# MOX Environmental Report Reference Input Sheet

| | |
|---|---|
| | **1. Date** |
| | May 29, 2001 |
| **2. ID Code (to be entered later)** | **3. Source (Report, EIS, FR, DOE Order, etc)** |
| 765 | Letter |
| **4. Originator (for correspondence)** | **5. To (for correspondence)** |
| A.B. Gould (SRS) | N. Brock (SC SHPO) |
| **6. Author (for documents)** | |
| | |
| **7. Document Title** | |
| Data recovery Plans for SRS Surplus Plutonium Disposition Facility Sites | |
| **8. Document Number** | **9. Journal Number** |
| | |
| **10. Published Date** | **11. Published Month** / **12. Published Year** |
| 12 | March / 2001 |
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| **15. Classification (Public, SC)** | **16. Format (Photocopy, Bound Document, etc)** |
| | |
| **17. Current Status (Draft/Final)** | **18. Environment Report Section** |
| | **ER-5** |
| **19. Subject** | |
| Archaeological Mitigation Plan for MFFF site. | |

18-3

data recovery plan for the National Register of Historic Places (NRHP) eligible site.

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cc: Tom Conroy (Archaeology
Dick Reynolds
Dick Tinsley
Mary Black (DCS)
Skip Kerschner (WGI Dur

MAR 1 2 2001

Ms. Nancy Brock
Review and Compliance Coordinator
South Carolina Department of Archives and History
8301 Parklane Road
Columbia, SC 29223

Dear Ms Brock:

SUBJECT: Data Recovery Plans for Savannah River Site (SRS) Surplus Plutonium Disposition Facility Sites

Ref: 1) Letter, Gould to Brock, dated 4/24/00 transmitting Archaeological Survey and Testing of the Surplus Plutonium Disposition Facilities (King and Stephenson 2000)
2) Letter, William Green to Gould, dated 5/19/00

This refers to our previous correspondence concerning the U.S. Department of Energy's (DOE) plans to construct surplus plutonium disposition facilities on the SRS in Aiken County.

As documented in our report, (Reference 1) reviewed this past year by the South Carolina State Historic Preservation Officer (Reference 2), these new facilities would impact two sites (i.e., 38AK757 and 38AK546) determined to be eligible for the National Register. Enclosed with this letter are two data recovery plans intended to mitigate damage to these sites by the proposed construction projects.

Because the Mixed Oxide Fuel Fabrication Facility project (38AK546) is planned as a Nuclear Regulatory Commission (NRC) licensed activity, we will begin discussions with the NRC regarding DOE serving in the role as lead agency for the purposes of National Historic Preservation Act archeological resource issues. We will coordinate with you as this communication develops.

Thank you for your continuing assistance in this review. We look forward to your input. If you have any questions please call me at (803) 725-3969 or contact Mary Baranek at (803) 725-8014.

Sincerely,

/S/

A. B. Gould, Director
Environmental Quality Management Division

EQMD: MMB:scm

OE-01-013

2 Enclosures
(1) Recommended Mitigation Plan for 38AK757
(2) Recommended Mitigation Plan for 38AK546

bc w/encl:
M. M. Baranek, EQMD
J. E. Bolen, EQMD
M. J. Brooks, SRARP
D. Bruner, ODNN
Keith Dyer, WSRC
B. T. Hays, OCC
J. Roberts, WSRC

MGR rd file
AMEST rd file
EQMD rd file
FILE CODE #

# RECOMMENDED MITIGATION PLAN FOR 38AK757

## Project Summary and Potential Impacts

As documented in King and Stephenson (2000), the Department of Energy has proposed the construction of the Surplus Plutonium Disposition Facilities at the Savannah River Site in Aiken County, South Carolina (Figure 1). Construction of a portion of this complex, known as the PDCF Facility, will result in impacts to the National Register eligible site 38AK757. The information contained in 38AK757 will be impacted directly by ground disturbance associated with construction activities, and indirectly by required security measures that will place the area covered by 38AK757 off limits to any future investigations. As a result, it is recommended that these impacts be mitigated through data recovery.

## Significant Components and Research Potential

Testing completed at 38AK757 indicates that the site was occupied during the Early Archaic, Early Woodland, Middle Woodland and Late Mississippian periods. The Middle Woodland and Early Archaic components appear to represent short-term, limited activity sites with low numbers of artifacts sparsely distributed over wide areas of the site. This combination of low artifact densities and lack of horizontal patterning suggests that even intensive investigations focused on these components would not produce artifact assemblages and contextual information sufficient to allow for meaningful interpretations.

In contrast, discrete activity loci were identified in the Late Mississippian and Early Woodland deposits, indicating that each component has the potential to provide important information on site structure and use during those two periods. Sassaman's (1993) detailed examination of Early Woodland deposits at nearby 38AK157 may make the Early Woodland data from 38AK757 somewhat redundant. Given our very limited understanding of Mississippian period occupations in the Aiken Plateau, the same is not true of the Late Mississippian deposits.

Also important at 38AK757 is the component associated with Fabric Impressed pottery. The temporal assignment of this ware is particularly poorly understood in the Aiken Plateau, and more importantly nothing is understood about the cultural adaptation of the people who made it. Any new information that can be collected on the dating of Fabric Impressed pottery and the range of activities associated with the Fabric Impressed occupation will be an important contribution.

## The Data Recovery Plan

The proposed data recovery plan will involve block excavation and extensive mechanical stripping. In brief, the plan is as follows:

1. A total of 250 $m^2$ of the site area will be investigated through the excavation of contiguous blocks of 1 m square test units. Excavation blocks will be located to investigate areas identified during previous testing as having the potential to contain significant information about the components present at the site. The final configuration of excavation blocks will be determined

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during the course of excavation. All 250 $m^2$ will be excavated to a depth of 40 cm below surface to record the Early Woodland and Late Mississippian components of the site. An additional 50 $m^2$ will be excavated to a depth of 50 cm below surface to record data on the Fabric Marked component.

Each 1 m square test unit will be excavated in 10 cm levels. Records of level provenience and depth, artifact and feature content, soil composition, and stratigraphy will be kept on standard SRARP forms. All soil will be screened through .64 cm wire mesh and artifacts will be collected by 1 m test unit and level. Because of the heavy root mat present at 38AK757, it is not possible to plot artifacts in situ in the first level. To maintain the strictest control possible over artifact location, the first level in each 1 m square test unit will be excavated in quadrants. Below the root mat, the horizontal and vertical location of all diagnostic and formal stone artifacts, and all pottery and other stone material larger than 3 cm in diameter will be plotted during excavation.

2. During excavation, soil samples will be collected from selected 1 m square units excavated across the site. Those samples will be subjected to grain size analysis. Results of grain size analyses, when compared to the vertical distribution of piece-plotted artifacts, can be useful in identifying occupational surfaces in sandy soils (Sassaman 1993). In each unit sampled, soil will be collected every 5 cm starting beneath the plowzone and continuing to the base of the unit.

3. After the block excavations have been completed, those portions of the site stripped as part of the construction schedule will be examined for features and artifact concentrations. All features and artifact concentrations will be located horizontally and vertically using the site grid and elevation system. Artifact collections will be made where possible and assigned the most restricted provenience appropriate.

4. All features encountered in the course of excavation and stripping will be recorded in plan and profile drawings and photographs. Feature fill will be removed separately and processed through flotation. Faunal, botanical, and materials suitable for radiocarbon dating will be analyzed qualified professionals.

5. Artifact processing, cataloging and analysis will be conducted in accordance with established SRARP laboratory procedures (Sassaman et al. 1990). All artifacts and associated project documentation will be curated in accordance with relevant federal regulations following established SRARP curation procedures (Crass 1991).

## References Cited


Crass, D. C.
1991 *Savannah River Archaeological Research Program Guide to Curation Procedures.* Savannah River Archaeological Research Technical Report Series 14.

King, A., and K. Stephenson
2000 *Archaeological Survey and Testing of the Surplus Plutonium Disposition Facilities.* Savannah River Archaeological Research Program Technical Report Series Number 24.

Sassaman, K. E.
1993 *Early Woodland Settlement in the Aiken Plateau: Archaeological Investigations at 38AK157, Savannah River Site, Aiken County, South Carolina.* Savannah River Archaeological Research Papers 3. Savannah River Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, University of South Carolina.

Sassaman, K. E. , M. J. Brooks, G. T. Hanson, and D. G. Anderson
1990 *Native American Prehistory of the Middle Savannah River Valley: A Synthesis of Archaeological Investigations on the Savannah River Site, Aiken and Barnwell Counties, South Carolina.* Savannah River Archaeological Research Papers 1. Savannah River Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, University of South Carolina.

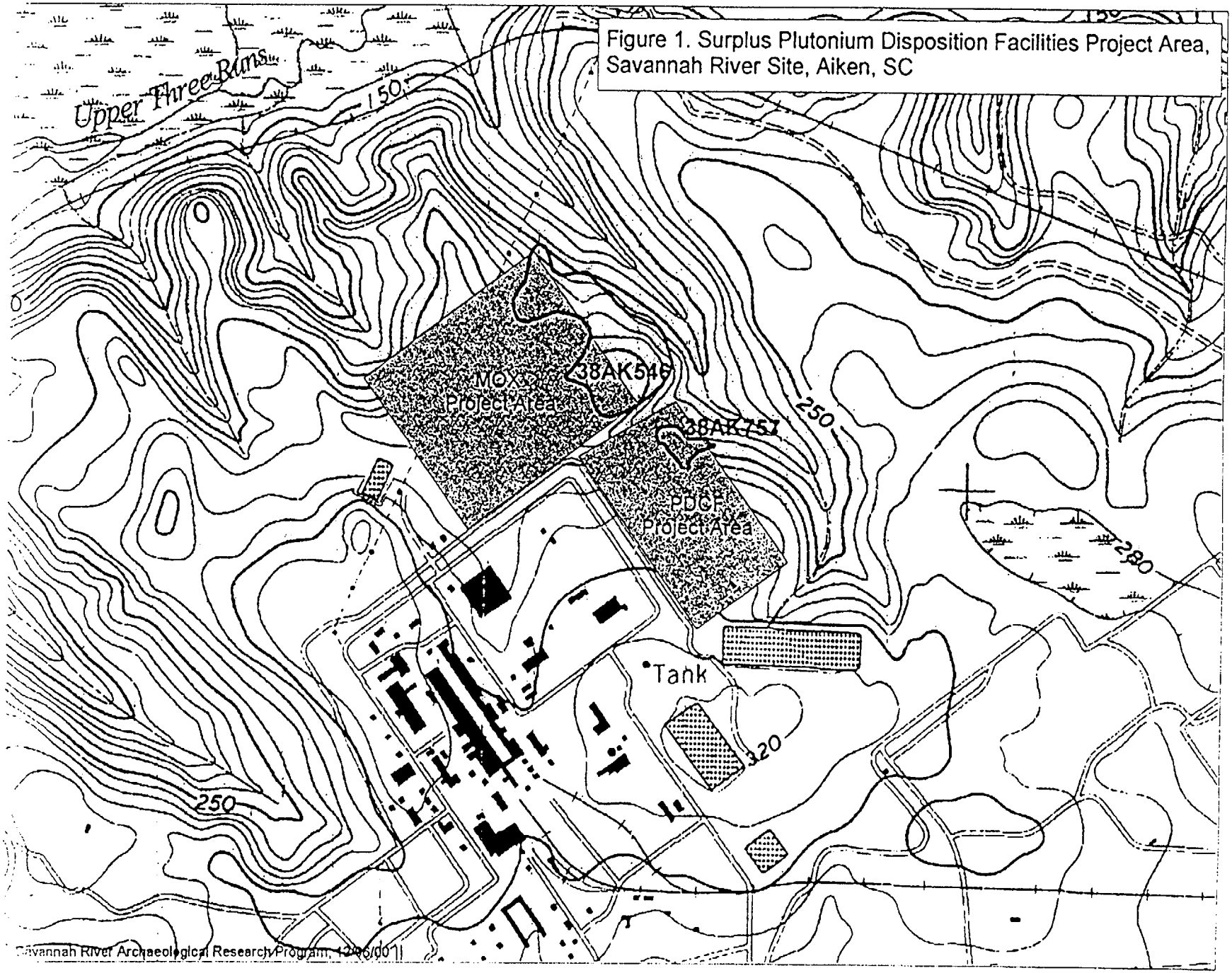


Figure 1. Surplus Plutonium Disposition Facilities Project Area, Savannah River Site, Aiken, SC

# RECOMMENDED MITIGATION PLAN FOR 38AK546

## Project Summary and Potential Impacts

As documented in King and Stephenson (2000), the Department of Energy has proposed the construction of the Surplus Plutonium Disposition Facilities at the Savannah River Site in Aiken County, South Carolina (Figure 1). Construction of a portion of this complex, known as the MOX Facility, will result in both direct and indirect impacts to the National Register eligible site 38AK546. The information contained in 38AK546 will be impacted directly by ground disturbance associated with construction activities, and indirectly by required security measures that will place the area covered by 38AK757 off limits to any future investigations. As a result, it is recommended that these impacts be mitigated through data recovery.

