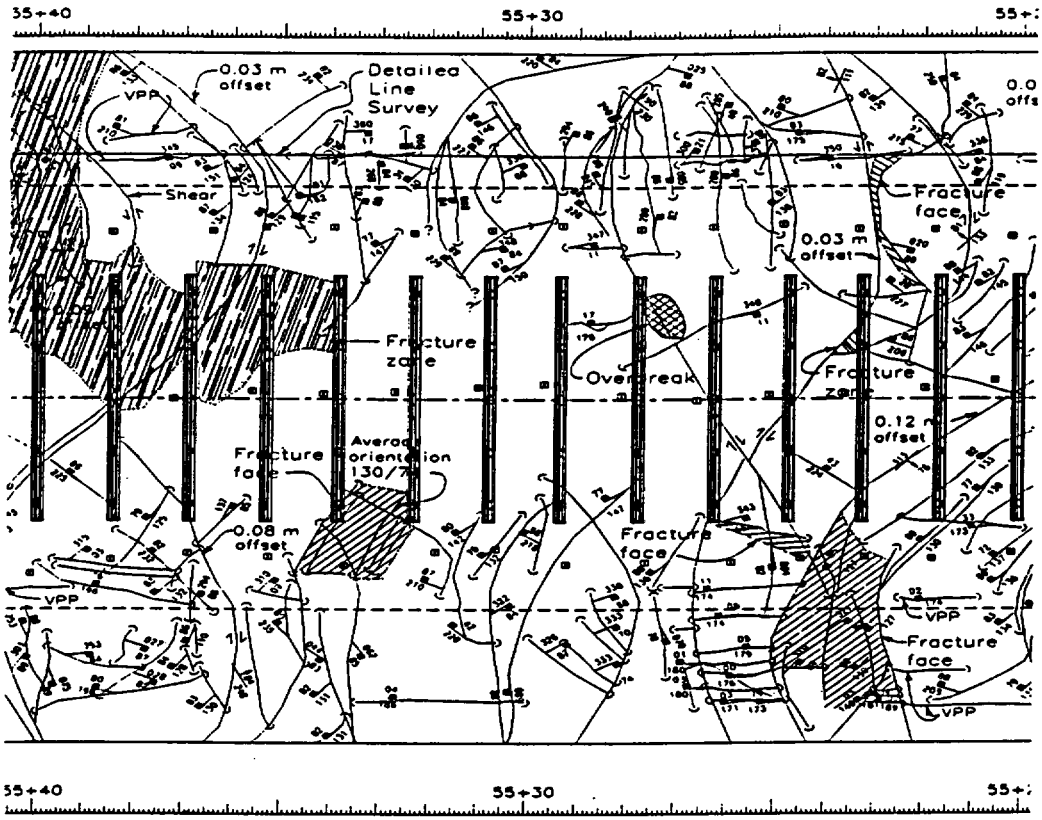
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5500	5505	5510	5515
End Station	5505	5510	5515	5520
Mapped RQD	75	81	84	93
Jn	6	6	9	6
Jr	1	2	2	3
Ja	2	2	2	6
JwQ	1	1	1	1
SRF	1	1	2.5	2.5
Q rating	6.3	14	3.7	3.1
Qualitative Description	Fair	Good	Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5500	5505	5510	5515
End Station	5505	5510	5515	5520
Mapped RQD	75	81	84	93
RQD Index	17	17	17	20
C	12	12	12	12
Js	15	15	15	15
Jcd	20	19	17	19
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	67	66	64	69
Qualitative Description	Good	Good	Good	Good

USGS/USBR Rock Mass Classification

Begin Station: 5520 **End Station:** 5540 **Date:** 11 Jun 96
Rated by: Jeanne Major



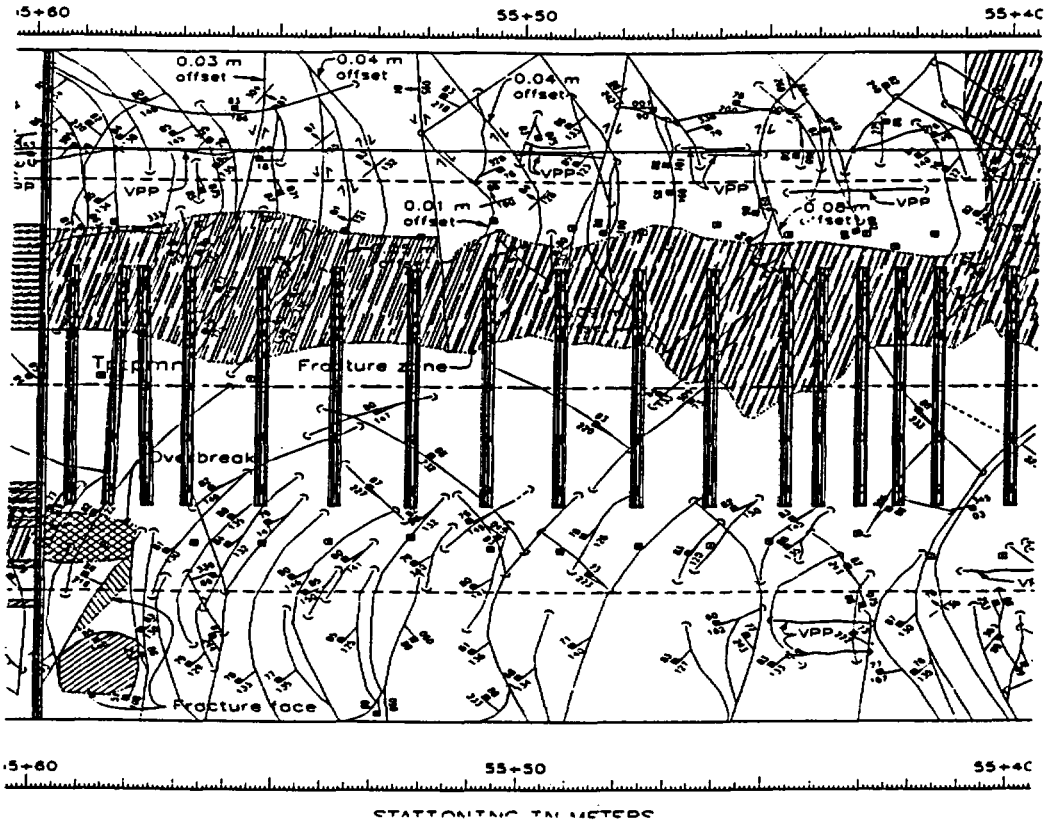
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5520	5525	5530	5535
End Station	5525.	5530	5535	5540
Mapped RQD	76	82	69	56
Jn	9	9	6	6
Jr	2	3	2	2
Ja	2	4	4	4
JwQ	1	1	1	1
SRF	2.5	2.5	1	2.5
Q rating	3.4	2.7	5.8	1.9
Qualitative Description	Poor	Poor	Fair	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5520	5525	5530	5535
End Station	5525	5530	5535	5540
Mapped RQD	76	82	69	56
RQD Index	17	17	13	13
C	12	12	12	12
Js	15	15	15	10
Jcd	16	9	14	11
JwR	15	15	15	15
AJO	-12	-12	-12	0
RMR rating	63	56	57	61
Qualitative Description	Good	Fair	Fair	Good

USGS/USBR Rock Mass Classification

Begin Station: 5540 **End Station:** 5560 **Date:** 12 Jun 96
Rated by: Jeanne Major



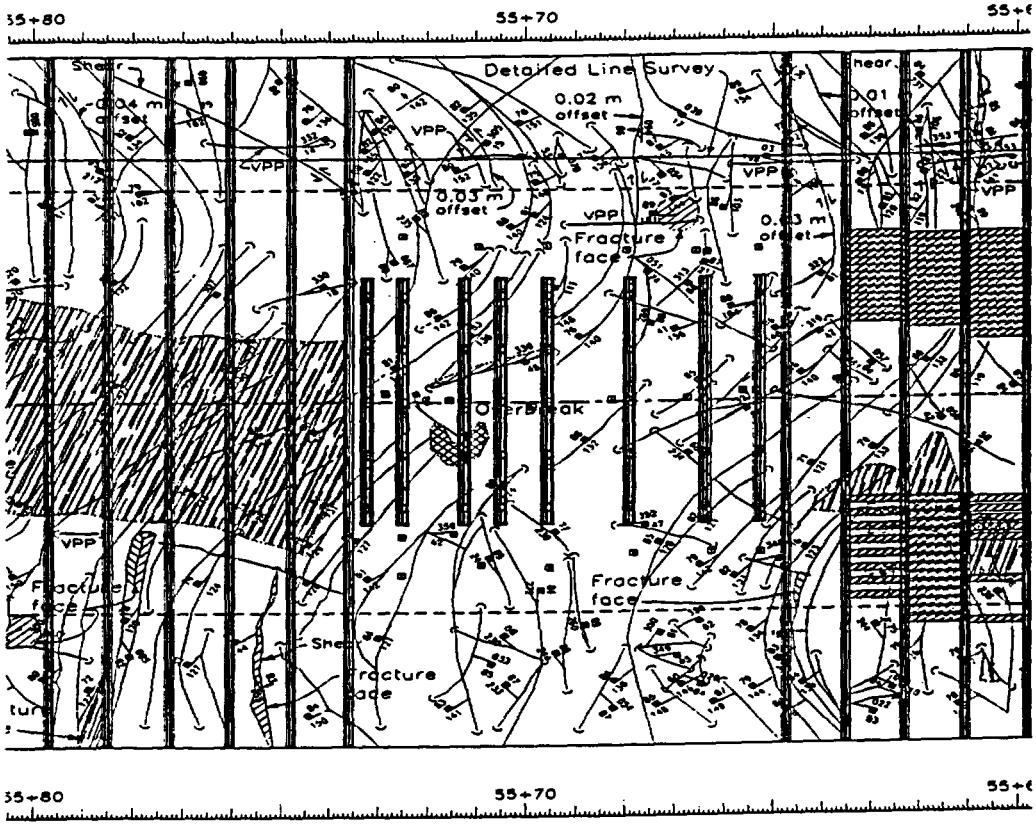
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5540	5545	5550	5555
End Station	5545	5550	5555	5560
Mapped RQD	57	67	62	63
Jn	12	12	12	12
Jr	2	2	2	2
Ja	4	2	2	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	0.95	2.2	2.1	2.1
Qualitative Description	Very Poor	Poor	Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5540	5545	5550	5555
End Station	5545	5550	5555	5560
Mapped RQD	57	67	62	63
RQD Index	13	13	13	13
C	12	12	12	12
Js	15	15	10	15
Jcd	13	21	23	24
JwR	15	15	15	15
AJO	-5	-12	-12	-12
RMR rating	63	64	61	67
Qualitative Description	Good	Good	Good	Good

USGS/USBR Rock Mass Classification

Begin Station: 5560 **End Station:** 5580 **Date:** 13 Jun 96
Rated by: Jeanne Major



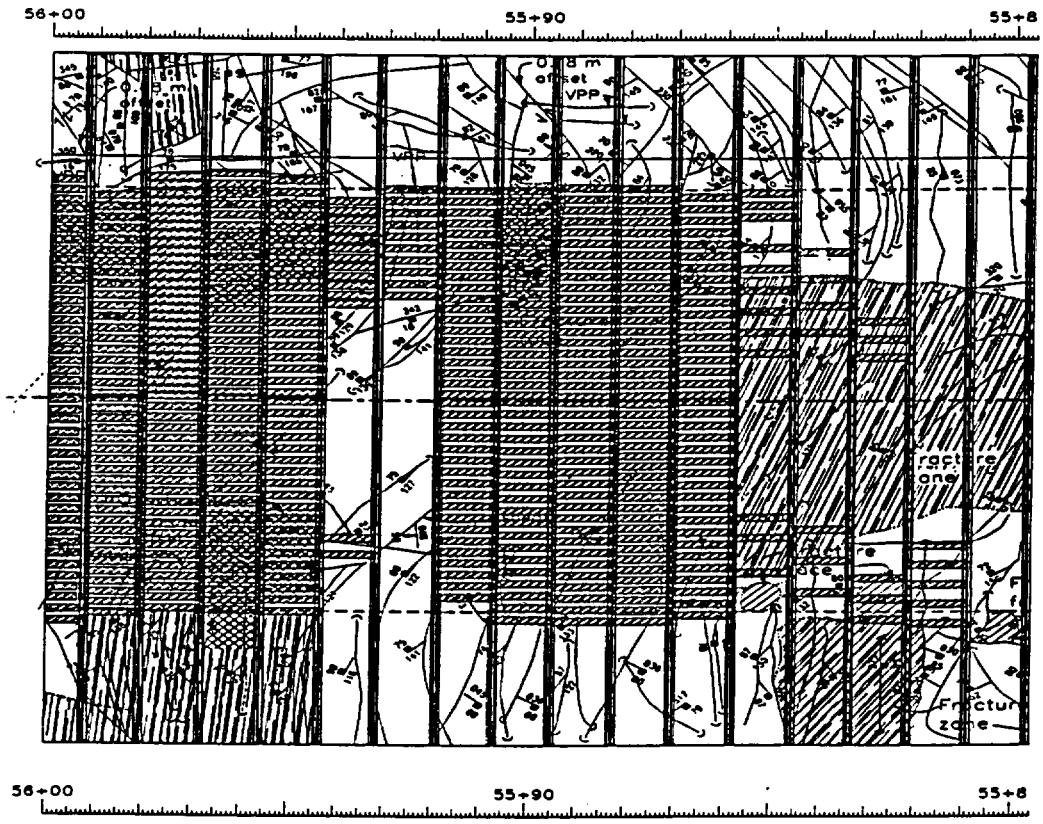
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5560	5565	5570	5575
End Station	5565	5570	5575	5580
Mapped RQD	58	61	81	83
Jn	6	12	6	6
Jr	2	3	1	1
Ja	5	2	2	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	1.5	3.1	2.7	2.8
Qualitative Description	Poor	Poor	Poor	Poor
Installed Ground Support Category	4	1	1	4

RMR Rating Parameters				
Begin Station	5560	5565	5570	5575
End Station	5565	5570	5575	5580
Mapped RQD	58	61	81	83
RQD Index	13	13	17	17
C	12	12	12	12
Js	10	15	10	15
Jcd	9	21	16	14
JwR	15	15	15	15
AJO	-5	-12	0	0
RMR rating	54	64	70	73
Qualitative Description	Fair	Good	Good	Good

USGS/USBR Rock Mass Classification

Begin Station: 5580 **End Station:** 5600 **Date:** 14 Jun 96
Rated by: Jeanne Major



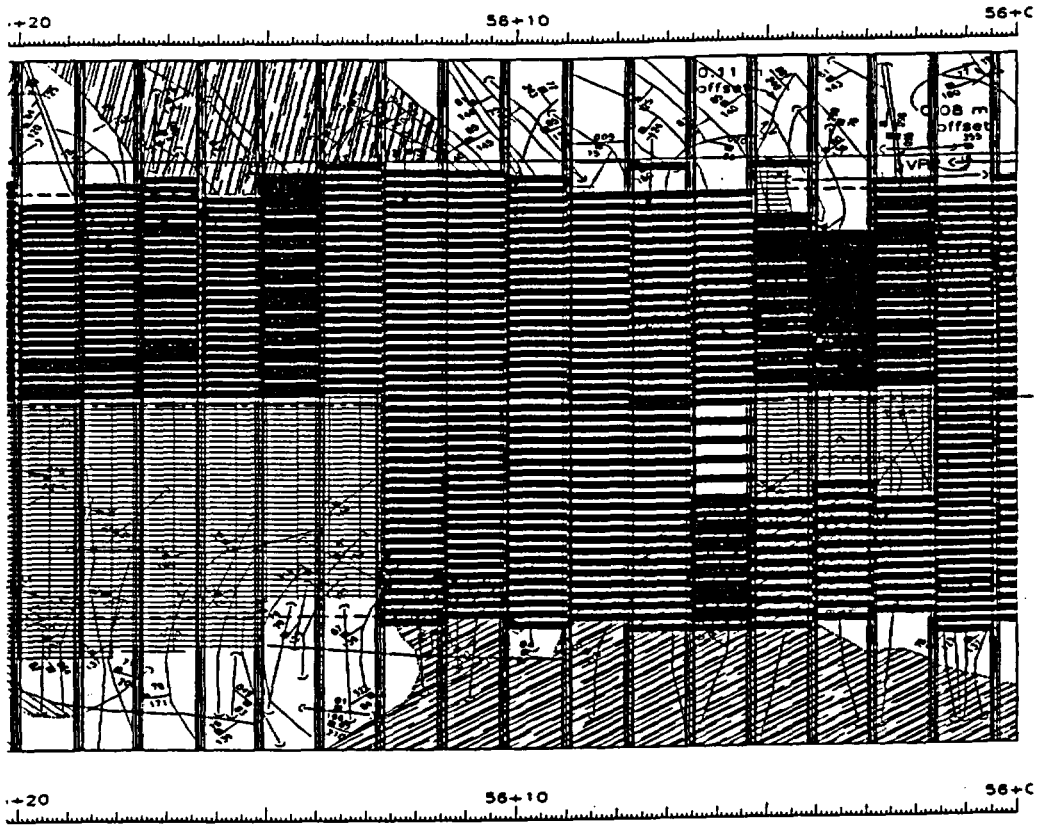
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5580	5585	5590	5595
End Station	5585	5590	5595	5600
Mapped RQD	47	51	53	53
Jn	6	6	6	12
Jr	2	1	1.5	2
Ja	4	2	2	8
JwQ	1	1	1	1
SRF	2.5	2.5	5	5
Q rating	1.6	1.7	1.3	0.22
Qualitative Description	Poor	Poor	Poor	Very Poor
Installed Ground Support Category	4	4	4	4

RMR Rating Parameters				
Begin Station	5580	5585	5590	5595
End Station	5585	5590	5595	5600
Mapped RQD	47	51	53	53
RQD Index	8	13	13	13
C	12	12	12	12
Js	10	15	15	10
Jcd	14	16	14	11
JwR	15	15	15	15
AJO	0	-12	-12	-12
RMR rating	59	59	57	49
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5600 **End Station:** 5620 **Date:** 18 Jun 96
Rated by: Jeanne Major



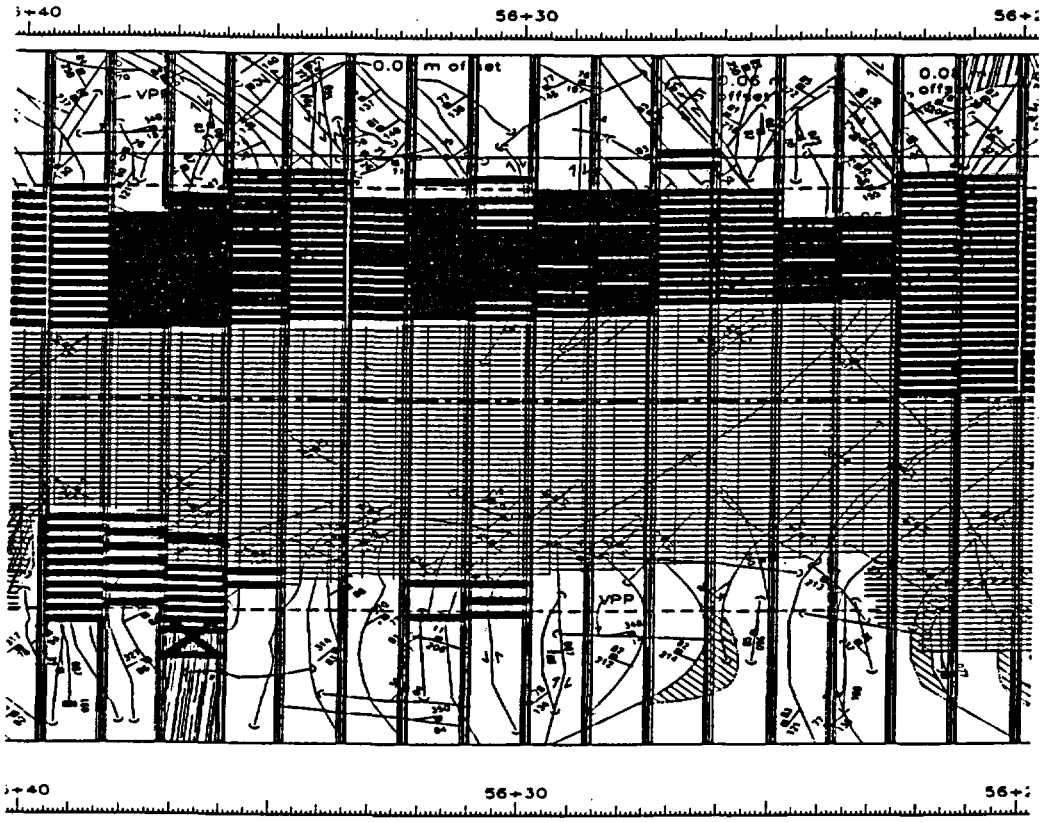
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5600	5605	5610	5615
End Station	5605	5610	5615	5620
Mapped RQD	54	75	61	72
Jn	12	12	12	12
Jr	1	1	1	2
Ja	4	4	4	4
JwQ	1	1	1	1
SRF	5	5	5	5
Q rating	0.23	0.31	0.25	0.6
Qualitative Description	Very Poor	Very Poor	Very Poor	Very Poor
Installed Ground Support Category	4	4	4	4

RMR Rating Parameters				
Begin Station	5600	5605	5610	5615
End Station	5605	5610	5615	5620
Mapped RQD	54	75	61	72
RQD Index	13	17	13	13
C	12	12	12	12
Js	15	15	10	15
Jcd	14	14	14	13
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	57	61	52	56
Qualitative Description	Fair	Good	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5620 **End Station:** 5640 **Date:** 25 Jun 96
Rated by: John Steighner



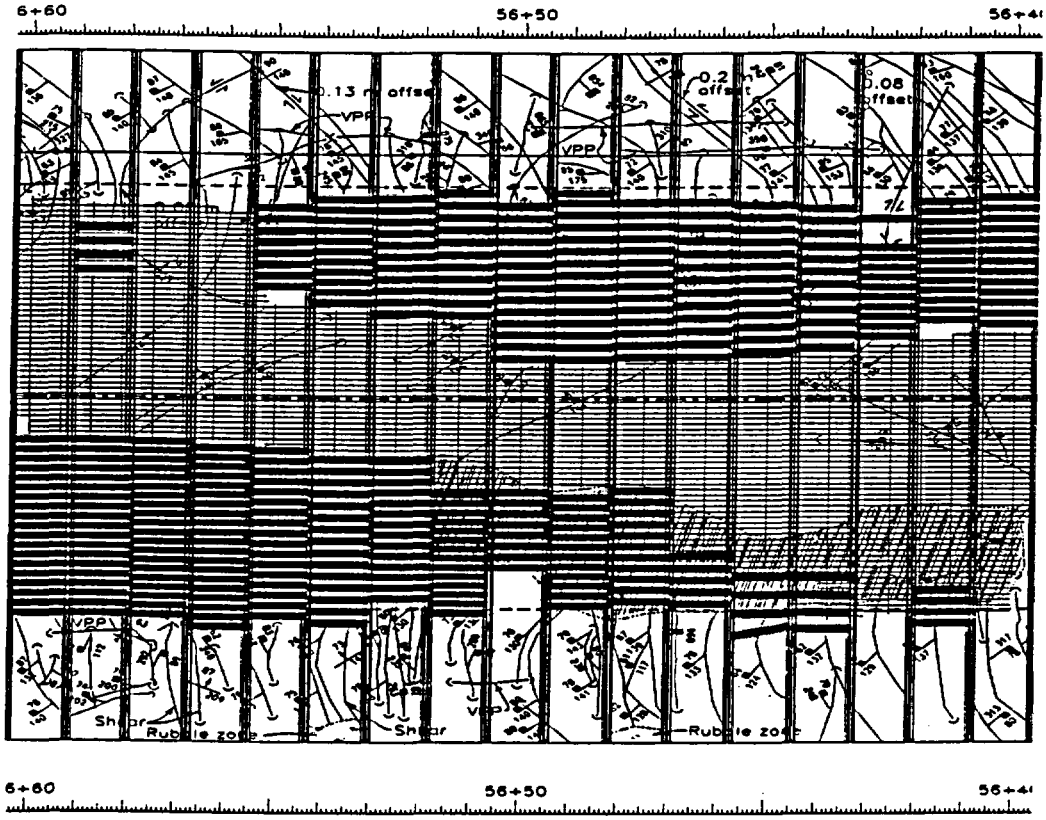
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5620	5625	5630	5635
End Station	5625	5630	5635	5640
Mapped RQD	51	77	81	47
Jn	6	6	12	9
Jr	1	1	1	1.5
Ja	2	3	4	4
JwQ	1	1	1	1
SRF	2.5	2.5	5	2.5
Q rating	1.7	1.7	0.34	0.78
Qualitative Description	Poor	Poor	Very Poor	Very Poor
Installed Ground Support Category	4	4	4	4

RMR Rating Parameters				
Begin Station	5620	5625	5630	5635
End Station	5625	5630	5635	5640
Mapped RQD	51	77	81	47
RQD Index	13	17	17	8
C	12	12	12	12
Js	10	10	10	10
Jcd	12	17	14	16
JwR	15	15	15	15
AJO	-12	-12	-12	0
RMR rating	50	59	56	61
Qualitative Description	Fair	Fair	Fair	Good

USGS/USBR Rock Mass Classification

Begin Station: 5640 **End Station:** 5660 **Date:** 25 Jun 96
Rated by: John Steighner



