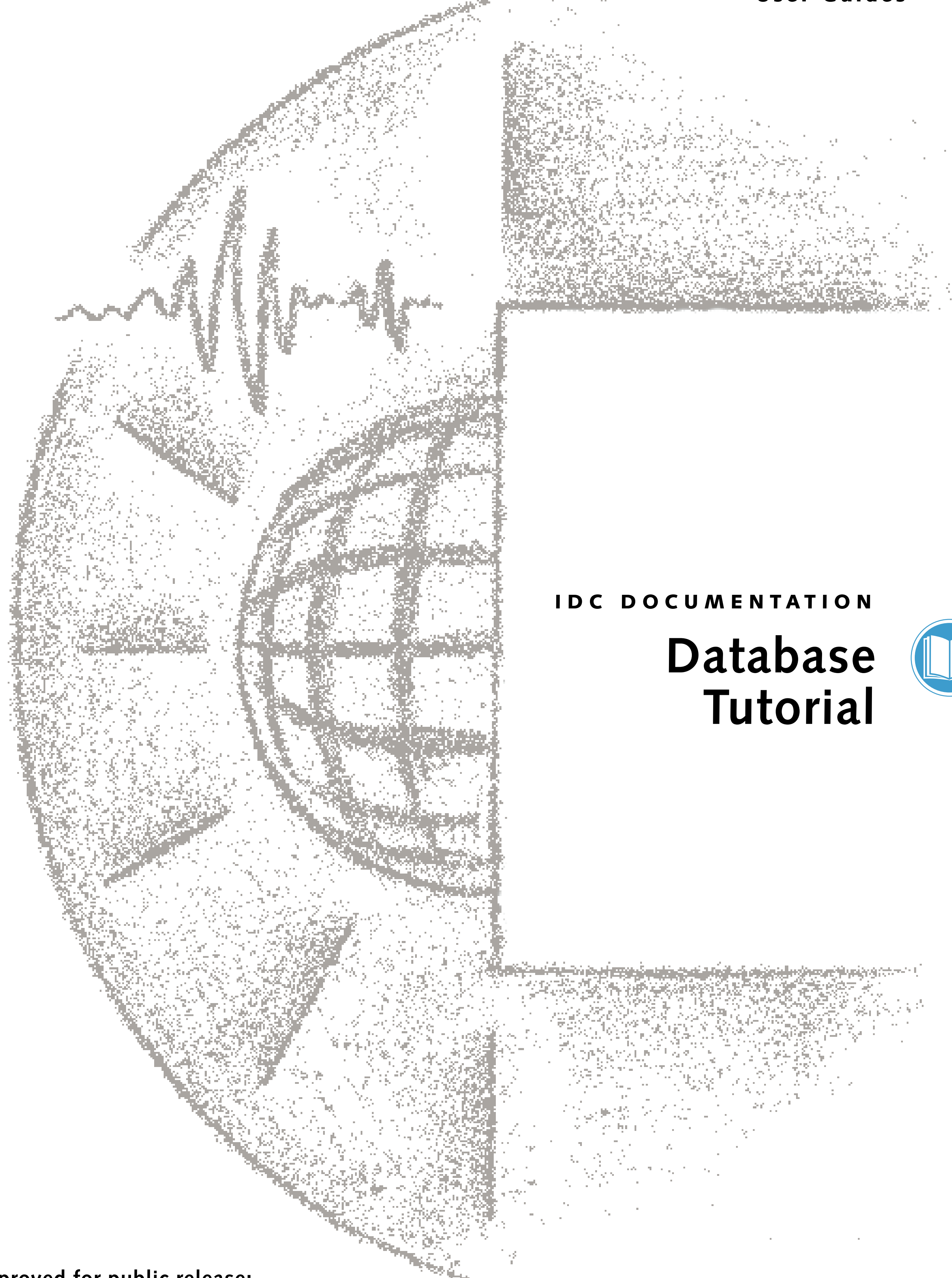
User Guides



IDC DOCUMENTATION

Database Tutorial

Approved for public release;
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Contributors

Jerry A. Carter, Science Applications International Corporation
Michael Pickering, Pacific-Sierra Research Corporation
Henry Swanger, Science Applications International Corporation

Ordering Information

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About this Document

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About this Document

PURPOSE

This document describes how to use the Structured Query Language (SQL) to access and extract information from the database tables at the International Data Centre (IDC).

SCOPE

This document introduces SQL*Plus commands that are used for obtaining and manipulating data within the databases of the IDC. It also introduces the anatomy of a database table and explains where to obtain information on the contents and relationships of the database tables. It does not describe the database schema or the organization of the databases.

AUDIENCE

This document is intended for scientists, technicians, and managers who operate, maintain, and/or use the IDC and the data products that it provides.

RELATED INFORMATION

Use this document in conjunction with [IDC5.1.1Rev1], *Database Schema*.

See "References" on page 105 for a listing of all the sources of information consulted in preparing this document. Among those references are the documents described below.

[ANS86] outlines the syntax for the SQL Language standard.

E. F. Codd [Cod90] formally proposed the relational model in 1969. Between 1968 and 1978 he published many papers on the relational model. From 1979–1988 he proposed extensions to the original relational model (hence *Version 2* in the title). This book consolidates the writings of two decades into a single reference and is intended for Database Administrators (DBAs) and developers.

Chris Date was on the IBM technical team that designed two of the first commercially marketed relational products: SQL/DS and DB2. Since that time he has been a database consultant. [Dat86] is a collection of articles he has written. It is intended for technical readers.

[Eme89] contains an introduction to relational databases, relational database design, and SQL. It is intended for novice SQL users and developers.

[Fle89] provides a practical approach and methodologies for designing tables. This handbook is a standard on how to make relational theory work in practice.

[Gil89] focuses on the performance differences between correlated (EXISTS) and uncorrelated (IN) subqueries. [Sch88] includes guidelines for ordering items in SQL clauses, such as the order of columns in the FROM clause and the order of predicates in the WHERE clause.

[Gru90], [Hur88], and [Lus88] are three of the better introductions to the SQL language. The first two books are simpler; the latter is intended for the experienced programmer or manager. Also of note is [van88a], which contains an introduction to SQL formulated around the creation of a sports club database. This introductory guide is geared for the novice and focuses on American National Standards Institute (ANSI) SQL standard queries. [van88b] is a companion guide to [van88a] and is a more readable version of the SQL standard than [ANS86].

The IDC uses an ORACLE database management system as well as the technical publications written by Oracle Corporation. [Koc97] provides a comprehensive reference for ORACLE releases 7 through 8 and includes examples of SQLPLUS, query optimization, programming interfaces, and more.

This document is based on [And90b]. The text herein is an update of that document.

About this Document

USING THIS DOCUMENT

This document is organized as follows:

- Introduction

  This chapter introduces SQL and relational databases.

- SQL Commands

  This chapter describes the basic SQL commands for obtaining and manipulating the information contained in the databases.

- SQL*Plus Extensions

  This chapter introduces the ORACLE extensions of SQL (SQL*Plus).

- Improving Query Performance

  This chapter suggests methods for improving query performance.

- Navigating Databases

  This chapter describes how the tables of the IDC databases are distributed among computers and accounts and where the information on accounts and tables is located.

- Advanced Seismology Queries

  This chapter contains examples of advanced queries used when manipulating seismological data.

- Advanced Radionuclide Queries

  This chapter contains examples of advanced queries used when manipulating radionuclide data.

- References

  This section lists the sources cited in this document.

- Glossary

  This section defines the terms, abbreviations, and acronyms used in this document.

- Index

  This section lists topics and features provided in this document along with page numbers for reference.

Conventions

This document uses a variety of conventions, which are described in the following tables. Table I shows the typographical conventions. Table II explains certain technical terms that are not part of the standard Glossary, which is located at the end of this document. Most terms in this table pertain to SQL.

TABLE I: TYPOGRAPHICAL CONVENTIONS

Element	Font	Example
database table	**bold**	**dataready**
database table and attribute when written in the dot notation		**prodtrack.***status*
headings, figure titles, and table titles		**About this Document**
the first time a SQL command is used in an example		`select`
attributes of database tables when written separately	*italics*	*status*
processes and software units		*ParseSubs*
user-defined arguments		`delete-remarks` *object*
computer code and output	`courier`	`>(list 'a 'b 'c)`
filenames, directories, and websites		`amp.par`
text that should be typed in exactly as shown		`select`
ORACLE key words in the text of the document	CAPS	SELECT
All rows of the database are not shown, due to space limitations.		<more rows at the bottom>

TABLE II: TERMINOLOGY

Term	Description
account	group of unique tables that are the default tables for queries
Cartesian product	query result that returns every possible combination of all rows in all tables in the FROM clause (most likely an error)
correlation name	alias for the table name that fully qualifies the field names in SQL clauses (providing an easy way of specifying exactly which fields come from which tables)
database instance	unique set of database accounts
join	query that allows the selection of data from more than one table and combines the data returned into a single result table
key	column or set of columns that make each row of a database table unique
natural join	query that returns rows from a join having the specified join field value in both tables
outer join	query that returns rows from a join having the join field value in one table but not the other
predicates	search conditions that are part of the SQL WHERE clause (contains a comparison operator that narrows the search to specific rows)
sequence numbers	number in an ORDER BY clause that refers to the order of the columns listed in the SELECT clause
subquery	complete SQL statement on the right-hand side of a search predicate in the WHERE clause

TABLE II: TERMINOLOGY (CONTINUED)

Term	Description
transaction	operation made on a database table that changes the table in some manner
tuple	row or record in a table
view	pseudo-table derived from one or more tables, which can be queried in the same manner as a table

Introduction

This chapter reviews the principles of relational databases and introduces the databases used for this tutorial. It includes the following topics:

Introduction

STRUCTURED QUERY LANGUAGE

SQL is a language for manipulating data in a relational database. Originally created by IBM, many dialects of SQL have been developed by other database vendors. In the early 1980s, the ANSI started the development of a language standard for managing relational data. The SQL standard was published in 1986 [ANS86]. The International Standards Organization (ISO) has published a standard as well. SQL*Plus is ORACLE's interactive SQL dialect. SQL*Plus includes extensions that are not part of the SQL standard.

This tutorial demonstrates how to use SQL*Plus to access the IDC databases. It assumes no prior knowledge of relational databases or SQL*Plus. A succession of progressively more complex SQL queries is used to demonstrate each command. Complete information on each command is available in [Koc97]. Except where noted, all queries comply with the ANSI SQL standard.

RELATIONAL DATABASES

A relational database is composed of tables, also called relations. Table 1 is the **origin** table as defined in [IDC5.1.1Rev1].

TABLE 1: ORIGIN

Column	Storage Type	Description
1 *orid*	number(8)	origin identifier
2 *lat*	float(24)	estimated latitude
3 *lon*	float(24)	estimated longitude
4 *depth*	float(24)	estimated depth

TABLE 1: ORIGIN (CONTINUED)

Column	Storage Type	Description
5 *time*	float(53)	epoch time
6 *evid*	number(8)	event identifier
7 *jdate*	number(8)	Julian date
8 *nass*	number(4)	number of associated phases
9 *ndef*	number(4)	number of locating phases
10 *ndp*	number(4)	number of depth phases
11 *grn*	number(8)	geographic region number
12 *srn*	number(8)	seismic region number
13 *etype*	varchar2(7)	event type
14 *depdp*	float(24)	estimated depth from depth phases
15 *dtype*	varchar2(1)	depth method used
16 *mb*	float(24)	body wave magnitude
17 *mbid*	number(8)	body wave magnitude identifier
18 *ms*	float(24)	surface wave magnitude
19 *msid*	number(8)	surface wave magnitude identifier
20 *ml*	float(24)	local magnitude
21 *mlid*	number(8)	local wave magnitude identifier
22 *algorithm*	varchar2(15)	location algorithm used
23 *auth*	varchar2(15)	source/originator
24 *commid*	number(8)	comment identifier
25 *lddate*	date	load date

A table is made up of columns (vertical) and rows (horizontal). For example, the **origin** table has 25 columns. The number of rows depends on the size of the database. The first few rows of an **origin** table are listed below:

```
     LAT        LON    DEPTH          TIME  ORID  EVID    JDATE  ...
 42.7671   145.3814  51.1940 633669305.144  1115    -1  1990030  ...
 -6.5238   131.6238  57.1479 633670953.664  1116    -1  1990030  ...
-17.3021  -178.5890  58.8421 633674762.818  1118    -1  1990030  ...
-13.8659   173.5236 100.7905 633678421.987  1119    -1  1990030  ...
 -9.2605   125.4961 145.9096 633690606.505  1123    -1  1990030  ...
```
<more rows at the bottom>

Columns are sometimes called attributes or fields, and rows are sometimes called tuples or records.

Each row in a table is unique. Although the combination of all attributes in a record is unique, in most cases a single attribute or a combination of a few attributes is guaranteed to be unique. The attribute or combination of a few attributes that are unique and are commonly used to reference a single record are known as keys. In the **origin** table, the *orid* attribute is a key as is the collection of attributes: *lat*, *lon*, *depth*, and *time*. A table may have more than one key. One of the keys is usually designated the primary key, and the others are known as alternate keys. Primary and alternate keys may not be NULL (otherwise they would not be unique). A table will usually also contain foreign keys, which are primary or alternate keys in some other table in the database. Foreign keys need not be unique and may be NULL. In the **origin** table, *evid* and *commid* are foreign keys.

The power of a relational database is its ability to relate information in one table to information in another table; this is accomplished mostly through keys. When the tables are designed, the information that is to be stored in the database is distributed logically among several tables. In a seismological example, consider the problem of arrivals, origins, and events. Arrivals are recorded by stations of a seismic network. Information from several arrivals (for example, arrival time) is combined to form a hypothesis for the event location, which is known as the origin. Several location hypotheses (origins) may be made for every event. Four tables are used to represent this information: **arrival**, **assoc**, **origin,** and **event**. Each arrival may contribute to zero or more origins, and each origin requires several arrivals. The **assoc** table links (or associates) the arrival information to the origin information through the *arid* and *orid* keys. For any particular *orid* in the **origin** table, you can list all of the entries in the **assoc** table containing that *orid*. The **assoc** records list the associated *arids,* which can be used to obtain the **arrival** records. Conversely, you could find all of the origins that a particular arrival contributed by listing all of the **assoc** entries with a specific *arid*. The **assoc** records list the associated *orids,* which can be used to obtain the **origin** records. The **origin** records also contain the *evid* foreign key. Several **origin** records may have the same *evid*. Together these **origin** records contain the hypothesized locations for the particular event. The **event** table itself contains an *orid,* which identifies the preferred event solution.

TUTORIAL DATABASE

The database account used for the majority of the queries in this document can be installed and used to practice the queries introduced. The account is *geodemo* and it contains tables with data from the Prototype International Data Centre (PIDC). Not all of the queries will produce the same results, however. Those queries that use larger data sets, such as those in the chapters on advanced seismological and radionuclide queries, were run on larger data sets or on tables that are not included in the *geodemo* account. The *geodemo* data are not required to make this tutorial useful. The same queries may be run with any IDC data set.

A valid ORACLE account and password are required to run the SQL queries in this tutorial. The DBA will provide a database instance, an ORACLE account, and detailed instructions on how to connect to the database. You will also be issued a database password.