## Significant Components and Research Potential

Initial testing at 38AK546 indicates that the site contains components dating to the Early Archaic, Middle Archaic, Early Woodland, Middle Woodland, Late Woodland, and Mississippian periods. In the limited testing completed at the site, discrete activity loci were identified dating to the Early Woodland and Mississippian periods. Sassaman's (1993) detailed examination of Early Woodland deposits at nearby 38AK157 may make the Early Woodland data from 38AK546 somewhat redundant. Given the lack of data on the structure and function of Mississippian sites in the Aiken Plateau, the same cannot be said for the Mississippian component at 38AK546. The nature of the deposits associated with the other components at the site is not clearly understood, and can only be determined through close-interval shovel testing. Given the general paucity of excavation data in the Aiken Plateau, any information recorded on the structure and range of activities represented in the Early Archaic, Middle Archaic, Middle Woodland and Late Woodland components at 38AK546 will be significant.

## The Data Recovery Plan

The proposed data recovery plan will involve intensive shovel testing, block excavation, and extensive mechanical stripping. In brief, the plan is as follows:

1. Prior to the excavation of test units, shovel tests will be excavated at 10 m intervals across the entire area of the site. Those shovel tests will be 35 $cm^2$ and will be excavated to a depth 80 cm below surface. All soil will be screened through .64 cm wire mesh and all artifacts encountered will be bagged by shovel test.

2. Using the shovel test data as a guide, a total of 400 $m^2$ will be investigated in 1 m square test units. Test units will be grouped in contiguous blocks and located to investigate areas having the potential to contain significant information about the components present at the site. The final configuration of excavation blocks will be determined during the course of excavation. All 400 $m^2$ will be excavated to a depth of 20 cm below surface to record the Mississippian, Late Woodland, and Middle Woodland components of the site. One quarter of that area (100 $m^2$ ) will be extended to a depth of 40 cm below surface to record the Early Woodland component, while 50 $m^2$ will be excavated to a depth of 50 cm below surface to investigate the Middle and Early Archaic components.

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Each 1 m square test unit will be excavated in 10 cm levels. Records of level provenience and depth, artifact and feature content, soil composition, and stratigraphy will be kept on standard SRARP forms. All soil will be screened through .64 cm wire mesh and artifacts will be collected by 1 m test unit and level. Because of the heavy root mat present at 38AK546, it is not possible to plot artifacts in situ in the first level. To maintain the strictest control possible over artifact location, the first level in each 1 m square test unit will be excavated in quadrants. Below the root mat, the horizontal and vertical location of all diagnostic and formal stone artifacts, and all pottery and other stone material larger than 3 cm in diameter will be plotted during excavation.

3. During excavation, soil samples will be collected from selected 1 m square units excavated across the site. Those samples will be subjected to grain size analysis. Results of grain size analyses, when compared to the vertical distribution of piece-plotted artifacts, can be useful in identifying occupational surfaces in sandy soils (Sassaman 1993). In each unit sampled, soil will be collected every 5 cm starting beneath the plowzone and continuing to the base of the unit.

4. After the block excavations have been completed, those portions of the site stripped as part of the construction schedule will be examined for features and artifact concentrations. All features and artifact concentrations will be located horizontally and vertically using the site grid and elevation system. Artifact collections will be made where possible and assigned the most restricted provenience appropriate.

5. All features encountered in the course of excavation and stripping will be recorded in plan and profile drawings and photographs. Feature fill will be removed separately and processed through flotation. Faunal, botanical, and materials suitable for radiocarbon dating will be analyzed qualified professionals.

6. Artifact processing, cataloging and analysis will be conducted in accordance with established SRARP laboratory procedures (Sassaman et al. 1990). All artifacts and associated project documentation will be curated in accordance with relevant federal regulations following established SRARP curation procedures (Crass 1991).

## References Cited


Crass, D. C.
1991 *Savannah River Archaeological Research Program Guide to Curation Procedures.* Savannah River Archaeological Research Technical Report Series 14.

King, A., and K. Stephenson
2000 *Archaeological Survey and Testing of the Surplus Plutonium Disposition Facilities.* Savannah River Archaeological Research Program Technical Report Series Number 24.

Sassaman, K. E.
1993 *Early Woodland Settlement in the Aiken Plateau: Archaeological Investigations at 38AK157, Savannah River Site, Aiken County, South Carolina.* Savannah River Archaeological Research Papers 3. Savannah River Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, University of South Carolina.

Sassaman, K. E. , M. J. Brooks, G. T. Hanson, and D. G. Anderson
1990 *Native American Prehistory of the Middle Savannah River Valley: A Synthesis of Archaeological Investigations on the Savannah River Site, Aiken and Barnwell Counties, South Carolina.* Savannah River Archaeological Research Papers 1. Savannah River Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, University of South Carolina.

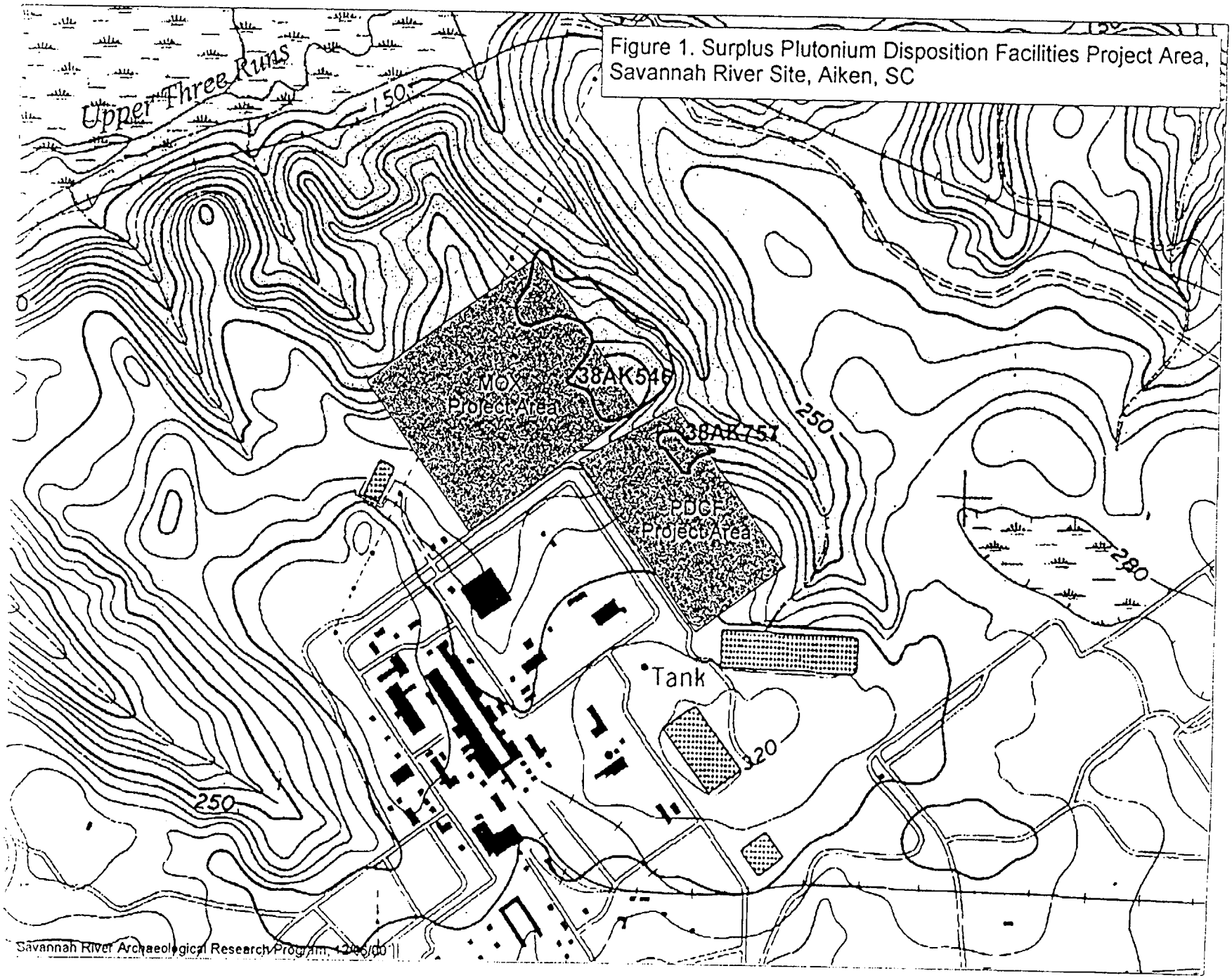


Figure 1. Surplus Plutonium Disposition Facilities Project Area, Savannah River Site, Aiken, SC

# MOX Environmental Report Reference Input Sheet

| | 1. Date |
|---|---|
| | June 6 |
| **2. ID Code (to be entered later)** | **3. Source (Report, EIS, FR, DOE Order, etc)** |
| 768 | Correspondence |
| **4. Originator (for correspondence)** | **5. To (for correspondence)** |
| V. Marcil (SC SHPO) | A.B. Gould (SRS) |
| **6. Author (for documents)** | |
| | |
| **7. Document Title** | |
| Mitigation Plans for Sites 38AK757 and 38AK546 at the Proposed Surplus Plutonium Disposition Facility, Savannah River Site, Aiken County, SC | |
| **8. Document Number** | **9. Journal Number** |
| | |
| **10. Published Date** | **11. Published Month** / **12. Published Year** |
| 11 | April / 2001 |
| **13. Publisher** | **14. Publisher Office** |
| | |
| **15. Classification (Public, SC)** | **16. Format (Photocopy, Bound Document, etc)** |
| | |
| **17. Current Status (Draft/Final)** | **18. Environment Report Section** |
| | |
| **19. Subject** | |
| SHPO Acceptance of Mitigation Plan for MOX site | |

18-4

Concurrence letter from the State Historic [redacted] Preservation Officer (SHPO)


April 11, 2001

Mr. A. B. Gould, Director
Environmental Quality Management Division
Department of Energy, Savannah River Operations Office
P.O. Box A
Aiken, South Carolina 29802

RE: Mitigation Plans for Sites 38AK757 and 38AK546 at the proposed Surplus Plutonium Disposition Facility, Savannah River Site, Aiken County, SC

Dear Mr. Gould:

I have reviewed the above referenced proposals for archaeological site mitigation and find them to be acceptable plans that address important questions and comply with state and federal standards and guidelines. The information resulting from this work should add significantly to our understanding of prehistory in the state of South Carolina.

These comments are being provided to you to assist you with your responsibilities Section 106 of the National Historic Preservation Act, as amended, and the regulations codified at 36 CFR Part 800. I can be contacted at (803) 896-6173 if you have any questions.