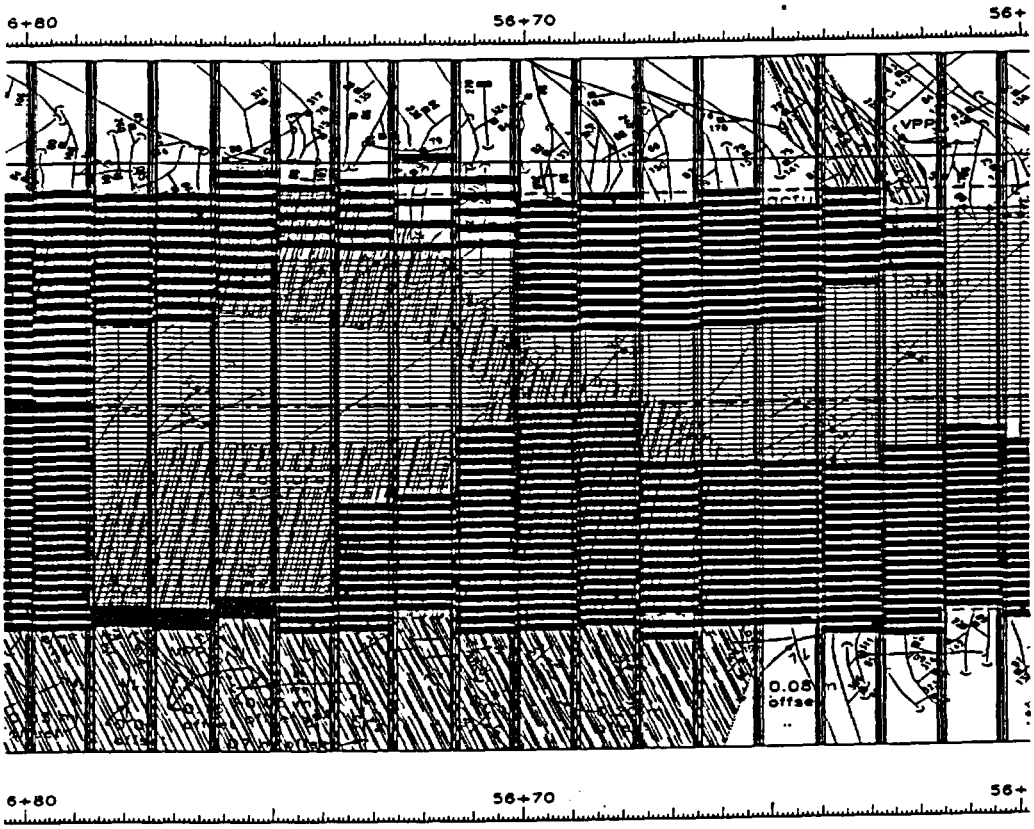
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5640	5645	5650	5655
End Station	5645	5650	5655	5660
Mapped RQD	79	58	74	67
Jn	6	6	6	6
Jr	1	1	3	2
Ja	8	4	4	5
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	0.66	0.97	3.7	1.8
Qualitative Description	Very Poor	Very Poor	Poor	Poor
Installed Ground Support Category	4	4	4	4

RMR Rating Parameters				
Begin Station	5640	5645	5650	5655
End Station	5645	5650	5655	5660
Mapped RQD	79	58	74	67
RQD Index	17	13	13	13
C	12	12	12	12
Js	15	10	15	15
Jcd	12	12	16	13
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	59	50	59	56
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5660 **End Station:** 5680 **Date:** 26 Jun 96
Rated by: John Steighner



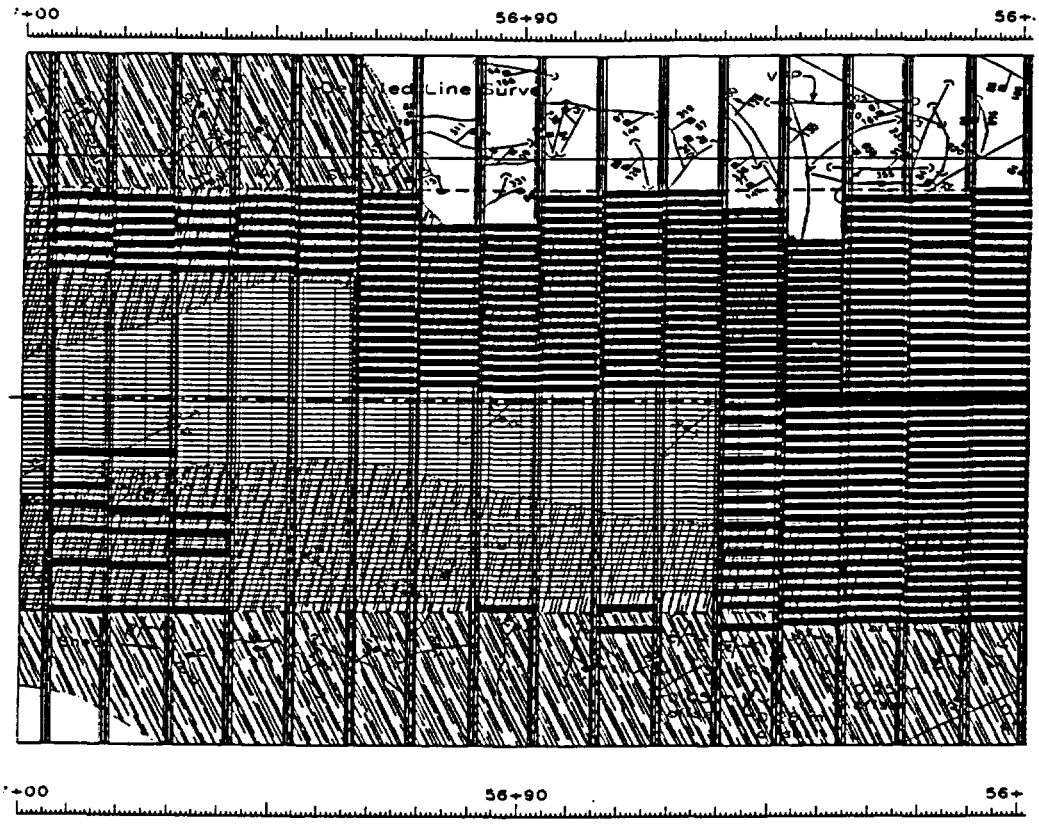
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5660	5665	5670	5675
End Station	5665	5670	5675	5680
Mapped RQD	46	74	49	67
Jn	6	6	9	9
Jr	1	2	2	2
Ja	2	3	4	2
JwQ	1	1	1	1
SRF	2.5	2.5	5	2.5
Q rating	1.5	3.3	0.54	3
Qualitative Description	Poor	Poor	Very Poor	Poor
Installed Ground Support Category	4	4	4	4

RMR Rating Parameters				
Begin Station	5660	5665	5670	5675
End Station	5665	5670	5675	5680
Mapped RQD	46	74	49	67
RQD Index	8	13	8	13
C	12	12	12	12
Js	10	15	10	10
Jcd	18	18	16	19
JwR	15	15	15	15
AJO	-12	-5	0	0
RMR rating	51	68	61	69
Qualitative Description	Fair	Good	Good	Good

USGS/USBR Rock Mass Classification

Begin Station: 5680 **End Station:** 5700 **Date:** 08 Jul 96
Rated by: Jeanne Major



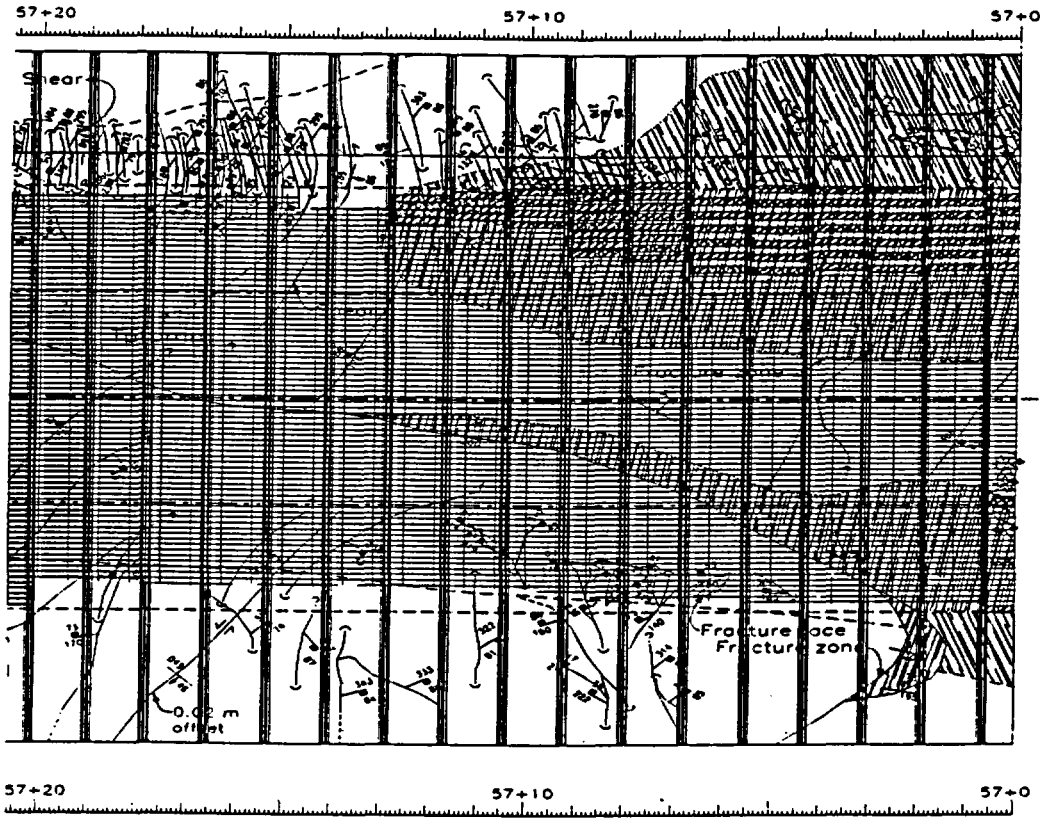
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5680	5685	5690	5695
End Station	5685	5690	5695	5700
Mapped RQD	66	46	33	45
Jn	12	12	15	12
Jr	2	3	2	2
Ja	4	4	4	4
JwQ	1	1	1	1
SRF	2.5	2.5	5	5
Q rating	1.1	1.2	0.22	0.38
Qualitative Description	Poor	Poor	Very Poor	Very Poor
Installed Ground Support Category	4	4	4	4

RMR Rating Parameters				
Begin Station	5680	5685	5690	5695
End Station	5685	5690	5695	5700
Mapped RQD	66	46	33	45
RQD Index	13	8	8	8
C	12	12	12	12
Js	15	10	10	10
Jcd	14	11	22	22
JwR	15	15	15	15
AJO	-5	0	-12	-12
RMR rating	64	56	55	55
Qualitative Description	Good	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5700 **End Station:** 5720 **Date:** 25 Jun 96
Rated by: John Steighner



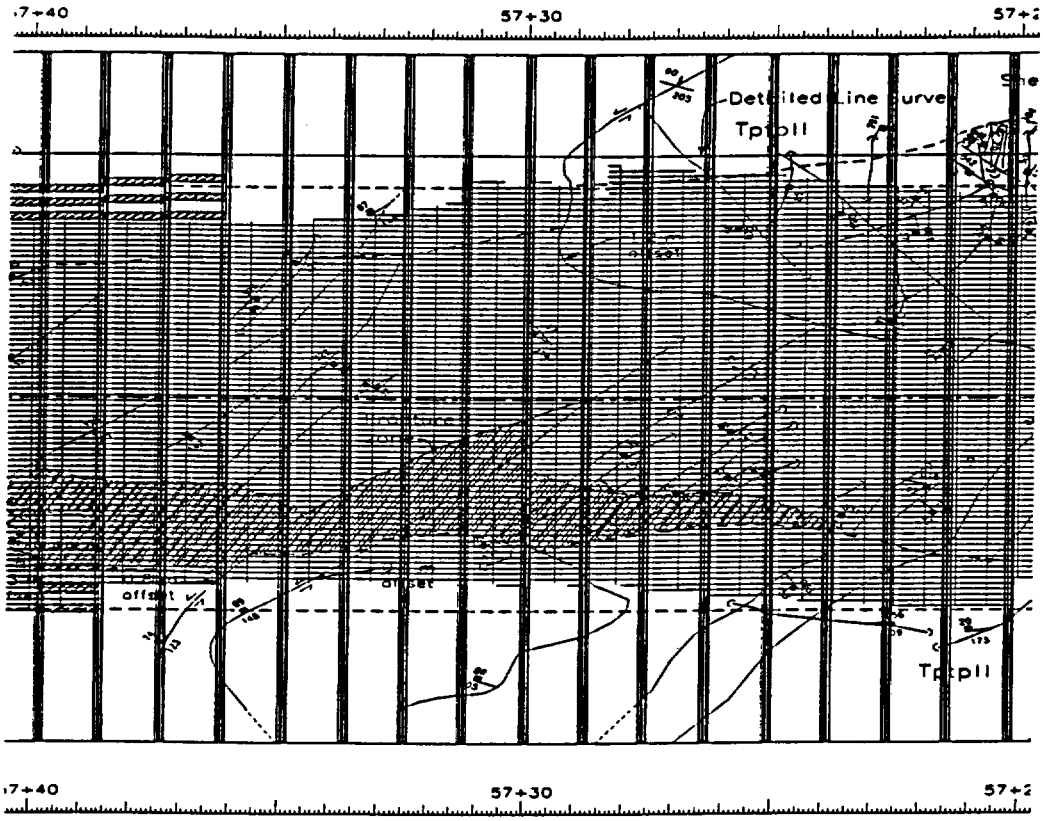
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5700	5705	5710	5715
End Station	5705	5710	5715	5720
Mapped RQD	57	47	49	37
Jn	6	6	6	6
Jr	2	2	2	2
Ja	2	2	4	1
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	3.8	3.1	1.6	4.9
Qualitative Description	Poor	Poor	Poor	Fair
Installed Ground Support Category	4	4	4	4

RMR Rating Parameters				
Begin Station	5700	5705	5710	5715
End Station	5705	5710	5715	5720
Mapped RQD	57	47	49	37
RQD Index	13	8	8	8
C	12	12	12	12
Js	0	15	10	10
Jcd	14	20	24	19
JwR	15	15	15	15
AJO	-12	-12	-5	-12
RMR rating	42	58	64	52
Qualitative Description	Fair	Fair	Good	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5720 **End Station:** 5740 **Date:** 26 Jun 96
Rated by: Bill Singleton



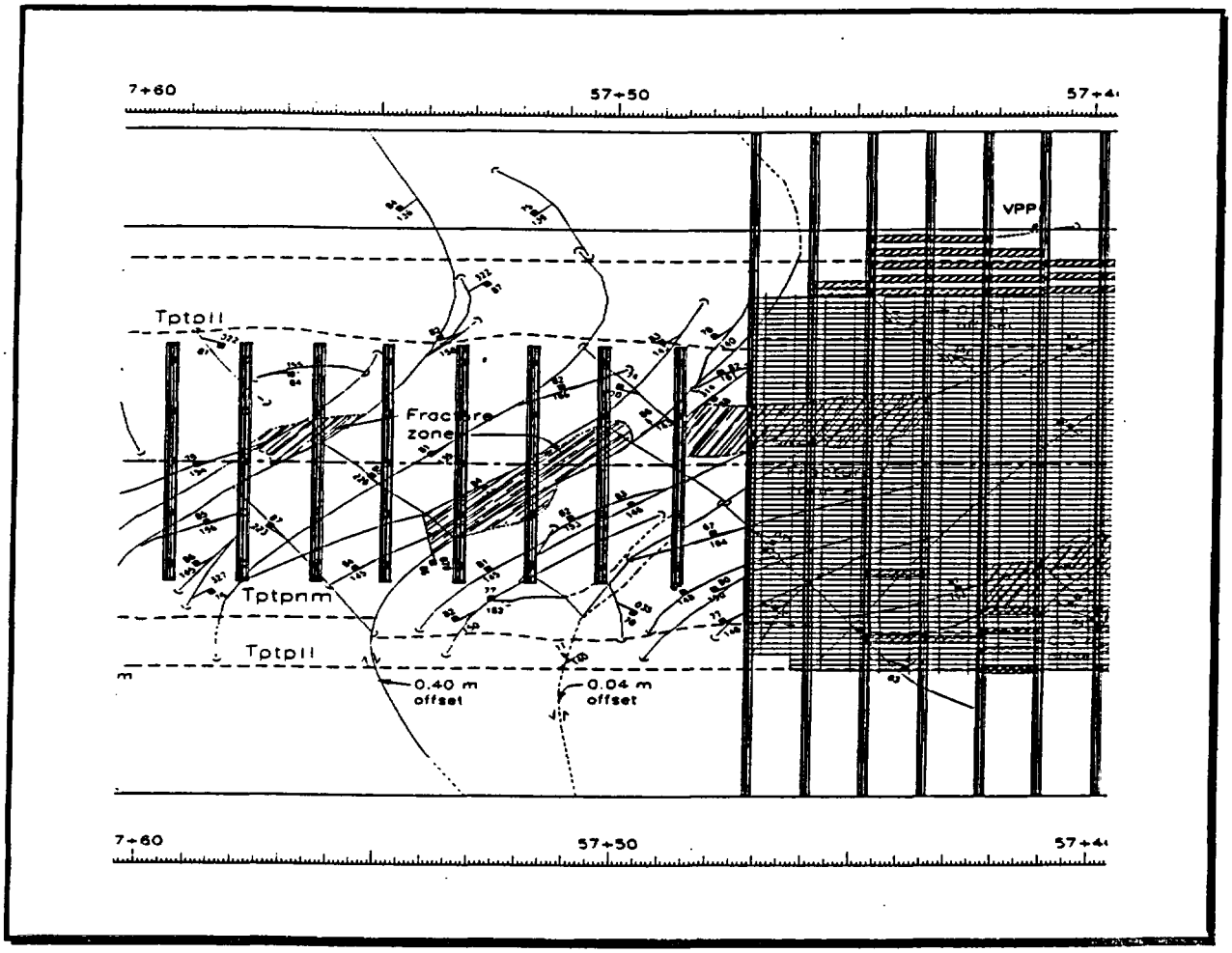
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5720	5725	5730	5735
End Station	5725	5730	5735	5740
Mapped RQD	37	47	45	30
Jn	6	6	3	4
Jr	3	3	3	3
Ja	2	8	5	2
JwQ	1	1	1	1
SRF	5	2.5	7.5	7.5
Q rating	1.9	1.2	1.2	1.5
Qualitative Description	Poor	Poor	Poor	Poor
Installed Ground Support Category	4	4	4	4

RMR Rating Parameters				
Begin Station	5720	5725	5730	5735
End Station	5725	5730	5735	5740
Mapped RQD	37	47	45	30
RQD Index	8	8	8	8
C	7	7	12	12
Js	8	15	15	15
Jcd	25	16	25	24
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	51	49	63	62
Qualitative Description	Fair	Fair	Good	Good

USGS/USBR Rock Mass Classification

Begin Station: 5740 **End Station:** 5760 **Date:** 11 Jul 96
Rated by: Jeanne Major



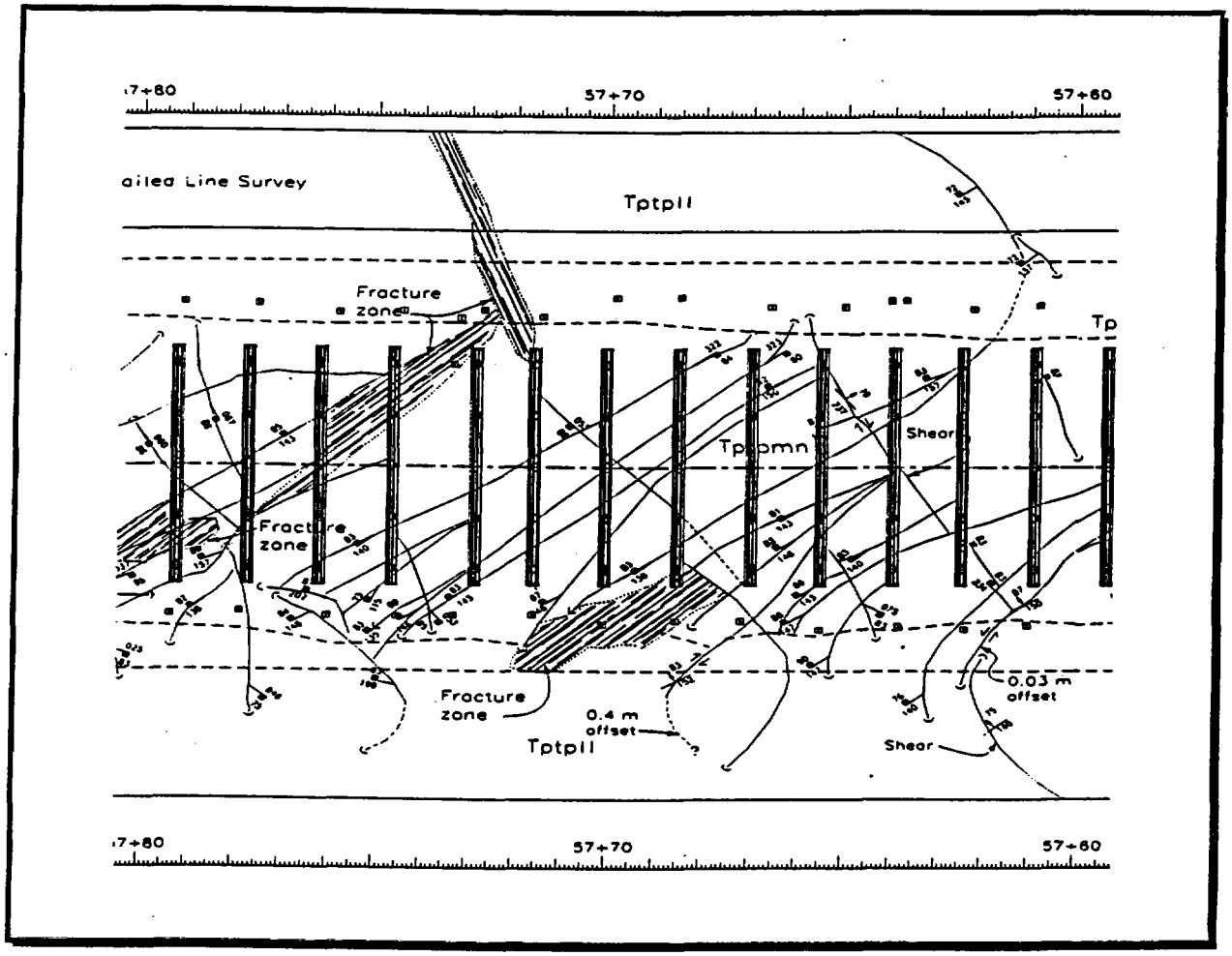
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5740	5745	5750	5755
End Station	5745	5750	5755	5760
Mapped RQD	14	10	15	25
Jn	6	9	6	6
Jr	2	2	2	2
Ja	2	1	2	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	0.93	0.89	1	1.7
Qualitative Description	Very Poor	Very Poor	Poor	Poor
Installed Ground Support Category	4	4	1	1

RMR Rating Parameters				
Begin Station	5740	5745	5750	5755
End Station	5745	5750	5755	5760
Mapped RQD	14	10	15	25
RQD Index	3	3	3	8
C	7	7	7	7
Js	15	8	10	15
Jcd	19	20	19	19
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	47	41	42	52
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5760 **End Station:** 5780 **Date:** 11 Jul 96
Rated by: Jeanne Major



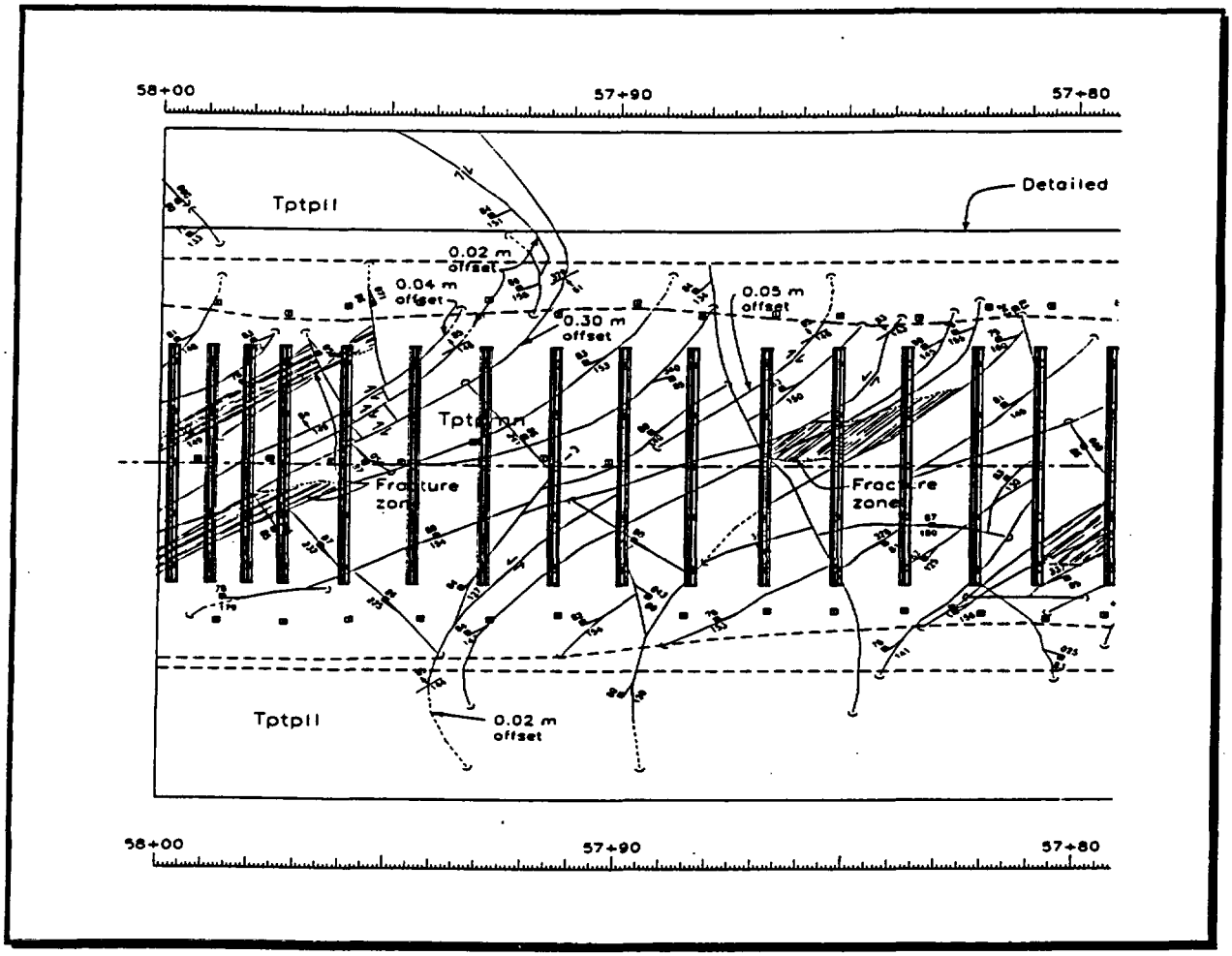
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5760	5765	5770	5775
End Station	5765	5770	5775	5780
Mapped RQD	16	10	12	25
Jn	6	6	6	3
Jr	3	3	2	2
Ja	2	2	3	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	1.6	1	0.53	3.3
Qualitative Description	Poor	Poor	Very Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5760	5765	5770	5775
End Station	5765	5770	5775	5780
Mapped RQD	16	10	12	25
RQD Index	3	3	3	8
C	7	7	7	7
Js	15	15	10	15
Jcd	18	23	17	21
JwR	15	15	15	15
AJO	-12	-12	-5	-5
RMR rating	46	51	47	61
Qualitative Description	Fair	Fair	Fair	Good

USGS/USBR Rock Mass Classification

Begin Station: 5780 **End Station:** 5800 **Date:** 11 Jul 96
Rated by: Bill Singleton