DBA Instructions

Use the following UNIX command to load the geodemo tutorial data set:

`geodemo` *account/password*

The *geodemo* program uses the ORACLE import command to load data into the account. The import commands that appear on the screen may be ignored. After the *geodemo* data set has been loaded, the data stay in the database until they are unloaded with the following UNIX command:

`geodemodrop` *account/password*

SQL Commands

This chapter introduces standard SQL commands and includes the following topics:

SQL Commands

CONNECTING TO DATABASE ACCOUNTS

SQL*Plus can be considered an interactive program because it must be manually started and terminated. After starting the program, you can change the account.

Starting SQL*Plus

Enter the following command at the UNIX prompt to start SQL*Plus:

```
sqlplus account@instance
```

A password prompt is displayed:

```
Enter password:
```

After you have entered the correct password (the password will not be echoed to the screen) an ORACLE database banner is displayed, followed by a new prompt:

```
SQL>
```

In this document, this prompt indicates that you may enter the next SQL query.

When starting SQL*Plus, a login startup file is executed. This file sets your user environment and defines commonly used commands. At the IDC, a global login startup file is provided for all users.

Changing Accounts

The CONNECT command changes the connection from one database account to another:

```
connect account@instance
```

As when the initial connection was made, a prompt for a password is displayed, and you must enter a valid password before the connection is allowed:

```
Enter password:
```

Terminating Connections

The EXIT command terminates the database connection:

```
SQL>  exit
```

SELECTING DATA FROM TABLES

Selecting data from the database is the most common SQL operation. A SELECT command consists of two or more clauses terminated by a semicolon (;):

```
select   some columns
from     a table;
```

The SELECT clause is always entered first, immediately followed by the FROM clause. SQL key words, tables, and fields can be entered in lowercase or uppercase. This document shows example tables and attributes in lowercase. Words can be separated by spaces or tabs and can be carried across multiple lines. This document displays each SQL clause on a separate line. A semicolon must always terminate the statement.

Query (1) selects a number of columns from the **origin** table. Your query output may differ from this output. For example, the format of decimal numbers may not be identical. Column formats are controlled by SQL*Plus commands (see "SQL*Plus Extensions" on page 47). An alternative way of displaying *time* is discussed in "Manipulating Dates and Times" on page 60.

(1)
```
SQL>   select   lat, lon, depth, time, orid, evid, jdate
       from     origin;

      LAT        LON      DEPTH             TIME       ORID      EVID  JDATE
--------- ---------- ---------- ---------------- ---------- --------- ------
   0.9815   131.5063     4.6399    636710596.450       3499        -1 1990065
  36.8840    73.3430    19.7271    636714964.102       3679        -1 1990065
  -6.4516   148.4892     0.0000    636715738.291       3680        -1 1990065
   1.2863   122.3456     0.0000    636719076.120       3681        -1 1990065
  -5.9693   147.6910   196.9389    636721535.597       3503        -1 1990065
  58.2493    26.7973     0.0000    636721753.664       3504        -1 1990065
  59.1539    27.1154     0.0000    636723173.244       3682        -1 1990065
  12.1327   143.6159    22.1815    636723655.160       3506        -1 1990065
  -8.4487   150.8799     0.0000    636725410.723       3507        -1 1990065
 -19.3829  -177.0614    70.8751    636726236.684       3508        -1 1990065
 -20.4274   -67.2272    68.9936    636728262.655       3509        -1 1990065
  -9.4297   125.8151    33.0000    636729740.586       3510        -1 1990065
 -10.8992   117.5039    29.6973    636730261.597       3683        -1 1990065
  36.8908    73.4689     9.1589    636732572.863       3512        -1 1990065
 -17.8557   168.0396    27.5160    636733569.784       3513        -1 1990065
  32.9234    74.9347    12.9065    636734589.275       3514        -1 1990065
  21.9599   142.8868     0.0000    636734894.155       3684        -1 1990065
 -10.5516   119.7778    37.6402    636737108.355       3516        -1 1990065
18 rows selected.

SQL>
```

The asterisk (*) character represents all columns. Query (2) would return the same number of rows as Query (1) but would display all columns of the **origin** table.

(2)
```
SQL>   select   *
       from     origin;
```

The result of any query is a table of columns and rows. The order of columns in the SELECT clause determines the display sequence. If all fields are selected with SELECT *, they are output in the sequence that they were created.

Query (1) showed how the SELECT clause restricts which columns are displayed. Query (3) shows how the WHERE clause restricts which rows are returned.

(3)

```
SQL>   select   arid, orid, sta, phase, delta, seaz
       from     assoc
       where    orid=3508;

     ARID       ORID STA    PHASE        DELTA    SEAZ
--------- ---------- ------ --------- --------- -------
    67869       3508 YKA    P           95.330  237.14
    67669       3508 ASAR   P           45.601   94.47
    67671       3508 ASAR   PcP         45.601   94.47
    67672       3508 ASAR   ScP         45.601   94.47
    66946       3508 MAT    P           70.075  135.08
    67522       3508 ASPA   P           45.601   94.47
    67026       3508 ARA0   PKP        127.988   27.34
    66814       3508 EKA    PKP        143.755  350.24
8 rows selected.

SQL>
```

The WHERE clause contains search conditions, called predicates, which narrow the search to specific rows. The predicate contains a comparison operator that compares two expressions (see Table 2 for a list of the comparison operators.) In Query (3), the *orid* column is the left-hand expression, and the constant `3508` is the right-hand expression. These expressions are tested for equality with the **=** operator, and only those rows containing an *orid* of `3508` are returned. The test for inequality uses the **!=** (not equal) operator. The **=** operator also tests strings for equality. Query (4) shows how the text of the string must be enclosed by single quotes.

(4)

```
SQL>  select   arid, orid, sta, phase, delta, seaz
      from     assoc
      where    sta = 'MAT';

     ARID       ORID STA    PHASE        DELTA    SEAZ
--------- ---------- ------ --------- --------- -------
    66946       3508 MAT    P          70.075   135.08
    66949       3683 MAT    P          51.289    21.35
    66951       3683 MAT    LR         51.289    21.35

SQL>
```

Although SQL key words can be entered in either uppercase or lowercase, string searches are case sensitive depending on how data are stored in the database. For example, the range defined for the *sta* attribute is any uppercase string up to six characters (see [IDC5.1.1Rev1]). Because *sta* is stored in uppercase, the following WHERE clause condition would return no rows:

```
where sta='mat'
```

The LIKE operator matches partial strings. The underscore character (_) matches any single character. Query (5) uses two-letter phase names beginning with 'S' to limit the results.

(5)

```
SQL>  select   arid, orid, sta, phase, delta, seaz
      from     assoc
      where    phase like 'S_';

     ARID       ORID STA    PHASE       DELTA     SEAZ
--------- --------- ------ -------- -------- -------
    67021       3682 ARA0   Sn         10.404   356.88
    71464       3682 KAF    Sn          2.985   352.71

SQL>
```

The percent sign (%) matches zero, one, or more characters. Query (6) obtains the information for all s-type phases.

(6)

```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    phase like 'S%';

     ARID       ORID STA    PHASE        DELTA    SEAZ
--------- ---------- ------ --------- -------- -------
    68225       3503 ASPA   S           22.114   39.02
    67507       3503 ASAR   S           22.114   39.02
    67672       3508 ASAR   ScP         45.601   94.47
    67531       3510 ASPA   S           16.199  330.16
    67095       3512 GAR    S            3.270  129.18
    67542       3516 ASPA   S           18.793  311.86
    68086       3679 GAR    S            3.199  312.33
    67021       3682 ARA0   Sn          10.404  356.88
    71464       3682 KAF    Sn           2.985  352.71
    67092       3683 GAR    S           66.455  321.53
10 rows selected.

SQL>
```

Three logical operators (AND, OR, and NOT) may be used to combine multiple predicates in a WHERE clause. AND specifies that both predicates must be satisfied for a row of data to be returned, as shown in Query (7).

(7)

```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    orid=3508
     and      sta='ASAR';

     ARID       ORID STA    PHASE        DELTA    SEAZ
--------- ---------- ------ --------- -------- -------
    67669       3508 ASAR   P           45.601   94.47
    67671       3508 ASAR   PcP         45.601   94.47
    67672       3508 ASAR   ScP         45.601   94.47

SQL>
```

OR specifies that the row should be returned if either predicate is satisfied, as shown in Query (8).

(8)

```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    orid=3508
     or       sta='ASAR';

     ARID       ORID STA    PHASE        DELTA    SEAZ
--------- --------- ------ -------- -------- -------
    67490       3499 ASAR   P          24.757  354.27
    67506       3503 ASAR   P          22.114   39.02
    67507       3503 ASAR   S          22.114   39.02
    67510       3506 ASAR   P          37.037   15.89
    67664       3507 ASAR   P          22.262   49.67
    67869       3508 YKA    P          95.330  237.14
    67669       3508 ASAR   P          45.601   94.47
    67671       3508 ASAR   PcP        45.601   94.47
    67672       3508 ASAR   ScP        45.601   94.47
    66946       3508 MAT    P          70.075  135.08
    67522       3508 ASPA   P          45.601   94.47
    67026       3508 ARA0   PKP       127.988   27.34
    66814       3508 EKA    PKP       143.755  350.24
    67680       3510 ASAR   P          16.199  330.16
    67691       3512 ASAR   P          83.081  315.51
    67692       3513 ASAR   P          32.364   86.21
    67694       3513 ASAR   pP         32.364   86.21
    67695       3514 ASAR   P          79.738  313.03
    67697       3516 ASAR   P          18.793  311.86
    67492       3679 ASAR   P          83.157  126.55
    67494       3680 ASAR   P          22.199  217.62
    67686       3683 ASAR   P          20.168  131.41
22 rows selected.

SQL>
```

Other comparison operators allow tests for a range of values. Query (9) tests for an *orid* < (less than) 3508.

(9)

```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    orid < 3508
     and      sta = 'ASAR';

     ARID       ORID STA    PHASE         DELTA     SEAZ
---------- ---------- ------ --------- --------- -------
    67490       3499 ASAR   P            24.757   354.27
    67506       3503 ASAR   P            22.114    39.02
    67507       3503 ASAR   S            22.114    39.02
    67510       3506 ASAR   P            37.037    15.89
    67664       3507 ASAR   P            22.262    49.67

SQL>
```

Query (10) tests for an *orid* <= (less than or equal to) 3508.

(10)

```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    orid <= 3508
     and      sta = 'ASAR';

     ARID       ORID STA    PHASE         DELTA     SEAZ
---------- ---------- ------ --------- --------- -------
    67490       3499 ASAR   P            24.757   354.27
    67506       3503 ASAR   P            22.114    39.02
    67507       3503 ASAR   S            22.114    39.02
    67510       3506 ASAR   P            37.037    15.89
    67664       3507 ASAR   P            22.262    49.67
    67669       3508 ASAR   P            45.601    94.47
    67671       3508 ASAR   PcP          45.601    94.47
    67672       3508 ASAR   ScP          45.601    94.47
8 rows selected.

SQL>
```

Query (11) adds a search for a value >= (greater than or equal to) 3500 to Query (10).

(11)
```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    orid >= 3500
     and      orid <= 3508
     and      sta = 'ASAR';

     ARID       ORID STA    PHASE       DELTA    SEAZ
--------- --------- ------ -------- -------- -------
    67506       3503 ASAR   P          22.114   39.02
    67507       3503 ASAR   S          22.114   39.02
    67510       3506 ASAR   P          37.037   15.89
    67664       3507 ASAR   P          22.262   49.67
    67669       3508 ASAR   P          45.601   94.47
    67671       3508 ASAR   PcP        45.601   94.47
    67672       3508 ASAR   ScP        45.601   94.47
7 rows selected.

SQL>
```

The BETWEEN operator used in Query (12) offers a shortcut for Query (11).

(12)
```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    orid between 3500 and 3508
     and      sta = 'ASAR';

     ARID       ORID STA    PHASE       DELTA    SEAZ
--------- --------- ------ -------- -------- -------
    67506       3503 ASAR   P          22.114   39.02
    67507       3503 ASAR   S          22.114   39.02
    67510       3506 ASAR   P          37.037   15.89
    67664       3507 ASAR   P          22.262   49.67
    67669       3508 ASAR   P          45.601   94.47
    67671       3508 ASAR   PcP        45.601   94.47
    67672       3508 ASAR   ScP        45.601   94.47
7 rows selected.

SQL>
```

In Query (13) the IN operator searches for a specific list of values.

(13)
```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    orid between 3500 and 3508
     and      sta = 'ASAR'
     and      phase in ('P','S');

     ARID      ORID STA    PHASE        DELTA    SEAZ
--------- --------- ------ -------- --------- -------
    67506      3503 ASAR   P           22.114   39.02
    67507      3503 ASAR   S           22.114   39.02
    67510      3506 ASAR   P           37.037   15.89
    67664      3507 ASAR   P           22.262   49.67
    67669      3508 ASAR   P           45.601   94.47
SQL>
```

You can specify the reverse of any operator, as shown in Query (14), where NOT IN specifies the reverse of IN.

(14)
```
SQL> select   arid, orid, sta, phase, delta, seaz
     from     assoc
     where    orid between 3500 and 3508
     and      sta = 'ASAR'
     and      phase not in ('P','S');

     ARID      ORID STA    PHASE        DELTA    SEAZ
--------- --------- ------ -------- --------- -------
    67671      3508 ASAR   PcP         45.601   94.47
    67672      3508 ASAR   ScP         45.601   94.47

SQL>
```

Table 2 summarizes the comparison operators introduced in this section.

TABLE 2: COMPARISON OPERATORS

Operator	Sample 'WHERE' Clause
=	`where orid = 3508`
>	`where orid > 3508`
>=	`where orid >= 3508`
<	`where orid < 3508`
<=	`where orid <= 3508`
BETWEEN	`where orid between 3508 and 3510`
IN	`where phase in ('Pn', 'Sn', 'Lg')`
NOT IN	`where orid not in ('Pn', 'Sn', 'Lg')`
LIKE	`where phase like 'P_'`

ORDERING ROWS OF RESULTS

In the previous examples, the rows of query results were displayed in an order determined by ORACLE. You can specify the order by using the ORDER BY clause. Query (15) sorts the result by phase.

(15)

```
SQL> select    arid, orid, sta, phase, delta, seaz
     from      assoc
     where     orid=3508
     and       phase like 'P%'
     order by  phase;

     ARID       ORID STA    PHASE         DELTA    SEAZ
--------- --------- ------ --------- --------- -------
    67869       3508 YKA    P            95.330  237.14
    67669       3508 ASAR   P            45.601   94.47
    66946       3508 MAT    P            70.075  135.08
    67522       3508 ASPA   P            45.601   94.47
    67026       3508 ARA0   PKP         127.988   27.34
```

```
    66814       3508 EKA    PKP        143.755  350.24
    67671       3508 ASAR   PcP         45.601   94.47
7 rows selected.

SQL>
```

Query (16) references more than one column in the ORDER BY clause:

(16)

```
SQL> select    arid, orid, sta, phase, delta, seaz
     from      assoc
     where     orid=3508
     and       phase like 'P%'
     order by  phase, delta;

     ARID       ORID STA    PHASE         DELTA    SEAZ
--------- --------- ------ -------- -------- -------
    67669       3508 ASAR   P           45.601   94.47
    67522       3508 ASPA   P           45.601   94.47
    66946       3508 MAT    P           70.075  135.08
    67869       3508 YKA    P           95.330  237.14
    67026       3508 ARA0   PKP        127.988   27.34
    66814       3508 EKA    PKP        143.755  350.24
    67671       3508 ASAR   PcP         45.601   94.47
7 rows selected.

SQL>
```

By default, ORACLE sorts in ascending order. You can specify that the results be sorted in descending order or in a combination of both ascending and descending order. Query (17) sorts first by *phase* in ascending (ASC) order, then by *delta* in descending (DESC) order.