Sincerely,

Valerie Marcil
Staff Archaeologist
State Historic Preservation Office

cc: Mark Brooks, Savannah River Archaeological Research Program
Keith Derting, South Carolina Institute of Archaeology and Anthropology

DOE - SR BY ZIP AND COUNTY

| City | State | Zip | Number |
|---|---|---|---|
| ASHBURN | VA | 20147 | 1 |
| MORGANTOWN | WV | 26501 | 1 |
| EHRHARDT | SC | 29081 | 1 |
| MONETTA | SC | 29105 | 1 |
| ORANGEBURG | SC | 29115 | 1 |
| ROWESVILLE | SC | 29133 | 1 |
| SALUDA | SC | 29138 | 1 |
| WEST COLUMBIA | SC | 29170 | 1 |
| COTTAGEVILLE | SC | 29435 | 1 |
| MT. PLEASANT | SC | 29466 | 1 |
| SUMMERVILLE | SC | 29485 | 1 |
| WALTERBORO | SC | 29488 | 1 |
| AIKEN | SC | 29803 | 217 |
| NEW ELLENTON | SC | 29809 | 13 |
| ALLENDALE | SC | 29810 | 1 |
| HILDA | SC | 29813 | 1 |
| BLACKVILLE | SC | 29817 | 1 |
| CLARKS HILL | SC | 29821 | 1 |
| EDGEFIELD | SC | 29824 | 2 |
| ELKO | SC | 29826 | 1 |
| GRANITEVILLE | SC | 29829 | 3 |
| JACKSON | SC | 29831 | 10 |
| MODOC | SC | 29838 | 1 |
| MONTMORENCI | SC | 29839 | 1 |
| BELVEDERE | SC | 29841 | 2 |
| BEECH ISLAND | SC | 29842 | 3 |
| TRENTON, | SC | 29847 | 1 |
| TRENTON | SC | 29847 | 1 |
| WILLISTON | SC | 29853 | 9 |
| NORTH AUGUSTA | SC | 29860 | 57 |
| ESTILL | SC | 29918 | 1 |
| DECATUR | GA | 30035 | 1 |
| LOUISVILLE | GA | 30434 | 1 |
| APPLING | GA | 30802 | 4 |
| EVANS | GA | 30809 | 38 |
| GROVETOWN | GA | 30813 | 6 |
| HEPHZIBAH | GA | 30815 | 15 |
| AUGUSTA | GA | 30901 | 48 |
| MARTINEZ | GA | 30907 | 25 |
| NEWBERRY | FL | 32669 | 1 |
| LOS ALAMOS | NM | 87544 | 1 |

19-1

listing of number of employees for each SRS contractor by county &/or zip code

WSRC BY COUNTY

# WSRC/BSRI/BNFL/BWXT-SR EMPLOYEE RESIDENCE REPORT
## [FULL SERVICE EMPLOYEES]
10/6/00

| | |
|---|---|
| **GEORGIA** | |
| COLUMBIA | 1,835 |
| RICHMOND | 1,571 |
| SCREVIN | 56 |
| BURKE | 55 |
| MCDUFFIE | 24 |
| LINCOLN | 20 |
| JEFFERSON | 11 |
| JENKINS | 5 |
| GWINNETT | 2 |
| BRYAN | 1 |
| CHATHAM | 1 |
| CLAYTON | 1 |
| COBB | 1 |
| DEKALB | 1 |
| EMANUEL | 1 |
| STEPHENS | 1 |
| TATNALL | 1 |
| WAYNESBORO | 1 |
| **TOTAL GEORGIA** | 3,588 |
| **SOUTH CAROLINA** | |
| AIKEN | 6,353 |
| BARNWELL | 862 |
| EDGEFIELD | 212 |
| BAMBERG | 184 |
| ORANGEBURG | 180 |
| LEXINGTON | 125 |
| ALLENDALE | 105 |
| HAMPTON | 102 |
| SALUDA | 64 |
| MCCORMICK | 62 |
| COLLETON | 34 |
| RICHLAND | 24 |
| JASPER | 7 |
| NEWBERRY | 6 |
| GREENWOOD | 5 |
| ABBEVILLE | 4 |
| BEAUFORT | 3 |
| KERSHAW | 3 |
| CALHOUN | 2 |
| CHARLESTON | 2 |
| OCONEE | 2 |
| SUMTER | 2 |
| BERKELEY | 1 |
| CLARENDON | 1 |
| DORCHESTER | 1 |
| FAIRFIELD | 1 |
| GREENVILLE | 1 |
| LAURENS | 1 |
| **TOTAL SOUTH CAROLINA** | 8,349 |
| **OTHER STATES** | 32 |
| **TOTAL** | 11,969 |

WSRC - BY ZIPCODE

# Query Results 7

| Zip Code | COUNT Social Security Number |
|---|---|
| 15672 | 1 |
| 22181 | 1 |
| 28105 | 1 |
| 28269 | 1 |
| 28277 | 1 |
| 28412 | 1 |
| 28681 | 1 |
| 28910 | 1 |
| 28941 | 1 |
| 29003 | 80 |
| 29006 | 35 |
| 29018 | 2 |
| 29020 | 1 |
| 29036 | 1 |
| 29038 | 16 |
| 29039 | 1 |
| 29042 | 54 |
| 29044 | 1 |
| 29048 | 2 |
| 29053 | 1 |
| 29054 | 10 |
| 29061 | 1 |
| 29063 | 3 |
| 29065 | 1 |
| 29070 | 32 |
| 29072 | 20 |
| 29073 | 11 |
| 29078 | 2 |
| 29081 | 22 |
| 29082 | 2 |
| 29102 | 1 |
| 29105 | 15 |
| 29107 | 28 |
| 29108 | 2 |
| 29112 | 16 |
| 29113 | 14 |
| 29115 | 43 |
| 29116 | 6 |
| 29118 | 10 |

| Zip Code | COUNT Social Security Number |
|---|---|
| 29123 | 8 |
| 29127 | 6 |
| 29129 | 41 |
| 29135 | 1 |
| 29137 | 34 |
| 29138 | 14 |
| 29142 | 2 |
| 29145 | 1 |
| 29146 | 40 |
| 29148 | 1 |
| 29150 | 1 |
| 29153 | 1 |
| 29160 | 7 |
| 29164 | 75 |
| 29166 | 4 |
| 29169 | 1 |
| 29170 | 4 |
| 29172 | 4 |
| 29201 | 1 |
| 29203 | 2 |
| 29204 | 1 |
| 29206 | 1 |
| 29209 | 2 |
| 29210 | 4 |
| 29212 | 8 |
| 29223 | 5 |
| 29379 | 1 |
| 29401 | 1 |
| 29407 | 1 |
| 29432 | 10 |
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| 29445 | 1 |
| 29472 | 1 |
| 29475 | 9 |
| 29481 | 5 |
| 29488 | 6 |
| 29620 | 2 |
| 29649 | 2 |
| 29659 | 1 |
| 29662 | 2 |
| 29666 | 2 |

| Zip Code | COUNT Social Security Number |
|---|---|
| 29692 | 2 |
| 29696 | 1 |
| 29801 | 1,010 |
| 29802 | 53 |
| 29803 | 2,161 |
| 29804 | 34 |
| 29805 | 58 |
| 29808 | 1 |
| 29809 | 185 |
| 29810 | 62 |
| 29812 | 486 |
| 29813 | 4 |
| 29816 | 29 |
| 29817 | 128 |
| 29821 | 41 |
| 29822 | 40 |
| 29824 | 81 |
| 29826 | 11 |
| 29827 | 31 |
| 29828 | 30 |
| 29829 | 178 |
| 29831 | 258 |
| 29832 | 41 |
| 29834 | 42 |
| 29835 | 11 |
| 29836 | 17 |
| 29837 | 1 |
| 29838 | 13 |
| 29839 | 34 |
| 29841 | 1,571 |
| 29842 | 65 |
| 29843 | 30 |
| 29845 | 4 |
| 29847 | 89 |
| 29849 | 6 |
| 29850 | 2 |
| 29851 | 135 |
| 29852 | 1 |
| 29853 | 279 |
| 29856 | 59 |
| 29860 | 262 |

| Zip Code | COUNT Social Security Number |
|---|---|
| 29861 | 24 |
| 29863 | 1 |
| 29902 | 1 |
| 29911 | 21 |
| 29916 | 4 |
| 29918 | 14 |
| 29920 | 2 |
| 29921 | 1 |
| 29922 | 1 |
| 29923 | 3 |
| 29924 | 22 |
| 29926 | 1 |
| 29929 | 11 |
| 29934 | 3 |
| 29936 | 3 |
| 29944 | 31 |
| 29945 | 1 |
| 30044 | 1 |
| 30062 | 1 |
| 30078 | 1 |
| 30092 | 1 |
| 30097 | 1 |
| 30307 | 1 |
| 30309 | 1 |
| 30401 | 2 |
| 30425 | 1 |
| 30426 | 6 |
| 30434 | 5 |
| 30441 | 1 |
| 30442 | 4 |
| 30446 | 2 |
| 30456 | 8 |
| 30461 | 1 |
| 30467 | 54 |
| 30677 | 1 |
| 30802 | 33 |
| 30803 | 1 |
| 30805 | 9 |
| 30807 | 3 |
| 30808 | 10 |
| 30809 | 667 |

| Zip Code | COUNT Social Security Number |
|---|---|
| 30811 | 1 |
| 30813 | 153 |
| 30814 | 33 |
| 30815 | 282 |
| 30816 | 6 |
| 30817 | 20 |
| 30818 | 2 |
| 30820 | 1 |
| 30823 | 2 |
| 30824 | 16 |
| 30828 | 1 |
| 30830 | 32 |
| 30833 | 2 |
| 30882 | 1 |
| 30901 | 76 |
| 30903 | 11 |
| 30904 | 167 |
| 30906 | 452 |
| 30907 | 1,168 |
| 30908 | 3 |
| 30909 | 352 |
| 30914 | 5 |
| 30916 | 23 |
| 30917 | 12 |
| 30919 | 10 |
| 31321 | 1 |
| 31405 | 1 |
| 32034 | 1 |
| 32123 | 1 |
| 32250 | 1 |
| 35768 | 1 |
| 37027 | 1 |
| 37090 | 1 |
| 37660 | 1 |
| 37748 | 1 |
| 37922 | 2 |
| 38015 | 1 |
| 45056 | 1 |
| 48187 | 1 |
| 48864 | 1 |
| 76132 | 1 |

| Zip Code | COUNT Social Security Number |
|---|---|
| 79121 | 1 |
| 80124 | 1 |
| 80130 | 1 |
| 87501 | 2 |
| 87504 | 1 |
| 87544 | 3 |
| 94550 | 2 |
| 94568 | 1 |
| 94588 | 1 |
| 99352 | 1 |
| <null> | 1 |

End of Report

# Query Results 6

WSRC et al.

6/18/01

| COUNT Social Security Number | County |
|---|---|
| 3 | ABB |
| 6,363 | AIK |
| 114 | ALL |
| 186 | BAM |
| 891 | BAR |
| 3 | BEA |
| 1 | BER |
| 1 | BRY |
| 1 | BUL |
| 56 | BUR |
| 2 | CAL |
| 2 | CHR |
| 1 | CHT |
| 1,856 | CLB |
| 1 | CLD |
| 34 | CLL |
| 1 | COB |
| 1 | DEK |
| 1 | DOR |
| 223 | EDG |
| 2 | EMA |
| 1 | FAI |
| 1 | GLA |
| 1 | GRV |
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Barry

DEPARTMENT OF ENERGY
WACKENHUT
SAVANNAH RIVER SITE

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| HEPHZIBAH, GA | 61 |
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| AIKEN, SC | 166 |

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**Residence by County, July 2000**

| | |
|---|---|
| Aiken | 122 |
| Barnwell | 3 |
| Burke | 2 |
| Clarke | 11 |
| Columbia | 5 |
| Edgefield | 1 |
| Richland | 1 |
| Richmond | 20 |
| Saluda | 2 |
| Suffolk (NY) | 1 |
| Total | 168 |

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"Surplus Plutonium
Disposition (SPD)
Environmental Data
Summary"

**ESH-EMS-2000-849**
**Rev. 0**
**August 3, 2000**

# Surplus Plutonium Disposition (SPD)

# Environmental Data Summary

P.D. Fledderman
Environmental Monitoring Section

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# 1. Introduction

This document provides an overview of existing environmental and ecological information at areas identified as potential locations of the Savannah River Site's (SRS) Surplus Plutonium Disposition (SPD) facilities. This information is required to document existing environmental and baseline conditions from which SPD construction and operation impacts can be defined. It will be used in developing the required preoperational monitoring plan to be used at specific SPD facilities construction sites. In general, the report is divided on the basis of exposure pathways. It has five sections, as follows:

1. *General Information*, which provides information on the SPD project
2. *Radiological Monitoring*, which describes the effluent monitoring and environmental surveillance monitoring programs and presents source term inventory and monitoring results, including both historical and current information
3. *Nonradiological (Chemical) Monitoring*, which defines major contaminants released from facilities impacting the SPD project area and presents an overview of monitoring activities
4. *Groundwater Monitoring*, which describes groundwater conditions and contaminants underlying the SPD project area
5. *Other Considerations*, which describes other issues which may impact the environment in the SPD project area

# 2. General Information

## 2.1 Project Description

As a result of the end of the cold war in 1991, significant quantities of excess plutonium exist in both domestic and foreign stockpiles. As part of its stockpile stewardship responsibility, one mission of the U.S. Department of Energy (DOE) is to reduce the threat of nuclear weapons proliferation by disposing of surplus plutonium in the United States. This disposition must be completed in a timely and environmentally safe manner to ensure that surplus plutonium is converted into proliferation-resistant forms. DOE's disposition strategy allows for the immobilization of surplus plutonium and for its use as a mixed oxide fuel in existing domestic commercial power reactors.