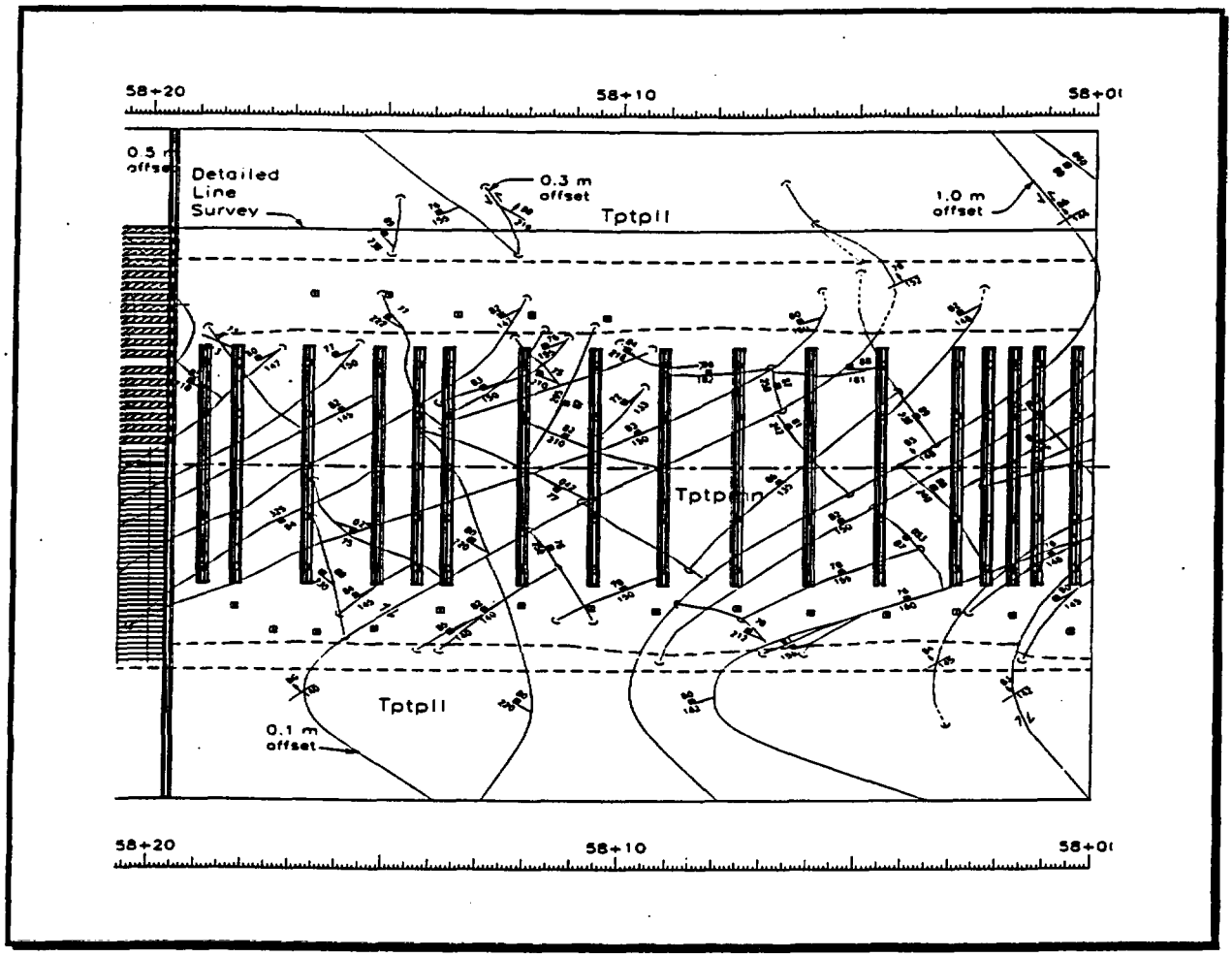
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5780	5785	5790	5795
End Station	5785	5790	5795	5800
Mapped RQD	14	10	22	16
Jn	6	6	6	9
Jr	3	2	2	3
Ja	2	2	6	4
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	1.4	0.67	0.49	0.53
Qualitative Description	Poor	Very Poor	Very Poor	Very Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5780	5785	5790	5795
End Station	5785	5790	5795	5800
Mapped RQD	14	10	22	16
RQD Index	3	3	3	3
C	7	7	7	4
Js	15	15	15	8
Jcd	12	15	11	19
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	40	43	39	37
Qualitative Description	Fair	Fair	Poor	Poor

USGS/USBR Rock Mass Classification

Begin Station: 5800 **End Station:** 5820 **Date:** 24 Jul 96
Rated by: Jack Tousell



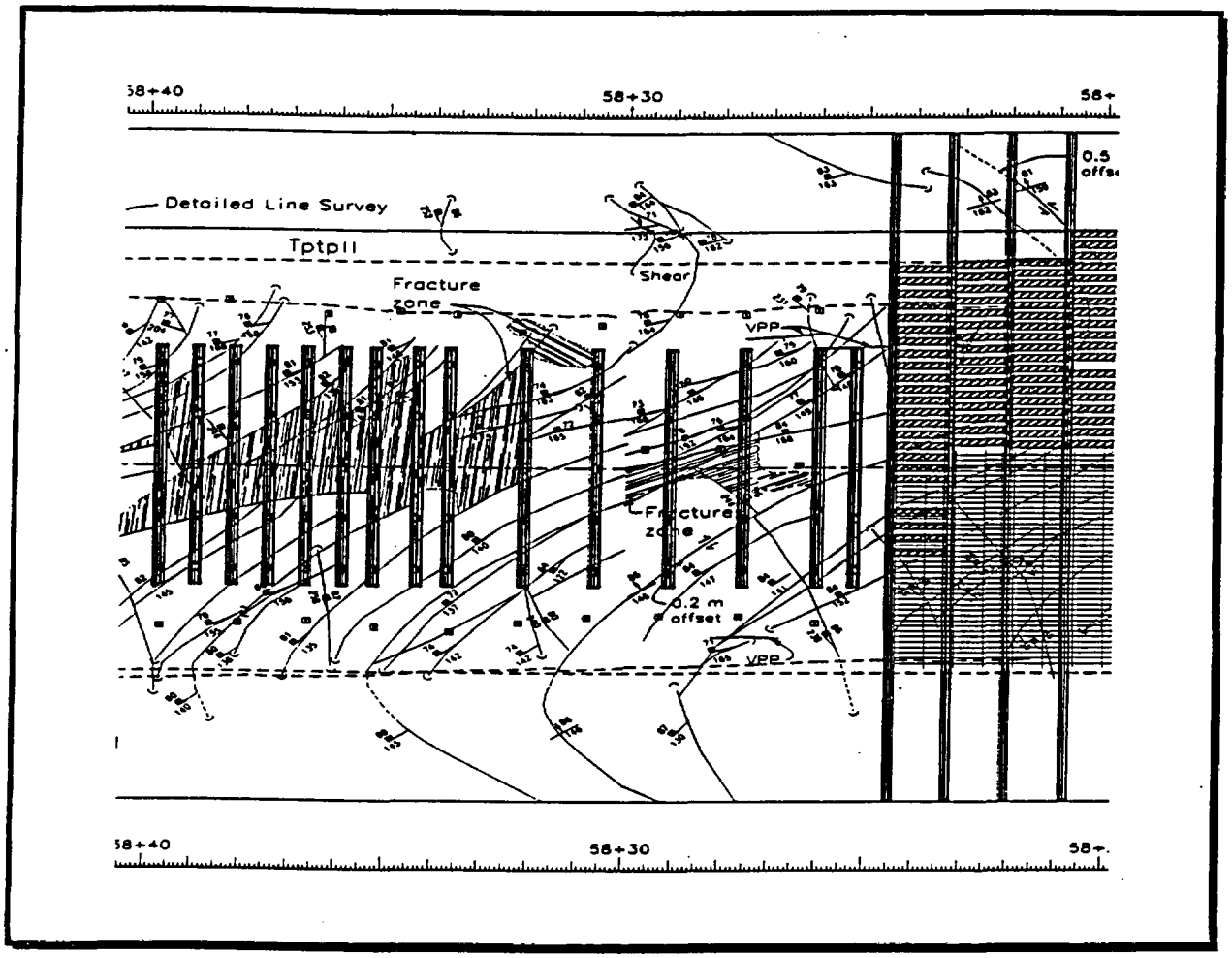
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5800	5805	5810	5815
End Station	5805	5810	5815	5820
Mapped RQD	21	10	10	24
Jn	6	6	9	9
Jr	2	2	3	2
Ja	1	5	4	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	2.8	0.27	0.33	1.1
Qualitative Description	Poor	Very Poor	Very Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5800	5805	5810	5815
End Station	5805	5810	5815	5820
Mapped RQD	21	10	10	24
RQD Index	3	3	3	3
C	7	7	7	7
Js	8	0	8	8
Jcd	14	19	13	18
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	35	32	34	39
Qualitative Description	Poor	Poor	Poor	Poor

USGS/USBR Rock Mass Classification

Begin Station: 5820 **End Station:** 5840 **Date:** 24 Jul 96
Rated by: Bill Singleton



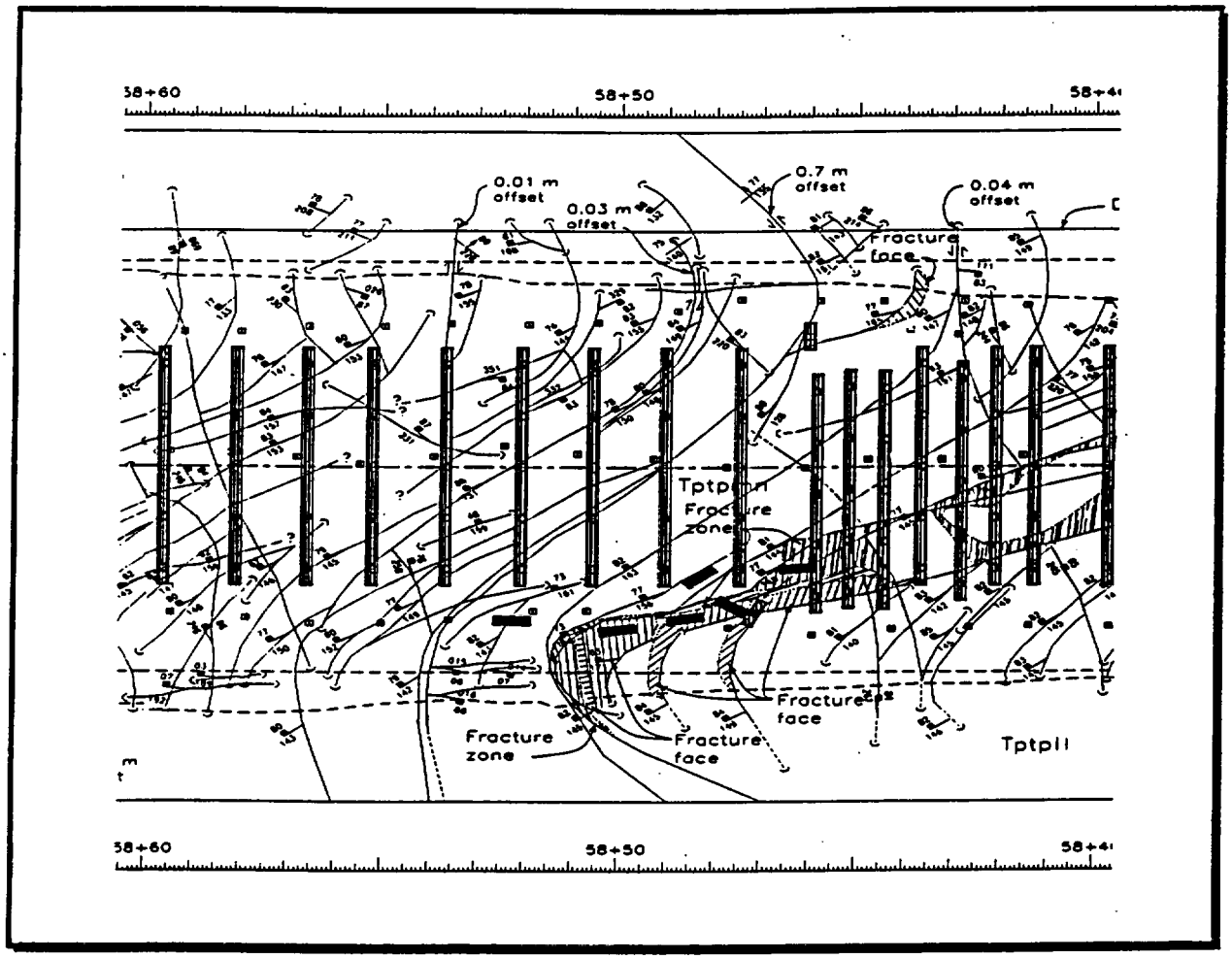
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5820	5825	5830	5835
End Station	5825	5830	5835	5840
Mapped RQD	54	20	23	44
Jn	9	9	6	6
Jr	2	3	2	2
Ja	2	2	3	3
JwQ	1	1	1	1
SRF	5	2.5	2.5	5
Q rating	1.2	1.3	1	0.98
Qualitative Description	Poor	Poor	Poor	Very Poor
Installed Ground Support Category	4	1	1	1

RMR Rating Parameters				
Begin Station	5820	5825	5830	5835
End Station	5825	5830	5835	5840
Mapped RQD	54	20	23	44
RQD Index	13	3	3	8
C	7	7	7	7
Js	8	10	15	15
Jcd	19	19	14	12
JwR	15	15	15	15
AJO	-12	-12	-5	-5
RMR rating	50	42	49	52
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5840 **End Station:** 5860 **Date:** 10 Jul 96
Rated by: Bill Singleton



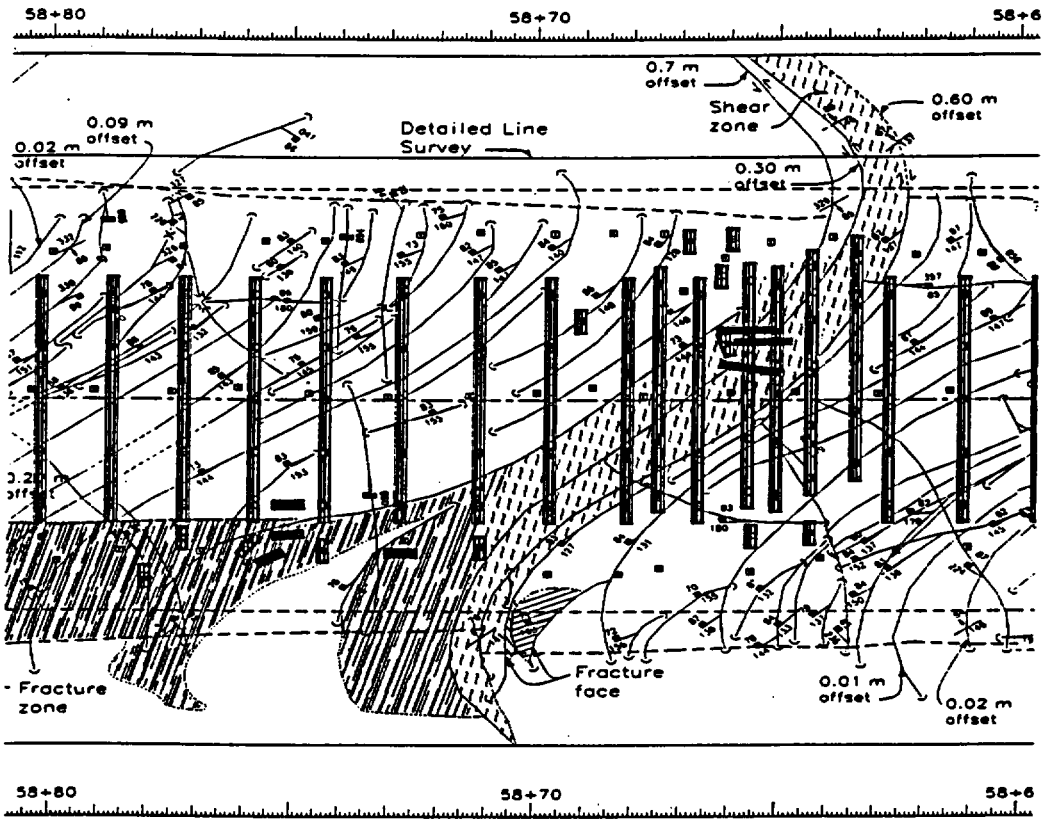
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5840	5845	5850	5855
End Station	5845	5850	5855	5860
Mapped RQD	44	50	38	13
Jn	6	6	6	6
Jr	2	2	2	2
Ja	2	3	2	4
JwQ	1	1	1	1
SRF	5	5	2.5	2.5
Q rating	1.5	1.1	2.5	0.43
Qualitative Description	Poor	Poor	Poor	Very Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5840	5845	5850	5855
End Station	5845	5850	5855	5860
Mapped RQD	44	50	38	13
RQD Index	8	13	8	3
C	7	7	7	7
Js	15	15	15	20
Jcd	19	21	19	17
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	52	59	52	50
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5860 **End Station:** 5880 **Date:** 10 Jul 96
Rated by: Jeanne Major



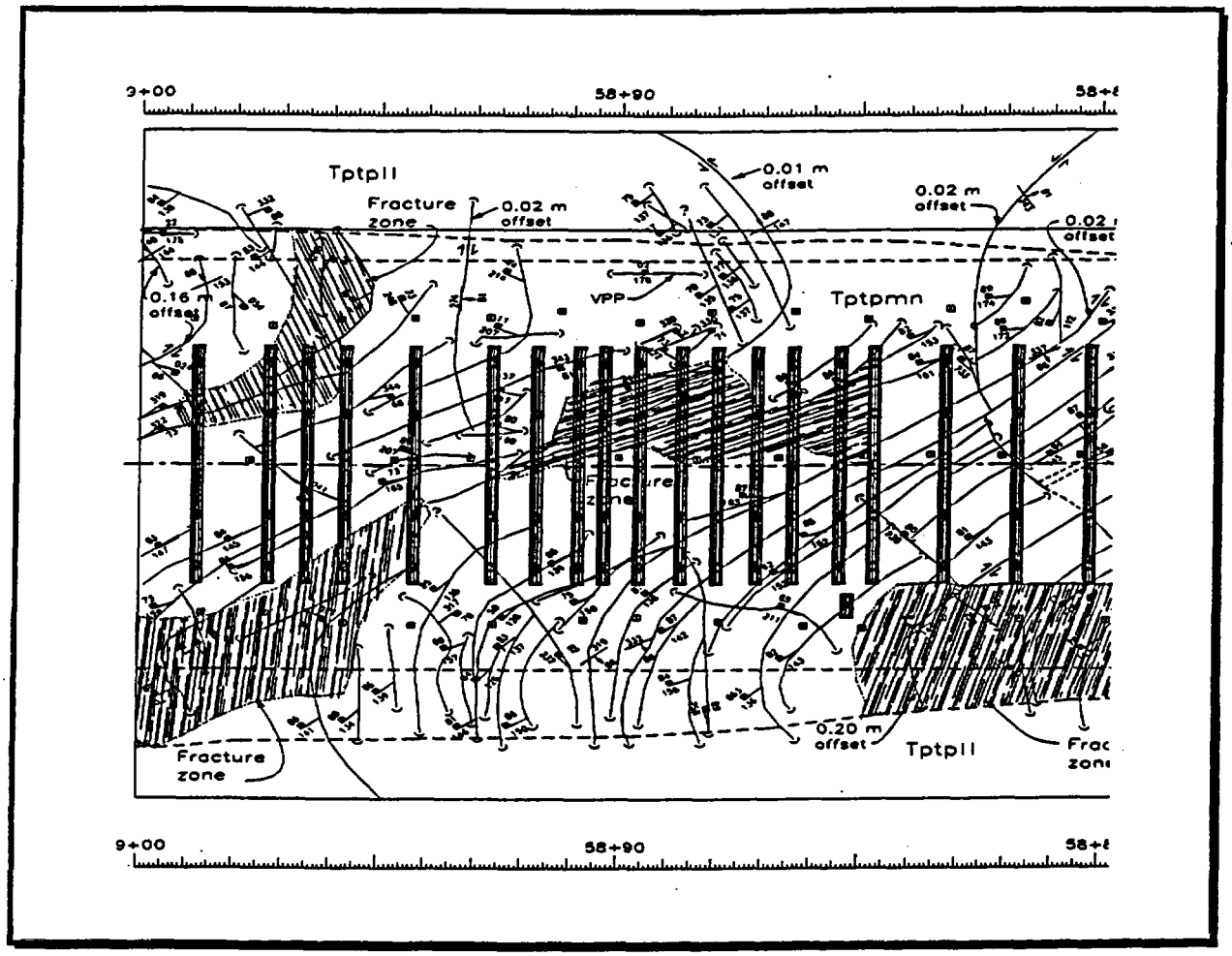
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5860	5865	5870	5875
End Station	5865	5870	5875	5880
Mapped RQD	10	36	18	43
Jn	6	6	9	9
Jr	2	2	2	2
Ja	2	5	2	2
JwQ	1	1	1	1
SRF	2.5	7.5	7.5	5
Q rating	0.67	0.32	0.27	0.96
Qualitative Description	Very Poor	Very Poor	Very Poor	Very Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5860	5865	5870	5875
End Station	5865	5870	5875	5880
Mapped RQD	10	36	18	43
RQD Index	3	8	3	8
C	7	7	7	7
Js	15	15	10	8
Jcd	19	9	13	13
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	47	42	36	39
Qualitative Description	Fair	Fair	Poor	Poor

USGS/USBR Rock Mass Classification

Begin Station: 5880 **End Station:** 5900 **Date:** 05 Aug 96
Rated by: Jeanne Major



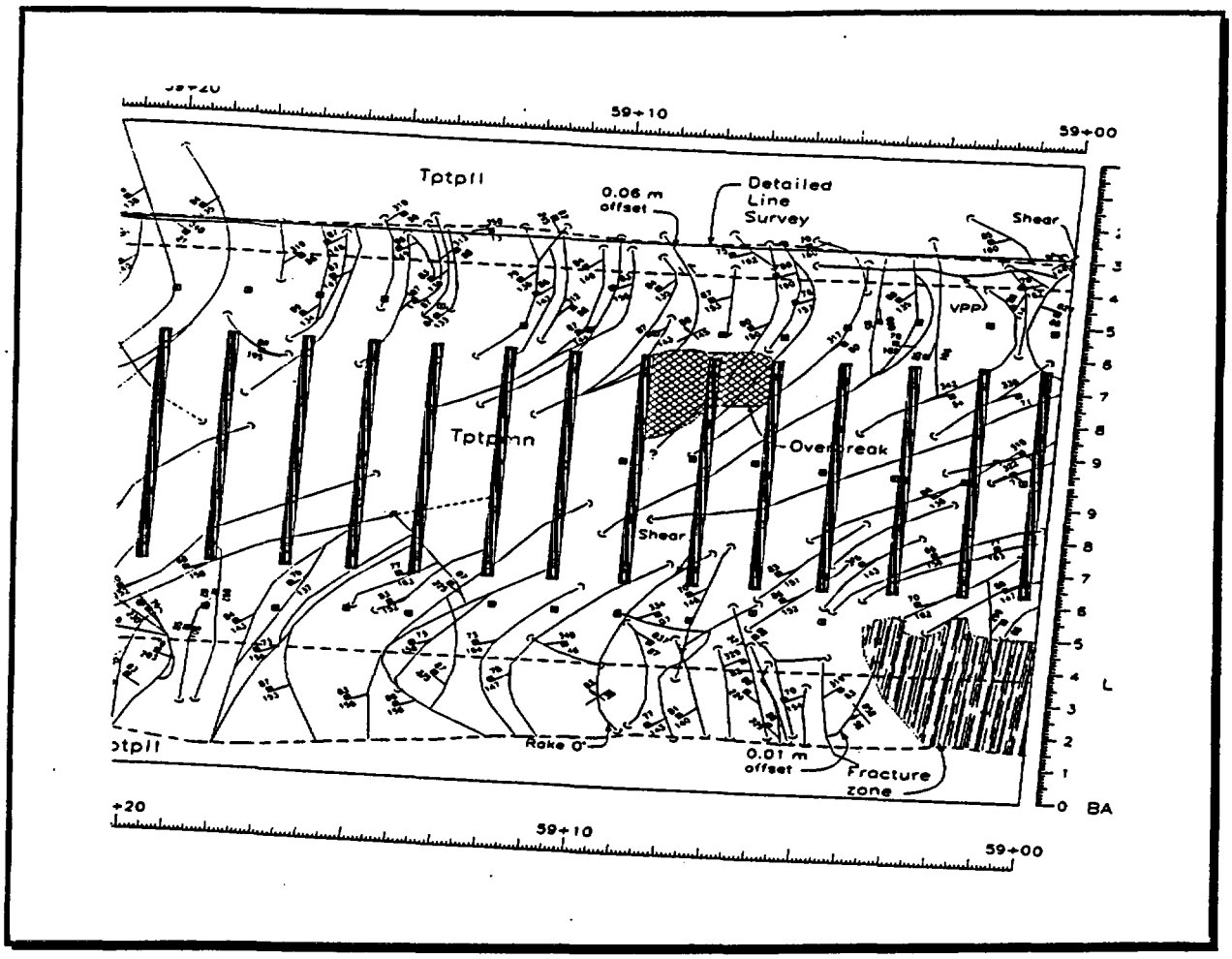
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5880	5885	5890	5895
End Station	5885	5890	5895	5900
Mapped RQD	36	64	62	67
Jn	4	6	9	9
Jr	2	2	1	1
Ja	4	2	2	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	1.8	4.3	1.4	1.5
Qualitative Description	Poor	Fair	Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5880	5885	5890	5895
End Station	5885	5890	5895	5900
Mapped RQD	36	64	62	67
RQD Index	8	13	13	13
C	12	12	12	12
Js	10	10	15	15
Jcd	19	19	17	17
JwR	15	15	15	15
AJO	-12	0	-12	-12
RMR rating	52	69	60	60
Qualitative Description	Fair	Good	Good	Good

USGS/USBR.Rock Mass Classification

Begin Station: 5900 **End Station:** 5920 **Date:** 06 Aug 96
Rated by: Jeanne Major