(17)

```
SQL>  select    arid, orid, sta, phase, delta, seaz
      from      assoc
      where     orid=3508
      and       phase like 'P%'
      order by  phase asc, delta desc;

     ARID       ORID STA    PHASE        DELTA    SEAZ
--------- --------- ------ -------- --------- -------
    67869       3508 YKA    P           95.330  237.14
    66946       3508 MAT    P           70.075  135.08
    67669       3508 ASAR   P           45.601   94.47
    67522       3508 ASPA   P           45.601   94.47
    66814       3508 EKA    PKP        143.755  350.24
    67026       3508 ARA0   PKP        127.988   27.34
    67671       3508 ASAR   PcP         45.601   94.47
7 rows selected.

SQL>
```

You can replace columns in the ORDER BY clause with sequence numbers that correspond to the position of the column in the SELECT clause. For example, in Query (17) *phase* is the fourth column, and *arid* is the first column. Query (18) produces the same result by referencing column numbers.

(18)

```
SQL>  select    arid, orid, sta, phase, delta, seaz
      from      assoc
      where     orid=3508
      and       phase like 'P%'
      order by  4 asc, 5 desc;

     ARID       ORID STA    PHASE        DELTA    SEAZ
--------- --------- ------ -------- --------- -------
    67869       3508 YKA    P           95.330  237.14
    66946       3508 MAT    P           70.075  135.08
    67669       3508 ASAR   P           45.601   94.47
    67522       3508 ASPA   P           45.601   94.47
    66814       3508 EKA    PKP        143.755  350.24
    67026       3508 ARA0   PKP        127.988   27.34
    67671       3508 ASAR   PcP         45.601   94.47
7 rows selected.

SQL>
```

ELIMINATING DUPLICATE ROWS

Sometimes a query will return duplicate rows. Query (19) selects all *orids* less than 3505 from the **assoc** table and consequently returns many duplicate rows.

(19)

```
SQL>  select   orid
      from     assoc
      where    orid < 3505;

     ORID
---------
     3499
     3499
     3503
     3503
     3503
     3503
     3503
     3503
     3504
     3504
     3504
     3504
12 rows selected.

SQL>
```

Specifying DISTINCT in the SELECT clause eliminates duplicate rows, as shown in Query (20).

(20)

```
SQL>  select   distinct orid
      from     assoc
      where    orid < 3505;

     ORID
---------
     3499
     3503
     3504

SQL>
```

Computing Functions on Groups of Rows

Group-value functions compute summary information across groups of rows. Table 3 lists common group functions, which appear in the SELECT clause and usually take column names as arguments.

TABLE 3: ORACLE GROUP-VALUE FUNCTIONS

Function	Definition
AVG(*value*)	average of *value* for a group of rows
COUNT(*value*)	count of the number of rows in a group of rows
MAX(*value*)	maximum of *value* for a group of rows
MIN(*value*)	minimum of *value* for a group of rows
STDDEV(*value*)	standard deviation of *value* for a group of rows
SUM(*value*)	sum of *value* for a group of rows
VARIANCE(*value*)	variance of *value* for a group of rows

The GROUP BY clause limits the rows to which the function is applied. The group-value function is applied to each group of rows for which the value of the GROUP BY column is unique.

Query (21) counts the number of events by day.

(21)

```
SQL>  select     jdate, count(orid)
      from       origin
      group by   jdate;

   JDATE COUNT(ORID)
-------- -----------
 1990065          18

SQL>
```

Query (22) counts the number of *arids* for each *orid* in the **assoc** table.

(22)
```
SQL>  select    orid, count(arid)
      from      assoc
      group by  orid;

     ORID COUNT(ARID)
--------- -----------
     3499           2
     3503           6
     3504           4
     3506          12
     3507           2
     3508           8
     3509           3
     3510           4
     3512           5
     3513           8
     3514           4
     3516           7
     3679          10
     3680           2
     3681           4
     3682          10
     3683          25
     3684           4
18 rows selected.

SQL>
```

Adding a WHERE clause reduces the number of source rows processed for the aggregate count as shown in Query (23).

(23)

```
SQL> select    orid, count(arid)
     from      assoc
     where     orid < 3510
     group by  orid;

     ORID COUNT(ARID)
--------- -----------
     3499           2
     3503           6
     3504           4
     3506          12
     3507           2
     3508           8
     3509           3
7 rows selected.

SQL>
```

The HAVING clause restricts the GROUP BY clause in the same way that the WHERE clause restricts the SELECT clause. Query (24) returns only those *orids* that have more than two *arids.*

(24)

```
SQL> select    orid, count(arid)
     from      assoc
     where     orid < 3510
     group by  orid
     having    count(arid) > 2;

     ORID COUNT(ARID)
--------- -----------
     3503           6
     3504           4
     3506          12
     3508           8
     3509           3

SQL>
```

Query (25) sorts the final result in decreasing order by the *orid* with the most *arids*. It uses all of the SQL SELECT clauses: SELECT, FROM, WHERE, GROUP BY, HAVING, and ORDER BY. In this query, the ORDER BY clause instructs ORACLE to sort by the second column, *count(arid),* in the SELECT clause.

(25)

```
SQL> select    orid, count(arid)
     from      assoc
     where     orid < 3510
     group by  orid
     having    count(arid) > 2
     order by  2 desc;

     ORID COUNT(ARID)
--------- -----------
     3506          12
     3508           8
     3503           6
     3504           4
     3509           3

SQL>
```

QUERYING MULTIPLE TABLES – JOINS

In previous examples, single tables were queried; however, the data will not always be available in one table. A "join" selects data from more than one table and returns a single table as a result. This section describes two types of joins: a natural join and an outer join. A natural join, which is the most common join, returns rows that have the join field value in all tables. An outer join returns rows that have the join field value in one table but not in the others (see "Outer Joins" on page 35). Query (26) is a single-table (**origin**) query that finds all origins in a given latitude, longitude window; however, the table does not contain *phase*. To find all phases associated with the origins, the **assoc** table, which contains *phase*, is needed. Both tables contain the *orid* column, which provides a link to join them. Query (27) uses the dot notation to specify this link in the WHERE clause. In dot notation, a dot separates the table name from the column name (**table**.*column*).

(26)

```
SQL>  select   lat, lon, depth, time
      from     origin
      where    lat between 35.0 and 40.0
      and      lon between 50.0 and 75.0;

      LAT       LON     DEPTH            TIME
--------- --------- --------- ---------------
  36.8840   73.3430   19.7271   636714964.102
  36.8908   73.4689    9.1589   636732572.863

SQL>
```

(27)

```
SQL>  select   arid, lat, lon, depth, time, phase
      from     assoc, origin
      where    assoc.orid=origin.orid
      and      lat between 35.0 and 40.0
      and      lon between 50.0 and 75.0;

     ARID       LAT       LON     DEPTH            TIME PHASE
--------- --------- --------- --------- --------------- --------
    67600   36.8908   73.4689    9.1589   636732572.863 P
    67093   36.8908   73.4689    9.1589   636732572.863 P
    67095   36.8908   73.4689    9.1589   636732572.863 S
    67891   36.8908   73.4689    9.1589   636732572.863 P
    67691   36.8908   73.4689    9.1589   636732572.863 P
    68114   36.8840   73.3430   19.7271   636714964.102 P
    68117   36.8840   73.3430   19.7271   636714964.102 pP
    67370   36.8840   73.3430   19.7271   636714964.102 P
    66866   36.8840   73.3430   19.7271   636714964.102 P
    67439   36.8840   73.3430   19.7271   636714964.102 P
    67492   36.8840   73.3430   19.7271   636714964.102 P
    67011   36.8840   73.3430   19.7271   636714964.102 P
    68083   36.8840   73.3430   19.7271   636714964.102 P
    68086   36.8840   73.3430   19.7271   636714964.102 S
    67834   36.8840   73.3430   19.7271   636714964.102 P
15 rows selected.

SQL>
```

When a column in the SELECT clause occurs in more than one table in the FROM clause, you must specify from which table the column should be displayed. Query (28) adds *orid* to Query (27)'s SELECT clause and specifies that the *orid* from the original table should be displayed.

(28)

```
SQL> select   origin.orid, arid, lat, lon, depth, time, phase
     from     assoc, origin
     where    assoc.orid=origin.orid
     and      lat between 35.0 and 40.0
     and      lon between 50.0 and 75.0;

     ORID       ARID        LAT        LON      DEPTH             TIME PHASE
---------- ---------- ---------- ---------- ---------- ---------------- ------
      3512      67600    36.8908    73.4689     9.1589   636732572.863 P
      3512      67093    36.8908    73.4689     9.1589   636732572.863 P
      3512      67095    36.8908    73.4689     9.1589   636732572.863 S
      3512      67891    36.8908    73.4689     9.1589   636732572.863 P
      3512      67691    36.8908    73.4689     9.1589   636732572.863 P
      3679      68114    36.8840    73.3430    19.7271   636714964.102 P
      3679      68117    36.8840    73.3430    19.7271   636714964.102 pP
      3679      67370    36.8840    73.3430    19.7271   636714964.102 P
      3679      66866    36.8840    73.3430    19.7271   636714964.102 P
      3679      67439    36.8840    73.3430    19.7271   636714964.102 P
      3679      67492    36.8840    73.3430    19.7271   636714964.102 P
      3679      67011    36.8840    73.3430    19.7271   636714964.102 P
      3679      68083    36.8840    73.3430    19.7271   636714964.102 P
      3679      68086    36.8840    73.3430    19.7271   636714964.102 S
      3679      67834    36.8840    73.3430    19.7271   636714964.102 P
15 rows selected.

SQL>
```

Query (28) used the name of the **origin** table to fully qualify *orid*. A field may also be qualified by using a correlation name, which is like an alias for the actual table. Query (29) uses correlation names to specify which fields come from which tables. This query would return the same result as Query (28).

(29)
```
SQL> select   o.orid, a.arid, o.lat, o.lon, o.depth, o.time, a.phase
     from     assoc a, origin o
     where    a.orid=o.orid
     and      o.lat between 35.0 and 40.0
     and      o.lon between 50.0 and 75.0;
```

The correlation name for the **assoc** table is **a** and the correlation name for the **origin** table is **o**. Query (29) specifies which attributes are to be selected from which tables. This feature is useful especially in complex queries.

Correlation names may consist of multiple characters but may not conflict with an SQL key word. For example, **ar** is a valid correlation name for the **arrival** table, but **as** is not a valid name for the **assoc** table. Query (30) results in an error, because the correlation name **as** conflicts with an SQL key word.

(30)
```
SQL> select   o.orid, as.arid, o.lat, o.lon, o.time, as.phase,
              ar.time, ar.azimuth, ar.slow
     from     assoc as, arrival ar, origin o
     where    as.orid=o.orid
     and      as.arid=ar.arid
     and      o.lat between 35.0 and 40.0
     and      o.lon between 50.0 and 75.0;

select  o.orid, as.arid, o.lat, o.lon, o.time, as.phase,
                *
ERROR at line 1:
ORA-00936: missing expression

SQL>
```

Likewise, **or** is an invalid correlation name for **origin**. Any number of tables may be joined. Query (31) builds on Query (29) and includes information from the **arrival** table.

(31)
```
SQL> select   o.orid, a.arid, o.lat, o.lon, o.time, a.phase, ar.time,
              ar.azimuth, ar.slow
     from     assoc a, arrival ar, origin o
     where    a.orid=o.orid
     and      a.arid=ar.arid
     and      o.lat between 35.0 and 40.0
     and      o.lon between 50.0 and 75.0;

ORID  ARID      LAT      LON          TIME PHASE         TIME AZIMUTH  SLOW
---- ----- ------- ------- ------------- ---- ------------- ------- -----
3679 66866 36.8840 73.3430 636714964.102 P    636715402.398      78  3.15
3679 67011 36.8840 73.3430 636714964.102 P    636715430.148      96  7.26
3512 67093 36.8908 73.4689 636732572.863 P    636732624.094      -1 -1.00
3512 67095 36.8908 73.4689 636732572.863 S    636732665.000      -1 -1.00
3679 67370 36.8840 73.3430 636714964.102 P    636715455.398      97  6.86
3679 67439 36.8840 73.3430 636714964.102 P    636715695.703     326  5.01
3679 67492 36.8840 73.3430 636714964.102 P    636715708.000     326  5.01
3512 67600 36.8908 73.4689 636732572.863 P    636733305.906     326  5.01
3512 67691 36.8908 73.4689 636732572.863 P    636733317.797     315  5.90
3679 67834 36.8840 73.3430 636714964.102 P    636715693.797     351  5.41
3512 67891 36.8908 73.4689 636732572.863 P    636733304.203     350  5.44
3679 68083 36.8840 73.3430 636714964.102 P    636715013.000      -1 -1.00
3679 68086 36.8840 73.3430 636714964.102 S    636715052.703      -1 -1.00
3679 68114 36.8840 73.3430 636714964.102 P    636715449.923      91  8.76
3679 68117 36.8840 73.3430 636714964.102 pP   636715454.326      -1 -1.00
15 rows selected.

SQL>
```

To summarize the join query:

- SELECT specifies which fields to display. If a field is in more than one table, specify which table to use. Query (28) selected an *orid* from the **origin** table. Query (29) used a correlation name to qualify each column.
- FROM lists all tables.
- A join predicate in the WHERE clause specifies the join column (the field appearing in more than one table). Query (27) showed a join predicate that joined **assoc** and **origin** on *orid.* Query (31) showed two join predicates: one joined **assoc** and **origin** on *orid*, and one joined **arrival** and **assoc** on *arid*.

Cartesian Products

All tables referenced in the FROM clause should have a join predicate in the WHERE clause. Otherwise, the result is a cartesian product consisting of every possible combination of all the rows in all the tables in the FROM clause. For example, in Query (32) the **origin** and **origerr** tables each have 18 rows. With a join on the *orid* column in the WHERE clause, a join returns a row count of 18. Without the join predicate, a cartesian product results in a row count of 324 (18 *origin* rows multiplied by 18 *origerr* rows).

(32)

```
SQL>  select   count(*)
      from     origin, origerr
      where    origin.orid=origerr.orid;

  COUNT(*)
----------
        18

SQL>  select   count(*)
      from     origin, origerr;

  COUNT(*)
----------
       324

SQL>
```

Query (33) and Query (34) were edited, but a table that was no longer needed was not removed from the FROM clause. Both queries ran on a data set containing eight weeks of data (the **arrival** table contains 46,856 rows, and the **assoc** table contains 4,396 rows). The ORACLE timing feature was used to gather performance statistics. Query (33) references the **arrival** table in the FROM clause, but the WHERE clause is missing a predicate joining it to **assoc**. It ran for more than 56 hours. By removing the reference to **arrival**, Query (34) ran for only 4 seconds.