The SPD project consists of the following types of facilities:

- A facility for disassembling pits (weapons components) and converting the recovered plutonium, as well as plutonium from other sources, into plutonium dioxide suitable for disposition. It is referred to as the Pit Disassembly and Conversion Facility (PDCF).

- A facility for immobilizing surplus plutonium for eventual disposal in a geologic repository, pursuant to the Nuclear Waste Policy Act. This facility will be able to convert nonpit plutonium materials into plutonium dioxide suitable for immobilization. It is referred to as the Plutonium Immobilization Plant (PIP).

- A facility for fabricating plutonium dioxide into a mixed oxide (MOX) fuel. This facility will be privately operated and licensed by the Nuclear Regulatory Commission. It is referred to as the MOX facility.

## 2.2 Area Description

The proposed sites for the SPD facilities are located along the existing F-Area perimeter, on the northeast and northwest sides. Six potential areas (including two supplemental areas) for facility construction have been identified for facility construction (figure 1, table 1). The PDCF will be located in Area X and the MOX fuel fabrication facility will be located in Areas 2 and 2A. The location of the PIP has not been determined.

The terrain of the areas under investigation is relatively level near the F-Area boundary. An unnamed tributary of Upper Three Runs originates in the general SPD project area. As the land descends to this tributary, fairly steep gradient drops are evident. Close to the F-Area boundary, the land is primarily cleared. Several areas include light industrial and administrative activities (office trailers, equipment storage areas, roads, and parking lots). Grass and shrubs are the primary vegetation in these areas. As the land approaches and drops to the Upper Three Runs tributary, the cover changes to thicker shrubs and forest.

## 2.3 Waste Units

Because of the SPD project's proximity to F-Area, areas of historical contamination may exist and are of interest. These could include both identified waste units and other areas of local increased contamination from facility operations and releases. In the SPD project area, a small number (12) of waste units and early construction and operation disposal (ECOD) sites have been identified. Table 2 and figure 2 provide details on these features.

## 2.4 Groundwater

Based on the groundwater flow patterns underlying the SPD site, the water table outcrops into Upper Three Runs and its tributaries (figure 3). The regional groundwater flow pattern for the deeper aquifers (Gordon and Dublin-Midville) is toward the Savannah River, and the overall pressure gradient in this area of the site is upward. As detailed elsewhere in this report, historical operations from E-Area and F-Area have resulted in groundwater contamination that impacts portions of the SPD project area.

## 2.5 Existing Monitoring Sites

A number of active and inactive sampling sites are located in the SPD project area. These include wells and sampling sites for liquid, soil, and/or vegetation. Tables 3 and 4 and figures 3 and 4 provide details on these monitoring points within the SPD project area.

Primary sources of historical monitoring information include the annual SRS environmental reports and quarterly SRS groundwater monitoring reports. A series of reports that details the release of radionuclides— such as tritium, plutonium, and cesium— to the environment has been published by the Savannah River Technology Center (SRTC) and represents a dependable source of historical release information.

# 3. RADIOLOGICAL MONITORING

## 3.1 Inventory

Routine manufacturing operations in F-Area have released quantities of material since operations began there in late 1954. Releases are documented in a series of technical reports issued by SRTC, in an EMS compilation of release data from 1954 to 1988, and in site environmental reports. Major contaminants released from operations include moderately- to long-lived fission products (primarily Cs-137 and Sr-89,90), isotopes of uranium (U-234, U-235, and U-238), plutonium (Pu-238 and Pu-239), and other actinides (Am-241 and Cm-244). Only those radionuclides with a half-life greater than one year have been considered for this report; likewise, noble gasses have been excluded. Except for tritium, airborne releases through 1999 totaled approximately 739 Ci, and direct liquid releases to streams totaled approximately 768 Ci. Because of changes in F-Area operation requirements, release rates vary both by radionuclide and by year. The majority of activity was released before 1970; although actual release rates vary with radionuclide. Table 5 details the quantities of materials released from F-Area.

## 3.2 Air Pathway

Exposure vectors considered in the air pathway include the airborne release of material from F-Area and the deposition of airborne material. Air and soil samples collected and analyzed through EMS's air surveillance and soil surveillance programs represent the environmental media that indicate the impact of this material.

### 3.2.1 Program Descriptions

The SRS air surveillance program consists of monitoring locations in and around the site at which ambient air samples are collected. Changes in the program requirements have resulted in both the addition and the elimination of certain monitoring sites. Historically, the monitoring stations have been divided into four networks: on site, at the site perimeter, at the 25-mile radius and at distant locations in major population centers. The media sampled by the air surveillance program consists of airborne particulates, volatiles, and atmospheric moisture.

In support of the SPD project, three monitoring sites are of particular interest--the F-Area, Burial Ground North, and Highway 301 stations. The F-Area site is located inside the F-Area fenceline on the northwest side. It is fairly close to SPD Area 1 and was operational until 1998. The Burial Ground North site is located along the outside of the old radioactive waste burial ground fenceline on the northwest side. It is fairly close to SPD Area 4 and has been operational since 1982. The Highway 301 site is located near the U.S. Highway 301 bridge across the Savannah River. It is in the least prevalent wind direction from SRS and represents the regional control site. It has been operational since 1965. Additional information about the SRS air surveillance program appears in the WSRC Environmental Monitoring Program document.

The SRS soil (deposition) program consists of monitoring locations in and around the site at which the deposition of airborne activity is measured. Changes in program requirements have resulted in both the addition and the elimination of certain monitoring sites. Historically, the media sampled has consisted of soil and/or rainwater.

In support of the SPD project, four soil monitoring locations are of particular interest— the F-Area 2000 E (F-E), F-Area 2000 W (F-W), F-Area 2000 N (F-N), and F-Area 2000 S (F-S) sites. Also, soil sampling for a consistent regional background characterization was begun in 1997 at the U.S. Highway 301 station. The F-E soil site is located in SPD Area 2, approximately 2000 feet east of the F-Area main stack. It was operational from 1976 to 1995. The F-N soil site is located in SPD Area 5, approximately 2000 feet north of the F-Area main stack. It also was operational from 1976-1995. The F-W soil site is located approximately 2000 feet west of the F-Area main stack. It has been operational since 1976. The F-S soil site is located approximately 2000 feet south of the F-Area main stack. It was operational from 1976 to 1996. Although the F-W and F-S sites are not located in the SPD project area, they provide additional information on soil radionuclide concentrations in the vicinity of F-Area that resulted from F-Area operations. Additional information about the SRS soil surveillance program appears in the WSRC Environmental Monitoring Program document.

### 3.2.2 Analytical Results

Analytical results from the air and soil surveillance programs from 1965 through 1999 were examined. These results are presented in figures 6 through 65. As with the numbers and locations of monitoring sites, changing program requirements and laboratory analytical capabilities have resulted in analytical protocols that vary from year to year. Based on the source term, environmental behavior, and exposure potential, key radionuclides are Sr-89,90, Cs-137, Pu-238, and Pu-239; where available, gross alpha and gross beta results are useful in providing general trending information.

A special one-time survey of soil in F-Area was conducted in 1973, during which 10 locations were sampled. Although the exact locations of the samples cannot be determined, the survey provides additional information on radionuclide levels in soil in and around F-Area. Results of this survey are presented in table 6.

## 3.3 Surface Water Pathway

Exposure vectors considered in the surface water pathway include the direct liquid release of material from FArea and the deposition of this material in stream beds. Liquid samples quantify the release and transport of the material, while sediment samples represent the indicating environmental media for long-term changes. These samples are collected and analyzed through EMS's liquid effluent, liquid surveillance, and sediment surveillance programs.

### 3.3.1 Program Descriptions

Overall, the liquid effluent program consists of a number of SRS monitoring sites at which samples of process discharge (effluent) water are collected. From these samples, the quantity of material directly released to the environment is determined. The liquid surveillance program consists of a number of monitoring sites located in and around SRS at which samples of stream and Savannah River water are collected. Generally, these sites are located downstream of a facility's process effluents, downstream of groundwater seeps, and downstream of the confluence of streams or tributaries with other tributaries, major streams, and/or the Savannah River. Changes in program requirements have resulted in both the addition and the elimination of certain monitoring.

In support of the SPD project, three monitoring sites are of particular interest— the Upper Three Runs-2 (U3R-2), Upper Three Runs-F3 (U3R-F3), and F-05 stations. Upper Three Runs-2 is an effluent monitoring site located in SPD Area 1 on the northwest side of F-Area. It receives nonprocess discharges and stormwater runoff from the northeast portion of F-Area. Upper Three Runs-F3 is an environmental surveillance monitoring site located in SPD Area 2 on the northwest side of F-Area. It receives stormwater runoff from the vicinity of the Naval Fuels Facility. The F-05 site is an environmental surveillance location located on the northeast side of FArea and is located in SPD Area X. It receives nonprocess water and stormwater runoff from the northeast portion of F-Area. Additional information about the SRS liquid effluent and liquid surveillance programs appears in the WSRC Environmental Monitoring Program document.

The sediment surveillance program consists of sites located in and around SRS at which the deposition of waterborne activity is measured. Changes in program requirements have resulted in both the addition and the elimination of certain monitoring sites. No sediment monitoring stations have been located in or near the SPD project area. Additionally, no sediment monitoring stations are located near areas where tributaries associated with the SPD project discharge into Upper Three Runs.

### 3.3.2 Analytical Results

Analytical results from the liquid effluent and surveillance monitoring programs from 1965 through 1999 were examined. As with the numbers and locations of monitoring sites, changing program requirements and laboratory analytical capabilities have resulted in analytical protocols that vary from year to year. Most process-related activity released from F-Area was discharged to seepage basins. Specific monitoring results are not presented, but are summarized in table 5. These results show that the majority of activity released to streams was H-3. Based on source term, environmental behavior, and exposure potential, key radionuclides are Sr89,90, Cs-137, U-234,

U-235, U-238, Pu-238, and Pu-239; where available, gross alpha and gross beta results are useful in providing general trending information.

# 4. NONRADIOLOGICAL (CHEMICAL) MONITORING

Information about releases of nonradiological material (chemicals) from F-Area is less detailed than it is about releases of radiological contaminants. Releases of chemicals from site facilities were examined during the first two phases of the SRS dose reconstruction project authorized by DOE and completed by the Centers for Disease Control in 1998. Although actual amounts released were not estimated, chemicals of specificconcern which may result in offsite impacts were identified.

Chemicals released via the air pathway that were examined included ammonia, ammonia nitrate, benzene, chlorinated solvents, chromium, coal and coal ash, gasoline and other fuel oils, hydrazine mononitrate, hydrogen sulfide, lead, manganese compounds, mercury, nickel, nitric acid, oxides of nitrogen, sulfur dioxide, and uranium. Chemicals released via the liquid pathway that were considered included arsenic, cadmium, chromium, coal and coal ash, gasoline, hydrogen sulfide, lead, manganese, mercury, nickel, nitrates, uranium, and zinc. From these analyses, the following chemicals were identified as those released in quantities large that could have posed an adverse health effects: ammonia, nitrate, cadmium, chromium, hydrazine, mercury, manganese, nitric acid, and oxides of nitrogen.

SRS airborne releases are regulated to ensure compliance with the Clean Air Act, while the site's liquid releases are regulated to ensure compliance with the Clean Water Act as implemented by the National Pollutant Discharge Elimination System (NPDES). As indicated in tables 3 and 7, three active NPDES outfalls are located in the SPD project area. The constituents monitored at these outfalls are identified in table 7. From this, it may be assumed that F-Area processes have some potential to release and/or impact these constituents.

# 5. GROUNDWATER MONITORING

Because of SRS operations, considerable groundwater contamination exists in the vicinity of separation and waste management areas. Sources of this contamination include buried material in E-Area and in seepage basins. Areas of concern in terms of the SPD project consist of the old F-Area seepage basin (located in SPD Area 1) and contamination originating from E-Area (which impacts SPD Areas 4 and 5). Figure 6 shows the extent of contaminated groundwater plumes, as indicated by tritium. As figure 6 shows, the most significant plume relating to the SPD project originates from the northwest portion of E-Area and has moved in a northwest direction towards Upper Three Runs. This plume impacts SPD Areas 4 and 5.