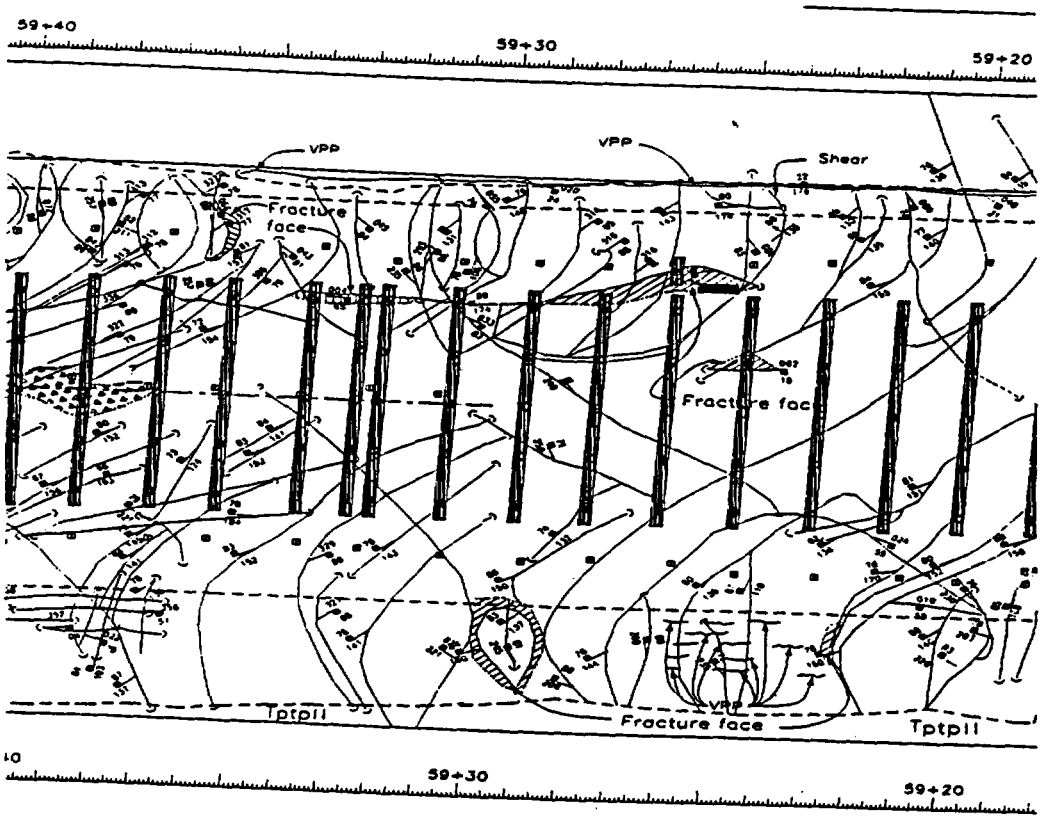
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5900	5905	5910	5915
End Station	5905	5910	5915	5920
Mapped RQD	41	39	26	46
Jn	6	6	6	4
Jr	2	1	3	2
Ja	2	2	4	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	2.7	1.3	1.3	4.6
Qualitative Description	Poor	Poor	Poor	Fair
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5900	5905	5910	5915
End Station	5905	5910	5915	5920
Mapped RQD	41	39	26	46
RQD Index	8	8	8	8
C	12	12	12	12
Js	15	10	15	10
Jcd	17	17	17	17
JwR	15	15	15	15
AJO	0	-12	-12	0
RMR rating	67	50	55	62
Qualitative Description	Good	Fair	Fair	Good

USGS/USBR Rock Mass Classification

Begin Station: 5920 **End Station:** 5940 **Date:** 06 Aug 96
Rated by: Jeanne Major



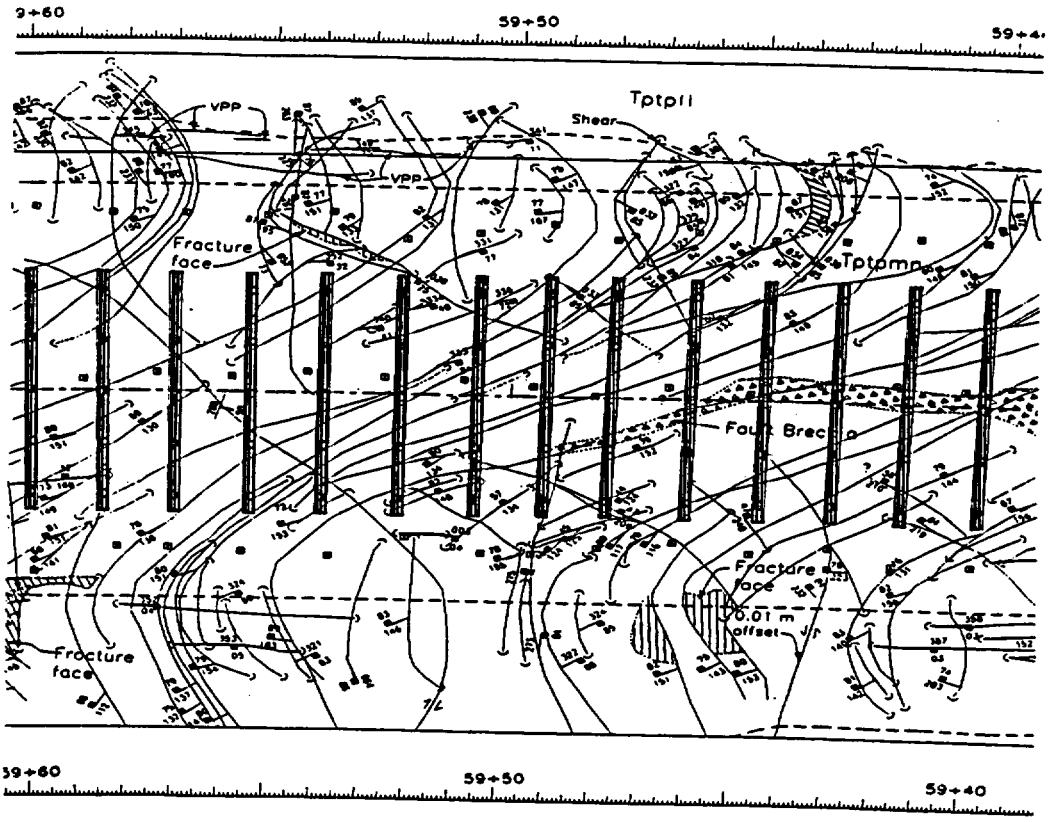
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5920	5925	5930	5935
End Station	5925	5930	5935	5940
Mapped RQD	42	49	61	42
Jn	9	9	9	6
Jr	2	2	2	2
Ja	2	2	2	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	1.9	2.2	2.7	2.8
Qualitative Description	Poor	Poor	Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5920	5925	5930	5935
End Station	5925	5930	5935	5940
Mapped RQD	42	49	61	42
RQD Index	8	8	13	8
C	12	12	12	12
Js	15	15	15	15
Jcd	19	17	17	17
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	57	55	60	55
Qualitative Description	Fair	Fair	Good	Fair

USGS/USBR Rock Mass Classification

Begin Station: 5940 **End Station:** 5960 **Date:** 05 Aug 96
Rated by: Jeanne Major



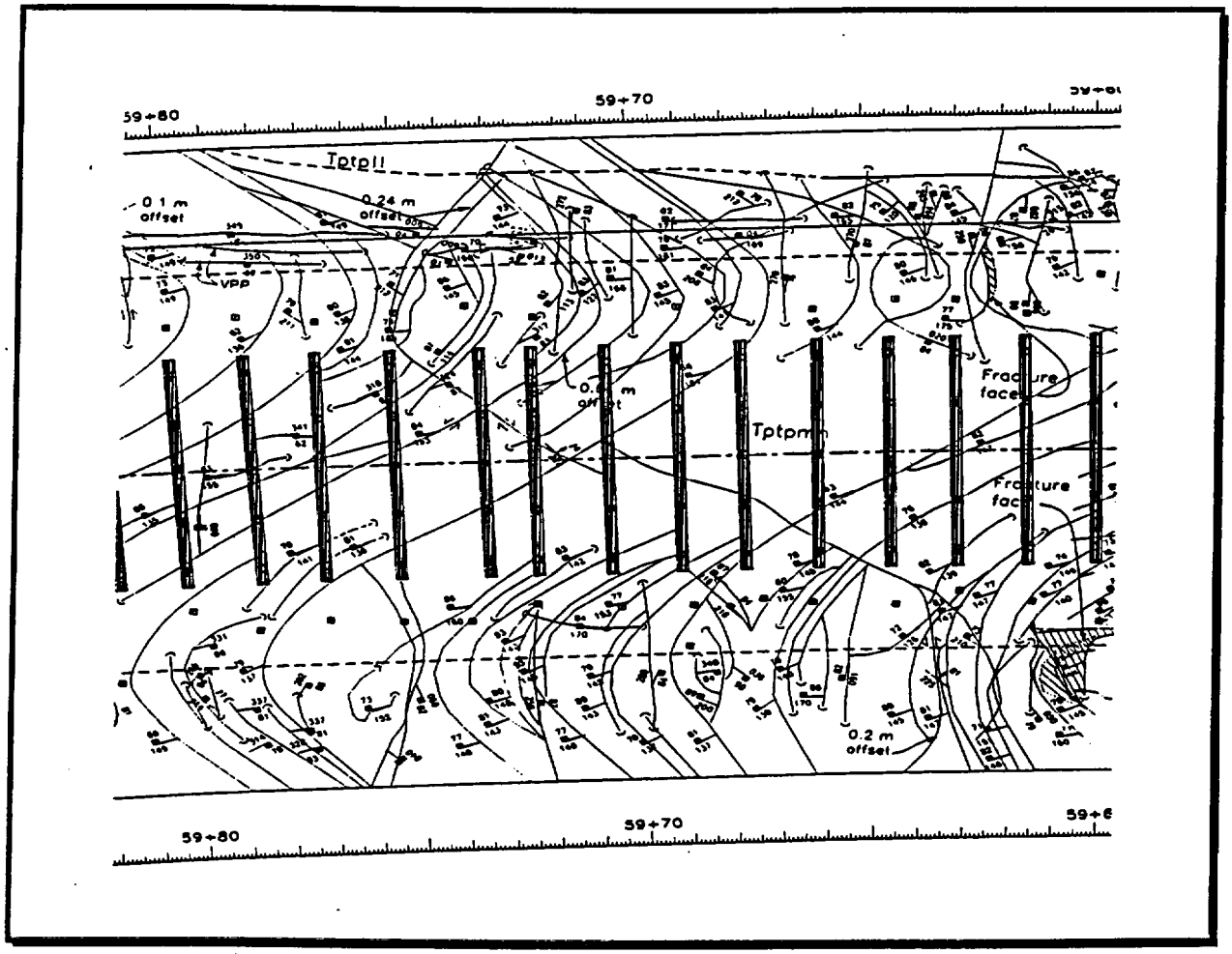
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5940	5945	5950	5955
End Station	5945	5950	5955	5960
Mapped RQD	58	88	96	92
Jn	9	9	9	9
Jr	2	2	2	2
Ja	2	4	2	4
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	2.6	2	4.3	2
Qualitative Description	Poor	Poor	Fair	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5940	5945	5950	5955
End Station	5945	5950	5955	5960
Mapped RQD	58	88	96	92
RQD Index	13	17	20	20
C	7	7	12	12
Js	15	10	15	15
Jcd	17	17	17	17
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	55	54	67	67
Qualitative Description	Fair	Fair	Good	Good

USGS/USBR Rock Mass Classification

Begin Station: 5960 **End Station:** 5980 **Date:** 07 Aug 96
Rated by: Jeanne Major



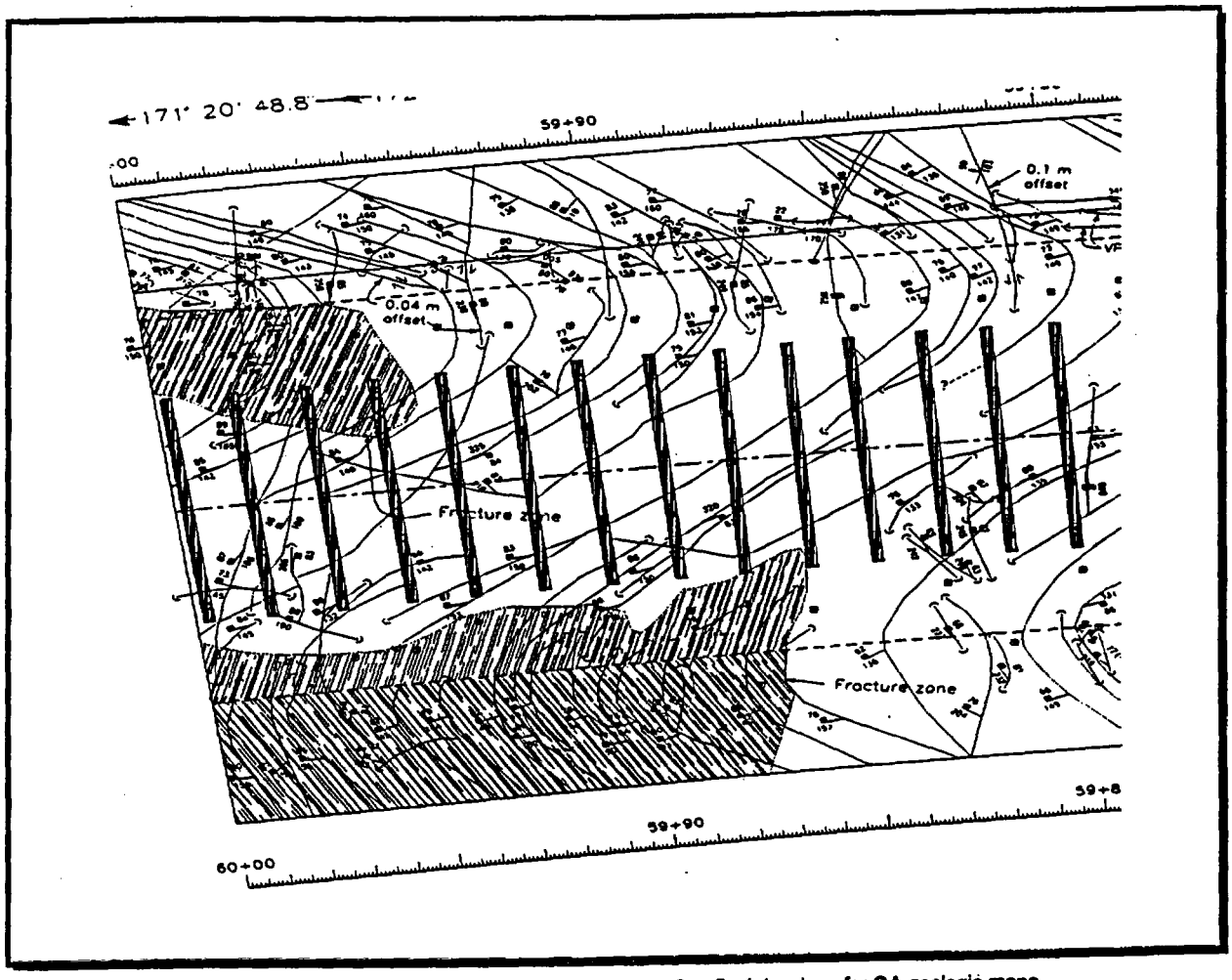
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5960	5965	5970	5975
End Station	5965	5970	5975	5980
Mapped RQD	89	93	64	83
Jn	9	12	12	6
Jr	2	1.5	2	1
Ja	2	2	4	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	4	2.3	1.1	2.8
Qualitative Description	Fair	Poor	Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5960	5965	5970	5975
End Station	5965	5970	5975	5980
Mapped RQD	89	93	64	83
RQD Index	17	20	13	17
C	12	12	12	12
Js	15	15	15	15
Jcd	17	17	17	14
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	64	67	60	61
Qualitative Description	Good	Good	Good	Good

USGS/USBR Rock Mass Classification

Begin Station: 5980 **End Station:** 6000 **Date:** 08 Aug 96
Rated by: Jeanne Major



The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	5980	5985	5990	5995
End Station	5985	5990	5995	6000
Mapped RQD	73	79	81	76
Jn	6	6	12	12
Jr	3	2	2	2
Ja	4	2	3	3
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	3.7	5.3	1.8	1.7
Qualitative Description	Poor	Fair	Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	5980	5985	5990	5995
End Station	5985	5990	5995	6000
Mapped RQD	73	79	81	76
RQD Index	13	17	17	17
C	12	12	12	12
Js	15	15	10	10
Jcd	17	17	19	19
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	60	64	61	61
Qualitative Description	Good	Good	Good	Good

U.S. Geological Survey
U.S. Bureau of Reclamation
Underground Mapping Team

Yucca Mountain Project

Geotechnical Report
Rock Mass Quality Ratings

South Ramp
of the
Exploratory Studies Facility (ESF)

Station 60 +00 to 65 + 00

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Prepared By:
John Steighner
Bill Singleton
Jeanne Major

U.S. Geological Survey
U.S. Bureau of Reclamation
Yucca Mountain Project

TABLE OF CONTENTS

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Abbreviations I
Introduction III

Section 1

USBR Rock Mass Classification 1.1
This section contains a summary of Q and RMR rating values, along with reference drawings. This report is submitted to the Technical Database.

Sections 2 thru 4
These sections not included in this report. They are included in the Supplemental and Supporting Information volume.

Section 2

Abbreviations 2.1

Q and RMR Spreadsheets 2.2
This section contains a summary of Q and RMR rating values in a Microsoft EXCEL spreadsheet format. These data will be submitted to the Technical Database in electronic format only.

Section 3

Q System and Rock Mass Rating Field Forms 3.1
This section contains the field forms utilized in the tunnel to record raw data. These forms will be submitted to the Project Records Center as supporting information.

Section 4

Rock Quality Designation Field Forms and Spreadsheet 4.1
This section contains RQD scanline field forms used in the tunnel to record the raw data. These forms were submitted to the Project Records Center as supporting information. An EXCEL spreadsheet used to calculate RQD will be submitted to the Technical Database in electronic format only.

Abbreviations

AJO	rating adjustment for joint orientation - RMR
BFZ	begin fault zone
BW	begin wedge
C	strength index - RMR
Cdl	condition of discontinuity, length - RMR
CDS	condition of discontinuity, separation - RMR
Cdr	condition of discontinuity, roughness - RMR
Cdf	condition of discontinuity, filling - RMR
Cdw	condition of discontinuity, weathering - RMR
dw	deep wedge
EZ	end zone
EW	end wedge
ESF	exploratory studies facility
fw	fracture wedge
fz	fracture zone
Gnd	ground
Jn	joint set number - Q
Ja	joint alteration number - Q
Jn	joint number set number - Q
Jr	joint roughness number - Q
JwQ	joint water reduction factor - Q
Jcd	joint discontinuity description - RMR
Jr/Ja	shear Strength ratio
Js	joint spacing index - RMR
JwR	joint groundwater index - RMR & Q
lith	lithophysae
NR	not rated
PI	principal investigator
pf	parallel fracture
Q	quality of rock mass
Rev	revision
RMR	rock mass rating
RQC	rock quality classification
RQD	rock quality designation
RQD/Jn	block size ratio
S over L	springline
SRF	stress reduction factor - Q
SS	steel set
sw	shallow wedge

Stratigraphic Units

Tmr	Rainier Mesa
Tpki	tuff unit "x"
Tpc	Tiva Canyon Tuff
Tpbt4	pre-Tiva Canyon bedded tuff
Tpy	Yucca Mountain Tuff
Tpbt3	pre-Yucca Mountain bedded tuff
Tpp	Pah Canyon Tuff
Tpbt2	pre-Pah Canyon bedded tuff
Tpt	Topopah Spring Tuff
Tptrv	Topopah Spring crystal rich vitric zone
Tptrn	Topopah Spring crystal-rich nonlithophysal zone
Tptrl	Topopah Spring crystal-rich lithophysal zone
Tptpul	Topopah Spring crystal-poor upper lithophysal zone
Tptpmn	Topopah Spring crystal-poor middle nonlithophysal zone
Tptpll	Topopah Spring crystal-poor lower lithophysal zone

INTRODUCTION

Norwegian Geotechnical Institute Q System Procedures

The Norwegian Geotechnical Institute Q rock mass classification system was selected by the underground designers for use in the North Ramp Tunnel of the Exploratory Studies Facility. The Q system establishes a numerical value for the quality of the rock for engineering purposes. A Q rating is calculated as the product of six parameters according to the following equation:

$$Q = (RQD/Jn) * (Jr/Ja) * (JwQ/SRF)$$

where:

- RQD is an integer number equal to the RQD percentage. In the equation above the numerical value of 90 is used for an RQD of 90%. See section 4.
- Jn is an index number based on assessment of the number of joint sets in the rating length considered.
- Jr is an index number representing the roughness of the joint set.
- Ja is an index number based on the alteration or filling of a given joint set.
- JwQ is an index number based on groundwater conditions. The "Q" is used to distinguish this index from the RMR system groundwater rating.
- SRF is an index number based on in-situ conditions which influence the stability of the excavation.

The rock quality can range from Q = 0.001 to Q = 1000 as shown in the following table:

Table 1: Q system Qualitative Rock Description

Q value	.001-.01	.01-.1	.1 - 1	1 - 4	4 - 10	10 - 40	40 - 100	100 - 400	400 - 1000
Rock Quality Description	Exceptionally Poor	Extremely Poor	Very Poor	Poor	Fair	Good	Very Good	Extremely Good	Exceptionally Good

The values of the six parameters along with the assigned minimum Q rating are reported in this data package. The minimum Q rating is used to represent the most conservative and safest rating of each section of tunnel. The supplemental section additionally provides a calculated maximum Q value which was determined as a result of the most favorable joint set characteristics.

Rock Mass Rating (RMR) Procedures

The RMR system, also known as the Geomechanics Classification, is an empirical rating system based on the sum of six rockmass parameters. Bieniawski developed the system in 1973 and, with the addition of case histories, revised it to the present form (Bieniawski, 1989). The numerical rock mass rating, RMR, is calculated according to the following equation:

$$RMR = C + RQD + Js + Jcd + JwR + AJO$$

where

C	is a numerical value associated with the intact rock compressive strength
RQD	is a numerical value associated with the rock mass RQD (the rating is not equal to the RQD value)
Js	is a numerical value associated with the fracture spacing of a given joint set
Jcd	is a numerical value associated with the condition of discontinuities
JwR	is a numerical value dependent on groundwater or inflow conditions. The "R" is used to distinguish this rating from the Q system joint water rating.
AJO	is a numerical value associated with the orientation of discontinuities

Compressive strength, joint spacing, joint condition, groundwater and joint orientation parameters are divided into five ranges of values. The rating numbers reflect the importance of each parameter. In this procedure the joint set with the lowest total rating for spacing, joint condition and orientation is used to calculate the RMR.

Table 2 RMR Rock Mass Classification

Rock Mass Rating	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100
Rock Quality Description	Very Poor	Poor	Fair	Good	Very Good

The values of the six parameters along with the assigned RMR rating are reported in this data package.

Rock Quality Designation (RQD) Procedures

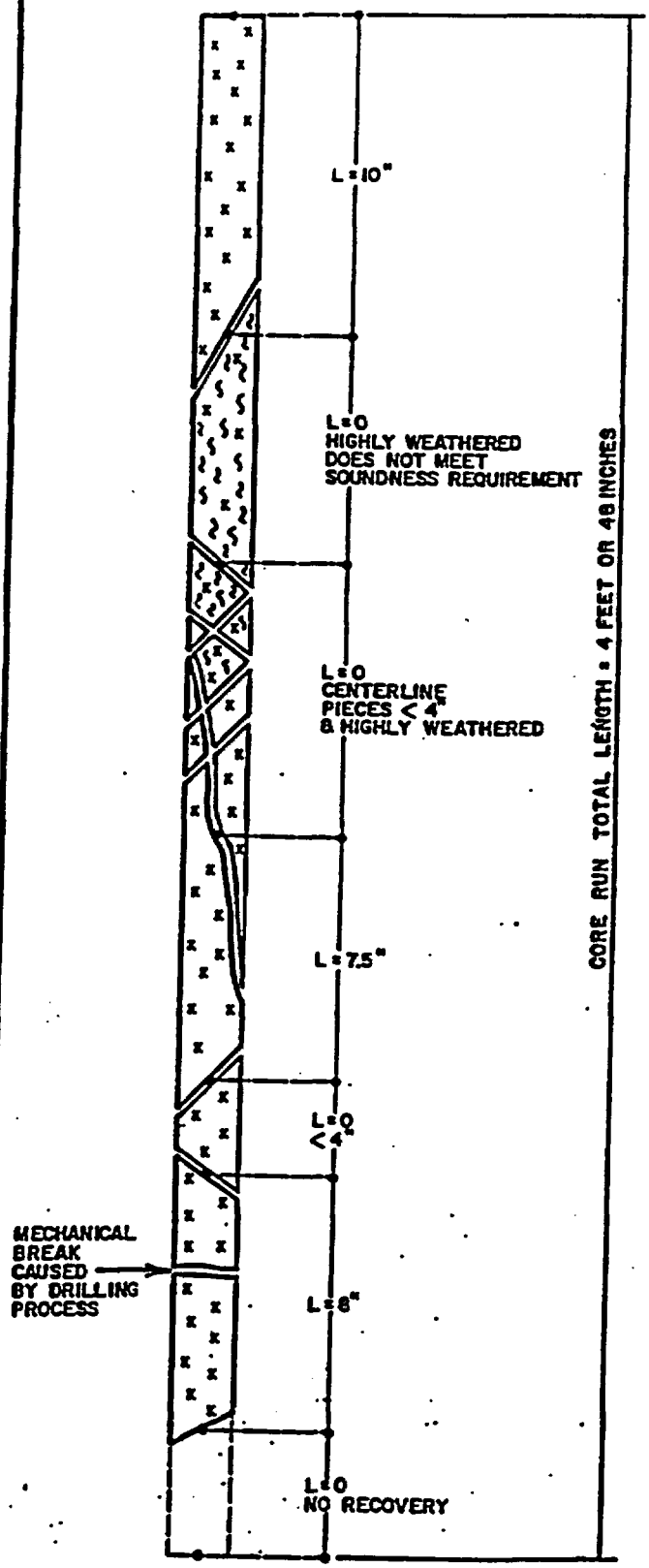
The rock quality designation (RQD) was developed as an index of rock quality for design and construction. At that time rock quality information was usually available only from geologic descriptions and the percentage of core recovery. D.U. Deere developed this index in 1964, published the concept in 1967 (Deere et al., 1967), and he revisited it 20 years later (Deere, 1989). RQD has been employed extensively in the United States and in Europe to identify low quality rock zones and to estimate tunnel support. RQD is a simple, inexpensive, and reproducible quantitative index. Problematic rock that is highly weathered, soft, fractured, sheared, and jointed is counted against the rock mass. Thus, it is simply a measurement of the percentage of "good" rock recovered from an interval of a borehole. The total length of core pieces which are 4 inches (about 100 mm) and longer, is divided by the length of the core run. The correct procedure for measuring RQD is illustrated in Figure 1. Rock mass classification based on RQD alone proved to be ineffective; however, RQD remains an important parameter. Both the RMR and Q systems use RQD as one rock mass rating factor. RQD is calculated using the following equation:

$$\text{RQD \%} = \frac{\sum \text{Length of sound core pieces} > 100 \text{ mm (4 in)}}{\text{Total core run length}} * 100\%$$

To calculate RQD from observation of the tunnel wall, lengths of intact rock along the DLS survey tape are estimated or calculated as the percentage of core pieces 100 mm or longer which would be recovered in an imaginary horizontal drill hole along the right wall of the excavation. The same piece of core could be measured three ways: along the centerline, from tip to tip, or along the fully circular barrel section (Fig. 2). The recommended procedure is to measure the core length along the centerline (Fig. 1).