(33)
```
SQL>  set timing on;
SQL>  select    ac.phase, count(ac.arid)
from            arrival ar, assoc ac
where           ac.phase in ('Pn', 'Pg', 'Sn', 'Lg')
group by        ac.phase;

PHASE    COUNT(AC.ARID)
-------- --------------
Lg             80311184
Pg             21085200
Pn             72533088
Sn             18320696
Elapsed: 56:25:20.45

SQL>
```

(34)
```
SQL>  select    ac.phase, count(ac.arid)
      from      assoc ac
      where     ac.phase in ('Pn', 'Pg', 'Sn', 'Lg')
      group by  ac.phase;

PHASE    COUNT(AC.ARID)
-------- --------------
Lg                 1714
Pg                  450
Pn                 1548
Sn                  391
Elapsed: 00:00:04.07

SQL>
```

SUBQUERIES

A predicate contains two expressions: one to the left of the comparison operator and one to the right. The previous examples used either a constant or the name of a join column in the right-hand expression. This expression may also contain a complete SQL statement enclosed by parentheses. The value resulting from the nested SQL statement is then applied to the left-hand expression. Query (35) uses an IN subquery to find the earliest arrival time associated with origin 3679.

(35)
```
SQL> select   min(time)
     from     arrival
     where    arid in
     (select  arid
     from     assoc
     where    orid=3679);

 MIN(TIME)
----------
 636715013

SQL>
```

Query (36) shows the same query rewritten as an EXISTS subquery:

(36)
```
SQL> select   min(time)
     from     arrival
     where    exists
        (select  arid
        from     assoc
        where    arrival.arid=assoc.arid
        and      orid=3679);

 MIN(TIME)
----------
 636715013

SQL>
```

Query (37) writes the same query as a straight join, demonstrating that a subquery often provides alternative syntax for a join.

(37)
```
SQL> select   min(time)
     from     arrival, assoc
     where    assoc.arid=arrival.arid
     and      assoc.orid=3679;

 MIN(TIME)
----------
 636715013

SQL>
```

Subqueries may be nested within other subqueries to an unlimited number of levels. Query (38) counts all associated arrivals by *phase* for a given time period, including only those stations that are in the GSETT network.

(38)

```
SQL>  select   sta, count(arid)
      from     assoc
      where    arid in
         (select  arid
         from     arrival
         where    time between 636725500 and 636730000
         and      sta in
            (select  sta
            from     affiliation
            where    net='GSETT'
            )
         )
      group by   sta
      order by   sta;

STA    COUNT(ARID)
------ -----------
ARA0             2
ASAR             5
ASPA             2
EKA              1
MAT              1
WRA              2
YKA              2
7 rows selected.

SQL>
```

A subquery can select the difference between two sets to find elements in one that are not in the other. A join cannot provide this function. For example, to identify the number of unassociated arrivals, Query (39) establishes that the **arrival** table contains `368` rows.

(39)
```
SQL> select  count(*) from arrival;

  COUNT(*)
----------
       368

SQL>
```

Query (40) and Query (41) show how both a join and a subquery can count the number of associated arrivals, the first with a join and the second with an EXISTS subquery.

(40)
```
SQL> select  count(ar.arid)
     from    arrival ar, assoc ac
     where   ar.arid=ac.arid;

COUNT(AR.ARID)
--------------
           120

SQL>
```

(41)
```
SQL> select  count(arid)
     from    arrival
     where   exists
        (select  arid
        from     assoc
        where    arrival.arid=assoc.arid);

COUNT(ARID)
-----------
        120

SQL>
```

A join, however, cannot find the number of arrivals that are not associated. The **arrival** table contains 368 rows, so Query (42)'s result is nonsense.

(42)

```
SQL> select   count(ar.arid)
     from     arrival ar, assoc ac
     where    ar.arid != ac.arid;

COUNT(AR.ARID)
--------------
         44040

SQL>
```

Query (43) uses a NOT EXISTS subquery to obtain the correct answer.

(43)

```
SQL> select   count(arid)
     from     arrival
     where    not exists
        (select  arid
        from     assoc
        where    arrival.arid=assoc.arid);

COUNT(ARID)
-----------
        248

SQL>
```

The ability to identify the empty set, as shown in Query (43), is necessary for solving the problem of the outer join, the subject of the next section.

OUTER JOINS

An outer join is a join between two tables, which returns (a) all the rows matching a join condition plus (b) all the rows from one table that do not match the join condition. For those rows in (b), the queried columns from the other table are set to NULL.

To fully understand joins, it is important to understand the relationships between tables in the database. In a **one-to-many** relationship, each row in one table relates to many rows in another table. For example, every **origin** row has many related

assoc rows. This relationship makes seismological sense because more than one phase is required to locate an event. Query (44) and Query (45) return different row counts for the same *orid*.

(44)

```
SQL> select   count(*)
     from     origin
     where    orid=3679;

COUNT(*)
--------
       1

SQL>
```

(45)

```
SQL> select   count(*)
     from     assoc
     where    orid=3679;

COUNT(*)
--------
      10

SQL>
```

Each row in the **assoc** table has one corresponding row (one-to-one relationship) in the **arrival** table.[1] However, some **arrival** phases are unassociated and do not have a corresponding **assoc** row. So, the relationship between **arrival** and **assoc** is one-to-one-or-none: every **arrival** row will have one or no **assoc** row. Query (39), Query (40), and Query (43) established that out of `368` arrivals, `120` arrivals were associated, and `248` arrivals were unassociated. As shown in Query (46), although **arrival** has `368` rows, a join between **arrival** and **assoc** returns only `120` rows, excluding all the unassociated arrivals.

1. This assumes that each **arrival** can have only one solution. This will not be the case for data sets that store intermediate results. In that case, every **arrival** row could have many **assoc** rows.

(46)

```
SQL> select    ar.arid, a.phase, ar.time, ar.azimuth, ar.slow
     from      arrival ar, assoc a
     where     ar.arid=a.arid
     order by  1;

     ARID PHASE                TIME    AZIMUTH    SLOW
--------- --------- --------------- ---------- -------
    66814 PKP       636727398.297          -1   -1.00
    66826 P         636730856.000          -1   -1.00
<many more rows>
120 rows selected.

SQL>
```

The natural join returns rows that have the same *arid* in both tables. The outer join returns these rows plus the rows having an *arid* in one table but not the other. For example, many **arrival** rows do not have a corresponding **assoc** row, because they are not associated with an event. Unassociated arrivals belong to the outer join of **arrival** and **assoc**. Query (47) uses the NOT EXISTS operator introduced in Query (43) to find rows in **arrival** that do not have a match in **assoc**.

(47)

```
SQL> select   arid, time, azimuth, slow
     from     arrival
     where    not exists
        (select  arid
        from     assoc
        where    arrival.arid=assoc.arid);

     ARID            TIME    AZIMUTH    SLOW
--------- --------------- ---------- -------
    67127   636710454.898         -1   -1.00
    67007   636711053.703         31    5.17
    67144   636711856.500         -1   -1.00
    67146   636711883.102         -1   -1.00
    66858   636713095.500        116   16.10
    66859   636713130.398        110   25.84
<many more rows>
248 rows selected.

SQL>
```

Query (46) and Query (47) provide information about all arrivals whether associated or unassociated. The two queries may be combined with the UNION operator to return all data in a single result table. The SELECT lists in the two UNIONed queries must have the same number of columns. Fields having no data, such as the *phase* field, which is in **assoc** but not **arrival**, need a place holder. Query (48) prints dashes for the *phase* field of the outer join rows.

(48)

```
SQL>  select    ar.arid, a.phase, ar.time, ar.azimuth, ar.slow
      from      arrival ar, assoc a
      where     ar.arid=a.arid
      union
      select    ar.arid, '--------', ar.time, ar.azimuth, ar.slow
      from      arrival ar
      where     not exists
         (select  arid
         from     assoc
         where    ar.arid=arid)
      order by  1;

     ARID PHASE               TIME    AZIMUTH     SLOW
--------- -------- --------------- ---------- --------
    66814 PKP        636727398.297         -1    -1.00
    66826 P          636730856.000         -1    -1.00
    66829 --------   636730479.906         -1    -1.00
    66858 --------   636713095.500        116    16.10
    66859 --------   636713130.398        110    25.84
    66860 --------   636713815.297        279    15.87
<many more rows>
368 rows selected.

SQL>
```

The ORACLE outer join operator, **+**, is easier to use, but is not ANSI SQL. In Query (49) the outer join operator tags which table will not have data. For example, **assoc** will not have rows for some *arids* in **arrival**, so **assoc** is tagged in the join predicate.

(49)
```
SQL> select    ar.arid, a.phase, ar.time, ar.azimuth, ar.slow
     from      arrival ar, assoc a
     where     ar.arid=a.arid(+)
     order by  1;

     ARID PHASE               TIME    AZIMUTH    SLOW
--------- -------- --------------- ---------- -------
    66814 PKP        636727398.297         -1   -1.00
    66826 P          636730856.000         -1   -1.00
    66829            636730479.906         -1   -1.00
    66858            636713095.500        116   16.10
    66859            636713130.398        110   25.84
    66860            636713815.297        279   15.87
    66861            636713832.000        285   34.72
    66862            636714355.797        149   15.87
    66863            636714387.102        167   27.78
    66864            636714565.398        168   15.22
    66865            636714594.500        172   27.78
    66866 P          636715402.398         78    3.15
<many more rows>
368 rows selected.

SQL>
```

CREATING TABLES

Up to this point, this document has focused on extracting data from existing tables. An often useful method is to create tables and populate them with intermediate results or with subsets of very large tables so that subsequent queries are more manageable. The *geodemo* account contains tables that were created as subsets of the operational database at the PIDC.

The CREATE TABLE command creates a new table. This command must include the name of the new table as well as definitions of the columns that will be included in the new table.

One method of defining a new table is to provide an explicit definition:

```
SQL>     create table name (
          column1   datatype1  [constraint1]
          column2    datatype2  [constraint2]
          ...
          );
```

Column1, *column2*, and so on are the names of the columns of the tables. *Datatype*s for the columns typically used at the IDC include VARCHAR2(*precision*) for characters, NUMBER(*precision*) for integers, FLOAT(*precision*) for floating point numbers, and DATE for ORACLE dates. *Precision* defines the number of digits that the number may have. *Constraints* such as NOT NULL and PRIMARY KEY can be placed on columns of a table. [Koc97] provides more information about these options.

Another method of creating a new table is to use the AS delimiter to generate the table from the results of a query:

```
SQL>     create table name as select...
          from...;
```

The column names and definitions for the new table are derived from the SELECT statement, and the table is populated with the results of the query. If no rows are returned, the table is created, but it is left empty. Query (50) creates a new table named **myevents** by using the results of a SELECT to include only events within the specified latitude and longitude range.

(50)
```
SQL>  create table myevents as
      select   *
      from     origin
      where    lat between 35.0 and 40.0
      and      lon between 50.0 and 75.0;
Table created.

SQL>  select orid, lat, lon, time, depth, mb
      from myevents;

     ORID        LAT        LON            TIME      DEPTH         MB
--------- ---------- ---------- --------------- ---------- ----------
     3679    36.8840    73.3430  636714964.102    19.7271       4.07
     3512    36.8908    73.4689  636732572.863     9.1589       3.98

SQL>
```

Use the DROP TABLE command to remove a table.

SQL> drop table *name*;

CHANGING TABLE CONTENTS

The contents of a table may be altered by inserting new rows, updating the values of columns in rows, and deleting rows.

INSERT

The INSERT INTO command inserts new rows in a table. The new row or rows may either be defined explicitly or as the result of a query. An explicit insertion uses a VALUES statement as follows:

SQL> insert into *name*
values (*value1* [, *value2* [, ...]]);

Character strings in the VALUES statement must be in single quotes. The values do not have to be in the order specified by the table as long as the column names into which they are being placed are defined:

```
SQL>  insert into name
      value1_column_name[, value2_column_name [, ...]])
      values (value1 [, value2 [, ...]]);
```

Use the following syntax to insert rows resulting from a query into a table:

```
SQL>  insert into name
      (column1 [, column2 [, ...]])
      select ...
      from ...;
```

Query (51) inserts a new row into the **myevents** table.

(51)

```
SQL> insert into myevents
     select   *
     from     origin
     where    lat between 30.0 and 35.0
     and      lon between 50.0 and 75.0;
1 row created.

SQL> select orid, lat, lon, time, depth, mb
     from myevents;

     ORID       LAT       LON            TIME     DEPTH        MB
--------- --------- --------- --------------- --------- ---------
     3679   36.8840   73.3430   636714964.102   19.7271      4.07
     3512   36.8908   73.4689   636732572.863    9.1589      3.98
     3514   32.9234   74.9347   636734589.275   12.9065      3.49

SQL>
```

DELETE

The DELETE FROM command deletes rows from a specified table. A WHERE clause is usually used in conjunction with DELETE FROM, because without it, the command deletes all of the rows of the table.

```
SQL>  delete from name
      where ...;
```

Query (52) deletes the new row from the **myevents** table.

(52)

```
SQL>  delete from myevents
      where    lat between 30.0 and 35.0
      and      lon between 50.0 and 75.0;
1 row deleted.

SQL> select orid, lat, lon, time, depth, mb
     from myevents;

     ORID        LAT        LON            TIME     DEPTH        MB
--------- ---------- ---------- --------------- --------- ---------
     3679    36.8840    73.3430  636714964.102   19.7271      4.07
     3512    36.8908    73.4689  636732572.863    9.1589      3.98

SQL>
```

UPDATE

The UPDATE command changes specific table entries. The SET command lists the columns that will be changed. The WHERE clause can limit the number of rows affected by the UPDATE.

```
SQL>  update name set column=value [, column=value [, ...]]
      where ...;
```

An embedded SELECT command also updates table entries:

```
SQL>  update name set column = (
      select ...
      from ...
      );
```

To change more than one column, enclose the columns to be changed in parentheses after the SET command:

```
SQL>   update name set (column [, column [, ...]]) = (
       select ...
       from ...
       );
```

When changing more than one column, match the number of columns in the SET list with the number of columns returned by the SELECT command.

Query (53) updates the magnitude (*mb*) field of the **myevents** table by using a conversion formula to increase the magnitudes by 5 percent.

(53)
```
SQL>  update myevents set mb=mb*1.05;
2 rows updated.

SQL>  select orid, lat, lon, time, depth, mb
      from myevents;

     ORID        LAT        LON            TIME      DEPTH         MB
--------- --------- --------- --------------- --------- ---------
     3679    36.8840    73.3430  636714964.102   19.7271       4.28
     3512    36.8908    73.4689  636732572.863    9.1589       4.18

SQL>
```

ROLLBACK and COMMIT

The results of the INSERT INTO, DELETE FROM, or UPDATE commands are not made permanent until you COMMIT them. Until the command is committed, only the user who made the changes can view the results of the changes. The COMMIT command is as follows:

```
SQL>   commit;
```

If you discover a mistake prior to committing the changes, you can reverse the changes by using the ROLLBACK command. After using COMMIT, however, you cannot ROLLBACK the changes.