Figure 6 shows the extent of the tritium-contaminated groundwater plumes, but E-Area releases a variety of other contaminants as well. The extent of groundwater contamination by other materials depends on their mobility; tritium is the most mobile. The only other contaminant showing a significant plume impacting the SPD project area is volatile organic compounds (VOC), although the plume is much smaller. However, other contaminants may be present.

There are 76 wells in the SPD project area, of which 37 are active (table 4). Figure 3 shows the water contours and the locations of monitoring wells. Analytical results are from these wells are not included in this report, but they have been tabulated and are available electronically. In addition to tritium and VOCs, a number of other contaminants are found in one or more wells at concentrations above their respective limits as established by the U.S. Environmental Protection Agency in the Safe Drinking Water Act's primary drinking water standards.

# 6. OTHER CONSIDERATIONS

Other environmental issues— such as unusual events/releases and ecological studies— were considered as part of this historical data summary. The major source of this information was personal conversations with individuals from a number of research, regulatory, and operational organizations.

A number of unusual operating events at F-Area have resulted in the unanticipated release of radioactive and/or nonradioactive material to the environment. Generally, the material was released to seepage basins (in the case of liquid releases) or was confined to the ground within F-Area (in the case of atmospheric releases). All known releases that may have impacted the environment have been categorized as known waste units orECODs. No site evaluation units or documented events have resulted in contamination within the SPD project area (Gracy, 2000).

The SPD project area contains a diverse ecosystem, well suited to environmental and ecological research. However, neither SRTC nor the Savannah River Ecology Laboratory have indicated that active research is ongoing in the project area (Friday, 2000; Gladden, 2000; Hinton, 2000).

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## TABLE 1
## SPD Project Potential Construction Sites

| Location | Area (acres) | Area ($m^2$) |
|---|---|---|
| X | 25.36 | 1.026e+5 |
| 1 | 25.09 | 1.015e+5 |
| 2 | 24.81 | 1.004e+5 |
| 2A | 8.04 | 3.254e+4 |
| 3 | 25.09 | 1.015e+5 |
| 4 | 45.85 | 1.855e+5 |
| 5 | 25.09 | 1.015e+5 |
| 5A | 17.50 | 7.085e+4 |

## Table 2
## Waste Units and ECODs within the SPD Project Area

| Waste Unit ID | Waste Unit Name | Index Number | SPD Construction Area |
|---|---|---|---|
| 474-3 | General Area, Other: Process and Sewer Lines as Abandoned, NBN | 474 | 1 |
| 105 | Old F-Area Seepage Basin, 904-49G | 105 | 1 |
| 523-1 | ECODS F-1 (Southeast of F-Ash Basin, 276-0F) | 523 | 4 |
| 523-2 | ECODS F-1 (Southeast of F-Ash Basin, 276-0F) | 523 | 4 |
| 523-4 | ECODS F-1 (Southeast of F-Ash Basin, 276-0F) | 523 | 4 |
| 523-5 | ECODS F-1 (Southeast of F-Ash Basin, 276-0F) | 523 | 4 |
| 276 | F-Area Ash Basin, 288-0F | 276 | 4 , 5 |
| 16-2 | Mixed Waste Management Facility (including the RCRA Regulated Portions of LLRWF 643-7E), 643-28E | 16 | 5 |
| 2 | F-Area Acid Caustic Basin, 904-47G | 2 | 5A |
| 284 | F-Area Acid/Caustic Basin (Groundwater) | 284 | 5A |
| 277 | F-Area Ash Basin, 288-1F | 277 | 5A |
| 71 | F-Area Coal Pile Runoff Basin, 289-F | 71 | 5A |

## TABLE 3
## Monitoring Locations within the SPD Project Area

| Sampling Point Name | Monitoring Program | Status | SPD Construction Area |
|---|---|---|---|
| F-02 | NPDES | Active | 1 |
| Upper Three Runs-2 | RAD Liquid Effluent | Active | 1 |
| F-03 | NPDES | Active | 2 |
| F-Area North | RAD Soil Surveillance | Inactive | 2 |
| Upper Three Runs-F3 | RAD Liquid Surveillance | Active | 2 |
| F-007 | NPDES | Inactive | 4 |
| F-Area East | RAD Soil Surveillance | Inactive | 5 |
| OBG-2 | RAD Vegetation Surveillance | Inactive | 5 |
| F-05 | NPDES | Active | X |
| F-05 | RAD ALARA | Active | X |

## Table 4
## Monitoring Wells within the SPD Project Area

| Well Name | Type | Date Installed | Date Abandoned | Catalog ID | SPD Construction Area |
|---|---|---|---|---|---|
| FNB 1 | Mw | 8/9/83 | | FNB1 | 1 |
| FNB 1A | Mw | 11/17/93 | | FNB1A | 1 |
| ZW 20 | | | | ZW20 | 2 |
| BG 93 | Ab,Mw | 10/12/81 | 1/22/97 | BG93 | 3 |
| DRB 1WW | Sp | 2/1/61 | | DRB1WW | 3 |
| F 51 | Ab | 5/18/67 | 1978 | F51 | 3 |
| HMD 2D | Mw | 2/1/91 | | HMD2D | 3 |
| BG 122 | Ab,Mw | | 1/21/97 | BG122 | 4 |
| BG 125 | Ab,Mw | | 1/23/97 | BG125 | 4 |
| BG 38 | Ab,Mw | 5/24/76 | 4/25/88 | BG38 | 4 |
| BG 39 | Ab,Mw | 5/25/76 | 4/22/88 | BG39 | 4 |
| BG 91 | Ab,Mw | 10/6/81 | 1/21/97 | BG91 | 4 |
| BG 92 | Ab,Mw | 10/8/81 | 1/22/97 | BG92 | 4 |
| BGO 11D | Ab,Mw | 8/24/87 | 11/1/95 | BGO11D | 4 |
| BGO 11DR | Mw | 9/7/95 | | BGO11DR | 4 |
| BGO 12A | Ab,Mw | 10/2/87 | 11/1/95 | BGO12A | 4 |
| BGO 12AR | Ab,Mw | 2/21/91 | 1/26/96 | BGO12AR | 4 |
| BGO 12AX | Mw | 10/3/95 | | BGO12AX | 4 |
| BGO 12C | Ab,Mw | 10/1/87 | 2/25/92 | BGO12C | 4 |
| BGO 12CR | Ab,Mw | 3/18/91 | 1/26/96 | BGO12CR | 4 |
| BGO 12CX | Mw | 9/29/95 | | BGO12CX | 4 |
| BGO 12D | Ab,Mw | 9/29/87 | 11/1/95 | BGO12D | 4 |
| BGO 12DR | Mw | 9/12/95 | | BGO12DR | 4 |
| BGO 43A | Mw | 4/26/91 | | BGO43A | 4 |
| BGO 43AA | Mw | 4/1/91 | | BGO43AA | 4 |
| BGO 43CR | Mw | 6/6/91 | | BGO43CR | 4 |
| BGO 43D | Mw | 4/29/91 | | BGO43D | 4 |
| F 43 | Ab | 2/13/67 | 1978 | F43 | 4 |
| F 55 | | 9/19/67 | | F55 | 4 |
| F 56 | | 10/25/67 | | F56 | 4 |
| F 57A | Ab | 10/30/67 | 1978 | F57A | 4 |
| F 57B | Ab | 11/8/67 | 1978 | F57B | 4 |
| F 57C | Ab | 11/8/67 | 1978 | F57C | 4 |
| F 58 | Ab | 11/16/67 | 1978 | F58 | 4 |
| F 59 | | 12/4/67 | | F59 | 4 |
| ZW 4 | Ab,Mw | 9/7/51 | 1/27/97 | ZW4 | 4 |
| BG 40 | Ab,Mw | 5/26/76 | 4/21/88 | BG40 | 5 |
| BGO 13D | Mw | 10/12/87 | | BGO13D | 5 |
| BGO 13DR | Mw | 2/27/91 | | BGO13DR | 5 |
| FAC 6P | Pz | 2/3/92 | | FAC6P | 5 |
| FAC 7 | Ab,Mw | 9/15/88 | 4/4/96 | FAC7 | 5 |
| FAC 8 | Ab,Mw | 9/9/88 | 4/4/96 | FAC8 | 5 |
| FAC 9C | Mw | 6/21/94 | | FAC9C | 5 |

## Table 4 (continued)
## Monitoring Wells within the SPD Project Area

| Well Name | Type | Date Installed | Date Abandoned | Catalog ID | SPD Construction Area |
|---|---|---|---|---|---|
| MZ 6 | Ab | | 1/27/97 | MZ6 | 5 |
| BG 13 | | 6/1/61 | | BG13 | 5A |
| BG 14 | | 5/26/61 | | BG14 | 5A |
| FAB 1 | Mw | 5/13/94 | | FAB1 | 5A |
| FAB 2 | Mw | 5/9/94 | | FAB2 | 5A |
| FAB 3 | Mw | 5/12/94 | | FAB3 | 5A |
| FAB 4 | Mw | 5/10/94 | | FAB4 | 5A |
| FAC 1P | Ab,Pz | 1/28/92 | 4/11/96 | FAC1P | 5A |
| FAC 2 | Ab,Mw | 8/24/83 | 3/10/89 | FAC2 | 5A |
| FAC 3 | Ab,Mw | 8/26/83 | 4/4/96 | FAC3 | 5A |
| FAC 3P | Ab,Pz | 1/21/92 | 4/4/96 | FAC3P | 5A |
| FAC 4P | Ab,Pz | 1/21/92 | 4/4/96 | FAC4P | 5A |
| FAC 5 | Ab,Mw | 9/2/88 | 4/4/96 | FAC5 | 5A |
| FAC 6 | Ab,Mw | 9/15/88 | 4/4/96 | FAC6 | 5A |
| FAC 10C | Mw | 6/21/94 | | FAC10C | 5A |
| FAC 11C | Ab,Mw | 6/24/94 | 4/4/96 | FAC11C | 5A |
| FAC 12C | Ab,Mw | 6/24/94 | 4/4/96 | FAC12C | 5A |
| FCB 1 | Ab,Mw | 10/16/81 | 7/13/88 | FCB1 | 5A |
| FCB 7 | Mw | 7/7/88 | | FCB7 | 5A |
| FAC 2P | Ab,Pz | 1/28/92 | 4/3/96 | FAC2P | X |
| FAC 4 | Ab,Mw | 7/20/84 | 4/3/96 | FAC4 | X |
| FC 2A | | 4/1/77 | | FC2A | X |
| FC 2B | | 4/7/77 | | FC2B | X |
| FC 2C | | 4/14/77 | | FC2C | X |
| FC 2D | | 4/18/77 | | FC2D | X |
| FC 2E | | 4/21/77 | | FC2E | X |
| FC 2F | | 4/22/77 | | FC2F | X |
| P 28A | Mw | 9/27/86 | | P28A | X |
| P 28TA | Mw | 7/8/86 | | P28TA | X |
| P 28TB | Mw | 10/2/86 | | P28TB | X |
| P 28TC | Mw | 10/7/86 | | P28TC | X |
| P 28TD | Mw | 10/9/86 | | P28TD | X |
| P 28TE | Mw | 10/14/86 | | P28TE | X |

Mw: monitoring well
Ab: abandoned
Pz: piezometer
Sp: special

## Table 5
## Inventory of Radionuclides Released from F-Area

| Radionuclide | Liquid Release (Ci)[1] | Airborne Release (Ci)[1] |
|---|---|---|
| Am-241 | 1.85e-5 | 4.68e-3 |
| C-14 | | 6.48e+2 |
| Cm-244 | 7.28e-6 | 5.35e-3 |
| Co-60 | | 1.91e-2 |
| Cs-134 | | 8.56e-4 |
| Cs-137 | 1.00e+0 | 5.97e-1 |
| Eu-154 | | 5.21e-7 |
| H-3 | 7.50e+2 | See note[2] |
| I-129 | | 1.92e-2[3] |
| Pm-147 | 6.13e-2 | |
| Pu-238 | 3.80e-5 | 1.46e-2 |
| Pu-239 | 9.28e-4 | 2.44e+0 |
| Ru-103,106 | | 3.85e+1 |
| Ru-106 | | 3.29e+1 |
| Sb-125 | | 2.93e-3 |
| Sr-89,90 | 3.69e-2 | 6.76e-1 |
| Sr-90 | 2.95e-1 | |
| U (nat) | 5.95e-5 | 5.80e-1 |
| U-234 | 2.13e-4 | 4.02e-4 |
| U-235 | 1.65e-5 | 2.07e-3 |
| U-238 | 4.17e-4 | 2.03e-3 |
| Unidentified Alpha[4] | 2.90e-1 | 7.41e-2 |
| Unidentified Beta[5] | 1.63e+1 | 1.53e+1 |