Two methods are used to estimate the RQD. RQD is first determined by visual observation of the tunnel wall. This visual estimate is recorded on data forms. The second method uses line survey data to calculate an RQD. Both the visual observation and the line survey data collection require procedures to describe fractures which occur in molds of wedges removed from the tunnel wall.

Visual RQD Procedure. The length of core not recovered (or recovered in lengths less than 10 cm) is estimated by visually scanning the DLS tape. For a five-meter reach, one technique is to count the number of 10 cm lengths not recovered. That number doubled and subtracted from 100 gives the RQD. For example, through a five-meter reach, if three lengths (10 cm each) of rock are estimated to be short pieces the visual RQD is 94%.



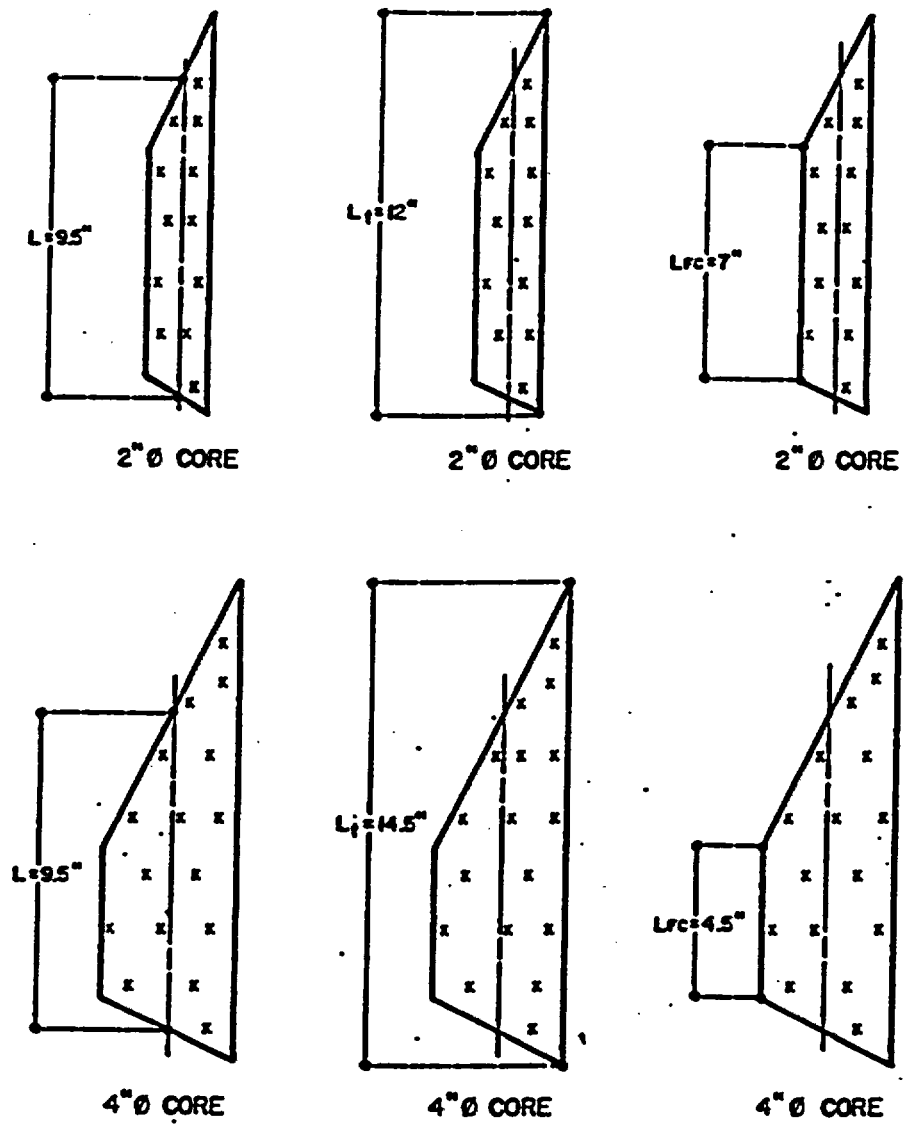
$$RQD = \frac{\sum \text{LENGTH OF SOUND CORE PIECES} > 4 \text{ INCHES (100mm)}}{\text{TOTAL CORE RUN LENGTH}}$$

$$RQD = \frac{10 + 7.5 + 8}{48} \times 100\%$$

RQD = 53% (FAIR)

RQD (ROCK QUALITY DESIGNATION)	DESCRIPTION OF ROCK QUALITY
0-25 %	VERY POOR
25-50 %	POOR
50-75 %	FAIR
75-90 %	GOOD
90-100%	EXCELLENT

FIG. 1 – RQD LOGGING



CENTERLINE

A. CORRECT METHOD FOR CORE LENGTH MEASUREMENT – LENGTH OF CORE INDEPENDENT OF CORE DIA.

TIP TO TIP

B. INCORRECT METHOD FOR CORE LENGTH MEASUREMENT – LENGTH DEPENDENT ON CORE DIA.

FULLY CIRCULAR

C. INCORRECT METHOD FOR CORE LENGTH MEASUREMENT – LENGTH DEPENDENT ON CORE DIA.

FIG. 2 – LENGTH MEASUREMENT OF CORE FOR RQD.

Fracture zones, wedge molds, subparallel fractures, fractures behind steel sets, and lithophysal zones are estimated as described below in the section titled *line survey RQD Procedures*. Experience indicates that the two independent visual estimates of RQD will usually fall within a five percentage point range.

Line Survey RQD Procedures. USBR/USGS collects fracture data along a line established on the right rib of the tunnel parallel to the tunnel axis and approximately one meter below the springline. A metric survey tape is attached to the tunnel rib or steel sets. The tape is used by mapping team Geologists to locate fractures exceeding a given length for the Detailed Line Survey (DLS), procedure GP-32. The same tape is used to determine RQD. For RQD all natural fractures are considered, thus ignoring mechanical breaks as a result of drilling or blasting. The station of each individual fracture is recorded or the beginning and ending stations of zones of zero RQD are recorded.

The fundamental assumption for calculation of RQD using the scanline data is that length of rock between recorded fractures is intact rock. From that assumption, the total of intact rock pieces which are longer than 10 cm are determined from the fracture spacing. That length, expressed as a percentage of the total length, is the line survey RQD. The reasons that the center-line measurement is preferred are that 1) it results in a standardized RQD that is not dependent on the core diameter, and 2) it avoids unduly penalizing the quality of the rock mass for cases where fractures parallel the borehole and are cut by a second set. Note this technique does not depend on an assumed fracture spacing distribution. In fact, the fracture-spacing distribution may be reduced from the RQD data collected in this procedure. The directional bias associated with a line survey in one direction is not eliminated.

The paragraphs below list several details applied to standardize the procedure.

Fracture Zones: An area of closely spaced fractures is described by noting the beginning and ending stations of the zone. Individual fractures are not recorded. The average fracture spacing is estimated. On the RQD Scanline Form, the notations *fz* and *EZ* are used to identify the beginning and ending stations of a fracture zone. The calculated length of intact rock is zero through these zones.

Shallow Wedge Molds: Generally, this mold will result from the intersection of two fractures subparallel to the scanline. This shallow mold appears to fracture the imaginary core so that the shortest side of the core is less than 100mm. The length between beginning and ending fractures is not counted as intact rock for calculation of the RQD. The beginning and ending stations of this zero RQD zone are identified on the scanline form as *sw* and *EZ*.

Fractured Wedge Molds: Fractures through a wedge zone are projected along strike to the DLS tape. The fracture stations are recorded and the RQD is calculated normally using only the fracture stations. The notation *fw* for fractured wedge or *dw* for deep wedge are optionally

SECTION 1 - USBR Rock Mass Classification

Page

USBR Rock Mass Classification
Q Rock Quality and Rock Mass Ratings 1.1

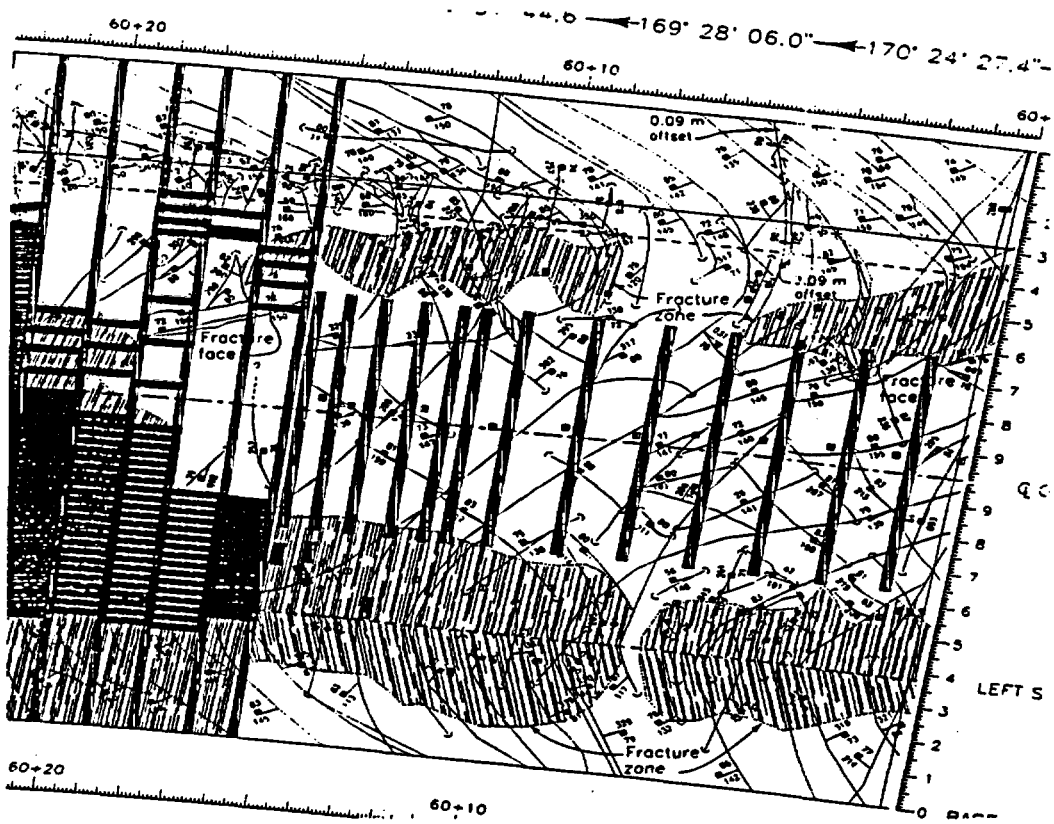
Notes:

1. The full periphery tunnel maps shown in this section are for reference only. See the final QA approved maps for geologic details.

2. The **Rated by** line on the following pages lists person(s) who gathered the information by analyzing the tunnel's wall.

USGS/USBR Rock Mass Classification

Begin Station: 6000 **End Station:** 6020 **Date:** 13 Aug 96
Rated by: Bill Singleton



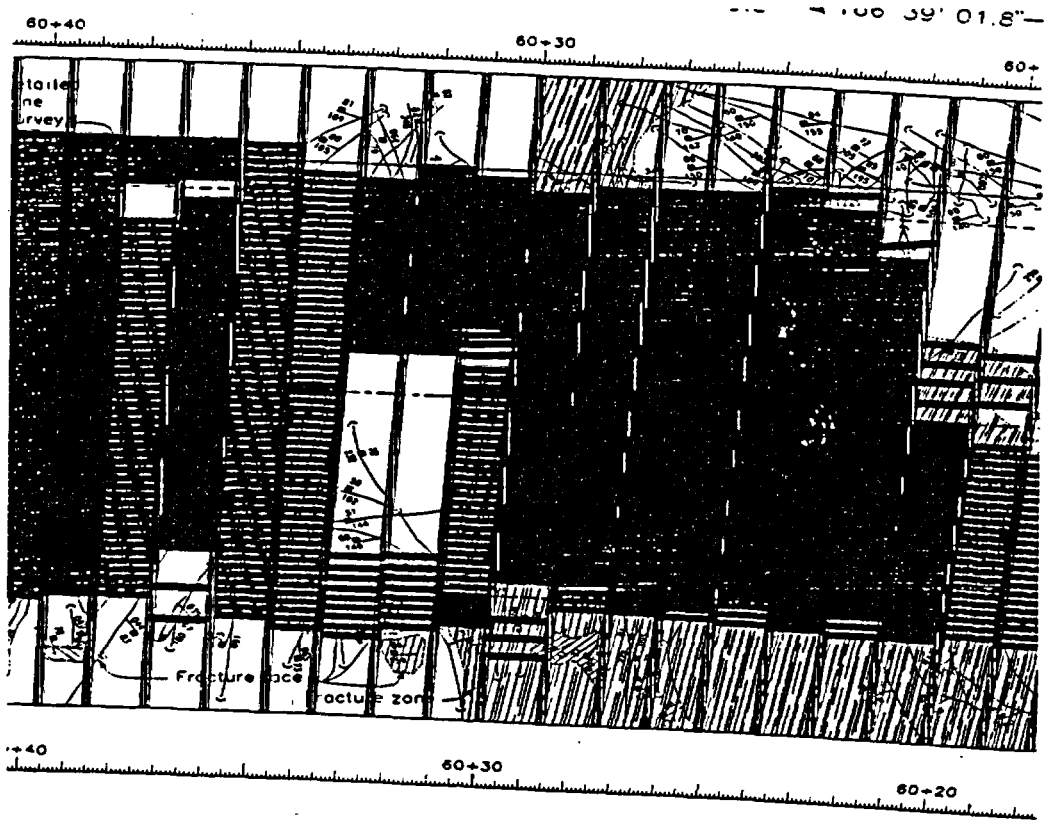
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6000	6005	6010	6015
End Station	6005	6010	6015	6020
Mapped RQD	83	76	59	61
Jn	9	6	9	12
Jr	1.5	1	2	1.5
Ja	2	2	2	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	5
Q rating	2.8	2.5	2.6	0.76
Qualitative Description	Poor	Poor	Poor	Very Poor
Installed Ground Support Category	1	1	1	3

RMR Rating Parameters				
Begin Station	6000	6005	6010	6015
End Station	6005	6010	6015	6020
Mapped RQD	83	76	59	61
RQD Index	17	17	13	13
C	12	12	12	12
Js	10	15	15	15
Jcd	19	17	14	14
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	61	64	57	57
Qualitative Description	Good	Good	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6020 **End Station:** 6040 **Date:** 13 Aug 96
Rated by: Jack Tousell



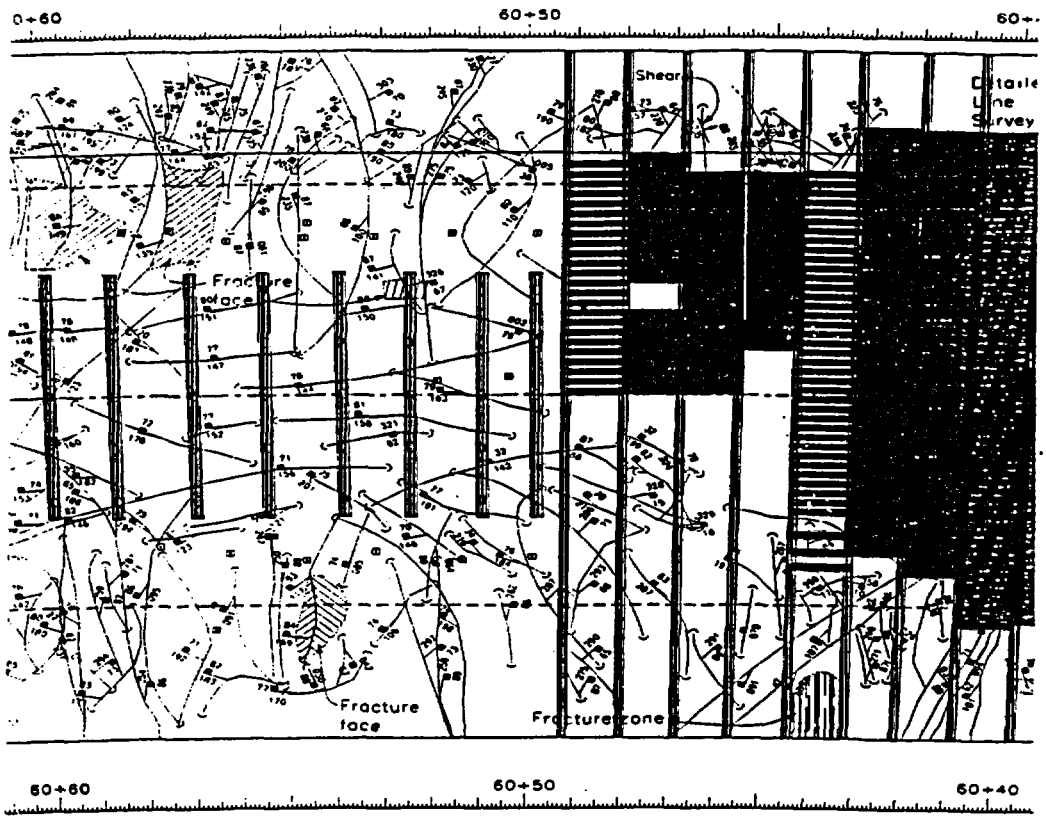
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6020	6025	6030	6035
End Station	6025	6030	6035	6040
Mapped RQD	58	62	34	46
Jn	12	12	15	12
Jr	2	2	2	2
Ja	1	1	4	4
JwQ	1	1	1	1
SRF	10	7.5	5	5
Q rating	0.97	1.4	0.23	0.38
Qualitative Description	Very Poor	Poor	Very Poor	Very Poor
Installed Ground Support Category	3	3	3	3

RMR Rating Parameters				
Begin Station	6020	6025	6030	6035
End Station	6025	6030	6035	6040
Mapped RQD	58	62	34	46
RQD Index	13	13	8	8
C	12	12	12	12
Js	15	15	8	10
Jcd	16	12	14	15
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	59	55	45	48
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6040 **End Station:** 6060 **Date:** 15 Aug 96
Rated by: Jack Tousell



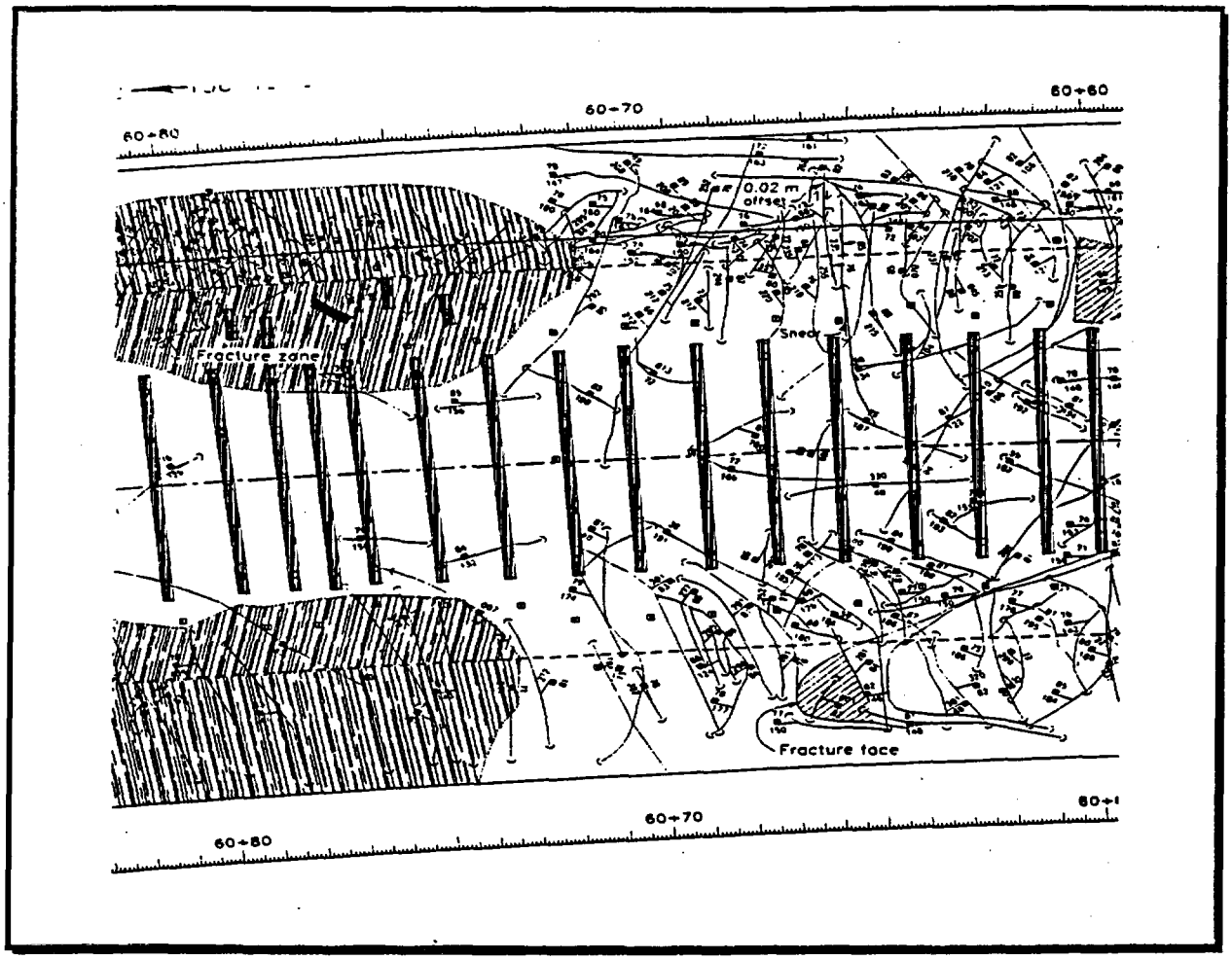
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6040	6045	6050	6055
End Station	6045	6050	6055	6060
Mapped RQD	47	49	73	61
Jn	15	15	12	12
Jr	1	1	2	2
Ja	2	4	4	4
JwQ	1	1	1	1
SRF	7.5	7.5	2.5	2.5
Q rating	0.21	0.11	1.2	1
Qualitative Description	Very Poor	Very Poor	Poor	Poor
Installed Ground Support Category	3	3	1	1

RMR Rating Parameters				
Begin Station	6040	6045	6050	6055
End Station	6045	6050	6055	6060
Mapped RQD	47	49	73	61
RQD Index	8	8	13	13
C	12	12	12	12
Js	8	8	15	10
Jcd	16	17	14	16
JwR	15	15	15	15
AJO	-12	-12	-12	-5
RMR rating	47	48	57	61
Qualitative Description	Fair	Fair	Fair	Good

USGS/USBR Rock Mass Classification

Begin Station: 6060 **End Station:** 6080 **Date:** 28 Aug 96
Rated by: Jeanne Major



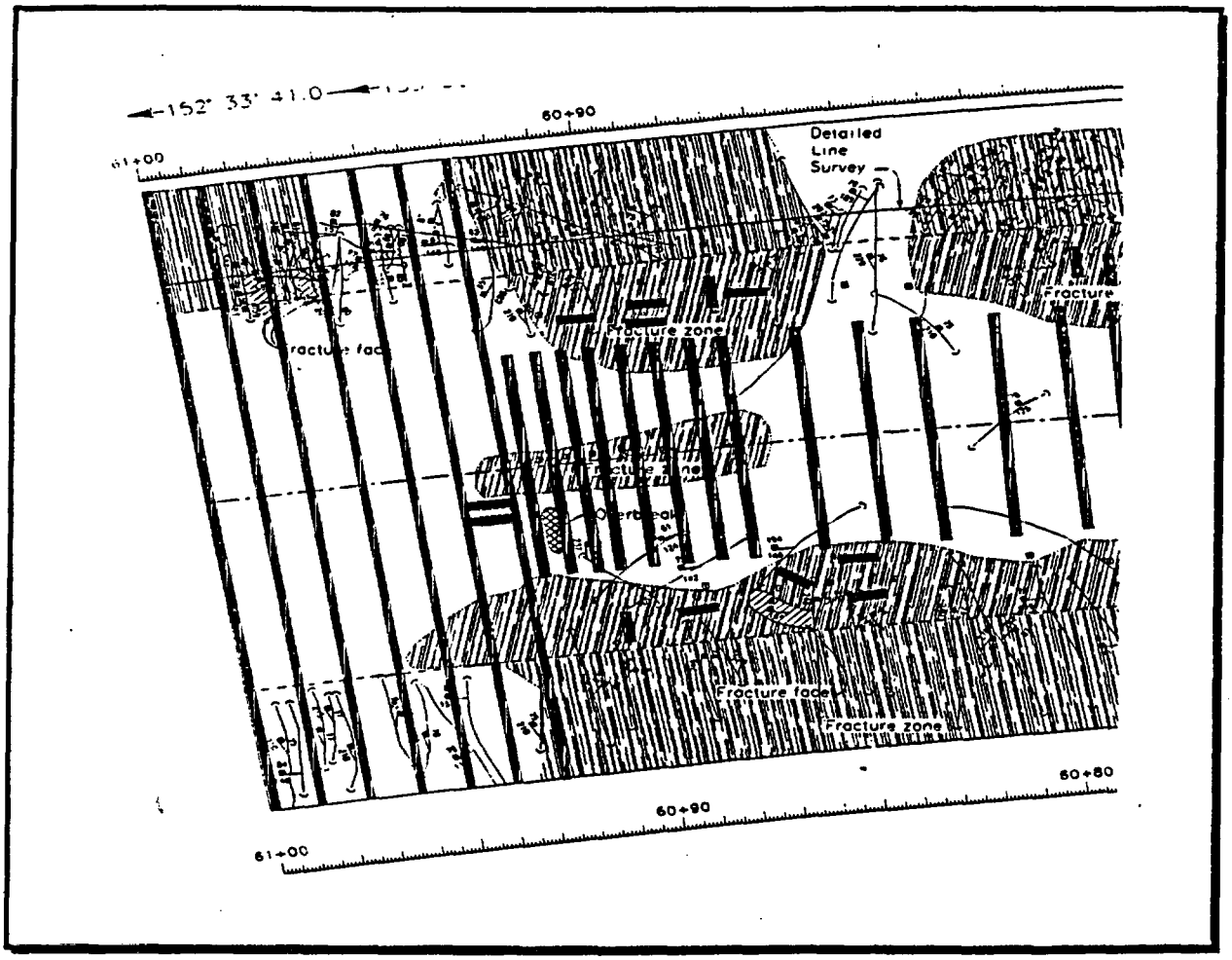
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6060	6065	6070	6075
End Station	6065	6070	6075	6080
Mapped RQD	62	74	65	61
Jn	12	9	15	15
Jr	2	2	1	2
Ja	4	1	1	3
JwQ	1	1	1	1
SRF	2.5	2.5	5	5
Q rating	1	6.6	0.87	0.54
Qualitative Description	Poor	Fair	Very Poor	Very Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6060	6065	6070	6075
End Station	6065	6070	6075	6080
Mapped RQD	62	74	65	61
RQD Index	13	13	13	13
C	12	12	12	12
Js	10	10	8	10
Jcd	19	19	17	14
JwR	15	15	15	15
AJO	-12	-12	-5	-12
RMR rating	57	57	60	52
Qualitative Description	Fair	Fair	Good	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6080 **End Station:** 6100 **Date:** 13 Aug 96
Rated by: Bill Singleton