Query (54) returns the magnitude (*mb*) field of the **myevents** table to the original values and removes this table from the database.

(54)

```
SQL>  rollback;
Rollback complete.

SQL>  select orid, lat, lon, time, depth, mb
      from myevents;

     ORID        LAT        LON            TIME      DEPTH         MB
--------- ---------- ---------- --------------- ---------- ----------
     3679    36.8840    73.3430   636714964.102    19.7271       4.07
     3512    36.8908    73.4689   636732572.863     9.1589       3.98

SQL>  drop table myevents;

Table dropped.

SQL>
```

SQL*Plus Extensions

This chapter describes the SQL*Plus extensions used at the IDC and includes the following topics:

SQL*Plus Extensions and Functions

The SQL standard does not include an interactive query interface for entering and modifying queries. Additionally, a date data type is not included in the SQL standard; therefore, any definition, storage, or manipulation of dates is a vendor-specific extension to SQL. The data dictionary, which stores information about objects in the database, also varies from one vendor to the next.

This chapter addresses a few ORACLE extensions to the SQL standard and describes many of the functions available for manipulating data.

QUERY BUFFER

SQL*Plus maintains an active query buffer containing the last query run. This section introduces a few of the many commands available for working with the query buffer. Complete information about query buffers is available in [Koc97].

One common use of the query buffer is to edit and resubmit a query. For example, Query (55) selects the latest time from the **arrival** table.

(55)

```
SQL>  select   max(time)
      from     arrival;

 MAX(TIME)
----------
 636739132
```

Query (56) uses the LIST command to print the query buffer to the screen.

(56)
```
SQL>  list
      1   select  max(time)
      2*  from  arrival
```

The active line of the query buffer is tagged with an asterisk. You can specify what line should be active by entering the line number at the SQL prompt. For example, Query (57) makes the first line active.

(57)
```
SQKL>  1
1*     select  max(time)
```

The CHANGE command edits text on the active line. Query (58) changes `max` to `min`.

(58)
```
SQL>  change/max/min
1*    select  min(time)
```

The RUN or / command reruns the query. Query (59) uses / to rerun Query (58).

(59)
```
SQL>  /

 MIN(TIME)
----------
 636710455
```

The FORMAT command controls the output displayed for the named COLUMN. For example, Query (59) returned the minimum time from **arrival** but did not include any decimal digits. Query (60) uses the nine numeric template to format the output to include three decimal digits and then reruns the query.

(60)
```
SQL>  column min(time) format 999999999.999
SQL>  /

     MIN(TIME)
--------------
 636710455.898

SQL>
```

Column headings may be reset. Query (61) makes the first line of the query buffer active and then appends text to the end of the line using the APPEND command. This query names the column heading *min_time*.

(61)
```
SQL>  1
1* select  min(time)
SQL>  append min_time
1* select min(time)min_time
SQL>  list
1  select min(time)min_time
2* from arrival
SQL>   /

  MIN_TIME
----------
 636710455

SQL>
```

Query (62) formats column *min_time* to include three decimal digits.

(62)
```
SQL>  column min_time format 999999999.999
SQL>   /

      MIN_TIME
--------------
 636710455.898

SQL>
```

You can edit the query buffer through a UNIX editor, such as *vi*. Query (63) first uses the DEFINE command to set the SQL*Plus _EDITOR to `/usr/ucb/vi` and then uses the EDIT command to invoke the editor (*vi*) on the query buffer. The boxed information represents the commands entered in *vi*.

(63)

```
SQL>  define _editor=/usr/ucb/vi
SQL>  edit
```

```
select min(time)min_time
from arrival
/
~
~
~
~
~
```

At this point, use *vi* commands to edit the query. The following commands change all occurrences of *min* back to *max*:

```
select max(time)max_time
from arrival
/
~
~
~
~
~
~
```

Upon saving the changes with the *vi* commands ZZ or :wq, the changed query is displayed followed by the `SQL>` prompt. Query (64) uses the backslash (/) command to rerun the query.

(64)

```
1     select max(time)max_time
2*    from arrival
SQL>  /

 MAX(TIME)
----------
 636739132

SQL>
```

Query (65) uses the SAVE command to write the query buffer to a UNIX file called `max_arrival_time` and then runs it from the version in the file either with the START command or by prepending the filename with the @ character.

(65)

```
SQL>  save   max_arrival_time
Created file max_arrival_time

SQL>  start  max_arrival_time

 MAX(TIME)
----------
 636739132

SQL>
```

The SQL*Plus HOST command allows a UNIX command to run inside SQL*Plus. The file created with the SAVE command may be listed with the UNIX command `ls`. SQL*Plus automatically adds the `.sql` extension to the file name.

(66)

```
SQL>  host ls -l max_arrival_time
max_arrival_time not found

SQL>  host ls -l max_arrival_time.sql
-rw-rw-r--   1 demo           40 Aug 28 15:36 max_arrival_time.sql

SQL>
```

The query buffer processes one command at a time. A group of commands can be put in a file and run with the START command as shown in Query (65). Each command in the file must be terminated with **;** or /. Query (67) edits the file `max_arrival_time.sql` to include a command that formats the *output* column. The query buffer is still being edited through the UNIX editor, *vi*.

(67) `SQL>  edit max_arrival_time`

```
select max(time)max_time
from arrival
/
~
~
~
~
~
~
```

The FORMAT command is added for the *max_time* column:

```
column max_time format 999999999.999;
select max(time) max_time
from arrival
/
~
~
~
~
~
~
```

```
SQL>  start max_arrival_time

      MAX_TIME
--------------
 636739132.406

SQL>
```

In Query (68), the CLEAR BUFFER command is used to clear the query buffer.

(68)
```
SQL>  clear buffer
buffer cleared
```

You can save user-defined SQL*Plus startup commands in a file called `login.sql`. When invoked, SQL*Plus executes an installation command file that was created by your ORACLE DBA. Next it searches for `login.sql`, first in the current working directory, then in a search path specified in the SQLPATH environmental variable. The following UNIX command shows how to set a search path for SQL*Plus.

```
setenv SQLPATH /usr/local/scripts:/myhome:/myhome
/oracle/scripts
```

By default, query results are displayed interactively on the computer screen. The information that appears on the screen can be written or spooled to a file through the SPOOL command:

```
spool filename
```

This command deletes the contents of the *filename* and writes the information that appears on the screen until the SPOOL OFF command is given:

```
spool off
```

Table 4 summarizes the query buffer commands described in this section. Commands that can be abbreviated to the first character are noted with parentheses.

TABLE 4: SQL*PLUS QUERY BUFFER COMMANDS

Command	Description
(A)PPEND	appends text to the active line
(C)HANGE	changes the contents of the query buffer
CLEAR BUFFER	clears the query buffer
COLUMN *column_name* FORMAT *template*	sets the display format
DEFINE _EDITOR=/usr/ucb/vi	sets the editor to *vi*

TABLE 4: SQL*PLUS QUERY BUFFER COMMANDS (CONTINUED)

Command	Description
EDIT	edits the query buffer
EDIT *filename*	edits the named file
HOST *command*	runs a UNIX command
(L)IST	lists the contents of the query buffer
(R)UN	runs the query in the buffer
/	runs the query in the buffer
SAVE *filename*	writes the query buffer to *filename*
SPOOL *filename*	turns on the spooling to *filename*
SPOOL OFF	turns off spooling
START *filename*	runs the commands in the named file
@ *filename*	runs the commands in the named file

CHARACTER FUNCTIONS

Character functions manipulate strings of characters. Some of the functions modify the original strings, and some provide information about the strings (such as where certain sequences of characters appear in a string). Table 5 lists many of the character functions available through ORACLE. Most of these functions are not described in this tutorial; see [Koc97] for descriptions of their use.

TABLE 5: CHARACTER FUNCTIONS

Function	Definition
string1 || *string2*	concatenates the two strings
ASCII(*string*)	returns the ASCII value of the first character of *string*
CHR(*ASCII value*)	returns the printable character that *ASCII value* represents

TABLE 5: CHARACTER FUNCTIONS (CONTINUED)

Function	Definition
CONCAT(*string1*, *string2*)	concatenates the two strings
INITCAP(*string*)	returns *string* with initial characters in upper case
INSTR(*string*, *set* [,*start* [,*occurrence*]])	returns the location of the *occurrence* of *set* characters in *string*; the search begins at character number *start*.
LENGTH(*string*)	returns the number of characters in *string*
LOWER(*string*)	returns *string* in lower case
LPAD(*string*, *length*[, '*set*'])	pads *string* on the left with the optional *set* characters (blank is default) to make *string length*-characters long
LTRIM(*string*[,'*set*'])	trims *string* on the left of the optional *set* characters (blank is default)
RPAD(*string*, *length*[, '*set*'])	pads *string* on the right with the optional *set* characters (blank is default) to make *string length*-characters long
RTRIM(*string*[,'*set*'])	trims *string* on the right of the optional *set* characters (blank is default)
SUBSTR(*string*, *start* [, *count*])	returns *count* letters from *string* beginning at character number *start*
UPPER(*string*)	returns *string* in upper case
VALUE(*string*)	returns a mathematical value for *string*, assuming that *string* is a set of characters representing numbers

NUMBER FUNCTIONS

ORACLE includes three types of number functions: single-value functions, group-value functions, and list functions. In addition to these, the IDC has added functions that apply particularly to monitoring. Many of these functions and their definitions are listed in Tables 6 through 8. Group-value functions are described in Table 3 on page 22. Examples of the IDC functions are provided after the tables.

TABLE 6: ORACLE SINGLE-VALUE FUNCTIONS

Function	Definition
value1 + *value2*	addition
value1 - *value2*	subtraction
value1 * *value2*	multiplication
value1 / *value2*	division
ABS(*value*)	absolute value of *value*
ACOS(*value*)	arc cosine of *value* in radians
ASIN(*value*)	arc sine of *value* in radians
ATAN(*value*)	arc tangent of *value* in radians
ATAN2(*value1*, *value2*)	arc tangent of *value1*/*value2* in radians
CEIL(*value*)	*value* is a decimal number rounded upwards to an integer
COS(*value*)	cosine of *value*
COSH(*value*)	hyperbolic cosine of *value*
EXP(*value*)	e raised to *value* power
FLOOR(*value*)	*value* is a decimal number rounded downwards to an integer
LOG(*base*, *value*)	logarithm to base *base* of *value*
MOD(*value*, *divisor*)	modulus (remainder) of *value*/*divisor*
NVL(*value*, *substitute*)	replaces *value* with substitute, if substitute is NULL

TABLE 6: ORACLE SINGLE-VALUE FUNCTIONS (CONTINUED)

Function	Definition
POWER(*value*, *exponent*)	*value* to *exponent* power
ROUND(*value*, *precision*)	rounds *value* to *precision* decimal places
SIGN(*value*)	–1 if *value* < 0 and +1 otherwise
SIN(*value*)	sine of *value*
SINH(*value*)	hyperbolic sine of *value*
SQRT(*value*)	square root of *value*
TAN(*value*)	tangent of *value*
TANH(*value*)	hyperbolic tangent of *value*
TRUNC(value)	truncates *value* to an integer without rounding

TABLE 7: ORACLE LIST FUNCTIONS

Function	Definition
GREATEST(*value1*, *value2*,...)	greatest of *value1*, *value2*,...
LEAST(*value1*, *value2*,...)	least of *value1*, *value2*,...

TABLE 8: IDC FUNCTIONS

Function	Definition
AZIMUTH(*lat1*, *lon1*, *lat2*, *lon2*, *back*)	returns azimuth in degrees, clockwise from north of point 2 *(lat2, lon2)* as seen from point 1 *(lat1, lon1)* when *back* is 0, and returns backazimuth when *back* is 1
DEGACOS(*value*)	arc cosine of *value* in degrees
DEGASIN(*value*)	arc sine of *value* in degrees
DEGATAN(*value*)	arc tangent of *value* in degrees

TABLE 8: IDC FUNCTIONS (CONTINUED)

Function	Definition
DEGATAN2(*value1*, *value2*)	arc tangent of *value1*/*value2* in degrees
DEG_DISTANCE(*lat1*, *lon1*, *lat2*, *lon2*)	returns the distance in degrees between point 1 *(lat1, lon1)* and point 2 *(lat2, lon2)* on the earth's surface
KM_DISTANCE(*lat1*, *lon1*, *lat2*, *lon2*)	returns the distance in kilometers between point 1 *(lat1, lon1)* and point 2 *(lat2, lon2)* on the earth's surface

The **assoc** table provides the azimuth, backazimuth, and distance calculated from the origin to the stations of every phase associated with an origin: *seaz* (station-to-event azimuth), *esaz* (event-to-station azimuth), and *delta*. For stations that do not have associated phases, however, the distance and azimuth must be calculated. Query (69) uses the IDC functions to obtain the azimuth, backazimuth, distance in degrees, and distance in kilometers from station `EKA` to origin `3679`.

(69)

```
SQL>  select   azimuth(s.lat, s.lon, o.lat, o.lon, 0) azimuth,
               azimuth(s.lat, s.lon, o.lat, o.lon, 1) back_azimuth,
               deg_distance(s.lat, s.lon, o.lat, o.lon) deg_distance,
               km_distance(s.lat, s.lon, o.lat, o.lon) km_distance
      from     origin o, site s
      where    o.orid=3679
      and      s.sta='EKA';

   AZIMUTH BACK_AZIMUTH DEG_DISTANCE KM_DISTANCE
---------- ------------ ------------ -----------
76.4222298   316.270036    53.141544  5909.07614

SQL>
```

MANIPULATING DATES AND TIMES

A *date* field may be used in any SQL clause that allows a number or character field. ORACLE *date* fields are stored in an internal format. All database operations must convert to and from this internal format using the TO_CHAR( ) and TO_DATE() functions. TO_CHAR( ) converts a field from ORACLE's internal format to a character string. TO_DATE() converts a field from a character string or number to ORACLE's internal date format. ORACLE date and time functions are summarized in Table 9, and some of the date formats are listed in Table 10.

All IDC database dates use Greenwich Mean Time (GMT).

TABLE 9: ORACLE DATE AND TIME FUNCTIONS

Function	Definition
TO_CHAR(*date*, '*format*')	converts an ORACLE *date* into a string using *format*
TO_DATE(*string*, '*format*')	converts *string* into an ORACLE date using *format*

TABLE 10: ORACLE DATE AND TIME FORMATS

Format	Definition	Example
DD	day of month number	01
DY	three-character day of week in capital letters	FRI
Dy	three-character day of week with initial letter capitalized	Fri
dy	three-character day of week in lower case letters	fri
DAY	day of week in capital letters	FRIDAY
Day	day of week with initial letter capitalized	Friday
day	day of week in lower case letters	friday
DDD	day of year	365
MI	minute of hour	30
MM	month number of year	06

TABLE 10: ORACLE DATE AND TIME FORMATS (CONTINUED)

Format	Definition	Example
MON	three-character month name in capital letters	JUN
Mon	three-character month name with initial letter capitalized	Jun
mon	three-character month name in lower case letters	jun
MONTH	month name in capital letters	JUNE
Month	month name with initial letter capitalized	June
month	month name in lower case letters	june
SS	second of minute	04
YYYY	four-character year number	1998
YY	last two characters of the year number	98

In the following examples, dates are represented as two-digit years (the YY format) for display purposes. Internally, ORACLE represents dates as four-digit years (the YYYY format). The following data template is used for the examples:

```
'MM/DD/YY HH24:MI:SS'
```

January 15, 1970 at 11 p.m. is formatted as follows:

```
01/15/70 23:00:00
```

The date template must be enclosed by single quotes. The characters / and :, and the space separating the date from the time are optional string characters. The following template omits those characters:

```
'MMDDYYHH24MISS'
```

January 15, 1970 at 11 p.m. would then be output as follows:

```
011570230000
```

The HH24 format instructs ORACLE to output dates on a 24-hour clock.