Notes
[1]Blanks indicate either no quantifiable activity or monitoring for theradionuclide is not conducted.
[2]Airborne releases of tritium from F-Area and H-Area are combined
[3]Releases from F-Area and H-Area combined until 1991.
[4]Assumed to be Pu-239
[5]Assumed to be Sr-89,90

## Table 6
## 1973 F-Area Special Soil Survey
**Results in pCi/g**

| Location | Cs-137 | Sr-90 | Pu-238 | Pu-239 |
|---|---|---|---|---|
| 1 | 3.90E-01 | 3.20E-01 | 4.66E-02 | 3.70E-02 |
| 2 | 3.70E-01 | 4.58E-01 | 1.00E-03 | 3.13E-02 |
| 9 | 5.00E-01 | 2.88E-01 | 3.00E-03 | 3.39E-02 |
| 10 | 5.00E-01 | 4.80E-02 | 9.72E-02 | 3.75E-02 |
| 11 | 3.10E-01 | 1.18E-01 | 6.80E-03 | 1.15E-01 |
| 12 | 3.80E-01 | 3.08E-01 | 7.20E-03 | 1.64E-01 |
| 13 | 4.00E-01 | 5.70E-02 | 4.00E-03 | 5.32E-02 |
| 14 | 2.50E-01 | 1.62E-01 | 2.80E-03 | 1.40E-02 |
| 15 | 5.50E-01 | 3.88E-01 | not detected | 9.36E-02 |
| 16 | 3.20E-01 | 1.40E-01 | 4.80E-03 | 2.89E-02 |

## Table 7
## Current NPDES Monitoring Requirements

| Outfall | Measurement and Monitoring Parameters |
|---|---|
| F-02 | Flow<br>Total suspended solids<br>Temperature<br>pH |
| F-03 | Flow<br>Total suspended solids<br>Temperature<br>pH<br>Lead |
| F-05 | Flow<br>Total suspended solids<br>Temperature<br>pH<br>Oil and grease |