The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6080	6085	6090	6095
End Station	6085	6090	6095	6100
Mapped RQD	71	10	51	85
Jn	12	12	12	15
Jr	2	2	2	1
Ja	3	3	1	2
JwQ	1	1	1	1
SRF	5	5	10	5
Q rating	0.79	0.11	0.85	0.57
Qualitative Description	Very Poor	Very Poor	Very Poor	Very Poor
Installed Ground Support Category	1	1	3	3

RMR Rating Parameters				
Begin Station	6080	6085	6090	6095
End Station	6085	6090	6095	6100
Mapped RQD	71	10	51	85
RQD Index	13	3	13	17
C	12	12	7	7
Js	10	10	15	10
Jcd	18	20	17	19
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	56	48	55	56
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6100 **End Station:** 6120 **Date:** 14 Aug 96
Rated by: Jack Tousell

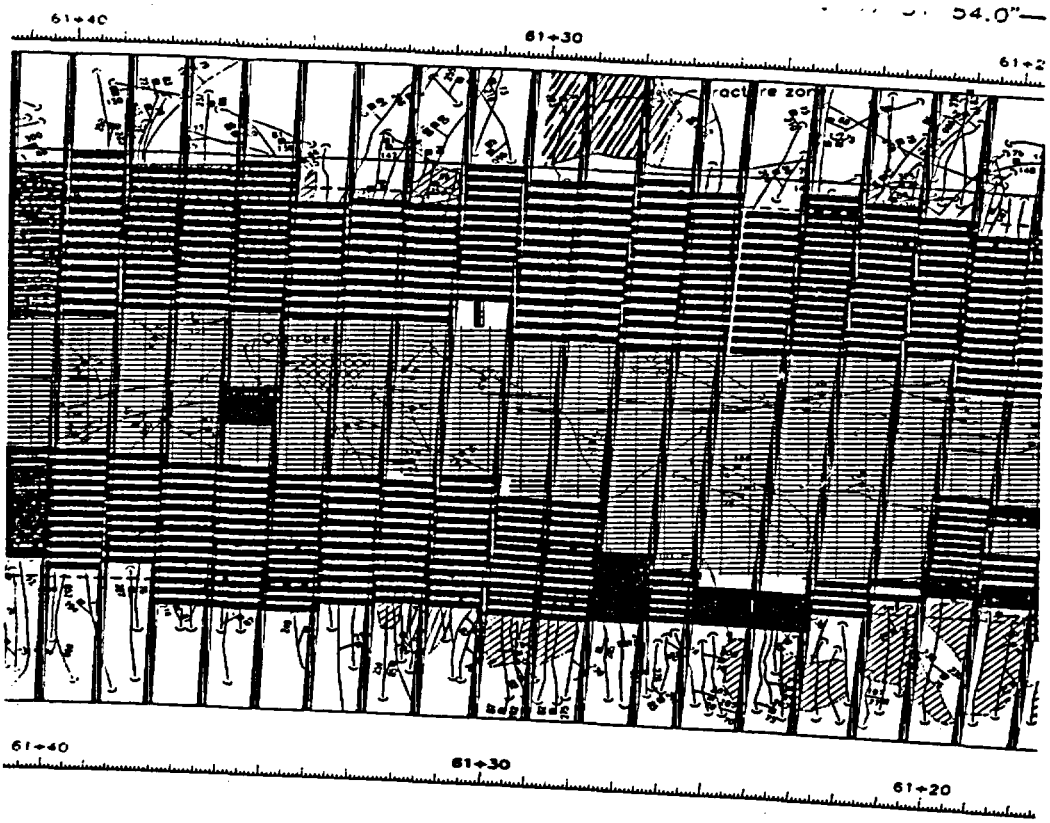
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6100	6105	6110	6115
End Station	6105	6110	6115	6120
Mapped RQD	68	44	58	41
Jn	15	15	12	12
Jr	2	2	2	2
Ja	2	2	2	2
JwQ	1	1	1	1
SRF	5	5	5	2.5
Q rating	0.91	0.59	0.97	1.4
Qualitative Description	Very Poor	Very Poor	Very Poor	Poor
Installed Ground Support Category	3	3	3	3

RMR Rating Parameters				
Begin Station	6100	6105	6110	6115
End Station	6105	6110	6115	6120
Mapped RQD	68	44	58	41
RQD Index	13	8	13	8
C	7	7	12	12
Js	8	8	10	0
Jcd	16	17	22	17
JwR	15	15	15	15
AJO	-12	-12	-12	-5
RMR rating	47	43	60	47
Qualitative Description	Fair	Fair	Good	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6120 **End Station:** 6140 **Date:** 22 Aug 96
Rated by: John Steighner



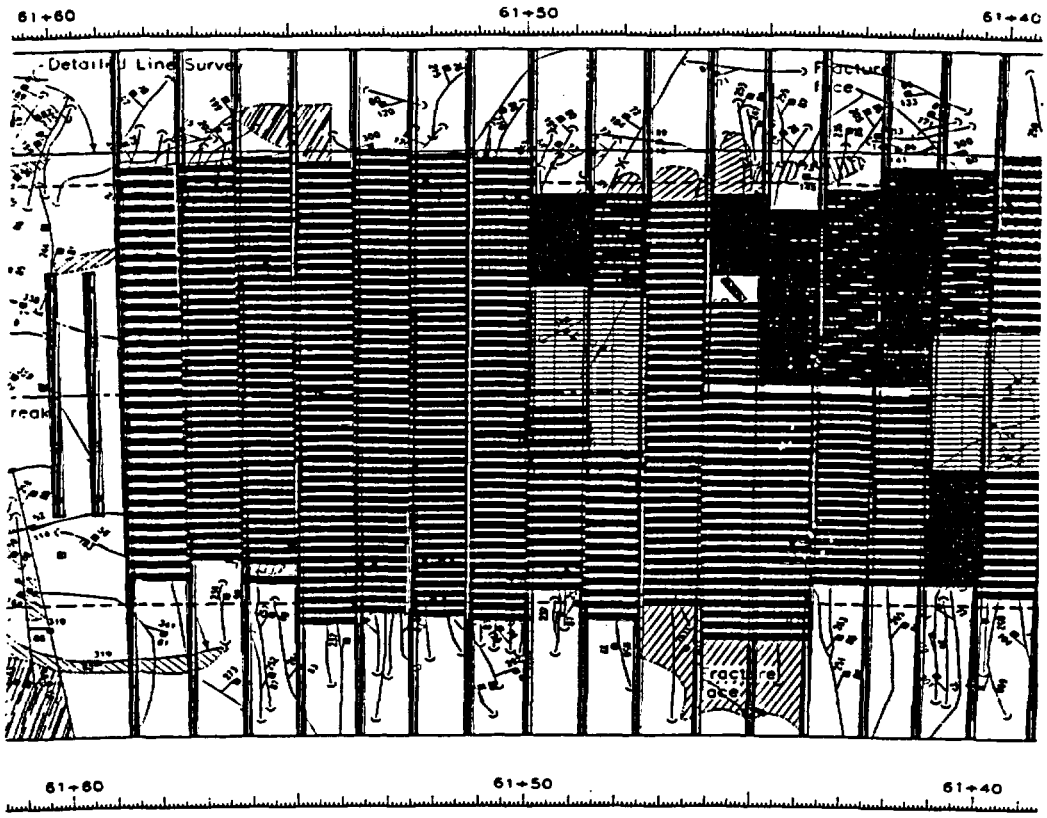
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6120	6125	6130	6135
End Station	6125	6130	6135	6140
Mapped RQD	51	58	35	30
Jn	12	12	12	12
Jr	2	2	2	2
Ja	2	2	2	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	1.7	1.9	1.2	1
Qualitative Description	Poor	Poor	Poor	Poor
Installed Ground Support Category	3	3	3	3

RMR Rating Parameters				
Begin Station	6120	6125	6130	6135
End Station	6125	6130	6135	6140
Mapped RQD	51	58	35	30
RQD Index	13	13	8	8
C	12	12	12	12
Js	8	8	10	10
Jcd	20	20	14	18
JwR	15	15	15	15
AJO	-12	-12	-5	-12
RMR rating	56	56	54	51
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6140 **End Station:** 6160 **Date:** 29 Aug 96
Rated by: Jeanne Major



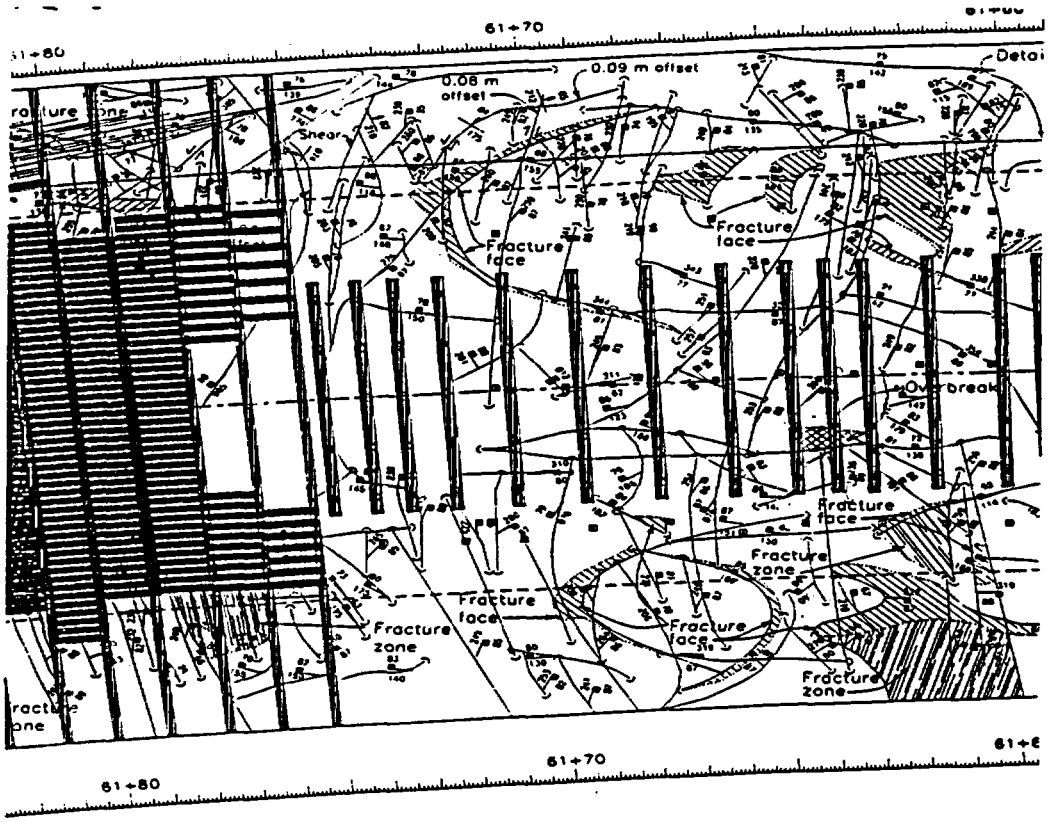
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6140	6145	6150	6155
End Station	6145	6150	6155	6160
Mapped RQD	43	49	31	66
Jn	12	12	12	12
Jr	2	2	2	1
Ja	2	2	2	1
JwQ	1	1	1	1
SRF	5	5	5	5
Q rating	0.72	0.82	0.52	1.1
Qualitative Description	Very Poor	Very Poor	Very Poor	Poor
Installed Ground Support Category	3	3	3	3

RMR Rating Parameters				
Begin Station	6140	6145	6150	6155
End Station	6145	6150	6155	6160
Mapped RQD	43	49	31	66
RQD Index	8	8	8	13
C	12	12	12	12
Js	10	10	8	10
Jcd	20	17	12	19
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	53	50	43	57
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6160 **End Station:** 6180 **Date:** 01 Oct 96
Rated by: Bill Singleton



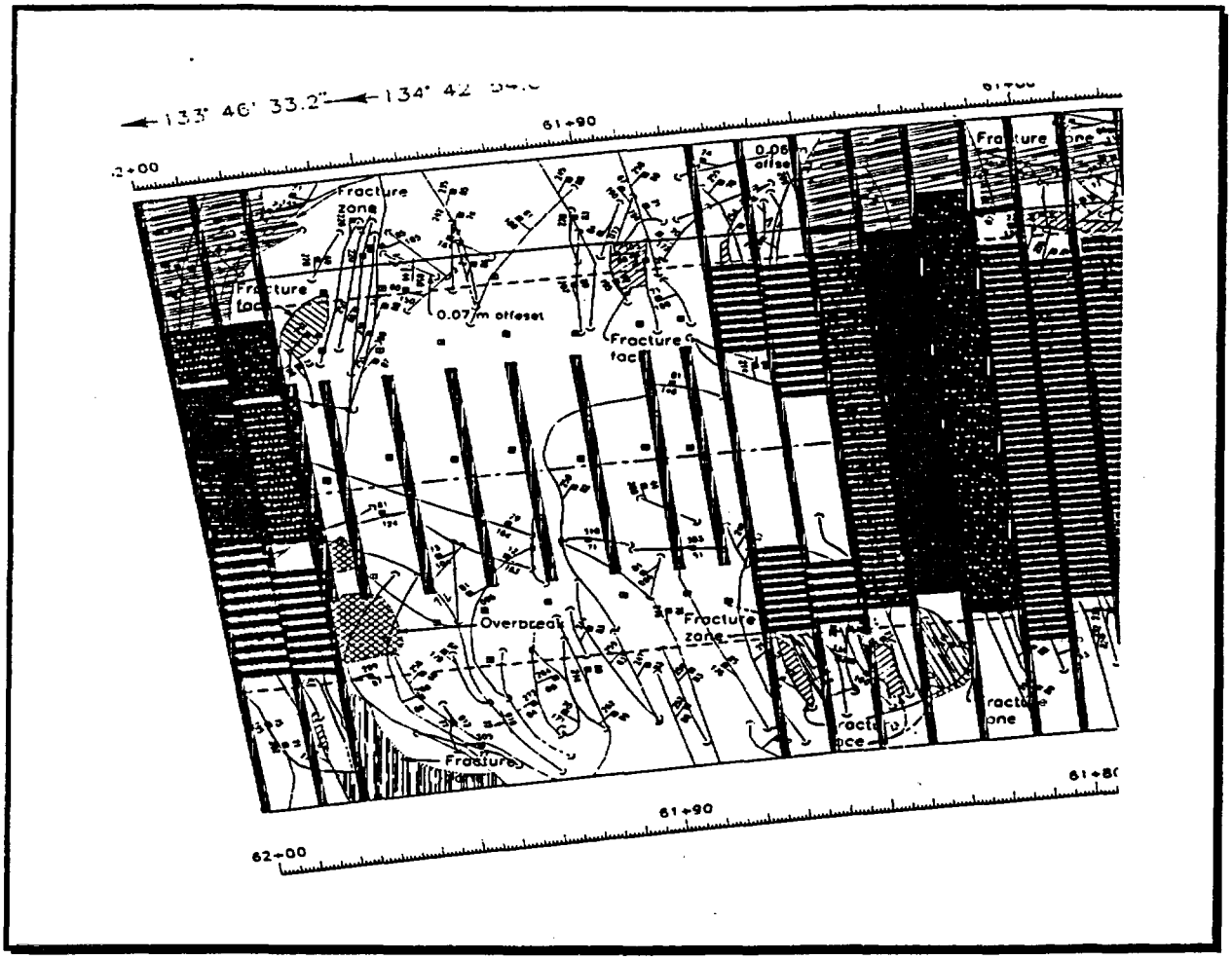
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6160	6165	6170	6175
End Station	6165	6170	6175	6180
Mapped RQD	50	44	59	52
Jn	15	15	12	12
Jr	3	3	2	2
Ja	2	2	1	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	5
Q rating	2	1.8	3.9	0.87
Qualitative Description	Poor	Poor	Poor	Very Poor
Installed Ground Support Category	1	1	1	3

RMR Rating Parameters				
Begin Station	6160	6165	6170	6175
End Station	6165	6170	6175	6180
Mapped RQD	50	44	59	52
RQD Index	13	8	13	13
C	12	12	12	12
Js	10	10	10	8
Jcd	18	18	16	20
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	56	51	54	56
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6180 **End Station:** 6200 **Date:** 28 Aug 96
Rated by: Jeanne Major



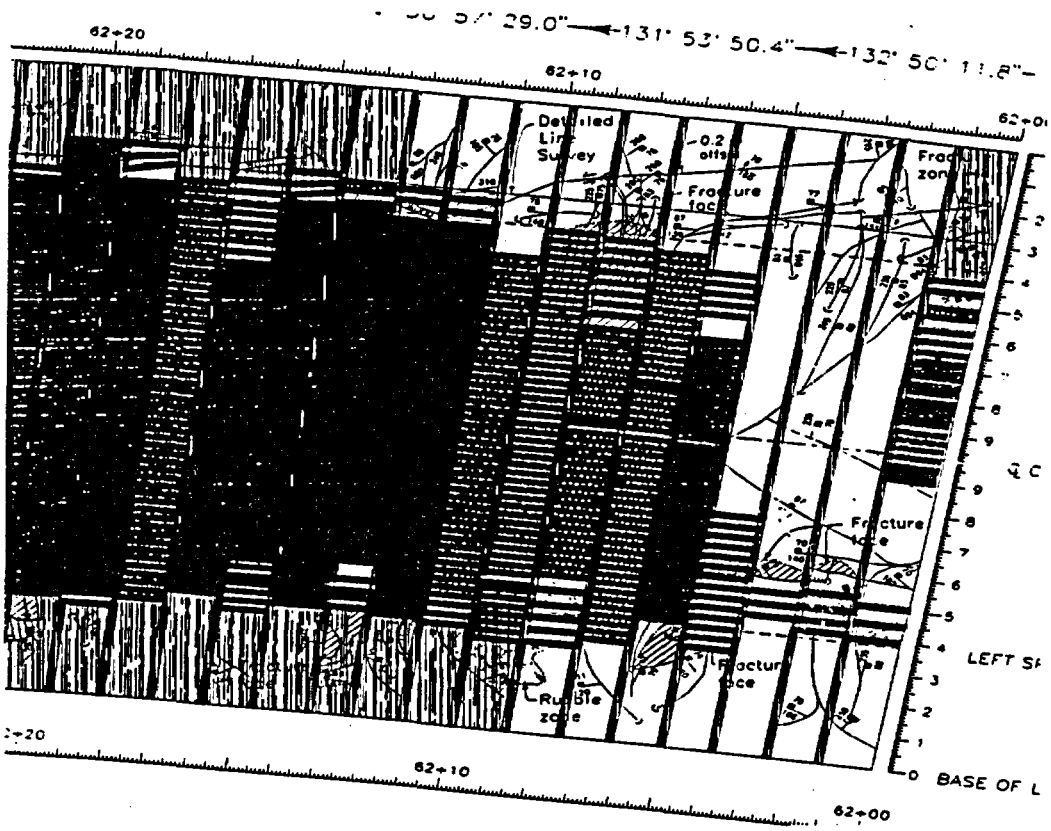
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6180	6185	6190	6195
End Station	6185	6190	6195	6200
Mapped RQD	54	43	31	50
Jn	12	12	12	12
Jr	2	3	2	2
Ja	4	4	4	3
JwQ	1	1	1	1
SRF	5	5	5	5
Q rating	0.45	0.54	0.26	0.56
Qualitative Description	Very Poor	Very Poor	Very Poor	Very Poor
Installed Ground Support Category	3	3	1	3

RMR Rating Parameters				
Begin Station	6180	6185	6190	6195
End Station	6185	6190	6195	6200
Mapped RQD	54	43	31	50
RQD Index	13	8	8	13
C	12	12	12	12
Js	10	10	10	8
Jcd	21	21	9	14
JwR	15	15	15	15
AJO	-12	-12	-5	-12
RMR rating	59	54	49	50
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6200 **End Station:** 6220 **Date:** 03 Oct 96
Rated by: Bill Singleton



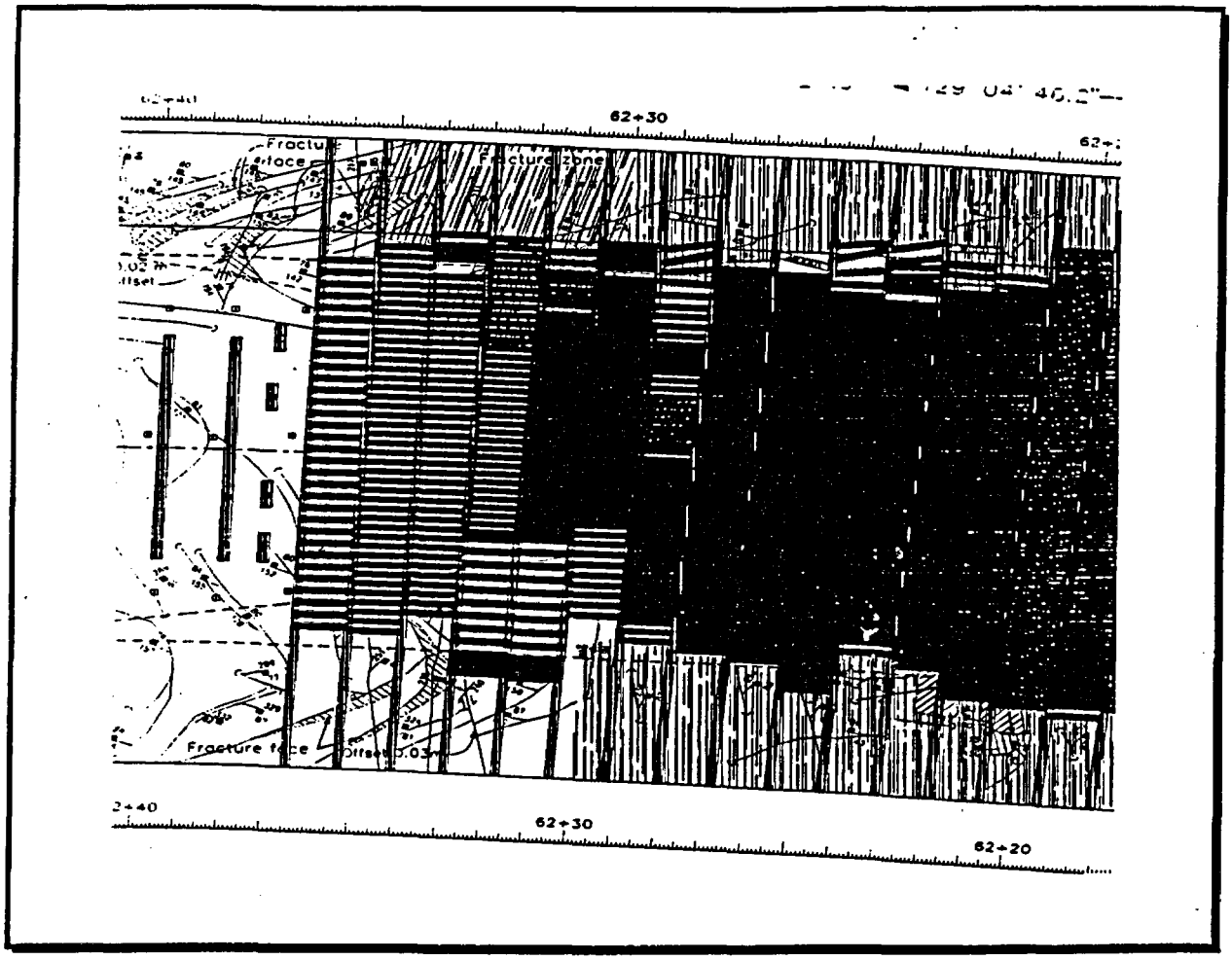
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6200	6205	6210	6215
End Station	6205	6210	6215	6220
Mapped RQD	64	71	48	28
Jn	15	12	15	15
Jr	1.5	1.5	2	2
Ja	2	2	3	3
JwQ	1	1	1	1
SRF	5	5	7.5	7.5
Q rating	0.64	0.89	0.28	0.17
Qualitative Description	Very Poor	Very Poor	Very Poor	Very Poor
Installed Ground Support Category	3	3	3	3

RMR Rating Parameters				
Begin Station	6200	6205	6210	6215
End Station	6205	6210	6215	6220
Mapped RQD	64	71	48	28
RQD Index	13	13	8	8
C	12	12	12	12
Js	10	10	10	10
Jcd	19	18	20	20
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	57	56	53	53
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6220 **End Station:** 6240 **Date:** 03 Oct 96
Rated by: Bill Singleton



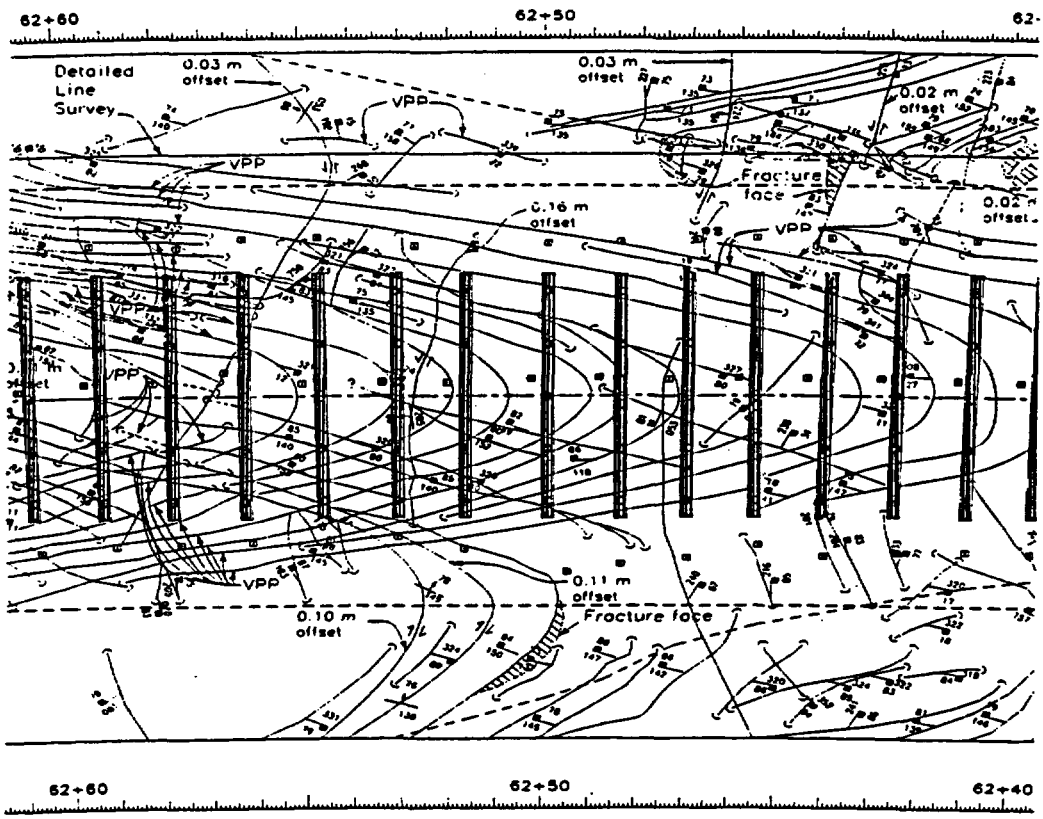
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6220	6225	6230	6235
End Station	6225	6230	6235	6240
Mapped RQD	20	18	48	54
Jn	15	15	9	9
Jr	2	2	2	2
Ja	3	3	4	3
JwQ	1	1	1	1
SRF	7.5	7.5	7.5	2.5
Q rating	0.12	0.11	0.36	1.6
Qualitative Description	Very Poor	Very Poor	Very Poor	Poor
Installed Ground Support Category	3	3	3	1