Selecting Dates

Given the name of the field to convert and a display format, the TO_CHAR() function converts the field from ORACLE's internal format to a character string. Query (70) selects *sysdate*, an ORACLE internal column containing the current date and time, from the table **dual**.

(70)
```
SQL>  select   sysdate
      from     dual;

SYSDATE
---------
23-SEP-97

SQL>
```

By default, ORACLE returns only the date portion. Query (71) reformats the output to change the date format and include the time.

(71)
```
SQL>  select   to_char(sysdate,'MM/DD/YY HH24:MI:SS')
      from     dual;

TO_CHAR(SYSDATE,'MM/DD/YYHH24:MI:SS')
--------------------------------------
09/23/97 13:44:06

SQL>
```

Query (72) changes the column heading to *now* and makes it 17 characters wide with the A (alphanumeric) display format.

(72)
```
SQL>  column   now format A17
SQL>  select   to_char(sysdate,'MM/DD/YY HH24:MI:SS') now
from           dual;

NOW
-----------------
09/23/97 13:45:38

SQL>
```

Query (73) DEFINEs *now* and *lddate* to be substitution variables. The query also renames the columns *now* and *lddate,* respectively, and so requires quotes around the definition. The character & substitutes the defined string in the place of *&now* or *&lddate*. These definitions are included in the global login startup file at the IDC and can be used in any query. The & operator prints the value of a substitution variable.

(73)

```
SQL> define   now="to_char(sysdate,'MM/DD/YY HH24:MI:SS') now"
SQL> column   now format A17
SQL> define   lddate="to_char(lddate,'MM/DD/YY HH24:MI:SS') lddate"
SQL> column   lddate format A17
SQL> select   &lddate
     from     origin
     where    orid=3509;

LDDATE
-------------------------
03/12/90 16:15:51

SQL>
```

Converting between Epoch Times and Dates

All times in the PIDC and IDC databases are recorded in epoch time. This time counts, to millisecond accuracy, the number of seconds since midnight January 1, 1970. Query (74) displays the time for *wfid* 5532.

(74)

```
SQL> column   time format 999999999.999
SQL> select   wfid, time
     from     wfdisc
     where    wfid=5532;

      WFID           TIME
---------- --------------
      5532  636737307.566

SQL>
```

Epoch time has little meaning to people, so substitution variables are included in the IDC global startup file to convert epoch times to human-readable times.

In Query (74) *etoh* (epoch-to-human) combines ORACLE's TO_DATE and TO_CHAR functions to convert epoch time to a human-readable date. The *time* field is divided by 86400 (the number of seconds in a day) to calculate the number of days, hours, minutes, and seconds it represents. Fractional seconds are dropped. That result is added to January 1, 1970, to provide the date and time. Because January 1, 1970 is represented by the character string '01/01/1970' and *time* is a floating point field, the TO_DATE function is used to convert both the character string and *time* to the DATE data type so that they may be added. The TO_CHAR function is used to display the resulting date as a character string. The column heading is named *etoh* and made 17 characters wide.

(75)

```
SQL> define   etoh="to_char(to_date('01/01/1970','MM/DD/YYYY')+ -
       (time/86400),'MM/DD/YY HH24:MI:SS') etoh"
SQL> column   etoh format A17
SQL> select   time, &etoh
      from     wfdisc
      where    wfid=5532;

          TIME ETOH
-------------- -----------------
 636737307.566 03/06/90 15:28:28

SQL>
```

In Query (75) the substitution variable for *etoh* is too long to fit on a single line. Although SELECT statements may continue freely across lines, as shown in Query (73), if a DEFINE spans more than one line, a dash (–) must be used to alert ORACLE that the definition continues onto the next line.

Etoh substitutes a human readable version of the *time* column in a query. If the query joins two tables that each contain a *time* column, then using *&etoh* will cause an error because ORACLE cannot identify the specific *time* column to be converted. Two substitutions, *w_etoh* and *o_etoh*, provide specific time conversions for the **wfdisc** and **origin** tables of the IDC database. When using these substitutions, correlation names may not be used for the **origin** or **wfdisc** tables. Query (76) defines *w_etoh* and *o_etoh* and uses *o_etoh* to obtain the time of an origin in a join with the **arrival** table.

(76)

```
SQL>  define   w_etoh="to_char(to_date('01/01/1970','MM/DD/YYYY')+ -
        (wfdisc.time/86400),'MM/DD/YY HH24:MI:SS') w_etoh"
SQL>  column   w_etoh format A17
SQL>  define   o_etoh="to_char(to_date('01/01/1970','MM/DD/YYYY')+ -
        (origin.time/86400),'MM/DD/YY HH24:MI:SS') o_etoh"
SQL>  column   o_etoh format A17
SQL>  select   lat, lon, &o_etoh, phase, azimuth, slow
      from     assoc a, arrival ar, origin
      where    a.orid=3509
      and      origin.orid=3509
      and      a.arid=ar.arid;

      LAT        LON O_ETOH            PHASE       AZIMUTH    SLOW
--------- ---------- ----------------- -------- ---------- -------
 -20.4274   -67.2272 03/06/90 12:57:43 PKP             276    1.90
 -20.4274   -67.2272 03/06/90 12:57:43 LR               -1   -1.00
 -20.4274   -67.2272 03/06/90 12:57:43 P               131    4.30

SQL>
```

Etoh3 is the decimal version of *etoh* with time displayed to three decimal places. The decimals (obtained from subtracting the truncated time value from the complete time value) are concatenated onto the end of the standard *etoh* definition. *Dtime* is the same as *etoh* except that default null times in the database (9999999999.999) are returned as null date strings. Query (77) defines both *etoh3* and *dtime* and provides a result for *etoh3*.

(77)

```
SQL> define  etoh3="to_char(to_date('01/01/1970','MM/DD/YYYY')+ -
       (time/86400),'MM/DD/YY HH24:MI:SS'|| -
       ltrim(to_char(time-trunc(time),'.099')) etoh3"
SQL> column  etoh3 format A21
SQL> define  dtime="decode(time,-9999999999.999,'NO TIME PROVIDED ', -
       to_char(to_date('01/01/1970','MM/DD/YYYY')+ -
       (time/86400),'MM/DD/YY HH24:MI:SS')) dtime"
SQL> column  dtime format A17
SQL> select  time, &etoh3
     from    wfdisc
     where   wfid=5532;

           TIME ETOH3
--------------- ---------------------
  636737307.566 03/06/90 15:28:28.566

SQL>
```

Improving Query Performance

This chapter describes how to improve query performance and includes the following topics:

- Using Indexed Columns
- Listing Most Restrictive Tables Last
- Using IN Versus EXISTS

Improving Query Performance

Many factors, including system load and data set size, affect query performance. The more a system is loaded, the slower the results are returned. Additionally, all queries perform well on small data sets such as the *geodemo* data set. But a query that runs quickly on a small data set may have significant performance problems on a large data set.

Although you may not be able to control system load or data set size, you can control the syntax and wording of SQL queries, which can improve performance dramatically. In particular, the following tips will help you improve query performance:

- Reference indexed columns in the WHERE clause.
- List the most restrictive table last in the FROM clause.
- Use the size of the inner query and indexing to decide if IN or EXISTS will perform better.

This section explains each of these tips in greater detail. Most of the queries in this section were run on a data set containing eight weeks of data, so output will not match the same query run on the *geodemo* data set. The **arrival** and **assoc** tables in the eight-week data set contain 46,856 and 4,396 records respectively.

The ORACLE command SET TIMING ON is useful for comparing the performance time of different versions of the same query. Query (78) shows an elapsed time of .05 seconds.

(78)

```
SQL>  set timing on;
SQL>  select    orid, count(arid)
      from      assoc
      where     orid < 3510
      group by  orid
      having    count(arid) > 2
      order by  2 desc;

     ORID COUNT(ARID)
--------- -----------
     3506          12
     3508           8
     3503           6
     3504           4
     3509           3

Elapsed: 00:00:00.05

SQL>
```

USING INDEXED COLUMNS

To optimize query performance, the DBA will define indexes on columns. An index tracks data the way a card catalog at the library tracks books. Given the name of a book, the card catalog provides its location. A database index provides a similar mechanism for retrieving data and eliminates the time-consuming search of the whole table. In IDC databases, indexes can fill as much disk space as the data.

Indexed columns should be referenced in the WHERE clause. For example, given a query on the **wfdisc** table for a station and channel, the *sta* and *chan* columns must be indexed for the query to run efficiently. ORACLE databases contain data dictionary tables, **user_ind_columns** and **all_ind_columns,** which contain the indexed columns. **User_ind_columns** contains only the indexes for tables in the current account, and **all_ind_columns** contains the indexes for all tables in the database instance (table names and owners are stored in uppercase).

Query (79) shows that the **wfdisc** table of the *geodemo* instance has three indices: *wfidx*, *wfstax*, and *wftimex*. *wfidx* contains a single column, *wfstax* contains three columns, and *wftimex* contains two columns. An index containing more than one column is called a concatenated index. The index name should never be used in a query because the ORACLE optimizer decides which index to use.

(79)

```
SQL> column   index_name format A15
SQL> column   table_name format A15
SQL> column   column_name format A15
SQL> select   index_name, table_name, column_name, column_position,
                    column_length
     from     all_ind_columns
     where    table_name='WFDISC'
     and      table_owner='GEODEMO';

INDEX_NAME      TABLE_NAME      COLUMN_NAME     COLUMN_POSITION COL_LEN
--------------- --------------- --------------- --------------- -------
WFIDX           WFDISC          WFID                          1      22
WFSTAX          WFDISC          STA                           1       6
WFSTAX          WFDISC          CHAN                          2       8
WFSTAX          WFDISC          TIME                          3      22
WFTIMEX         WFDISC          TIME                          1      22
WFTIMEX         WFDISC          ENDTIME                       2      22

SQL>
```

Sometimes ORACLE ignores the indexed files and scans the whole table. The following list provides common reasons for these occurrences and strategies for improving query performance through the use of indexed columns:

1. An index is ignored if the left-most part of a concatenated index is not referenced.

   If the index is made up of more than one column, include the first (left-most) column in the query. You can omit columns to the right.

   The following query finds waveform data for all short-period instruments:

   ```
   SQL>  select   *
         from     wfdisc
         where    chan = 'se';
   ```

   To avoid a full table scan, specify the array of interest:

   ```
   SQL>  select   *
         from     wfdisc
         where    sta like 'AR%' and chan = 'se';
   ```

2. An index is ignored if a wildcard is the first character of the constant.

   The following query causes a full table scan:

   ```
   SQL>  select   *
         from     wfdisc
         where    sta like '%R';
   ```

3. An index is ignored if the column is modified by a function or an arithmetic operation, as shown in the following query:

   ```
   SQL>  select   *
         from     wfdisc
         where    sta = 'NRA0'
         and      substr(chan,1,1) = 's';
   ```

   By avoiding use of the SUBSTR function, an index on *chan* is used:

   ```
   SQL>  select   *
         from     wfdisc
         where    sta = 'NRA0'
         and      chan like 's%';
   ```

4. Performance suffers when functions are used. If a predicate mixes datatypes, avoid using functions on the column, as shown in the following query:

```
SQL>  select  wfid from wfdisc
      where   to_char(to_date('01/01/1970','MM/DD/YYYY')+
                (time/86400),'MM/DD/YY HH24:MI:SS')
                between '03/06/90' and '03/07/90';
```

   Instead, write the query as follows:

```
SQL>  select  wfid from wfdisc
      where   time between
                (to_date('03/06/90','MM/DD/YY')-
                to_date('70/01/01','YY/MM/DD'))*86400
                (to_date('03/07/90','MM/DD/YY')-
                to_date('70/01/01','YY/MM/DD'))*86400;
```

5. An index will not be used if a query contains `!=` or NOT, as shown in the following query:

```
SQL>  select  *
      from    arrival
      where   sta != 'ARC';
```

6. Even if an index is used, restrict the range if at all possible to avoid a wide scan, as shown in the following query:

```
SQL>  select  *
      from    arrival
      where   time <= 636720000 or time >= 636730000;
```

   Instead, restrict the range as follows:

```
SQL>  select  *
      from    arrival
      where   (time between 636720000-2400 and 636720000)
      or      (time between 636730000 and 636730000+2400);
```

Unless 75 to 80 percent of the table is eliminated by a WHERE clause, the use of an index will add more overhead than a table scan. These strategies may be used to deliberately disable indices.

Finally, ORACLE will use five indices at most. Disable indices on other columns to control which columns the optimizer considers as a candidate for an index.

LISTING MOST RESTRICTIVE TABLES LAST

ORACLE uses a query optimizer that attempts to determine the driving table for joins. ORACLE will use the table order, however, when querying tables that are both indexed, if no other information determines the driving table. When using the table order, the tables in the FROM clause are processed from right to left. The last table in the FROM clause is the driving table, so it should contain the fewest rows for ORACLE to process initially. For queries in which a WHERE clause condition returns very few rows from one of the tables, that table should be listed last. If full table scans are likely, the table with the fewest rows should be listed last. Query (80) and Query (81) were run on a data set containing eight weeks of data (**arrival** contains 46,856 records and **assoc** contains 4,396 records). Query (80) took over three minutes to complete, and Query (81) took only 40 seconds. The only difference between the two queries is the order of the tables in the FROM clause.

(80)

```
SQL>  set timing on;
SQL>  select     ac.phase, count(ac.arid), avg(ar.slow)
      from       assoc ac, arrival ar
      where      ac.arid=ar.arid
      and        ar.slow > 0.0
      and        ac.phase in ('Pn', 'Pg', 'Sn', 'Lg')
      group by   ac.phase;

PHASE     COUNT(AC.ARID) AVG(AR.SLOW)
-------- --------------- ------------
Lg                  1549   26.9432021
Pg                   417   15.6335971
Pn                  1468   13.9206676
Sn                   277   23.9224549

Elapsed: 00:03:11.48

SQL>
```

(81)
```
SQL> select    ac.phase, count(ac.arid), avg(ar.slow)
     from      arrival ar, assoc ac
     where     ac.arid=ar.arid
     and       ar.slow > 0.0
     and       ac.phase in ('Pn', 'Pg', 'Sn', 'Lg')
     group by  c.phase;

PHASE    COUNT(AC.ARID) AVG(AR.SLOW)
-------- -------------- ------------
Lg                 1549   26.9432021
Pg                  417   15.6335971
Pn                 1468   13.9206676
Sn                  277   23.9224549

Elapsed: 00:00:40.26

SQL>
```

In Query (80) and Query (81) neither *slow* nor *phase* are indexed, so the driving table is fully scanned. In fact, indices would not help in this case because most **arrival** records will have a slowness greater than 0.0 and most **assoc** records will occur within the specified phases. Given the 75 to 80 percent rule for indices as described in the previous section, scanning the whole table is more efficient than processing an index. The strategy is to limit the full table scan to the smaller of the two tables and extract data from the larger table based on the efficient *arid* join. The **assoc** table contains 4,396 records in this data set and the **arrival** table contains 46,856 records; therefore, **assoc** is a better driving table.