**Figure 1**
**SPD Project Areas with Topography (20'Contours)**

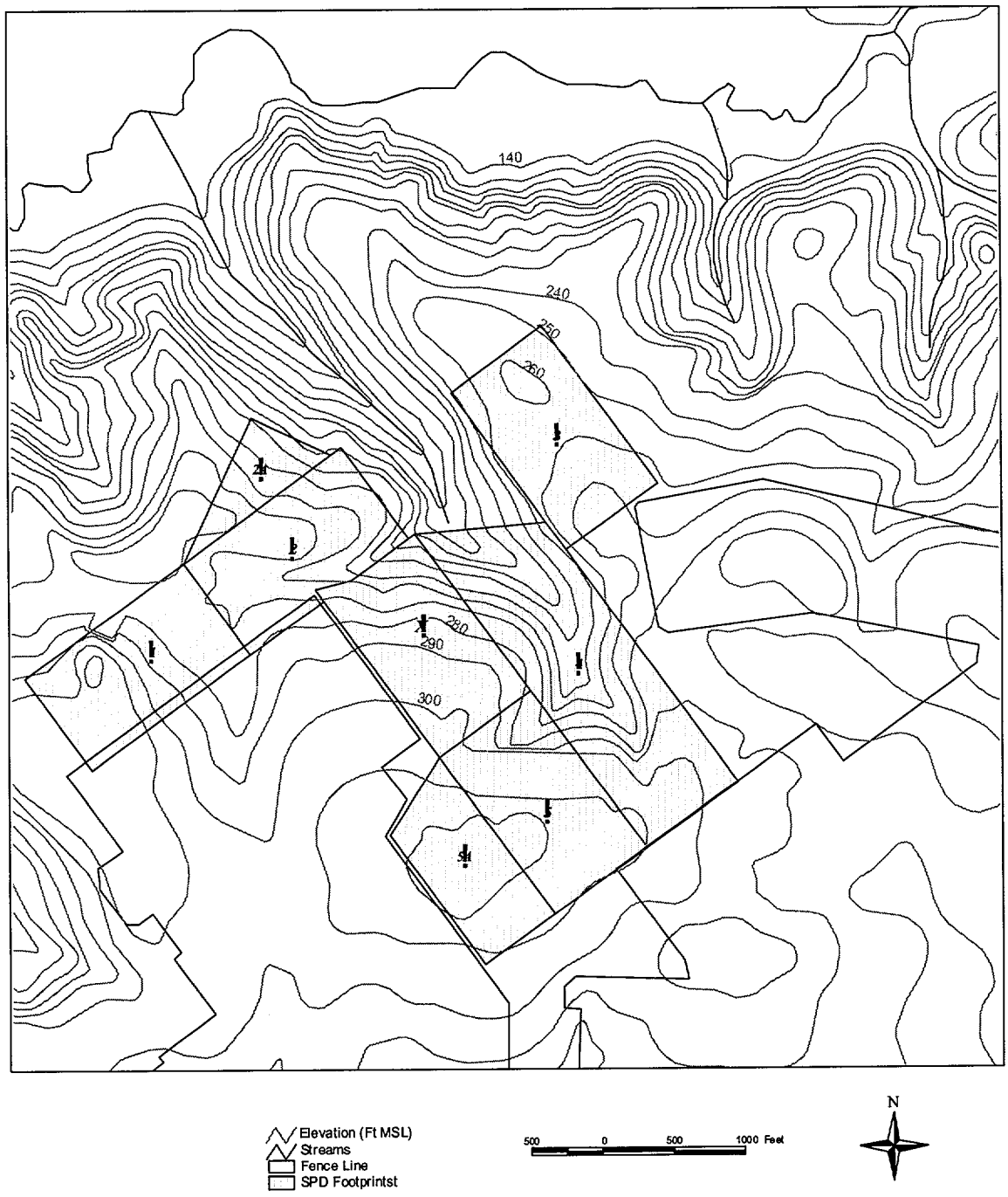


**Figure 2**
**Identified Waste Units and ECODs**

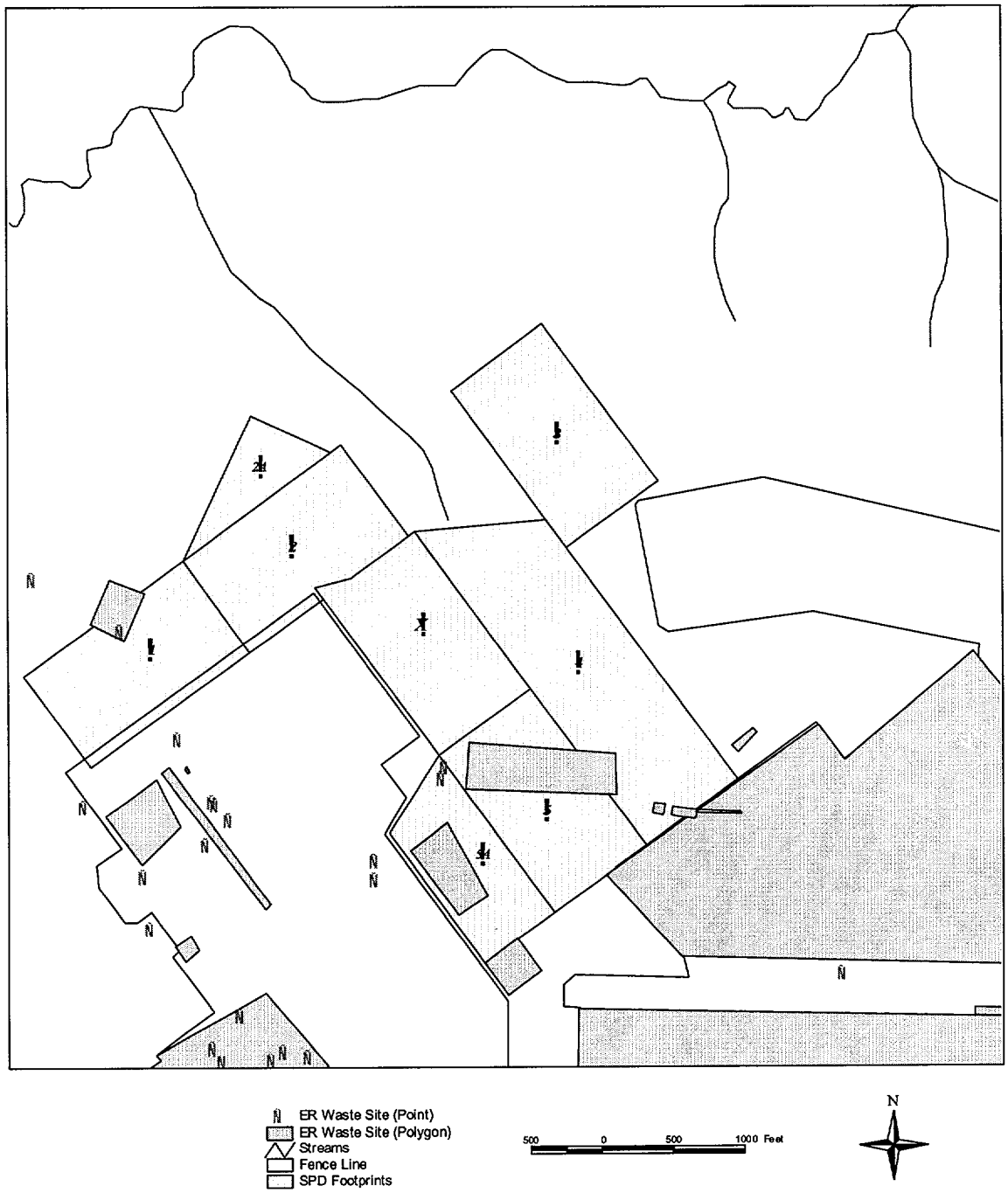


**Figure 3**
**Water Table Elevation and Well Locations**

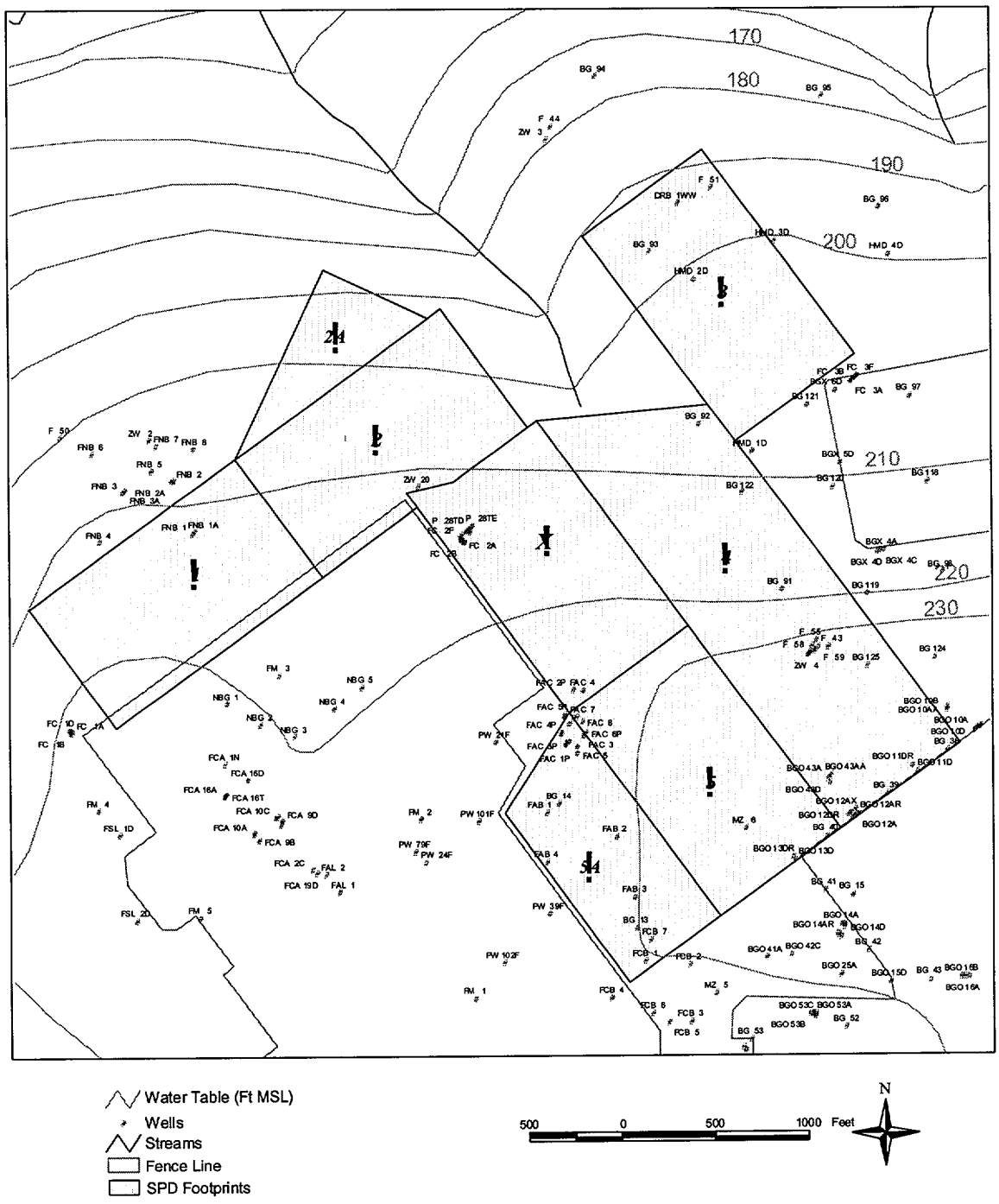


**Figure 4**
**Routine EMS Monitoring Locations**

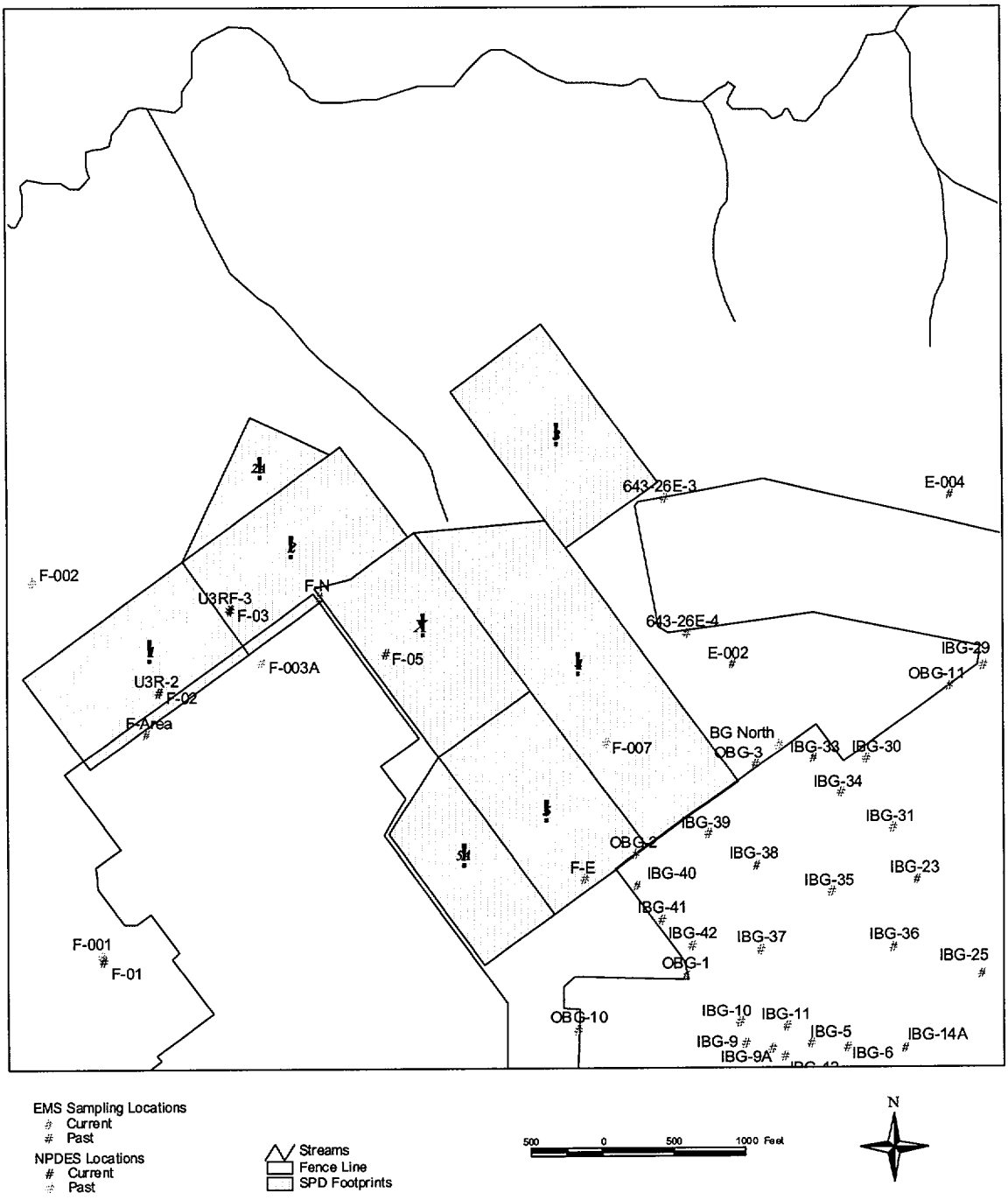


**Figure 5**
**Groundwater Tritium Plumes**

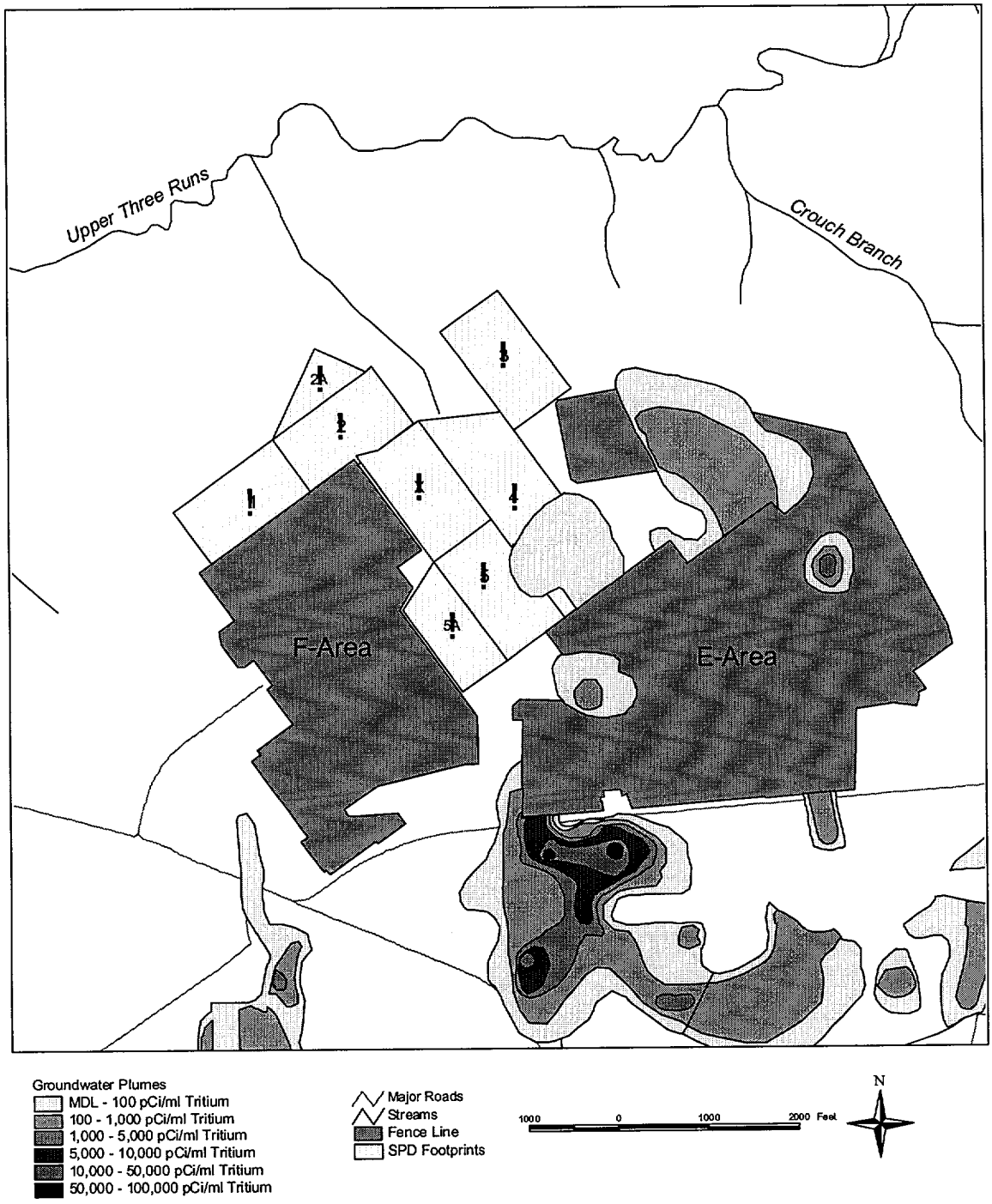