RMR Rating Parameters				
Begin Station	6220	6225	6230	6235
End Station	6225	6230	6235	6240
Mapped RQD	20	18	48	54
RQD Index	3	3	8	13
C	12	12	12	12
Js	10	10	8	10
Jcd	20	20	14	21
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	48	48	45	59
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6240 **End Station:** 6260 **Date:** 16 Sep 96
Rated by: Bill Singleton



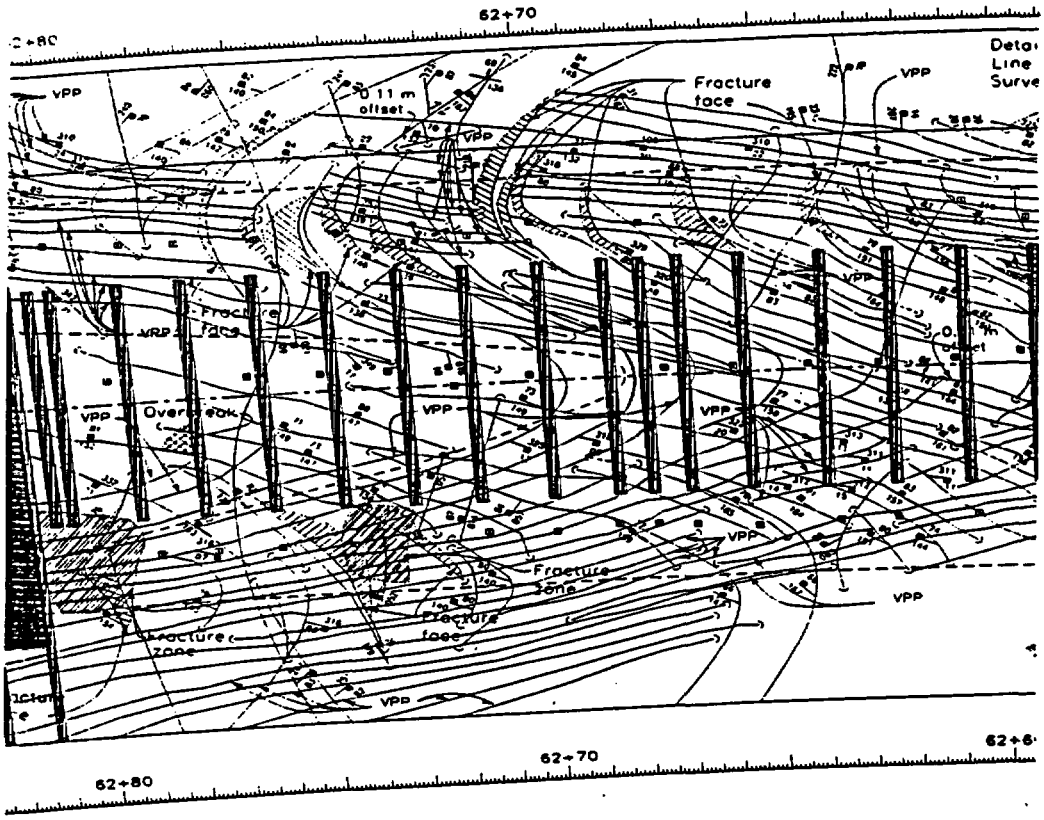
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6240	6245	6250	6255
End Station	6245	6250	6255	6260
Mapped RQD	22	54	85	83
Jn	9	9	9	4
Jr	3	3	3	3
Ja	4	4	2	2
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	2.5
Q rating	0.73	1.8	5.7	12
Qualitative Description	Very Poor	Poor	Fair	Good
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6240	6245	6250	6255
End Station	6245	6250	6255	6260
Mapped RQD	22	54	85	83
RQD Index	3	13	17	17
C	7	7	7	7
Js	10	15	15	10
Jcd	16	19	18	19
JwR	15	15	15	15
AJO	-12	-12	-12	-10
RMR rating	39	57	60	58
Qualitative Description	Poor	Fair	Good	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6260 **End Station:** 6280 **Date:** 10 Oct 96
Rated by: Bill Singleton



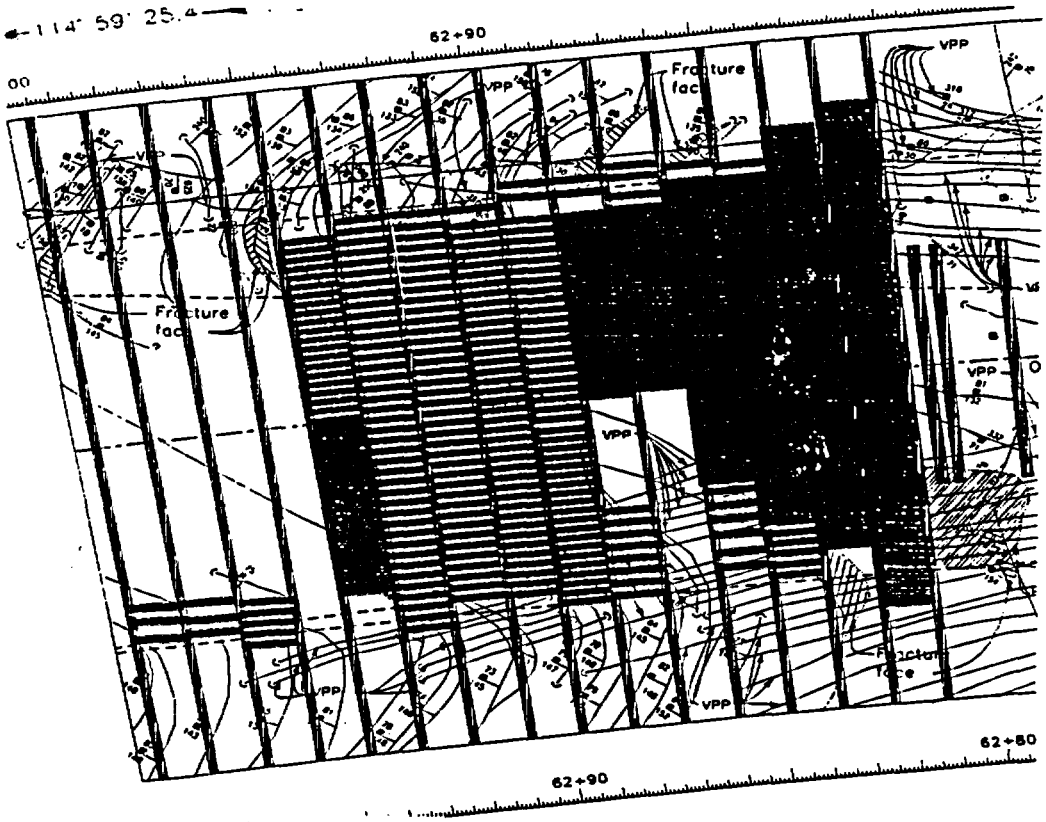
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6260	6265	6270	6275
End Station	6265	6270	6275	6280
Mapped RQD	99	56	43	53
Jn	6	9	9	9
Jr	2	2	2	2
Ja	2	2	4	4
JwQ	1	1	1	1
SRF	2.5	2.5	5	5
Q rating	6.6	2.5	0.48	0.59
Qualitative Description	Fair	Poor	Very Poor	Very Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6260	6265	6270	6275
End Station	6265	6270	6275	6280
Mapped RQD	99	56	43	53
RQD Index	20	13	8	13
C	7	7	7	7
Js	15	15	10	10
Jcd	15	15	13	15
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	60	53	41	48
Qualitative Description	Good	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6280 **End Station:** 6300 **Date:** 14 Oct 96
Rated by: Bill Singleton



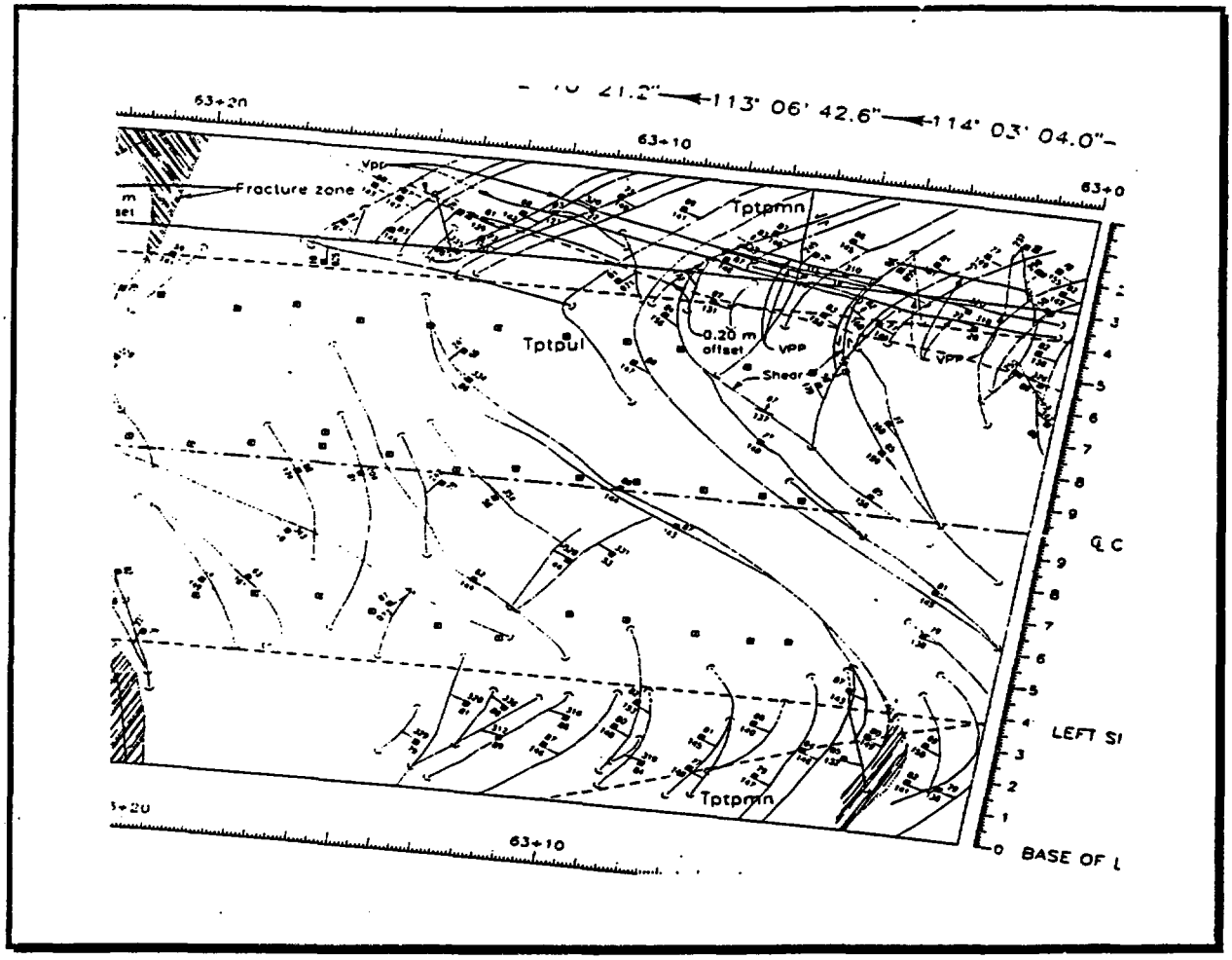
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6280	6285	6290	6295
End Station	6285	6290	6295	6300
Mapped RQD	54	55	65	75
Jn	9	9	9	9
Jr	3	3	2	2
Ja	2	2	4	4
JwQ	1	1	1	1
SRF	7.5	5	5	2.5
Q rating	1.2	1.8	0.72	1.7
Qualitative Description	Poor	Poor	Very Poor	Poor
Installed Ground Support Category	3	3	3	3

RMR Rating Parameters				
Begin Station	6280	6285	6290	6295
End Station	6285	6290	6295	6300
Mapped RQD	54	55	65	75
RQD Index	13	13	13	17
C	7	7	7	7
Js	0	0	10	10
Jcd	18	18	15	15
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	41	41	48	52
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6300 **End Station:** 6320 **Date:** 16 Oct 96
Rated by: Bill Singleton



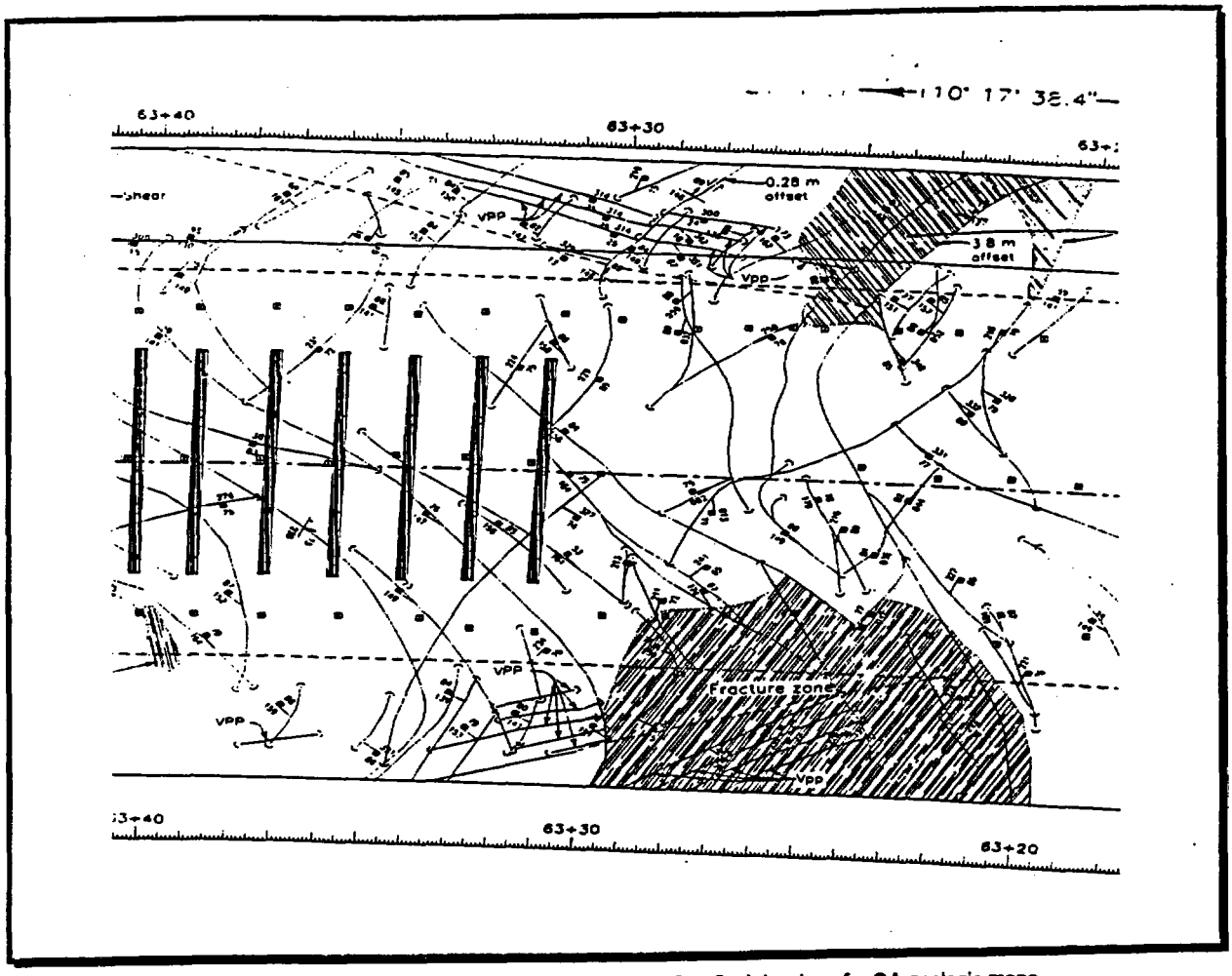
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6300	6305	6310	6315
End Station	6305	6310	6315	6320
Mapped RQD	65	47	74	72
Jn	9	6	9	6
Jr	2	3	3	3
Ja	4	4	4	5
JwQ	1	1	1	1
SRF	1	2.5	1	1
Q rating	3.6	2.4	6.2	7.2
Qualitative Description	Poor	Poor	Fair	Fair
Installed Ground Support Category	3	1	1	1

RMR Rating Parameters				
Begin Station	6300	6305	6310	6315
End Station	6305	6310	6315	6320
Mapped RQD	65	47	74	72
RQD Index	13	8	13	13
C	7	7	7	7
Js	10	10	10	15
Jcd	16	17	13	16
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	49	45	46	54
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6320 **End Station:** 6340 **Date:** 25 Oct 96
Rated by: Bill Singleton



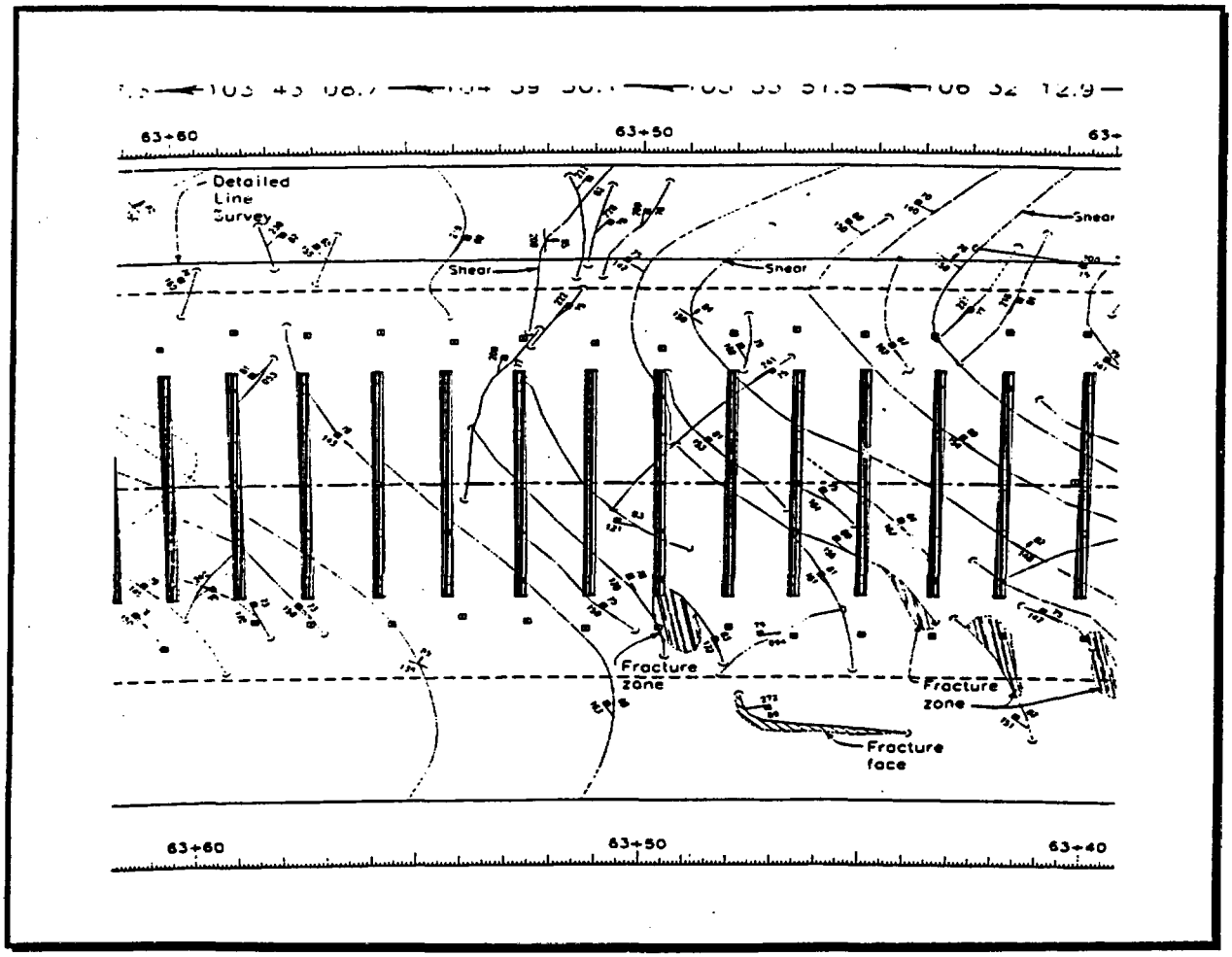
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6320	6325	6330	6335
End Station	6325	6330	6335	6340
Mapped RQD	43	28	48	79
Jn	15	15	9	4
Jr	3	3	3	3
Ja	6	4	4	4
JwQ	1	1	1	1
SRF	2.5	2.5	1	1
Q rating	0.57	0.56	4	15
Qualitative Description	Very Poor	Very Poor	Fair	Good
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6320	6325	6330	6335
End Station	6325	6330	6335	6340
Mapped RQD	43	28	48	79
RQD Index	8	8	8	17
C	7	7	7	7
Js	8	8	10	15
Jcd	15	13	18	21
JwR	15	15	15	15
AJO	-12	-12	-12	-12
RMR rating	41	39	46	63
Qualitative Description	Fair	Poor	Fair	Good

USGS/USBR Rock Mass Classification

Begin Station: 6340 **End Station:** 6360 **Date:** 04 Nov 96
Rated by: Bill Singleton



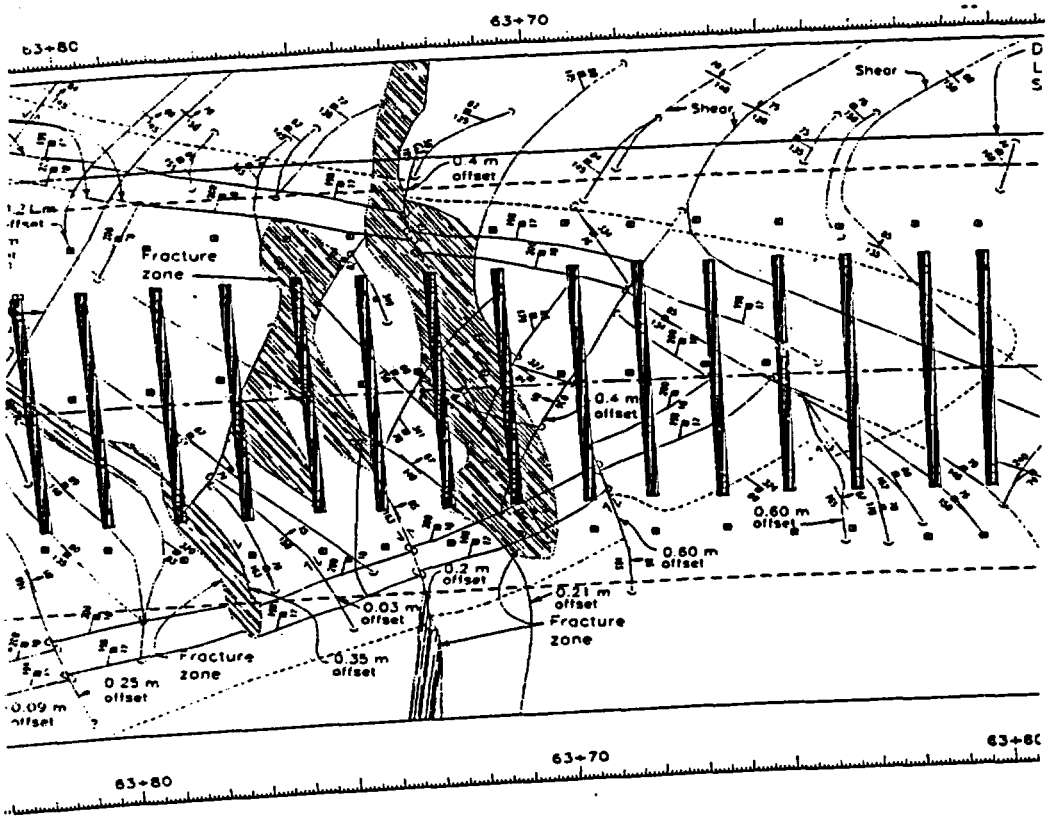
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6340	6345	6350	6355
End Station	6345	6350	6355	6360
Mapped RQD	70	47	35	69
Jn	6	4	3	3
Jr	3	3	3	3
Ja	3	4	4	4
JwQ	1	1	1	1
SRF	1	2.5	2.5	2.5
Q rating	12	3.5	3.5	6.9
Qualitative Description	Good	Poor	Poor	Fair
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6340	6345	6350	6355
End Station	6345	6350	6355	6360
Mapped RQD	70	47	35	69
RQD Index	13	8	8	13
C	7	7	7	7
Js	15	15	15	15
Jcd	19	16	17	16
JwR	15	15	15	15
AJO	-12	-12	-5	-5
RMR rating	57	49	57	61
Qualitative Description	Fair	Fair	Fair	Good

USGS/USBR Rock Mass Classification

Begin Station: 6360 **End Station:** 6380 **Date:** 03 Oct 96
Rated by: Bill Singleton