USING IN VERSUS EXISTS

An IN subquery returns the same result as an EXISTS subquery, but ORACLE processes each subquery differently. A subquery has two parts: the outer query and the inner query. The inner query of an IN subquery is executed once, and the results are stored in an unindexed temporary table. Each row in the outer query is then compared to the rows in the temporary table. If the outer row is found in the temporary table, it is returned to the user.

The inner query of an EXISTS subquery is executed repeatedly, once for each row in the outer query. The inner query returns TRUE or FALSE to the outer query. If it returns TRUE, then the row in the outer query is returned to the user.

Sometimes one subquery form will perform better than the other depending on the size of the inner query data set. Query (82) and Query (83) return the earliest associated *arrival* time for a given *orid* in the eight-week data set.

(82)

```
SQL> select   min(time)
     from     arrival
     where    arid in
       (select   arid
       from      assoc
       where     orid=105196);

 MIN(TIME)
----------
 623520155

Elapsed: 00:00:00.35

SQL>
```

(83)

```
SQL> select   min(time)
     from     arrival
     where    exists
       (select  *
       from     assoc
       where    arrival.arid=assoc.arid;

 MIN(TIME)
----------
 623520155
Elapsed: 00:00:01.46

SQL>
```

The difference in performance of Query (82) and Query (83) is negligible but suggests the IN might perform slightly better than the EXISTS. Because the **assoc** table has only three records for *orid* `105196`, the temporary table created for Query (82) is quite small, and the inner query for Query (83) is performed only three times.

Query (84) and Query (85), however, show a dramatic difference in performance. Each query returns a count of the unassociated arrivals by station in the eight-week data set.

(84)

```
SQL> select   sta, count(arid)
     from     arival
     where    arid not in
       (select   arid
       from      assoc)
       group by  sta;

STA    COUNT(ARID)
------ -----------
Query killed after 18 hours

SQL>
```

(85)

```
SQL> select   sta, count(arid)
     from     arrival
     where    not exists
       (select    arid
       from       assoc
       where      assoc.arid=arrival.arid)
     group by  sta;

STA    COUNT(ARID)
------ -----------
ARA0         27193
NRA0         15270

Elapsed: 00:02:40.92

SQL>
```

The inner query in Query (84) does not contain a WHERE clause to narrow the search; the intermediate table contains all 4,396 records from the **assoc** table. Because ORACLE cannot index the temporary table, each of the 46,856 rows in the outer query scans the entire intermediate table. Performance is probably comparable to the 56-hour cartesian product of Query (33). The EXISTS form in Query (85) performs much better than Query (84) because it uses any available index.

In summary, if the temporary table produced by the IN subquery is quite small, the IN could perform better than the EXISTS because it avoids repeated executions of the inner query. If the temporary table produced by the IN subquery is quite large, the EXISTS will perform better because it can use any available index.

Navigating Databases

This chapter describes how databases may be distributed and organized and how to obtain this type of information from a database. The following topics are discussed:

- Instances
- Accounts
- Tables

Navigating Databases

To use the IDC database most efficiently, you should be familiar with the database instances, the accounts that are included in each instance, and the database tables that are included in each account. You should also understand the relationships among the tables within the accounts and the contents of the tables themselves. The latter information is contained in [IDC5.1.1Rev1], and a description of the tables is in preparation. Much of the information is also available in the administrative tables included within the databases and can be accessed through simple queries.

INSTANCES

A database instance is everything needed to run the database (programs, memory, and so on). An instance contains a collection of database accounts with unique names. Using an analogy, consider the database instance as one computer in a network of computers. Several different database instances occur at the IDC, each of which serves a specific purpose. IDC database instances exist for processing of seismic, hydroacoustic, and infrasonic data, for IDC processing of radionuclide data, for archiving of processing results, and for testing new processing schemes.

Different database instances are usually installed on different computers of a computer network to prevent heavy loads on one database, which would affect the performance of the other databases, and as insurance against hardware failure.

ACCOUNTS

A database account is a collection of database tables that have unique names and that are protected by account passwords. In the computer network analogy where the database instances are the computers, database accounts are the user accounts. Each database instance may contain several database accounts. The database account names must be unique within the database instance, but the same account names may be (and often are) shared by several database instances. In the IDC database instances the accounts are used to separate static information (changed relatively infrequently) from dynamic information (changed regularly). The dynamic accounts represent various stages of data processing.

A list of the database accounts within the database instance is maintained in the **all_catalog** table. Query (86) obtains the names of all accounts.

(86)

```
SQL>  select   distinct owner
      from     all_catalog;

OWNER
---------------
AUTODRM
DFX
IDCEXPORT
IDCLEB
IDCREB
IDCWDB
IDCX
MAP
SEL1
SEL2
SEL3

12 rows selected.

SQL>
```

The DISTINCT command must be used in the query because the **all_catalog** table has one row for every table in the database instance.

TABLES

A table is a set of rows that each contain a specific set of columns. The four types of tables are base, synonym, view, and sequence. A base table contains data. A synonym contains no data itself, but points to a base table, usually in another account. To the user, the synonym looks and behaves like a base table, but queries to the synonym are actually made to the base table. Synonyms allow sharing of tables between accounts. A view also contains no data itself, but is a collection of pointers to the contents of base tables through execution of a query. The query acts like a window through which information is viewed. As the contents of the base tables change, so do the contents of the view. A sequence is used to track a unique sequence of numbers without having to create a special table.

The **user_catalog** table maintains a list of the tables within the current database account and the table type (TABLE, SYNONYM, VIEW, or SEQUENCE). The **all_catalog** table includes a list of all tables within the current database instance. Query (87) obtains the names of all tables in account *geodemo*.

(87)

```
SQL> select   table_name
     from     all_catalog
     where    owner='GEODEMO';

TABLE_NAME
------------------------------
AFFILIATION
ARRIVAL
ASSOC
GREGION
INSTRUMENT
LASTID
NETMAG
NETWORK
NEXTID
ORIGERR
ORIGIN
PATH
REMARK
SENSOR
SITE
SITECHAN
SREGION
```

```
STAMAG
WFDISC
WFTAG

20 rows selected.

SQL>
```

Query (88) uses the DESCRIBE command to obtain a description of the columns of any individual table. No semicolon is required after the DESCRIBE command.

(88)
```
SQL>  describe all_catalog

 Name                            Null?    Type
 ------------------------------- -------- ----
 OWNER                           NOT NULL VARCHAR2(30)
 TABLE_NAME                      NOT NULL VARCHAR2(30)
 TABLE_TYPE                               VARCHAR2(11)

SQL>
```

Advanced Seismology Queries

This chapter presents queries that are more complex than the previous examples. In some cases, the examples use special features of the IDC schema. Although all sample queries were run on the *geodemo* data set for demonstration purposes, most of them are not interesting unless they are run on a large data set. Queries in this section use ORACLE extensions to the ANSI SQL standard, such as substitution variables, which will not run on other databases. The following topics are included:

Advanced Seismology Queries

FINDING ALL EVENTS IN ARRIVAL TIME WINDOWS

Query (89) finds all events within an arrival time window. It also counts the number of arrivals in the time window.

(89)

```
SQL>  define    begin_time = 636725500
SQL>  define    end_time = 636730000
SQL>  select    ac.orid, count(ac.arid)
      from      assoc ac, arrival ar
      where     ac.arid=ar.arid
      and       ar.time between &begin_time and &end_time
      group by  ac.orid;

     ORID COUNT(AC.ARID)
--------- --------------
     3507              2
     3508              8
     3509              2
     3510              3

SQL>
```

Query (90) calculates the number of arrivals for each event. Observe the count of *arids* for each *orid*; two arrivals are outside of the original time window, one each for *orids* 3509 and 3510.

(90)
```
SQL> select    orid, count(arid)
     from      assoc
     where     orid in (3507, 3508, 3509, 3510)
     group by  orid;

     ORID COUNT(ARID)
--------- -----------
     3507           2
     3508           8
     3509           3
     3510           4

SQL>
```

Query (91) finds arrivals outside the original search time window for *orids* 3509 and 3510.

(91)
```
SQL> select   ac.orid, ar.arid, ar.time
     from     arrival ar, assoc ac
     where    ar.arid=ac.arid
     and      (ar.time < &begin_time or ar.time > &end_time)
     and      (ac.orid between 3509 and 3510);

     ORID      ARID           TIME
--------- --------- --------------
     3510     67531  636730145.594
     3509     67651  636731411.000

SQL>
```

One problem with this query is that the **arrival** table will be fully scanned because data before the *begin_time* and after the *end_time* comprise the majority of the table. Consequently, performance on large data sets will be degraded. You can improve efficiency by limiting the search to a specific duration between the begin and end times. For example, if you know that the travel time is less than 40 minutes, define a duration of 2400 epoch seconds and restate the query as shown in Query (92).

(92)
```
SQL> define   duration=2400
SQL> select   ac.orid, ar.arid, ar.time
     from     arrival ar, assoc ac
     where    ar.arid=ac.arid
     and      (ar.time between &begin_time - &duration and &begin_time
               or ar.time between &end_time and &end_time + &duration)
     and      (ac.orid between 3509 and 3510);

     ORID      ARID           TIME
--------- --------- --------------
     3510     67531  636730145.594
     3509     67651  636731411.000

SQL>
```

Query (93) avoids a search for specific *orids* by finding all arrivals outside a given time window that have *orids* within the given time window.

(93)
```
SQL> select   ar.arid, ar.time, ac.orid
     from     arrival ar, assoc ac
     where    ar.arid=ac.arid
       and    (ar.time between &begin_time - &duration and &begin_time
              or  ar.time between &end_time and &end_time + &duration)
       and    ac.orid  in
         (select   ac2.orid
         from      assoc ac2, arrival ar2
         where     ac2.arid=ar2.arid
           and     ar2.time between &begin_time and &end_time
         );

     ARID           TIME      ORID
--------- -------------- ---------
    67651  636731411.000      3509
    67531  636730145.594      3510

SQL>
```

RETRIEVING ORIGIN INFORMATION FROM EVENTS WITH DEPTH PHASES

Query (94) demonstrates an EXISTS subquery. Given an origin with a depth greater than 20 km, the **assoc** table is searched for an associated arrival with a *phase* of either 'pP' or 'sP.' If one exists, the origin information is retrieved.

(94)

```
SQL> select  o.orid, o.jdate, o.lat, o.lon, o.depth, o.mb, o.ms, o.ndef
     from    origin o
     where   o.depth > 20.0
     and     exists
       (select  arid
       from     assoc
       where    orid = o.orid
       and      phase in ('pP','sP')
       );

   ORID     JDATE        LAT        LON      DEPTH         MB          MS NDEF
------- --------- ---------- ---------- ---------- ---------- ----------- ----
   3506   1990065    12.1327   143.6159    22.1815       4.39        1.91   10
   3683   1990065   -10.8992   117.5039    29.6973       5.10        5.39   19
   3513   1990065   -17.8557   168.0396    27.5160       4.38         2.7    7

SQL>
```

ESTIMATING STATION RESIDUALS

Query (95) estimates station residuals by using the phase P associated with origins having at least four defining phases. It returns only those stations that have more than five such phases.

Query (95) uses four basic math and set functions: COUNT, AVG, SQRT, and STDDEV. The GROUP BY clause causes the average to be calculated on a station-by-station basis. The HAVING clause restricts the results to those stations with more than five observations.

Although this query executes properly on the *geodemo* data set, it returns more interesting results when run on larger data sets.

(95)
```
SQL> select    a.sta, count(a.arid) num,
               avg(a.timeres) avg_timeres_residual,
               stddev(a.timeres) stand_timeres_dev
     from      assoc a, origin o
     where     o.orid = a.orid
       and     a.phase = 'P'
       and     o.ndef >= 4
      group by a.sta
     having    count(a.arid) > 5;

STA           NUM AVG_TIMERES_RESIDUAL STAND_TIMERES_DEV
------ ---------- -------------------- -----------------
ASAR            9           -.46844444         .77499405
ASPA            6           -.97516667        .825876363
WRA             9           -.29188889        1.64798904
YKA             6                 .038        .267926109

SQL>
```

CALCULATING AZIMUTH RESOLUTION

Some IDC database tables contain summary information based on data from fields in other tables. The following queries calculate the *azres* field in the **assoc** table based on the *azimuth* field in the **arrival** table and the *seaz* field in the **assoc** table. By definition:

```
assoc.azres = arrival.azimuth - assoc.seaz
```

The range, however, must be between –180 and 180 degrees. *Azimuth* and *seaz* are defined to be within 0 and 360 degrees, so a simple difference may not fall within the prescribed range.

In Query (96) *azres* is initialized to the NA value.

(96)
```
SQL> update   assoc
     set      azres = -999;

120 records updated.
```

Without the WHERE clause in Query (97) any *arid* with an NA *azimuth* or *seaz* will get reset to a database NULL, overwriting the NA value.

(97)
```
SQL> update    assoc ac
     set       ac.azres =
     (select   max(azimuth)-max(ac.seaz)
     from      arival
     where     arid=ac.arid
       and     azimuth >= 0.0
       and     ac.seaz >= 0.0)
     where     exists
       (select arid
       from    arrival
       where   arid=ac.arid
         and   azimuth >= 0.0
         and   ac.seaz >= 0.0);

64 records updated.
```

If the resulting *azres* is less than –180, 360 must be added, as shown in Query (98).

(98)
```
SQL> update   assoc
     set      azres = azres + 360.0
     where    azres between -360.0 and -180.0;

14 records updated.
```

If *azres* is greater than 180, 360 must be subtracted, as shown in Query (99).

(99)
```
SQL> update   assoc
     set      azres = azres - 360.0
     where    azres > 180.0;

5 records updated.
```

Query (100) shows the result of the updates performed in Query (96) through Query (99).

(100)
```
SQL> select   arid, azres
      from     assoc;

     ARID   AZRES
--------- -------
    67437     1.1
    67490    -1.3
    67454    -4.9
    68223  -999.0
    67456    -5.9
    68225  -999.0
    67506     6.0
    67507  -999.0
    67377     2.9
    67378    -0.1
    66881     4.8
<many more rows>
120 records selected.

SQL>
```

In Query (101) these changes are made permanent in the database by the COMMIT command.

(101)
```
SQL>  commit;

Commit complete.
```

PERFORMING LINEAR REGRESSION

This section demonstrates the use of temporary tables by using SQL to perform a linear regression. Assume:

Y = A + B * X ± standard deviation

Suppose P-wave station residuals are correlated with station elevation, then:

residual = A + B * elevation ± error

In Query (102) a QR-decomposition method solves the system inside a temporary table.

(102)
```
rem
rem   A line that begins with "rem" is a remark.  ORACLE also allows
rem   comments between /* and */ delimiters.

rem
rem   Ignore error on drop table command--it means that the table does
rem   not exist and may be created.
rem
rem   A FLOAT(24) allows 7.2 decimal digits of precision.
rem
SQL>  drop table datamatrix;
drop table datamatrix
*
ERROR at line 1:
ORA-00942: table or view does not exist
SQL>  create table datamatrix (
      one   float(24),
      X     float(24),
      Y     float(24),
      d12   float(24),
      d13   float(24),
      d23   float(24)
      );
Table created.

rem   Insert X and Y values into a temporary table.
rem   Insert into data matrix elevations and residuals of defining
rem   P arrivals.  Check against NA values for timeres or elev.
rem
rem   This insert...select can be modified for any linear regression.
SQL>  insert into datamatrix (one, x, y, d12, d13, d23)
      select  1.0, s.elev, a.timeres, 0.0, 0.0, 0.0
      from    assoc a, site s
      where   s.sta = a.sta
      and     a.timedef = 'd'
```

```
      and     a.phase = 'P'
      and     a.timeres > (-999.0 * 0.9999)
      and     s.elev > (-999.0 * 0.9999);

68 records created.


rem
rem   Do the QR decomposition.
rem

SQL>  drop table qr_coeff;
drop table qr_coeff
*
ERROR at line 1:
ORA-00942: table or view does not exist

SQL>  create table qr_coeff (
      D12  float(24),
      D13  float(24),
      D23  float(24)
      );

Table created.


rem
rem   In the following insert, all that is really required for this data
rem    set is
rem
rem        select sum(X)/sum(one)
rem
rem   instead of
rem
rem        select sum(one*X)/sum(one*one)
rem
rem   The syntax actually used solves a more general case where the
rem   elements are variable in weight.
rem


SQL>  insert into qr_coeff (D12, D13)
      select  sum(one*X)/sum(one*one),
              sum(one*Y)/sum(one*one)
      from    datamatrix;

1 record created.
```

```
SQL>  select  *
      from    qr_coeff;

      D12         D13        D23
---------- ----------- ----------
 .39729118  -.09735294


rem
rem   The double update looks redundant but SQL will not
rem   allow use of subquery results in arithmetic expressions.
rem
SQL>  update datamatrix
      set  d12 = (select max(D12) from qr_coeff),
           d13 = (select max(D13) from qr_coeff);
68 records updated.

SQL>  update datamatrix
      set   X = X - one * d12,
            Y = Y - one * d13;
68 records updated.

SQL>  update qr_coeff
      set  D23 =
        (select  sum(X*Y)/sum(X*X)
        from    datamatrix);

1 record updated.

SQL>  update datamatrix
      set  d23 =
        (select  max(D23)
        from    qr_coeff);

68 records updated.

SQL>  update datamatrix
      set  Y = Y - X * d23;

68 records updated.
rem
rem  Print coefficients with unbiased variance.
rem
SQL>  select  D13 - D12*D23 A, D23 B
      from    qr_coeff;
```

```
         A           B
----------- -----------
 .386994551  -1.2191247

SQL>  select  stddev(Y) standev
      from    datamatrix;

    STANDEV
-----------
 1.06482491

rem
rem   Clean up.
rem
SQL>  drop table qr_coeff;
SQL>  drop table datamatrix;
```

Although this query executes properly on the *geodemo* data set, it returns more interesting results on larger data sets.

Advanced Radionuclide Queries

This chapter presents some complex queries, which are representative of the questions a radionuclide analyst would want answered. In some cases, the examples make subtle use of unique features of the IDC schema. Queries in this section use ORACLE extensions to the ANSI SQL standard, such as substitution variables, which will not run on other databases. The following sample queries are included:

- Searching for Unreviewed FULL Spectra
- Verifying Receipt of Spectra
- Searching for Specific Nuclides
- Determining Concentration Ranges
- Searching for Specific Peaks

Advanced Radionuclide Queries

In this section, multiple queries sometimes are grouped together under a single example to show the steps required for satisfying a particular question. These queries were run against the PIDC Operations database. The SQL queries can all be edited and tailored to the specific needs of the radionuclide specialist.

This chapter uses the following different methods for formatting output:

- Parentheses are used for clarity or to establish precedence.
- Double quotation marks (") are used to assign an alias to a column heading, for example, when the column name is too long for the specified output or when the alias is more self-explanatory than the actual column name.
- BREAK specifies where and how to make format changes to a report. BREAK ON specifies action(s) to be taken when the value of an expression changes. A typical action is to SKIP a line in the report. This expression can involve an alias assigned to a report column in a SELECT statement.
- CLEAR resets or erases the current value or setting for an option (clause). CLEAR BREAKS removes the breaks set by the BREAK command.

The SUBSTR character function, introduced in Table 5 on page 55, is used in the queries of this chapter. SUBSTR returns a portion of the character string, beginning at a specified character and including up to a specified number of characters.

SEARCHING FOR UNREVIEWED FULL SPECTRA

Radionuclide operations staff at the IDC are primarily responsible for the timely review of all incoming particulate and gaseous spectra; therefore, they must know what spectra are waiting to be reviewed. One way to get this information is to query the database. Query (103) searches for FULL spectra that were received after 01 August 1998 and have not yet been reviewed.

(103)

```
SQL>  clear breaks
breaks cleared

SQL>  break on " SITE"  skip 1

SQL>  select (station_code) " SITE", (detector_code) " DETECTOR",
             substr(to_char ((entry_date), 'YYYY-MM-DD HH24:MI'),1,16)
             " RMS ENTRY DATE", gards_sample_data.sample_id) "SAMPLE#",
             substr(to_char ((collect_stop), 'YYYY-MM-DD HH24:MI'),1,16)
             " COLLECTION STOP", auto_category) "CATEGORY",
             (gards_sample_status.status) "S"
      from   gards_sample_data, gards_sample_status, gards_stations,
             gards_detectors
      where  gards_sample_data.sample_id = gards_sample_status.sample_id
      and    gards_sample_data.station_id = gards_stations.station_id
      and    gards_sample_data.detector_id = gards_detectors.detector_id
      and    entry_date >= '01-Aug-98'
      and    data_type = 'S'
      and    gards_sample_status.status IN ('A','P')
      and    spectral_qualifier= 'FULL'
      and    collect_stop > collect_start
      order by station_code, collect_stop,
              detector_code, acquisition_start;

 SITE  DETECTOR  RMS ENTRY DATE     SAMPLE#  COLLECTION STOP  CATEGORY  S
----- --------- ---------------- ---------- ---------------- ---------- --
CA002 CA002CAA2 1998-08-19 23:12     40277 1998-08-17 23:02        4 P
DE002 DE002IAR3 1998-08-19 11:34     40267 1998-08-03 08:24        3 P
FI001 FI001F09  1998-08-10 20:04     40078 1998-08-03 05:32        3 P
      FI001F09  1998-08-17 10:25     40230 1998-08-10 06:51        3 P
SE001 SE001-ORI 1998-08-20 07:34     40285 1998-08-18 07:00          1 P

SQL>
```

VERIFYING RECEIPT OF SPECTRA

Radionuclide Operations staff must also verify that all spectra have been received from a given station, to prevent gaps in the air monitoring records. Query (104) searches the **gards_sample_data** table for all FULL spectra from the FI001 station (station 42) that were collected on or after 01 June 1998.

(104)

```
SQL> clear breaks
breaks cleared

SQL> break on " DETECTOR" skip 1

SQL> select substr((gards_sample_data.site_det_code),1,10)  " DETECTOR",
            (gards_sample_data.sample_id) "SAMPLE#",
            substr(to_char ((collect_start), 'YYYY-MM-DD HH24:MI'),1,16)
            "COLLECTION START",
            substr(to_char ((collect_stop), 'YYYY-MM-DD HH24:MI'),1,16)
            " COLLECTION STOP"
     from   gards_sample_data
     where  collect_stop >= '01-Jun-98'
     and    spectral_qualifier = 'FULL'
     and    data_type = 'S'
     and    collect_stop - collect_start > 0
     and    station_id = 42
     order by collect_stop, acquisition_start;

 DETECTOR     SAMPLE# COLLECTION START  COLLECTION STOP
---------- ---------- ----------------- -----------------
FI001F09        34803 1998-05-25 05:47 1998-06-01 05:04
                34934 1998-06-01 05:09 1998-06-08 05:02
                35158 1998-06-08 05:02 1998-06-15 06:04
                35282 1998-06-15 06:07 1998-06-22 05:08
                36885 1998-06-22 05:01 1998-06-29 06:29
                37120 1998-06-29 06:34 1998-07-07 05:58
                37696 1998-07-07 06:00 1998-07-13 06:13
                37697 1998-07-13 06:15 1998-07-20 05:53
                37699 1998-07-20 05:56 1998-07-27 05:23
                40078 1998-07-27 05:25 1998-08-03 05:32
                40230 1998-08-03 05:35 1998-08-10 06:51

SQL>
```

SEARCHING FOR SPECIFIC NUCLIDES

At some European stations, previous atomic bomb tests and the Chernoybyl nuclear accident in 1986 have resulted in ^{137}Cs being commonly observed in spectra. Query (105) indicates which spectra have ^{137}Cs. This query limits the search to FULL spectra acquired on or after 01 August 1998.

(105)

```
SQL> clear breaks
breaks cleared

SQL> break on " DETECTOR" skip 1

SQL> select substr((gards_sample_data.site_det_code),1,10)  " DETECTOR",
            substr(to_char ((gards_sample_data.sample_id),
            '9999999'),1,8) "SAMPLE#",
            substr(to_char ((collect_stop), 'YYYY-MM-DD HH24:MI'),1,16)
            " COLLECTION STOP",
            to_char ((activ_key), '99999999.00') "CONC(uBq/m3)",
            to_char (((activ_key_err / activ_key) * (100)), '9999.00')
            "%RELERR"
     from   gards_sample_data, gards_nucl_ided
     where  gards_sample_data.sample_id = gards_nucl_ided.sample_id
     and    gards_nucl_ided.name = 'CS-137'
     and    gards_sample_data.data_type = 'S'
     and    gards_sample_data.acquisition_start >= '01-Aug-98'
     and    gards_sample_data.spectral_qualifier = 'FULL'
     and    activ_key > 0
     order by site_det_code, collect_stop;

 DETECTOR   SAMPLE#  COLLECTION STOP  CONC(uBq/m3)  %RELERR
---------- -------- ---------------- ------------ --------
DE002IAR3     40267 1998-08-03 08:24          .52    22.23
FI001F09      40078 1998-08-03 05:32          .43    11.96
              40230 1998-08-10 06:51         1.01    12.50

SQL>
```

DETERMINING CONCENTRATION RANGES

As seen in the previous output, ^{137}Cs was identified in subsequent FI001 spectra; therefore, the analyst should determine the range of ^{137}Cs concentrations over a given time period, prior to the review of the newly arrived spectra. Query (106) determines the minimum, maximum, average, and standard deviation of ^{137}Cs concentrations at the FI001 station (station 42) measured in FULL spectra collected since 01 June 1998.

(106)

```
SQL> column  MINIMUM format 99999.00
SQL> column  MAXIMUM format 99999.00
SQL> column  AVERAGE format 99999.00
SQL> column  STDDEV  format 99999.00
SQL> clear breaks
breaks cleared

SQL> select min(activ_key) "MINIMUM", max(activ_key) "MAXIMUM",
              avg(activ_key) "AVERAGE", stddev(activ_key) "STDDEV"
     from   gards_sample_data, gards_nucl_ided
     where  gards_sample_data.sample_id = gards_nucl_ided.sample_id
     and    gards_sample_data.station_id = 42
     and    gards_sample_data.spectral_qualifier = 'FULL'
     and    gards_sample_data.data_type = 'S'
     and    gards_sample_data.collect_stop >= '01-Jun-98'
     and    gards_nucl_ided.name = 'CS-137'
     and    activ_key > 0
     and    collect_stop - collect_start > 0
     and    acquisition_real_sec > 3600;

  MINIMUM   MAXIMUM   AVERAGE    STDDEV
--------- --------- --------- ---------
      .43      3.08      1.37       .76

SQL>
```

SEARCHING FOR SPECIFIC PEAKS

During the spectral review process, if analysts observe a peak at a given energy deemed important to the IDC, they should determine whether any other spectra in the database indicate a peak at the same energy location. Query (107) indicates all spectra that contain a peak between 660 and 663 keV and were collected on or after 01 August 1998. (The output generated by Query (107) has been modified to fit on the page.)

(107)

```
SQL> clear breaks
breaks cleared

SQL> break on  " DETECTOR"  skip 1

SQL> select substr((gards_sample_data.site_det_code),1,10)  " DETECTOR",
            substr((gards_sample_data.sample_id),1,6) "SAMPLE#",
            substr(to_char ((collect_stop),'YYYY-MM-DD HH24:MI'),1,16)
            " COLLECTION STOP",
            to_char ((gards_peaks.energy), '9999.00') "  ENERGY",
            to_char ((gards_peaks.centroid), '9999.00') " CHANNEL",
            to_char ((fwhm), '9.00') " FWHM",
            to_char((area), '99999999.00') "   NET AREA",
            to_char(((area_err / area) * (100)), '9999.00') " %RELERR"
    from    gards_sample_data, gards_peaks
    where   gards_sample_data.sample_id= gards_peaks.sample_id
    and     gards_sample_data.data_type = 'S'
    and     gards_sample_data.spectral_qualifier = 'FULL'
    and     gards_sample_data.acquisition_real_sec > 3600
    and     gards_peaks.energy >=  660
    and     gards_peaks.energy <=  663
    and     gards_sample_data.collect_stop > '01-Aug-98'
    order by  site_det_code, collect_stop, acquisition_start;

 DETECTOR SAMPLE  COLLECTION STOP ENERGY  CHANNEL  FWHM NET AREA %RELERR
--------- ------ ---------------- ------ -------- ----- -------- -------
DE002IAR3  40267 1998-08-03 08:24 661.51  1292.28  3.13   299.57   22.19
FI001F09   40078 1998-08-03 05:32 661.68  1986.36  1.25   542.03   11.49
           40230 1998-08-10 06:51 661.61  1986.07  1.30   334.91   12.05
US001USA1  40212 1998-08-14 20:32 661.85  1356.34  1.10    92.43   58.74

SQL>
```

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Glossary

A

ANSI

American National Standards Institute

C

CMR

Center for Monitoring Research.

D

DB

Database.

DBA

Database Administrator.

DBMS

Database Management System.

E

epoch time

Number of seconds after January 1, 1970 00:00:00.0.

G

GMT

Greenwich Mean Time.

GSETT

Group of Scientific Experts Technical Test.

I

IDC

International Data Centre.

ISO

International Standards Organization.

O

Oracle

Vendor of PIDC and IDC database management system.

P

PIDC

Prototype International Data Centre.

R

RDBMS

Relational Database Management System.

S

SAIC

Science Applications International Corporation.

SQL

Structured Query Language; a language for manipulating data in a relational database.

T

time, epoch

See epoch time.

U

UNIX

Trade name of the operating system used by the Sun workstations.

UTC

Universal Coordinated Time.

W

workstation

High-end, powerful desktop computer preferred for graphics and usually networked.

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