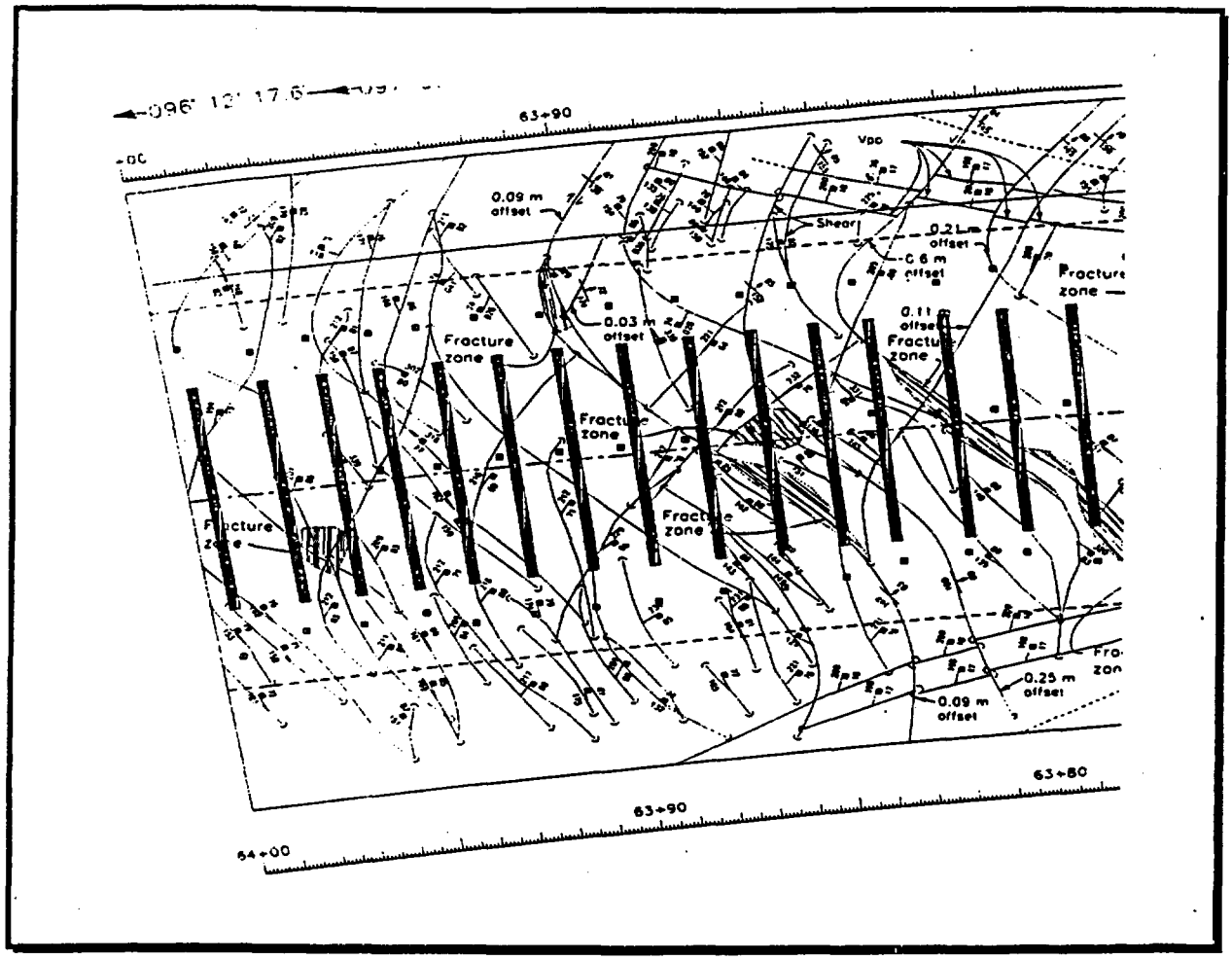
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6360	6365	6370	6375
End Station	6365	6370	6375	6380
Mapped RQD	82	79	40	79
Jn	3	4	6	6
Jr	3	3	3	2
Ja	4	5	5	4
JwQ	1	1	1	1
SRF	2.5	2.5	7.5	7.5
Q rating	8.2	4.7	0.53	0.88
Qualitative Description	Fair	Fair	Very Poor	Very Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6360	6365	6370	6375
End Station	6365	6370	6375	6380
Mapped RQD	82	79	40	79
RQD Index	17	17	8	17
C	7	7	7	7
Js	10	15	10	10
Jcd	16	12	14	9
JwR	15	15	15	15
AJO	-5	-12	-12	-5
RMR rating	60	54	42	53
Qualitative Description	Good	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6380 **End Station:** 6400 **Date:** 04 Nov 96
Rated by: Bill Singleton



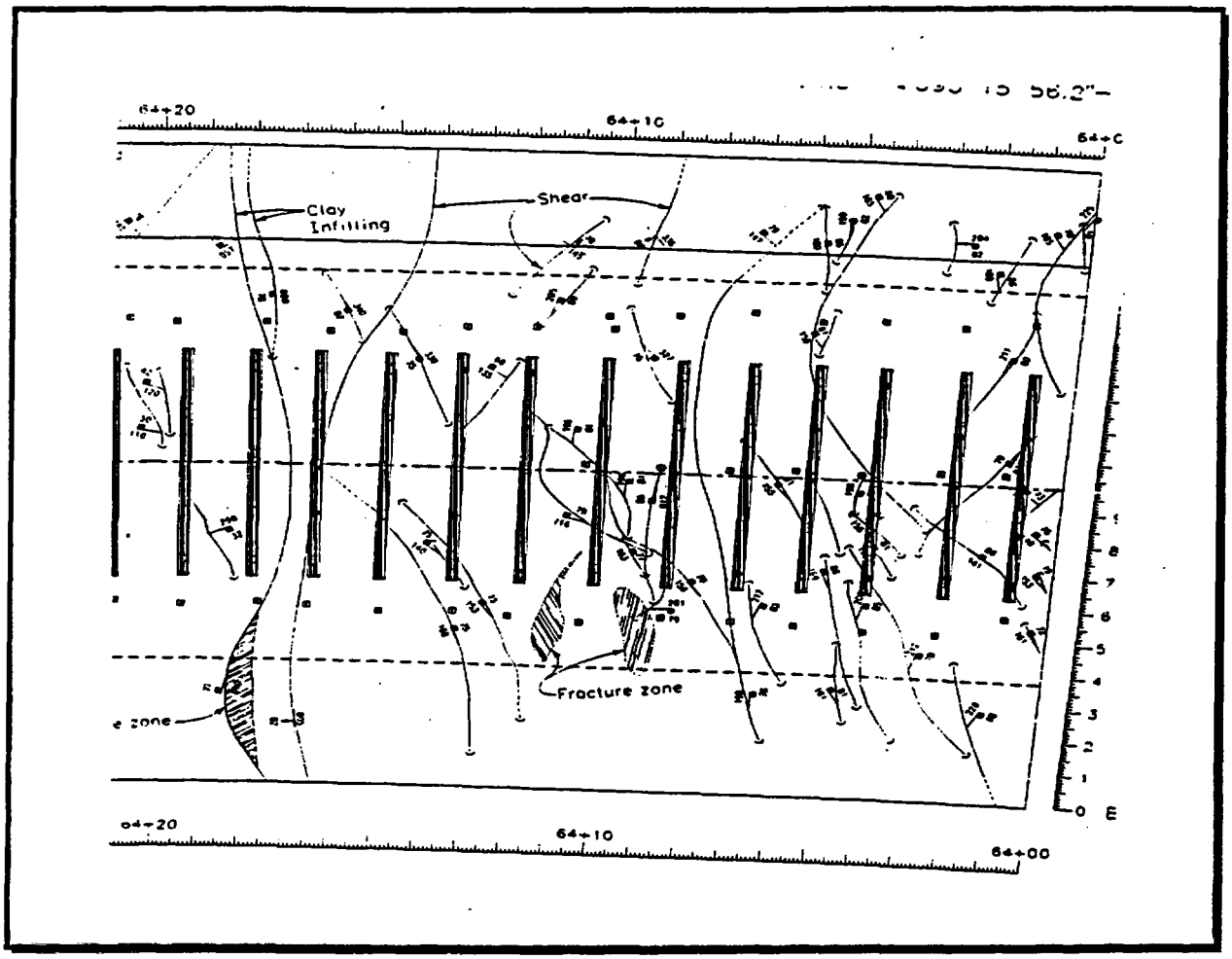
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6380	6385	6390	6395
End Station	6385	6390	6395	6400
Mapped RQD	78	73	61	66
Jn	6	4	4	4
Jr	3	3	3	2
Ja	8	4	4	3
JwQ	1	1	1	1
SRF	7.5	2.5	2.5	2.5
Q rating	0.65	5.5	4.6	4.4
Qualitative Description	Very Poor	Fair	Fair	Fair
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6380	6385	6390	6395
End Station	6385	6390	6395	6400
Mapped RQD	78	73	61	66
RQD Index	17	13	13	13
C	7	7	7	7
Js	15	10	15	10
Jcd	14	15	16	21
JwR	15	15	15	15
AJO	-5	-12	-5	-5
RMR rating	63	48	61	61
Qualitative Description	Good	Fair	Good	Good

USGS/USBR Rock Mass Classification

Begin Station: 6400 **End Station:** 6420 **Date:** 05 Nov 96
Rated by: Bill Singleton



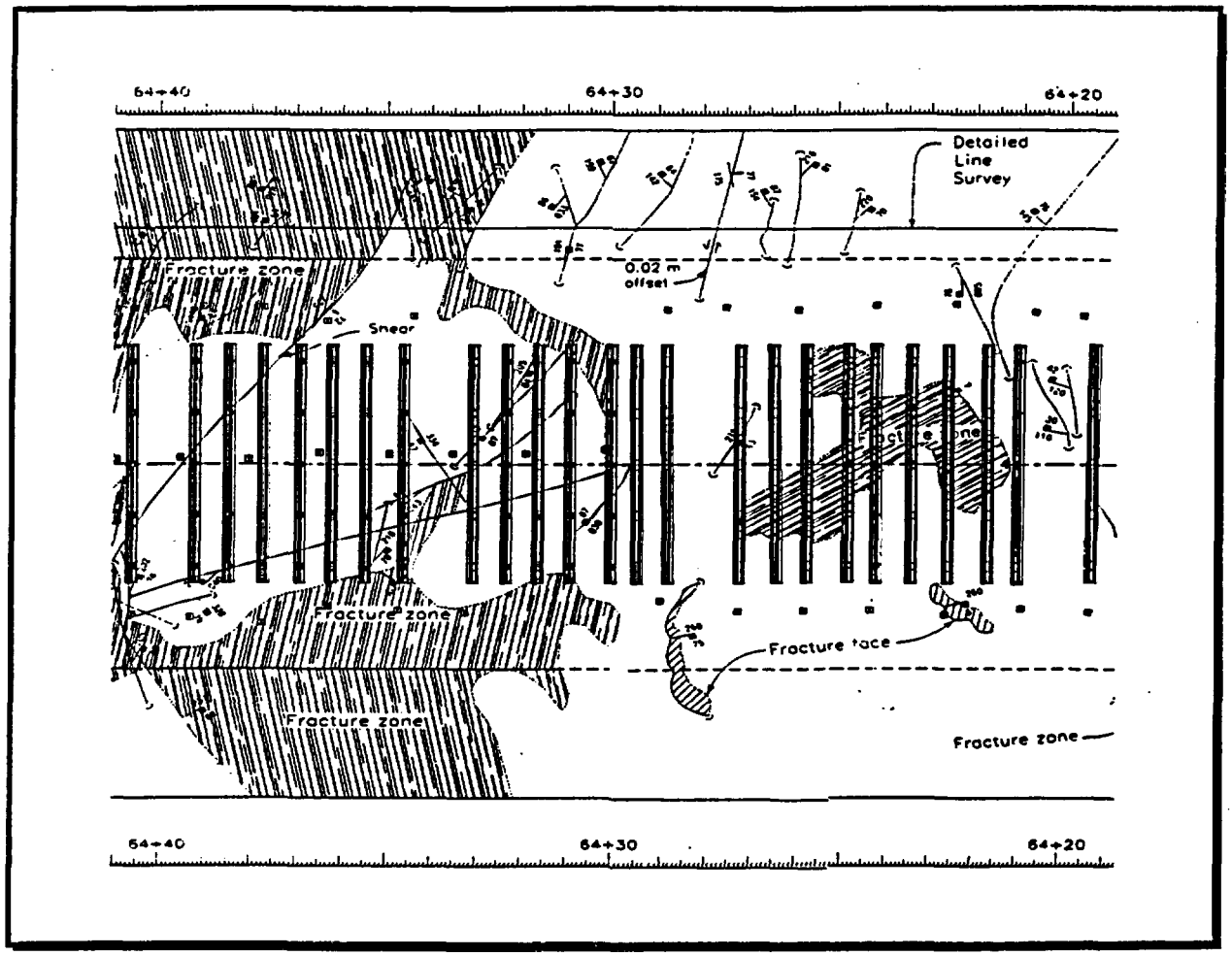
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6400	6405	6410	6415
End Station	6405	6410	6415	6420
Mapped RQD	22	44	21	45
Jn	4	4	4	4
Jr	3	3	3	3
Ja	4	4	4	3
JwQ	1	1	1	1
SRF	1	2.5	2.5	1
Q rating	4.1	3.3	1.6	11
Qualitative Description	Fair	Poor	Poor	Good
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6400	6405	6410	6415
End Station	6405	6410	6415	6420
Mapped RQD	22	44	21	45
RQD Index	3	8	3	8
C	7	7	7	4
Js	10	0	0	10
Jcd	14	23	18	22
JwR	15	15	15	15
AJO	-5	-5	-5	-5
RMR rating	44	48	38	54
Qualitative Description	Fair	Fair	Poor	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6420 **End Station:** 6440 **Date:** 05 Nov 96
Rated by: Bill Singleton



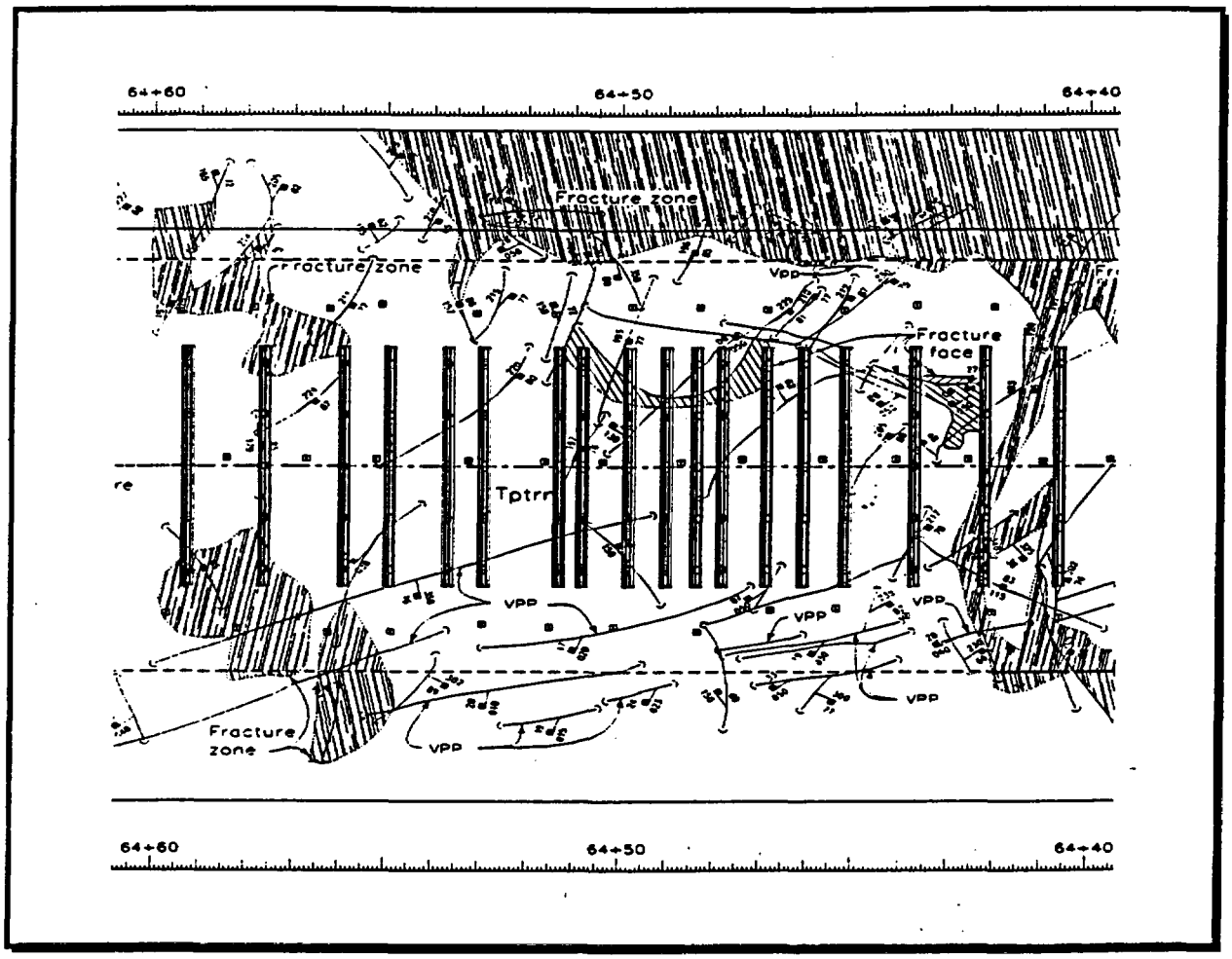
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6420	6425	6430	6435
End Station	6425	6430	6435	6440
Mapped RQD	35	36	45	34
Jn	4	4	6	15
Jr	1.5	3	2	3
Ja	2	4	2	4
JwQ	1	1	1	1
SRF	1	5	2.5	2.5
Q rating	6.6	1.4	3	0.68
Qualitative Description	Fair	Poor	Poor	Very Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6420	6425	6430	6435
End Station	6425	6430	6435	6440
Mapped RQD	35	36	45	34
RQD Index	8	8	8	8
C	4	4	4	4
Js	0	0	8	0
Jcd	23	18	21	22
JwR	15	15	15	15
AJO	-5	-5	-12	-12
RMR rating	45	40	44	37
Qualitative Description	Fair	Fair	Fair	Poor

USGS/USBR Rock Mass Classification

Begin Station: 6440 **End Station:** 6460 **Date:** 12 Nov 96
Rated by: Bill Singleton



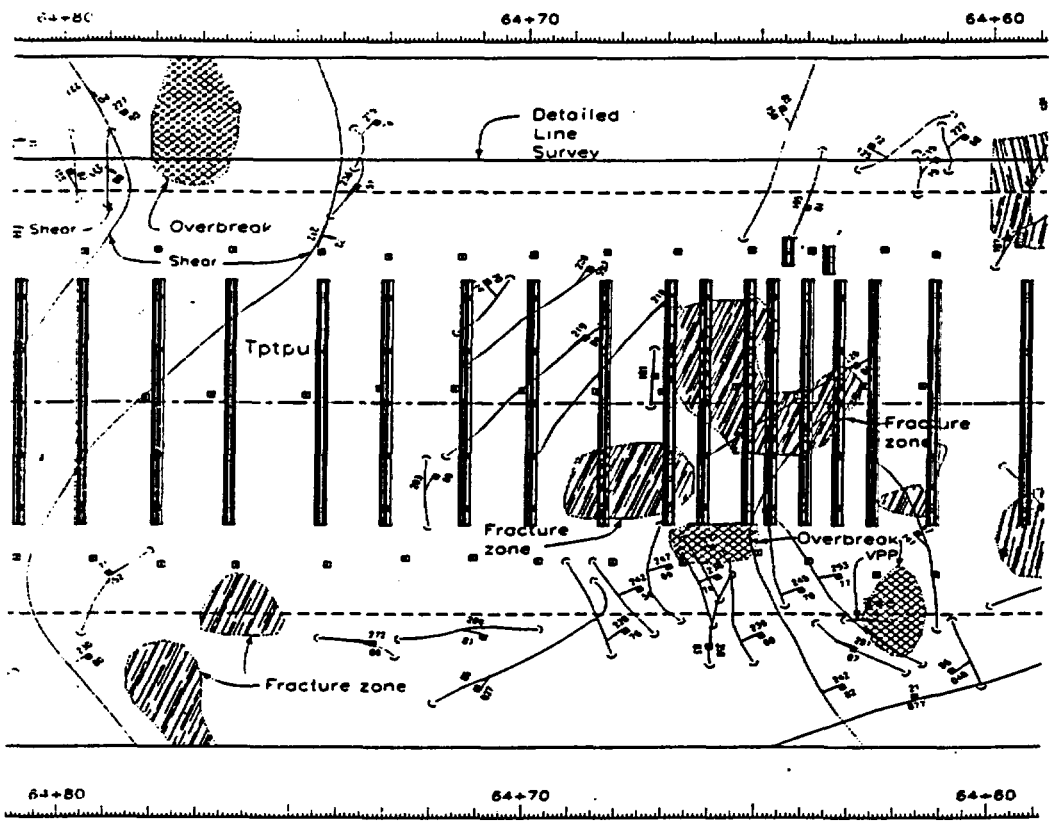
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6440	6445	6450	6455
End Station	6445	6450	6455	6460
Mapped RQD	26	34	27	48
Jn	15	15	15	12
Jr	3	3	3	3
Ja	4	4	4	4
JwQ	1	1	1	1
SRF	2.5	5	2.5	2.5
Q rating	0.52	0.34	0.54	1.2
Qualitative Description	Very Poor	Very Poor	Very Poor	Poor
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6440	6445	6450	6455
End Station	6445	6450	6455	6460
Mapped RQD	26	34	27	48
RQD Index	8	8	8	8
C	7	7	7	7
Js	8	0	0	0
Jcd	16	18	20	20
JwR	15	15	15	15
AJO	-5	-5	-5	-5
RMR rating	49	43	45	45
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6460 **End Station:** 6480 **Date:** 14 Nov 96
Rated by: Bill Singleton



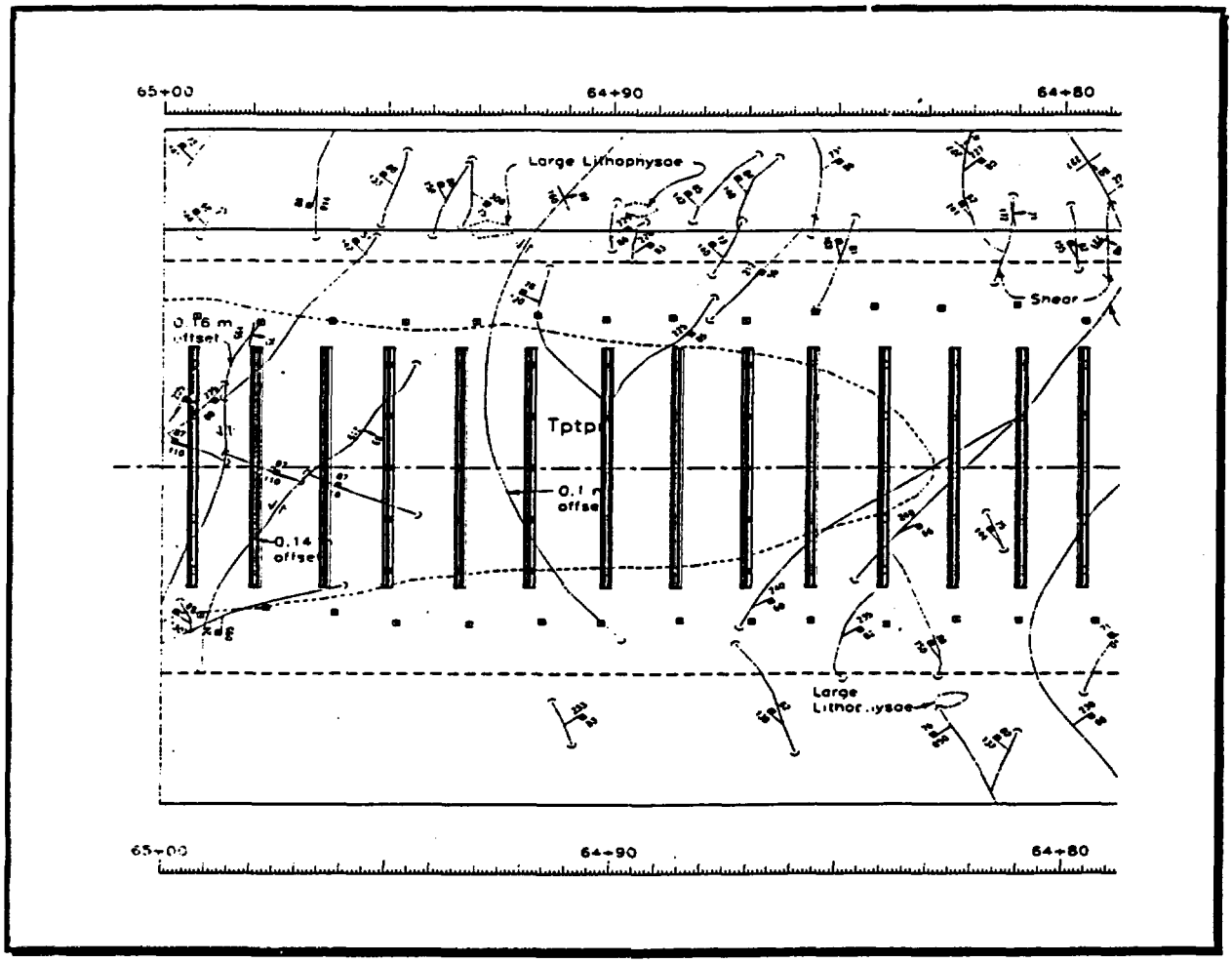
The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6460	6465	6470	6475
End Station	6465	6470	6475	6480
Mapped RQD	30	23	19	61
Jn	12	6	4	3
Jr	3	3	3	3
Ja	4	3	5	4
JwQ	1	1	1	1
SRF	2.5	2.5	1	1
Q rating	0.75	1.5	2.9	15
Qualitative Description	Very Poor	Poor	Poor	Good
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6460	6465	6470	6475
End Station	6465	6470	6475	6480
Mapped RQD	30	23	19	61
RQD Index	8	3	3	13
C	7	7	7	7
Js	0	8	10	10
Jcd	20	18	20	19
JwR	15	15	15	15
AJO	-5	-5	-5	-12
RMR rating	45	46	50	52
Qualitative Description	Fair	Fair	Fair	Fair

USGS/USBR Rock Mass Classification

Begin Station: 6480 **End Station:** 6500 **Date:** 14 Nov 96
Rated by: Bill Singleton



The full periphery tunnel map shown above is for reference only. See final drawings for QA geologic maps.

Q Rating Parameters				
Begin Station	6480	6485	6490	6495
End Station	6485	6490	6495	6500
Mapped RQD	44	73	59	50
Jn	4	6	9	6
Jr	3	3	3	3
Ja	8	4	4	4
JwQ	1	1	1	1
SRF	2.5	2.5	2.5	1
Q rating	1.7	3.7	2	6.3
Qualitative Description	Poor	Poor	Poor	Fair
Installed Ground Support Category	1	1	1	1

RMR Rating Parameters				
Begin Station	6480	6485	6490	6495
End Station	6485	6490	6495	6500
Mapped RQD	44	73	59	50
RQD Index	8	13	13	13
C	7	7	7	7
Js	10	10	10	10
Jcd	18	18	20	22
JwR	15	15	15	15
AJO	-5	-12	-12	-5
RMR rating	53	51	53	62
Qualitative Description	Fair	Fair	Fair	Good