**Figure 6**
**Comparison of Airborne Gross Alpha Concentrations at All Locations**

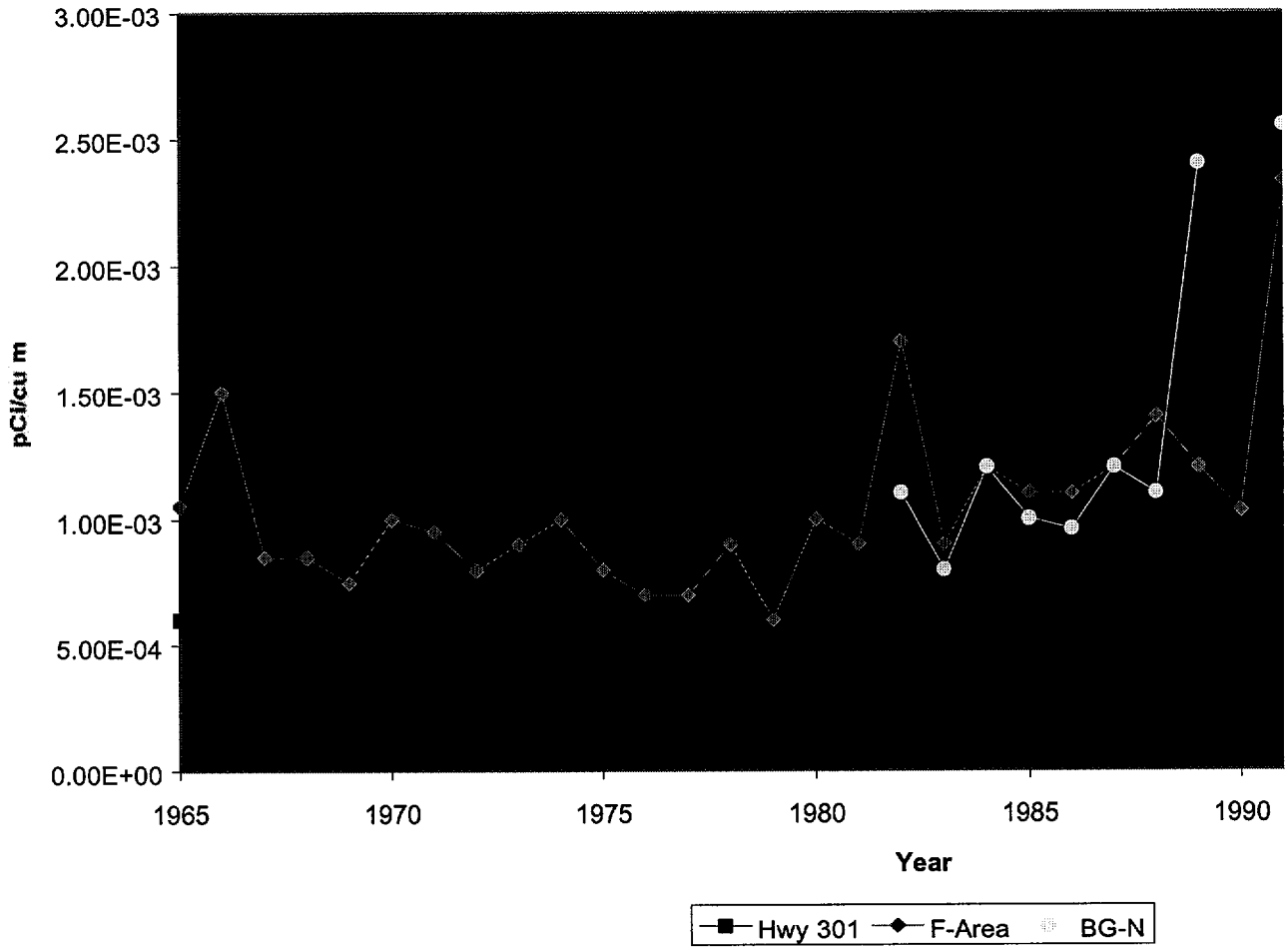


**Figure 7**
**Comparison of Airborne Gross Beta Concentrations at All Locations**

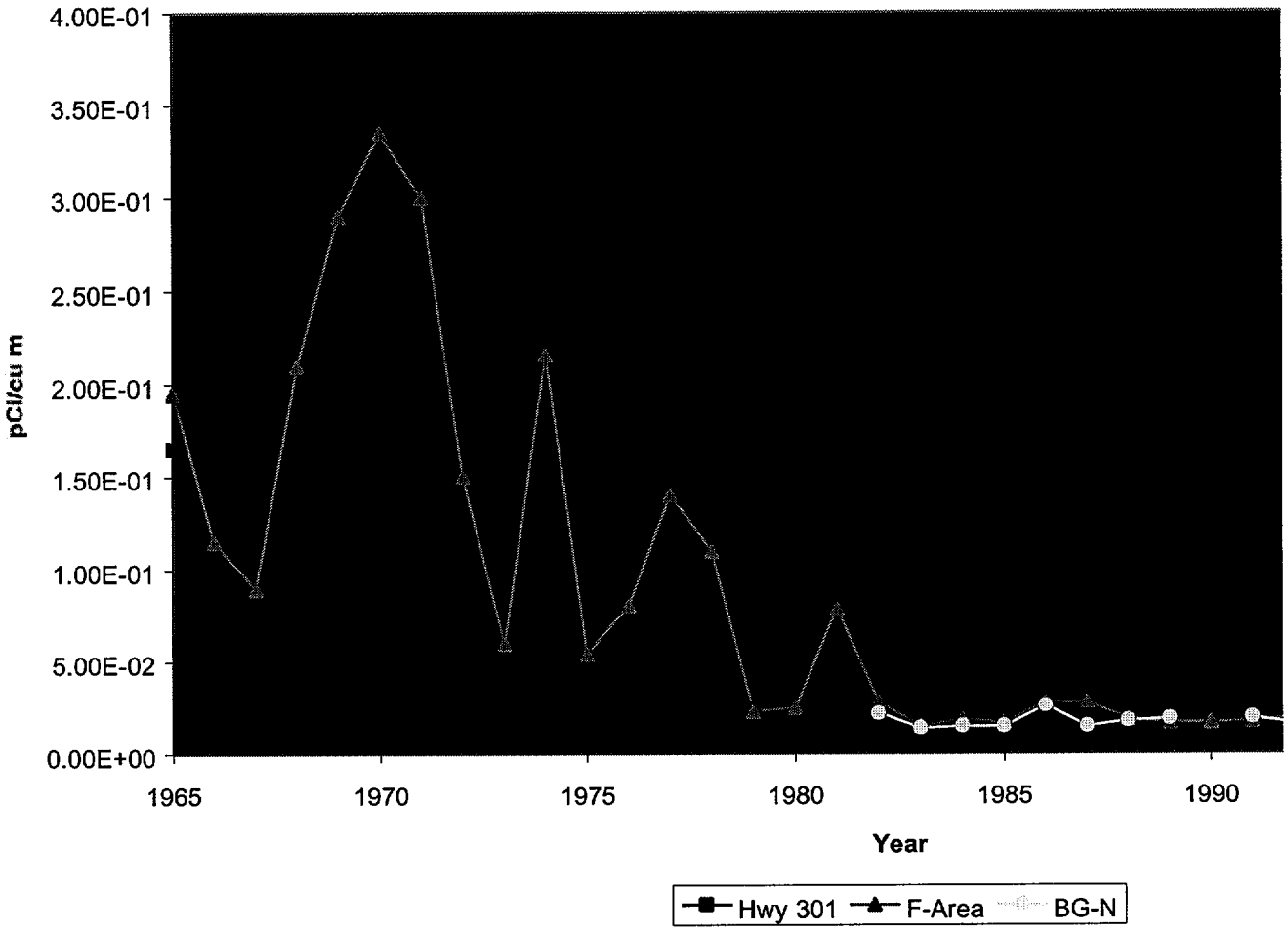


**Figure 8**
**Comparison of Tritium-in-Air**
**Concentrations at All Locations**

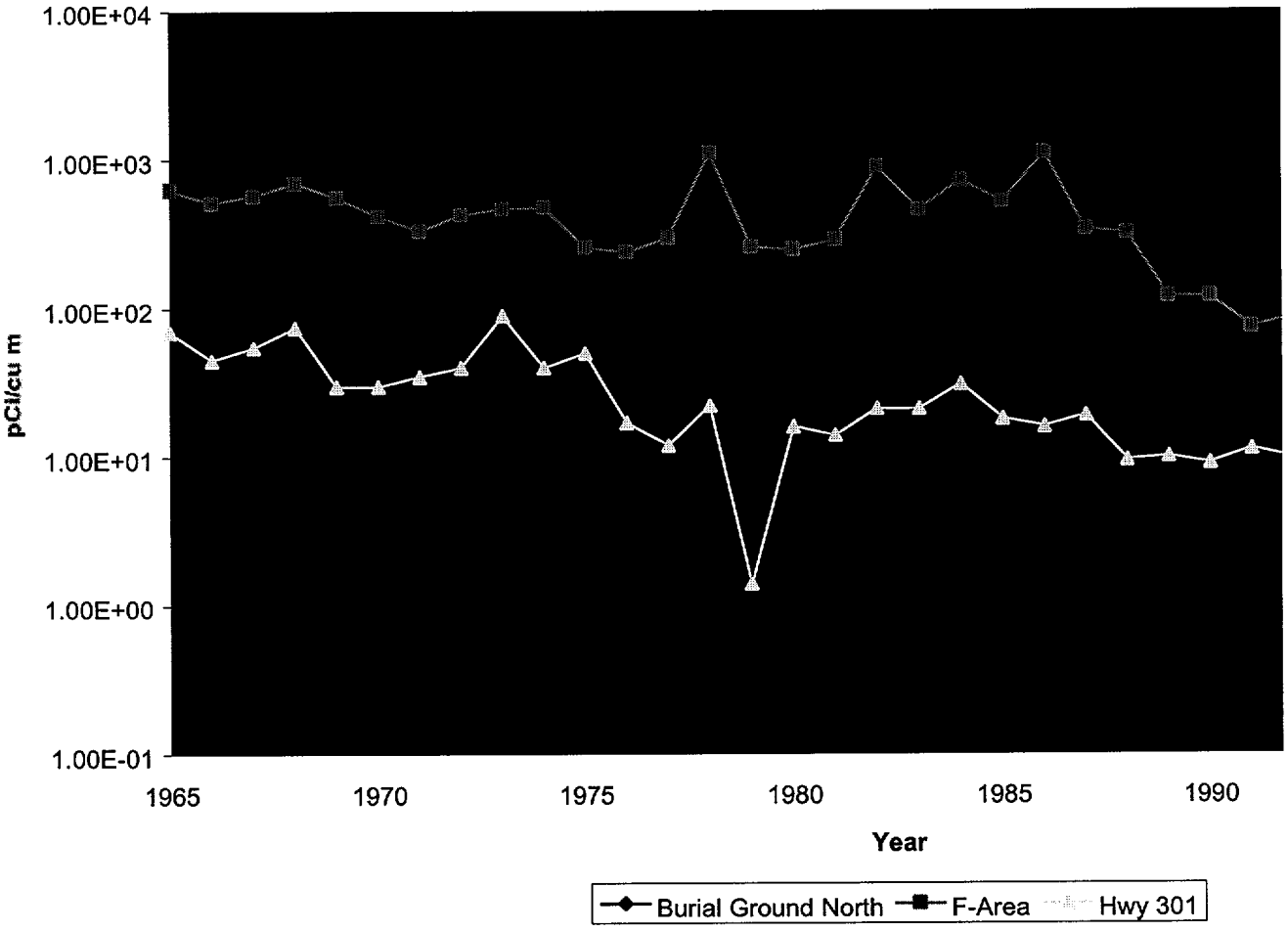


**Figure 9**
**Gross Alpha and Gross Beta Concentrations at F-Area**

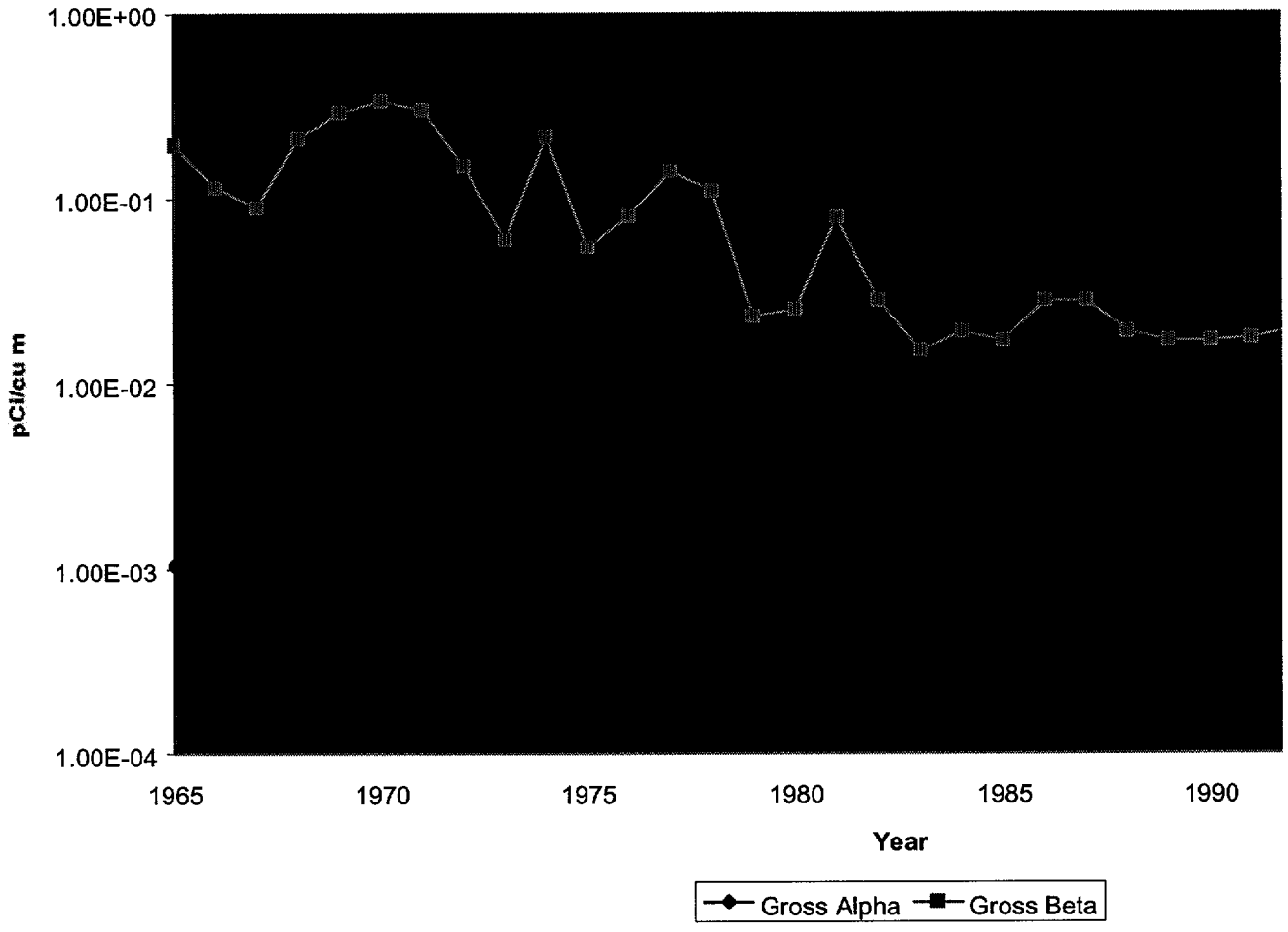


**Figure 10**
**Gross Alpha and Gross Beta Concentrations**
**at Burial Ground North**

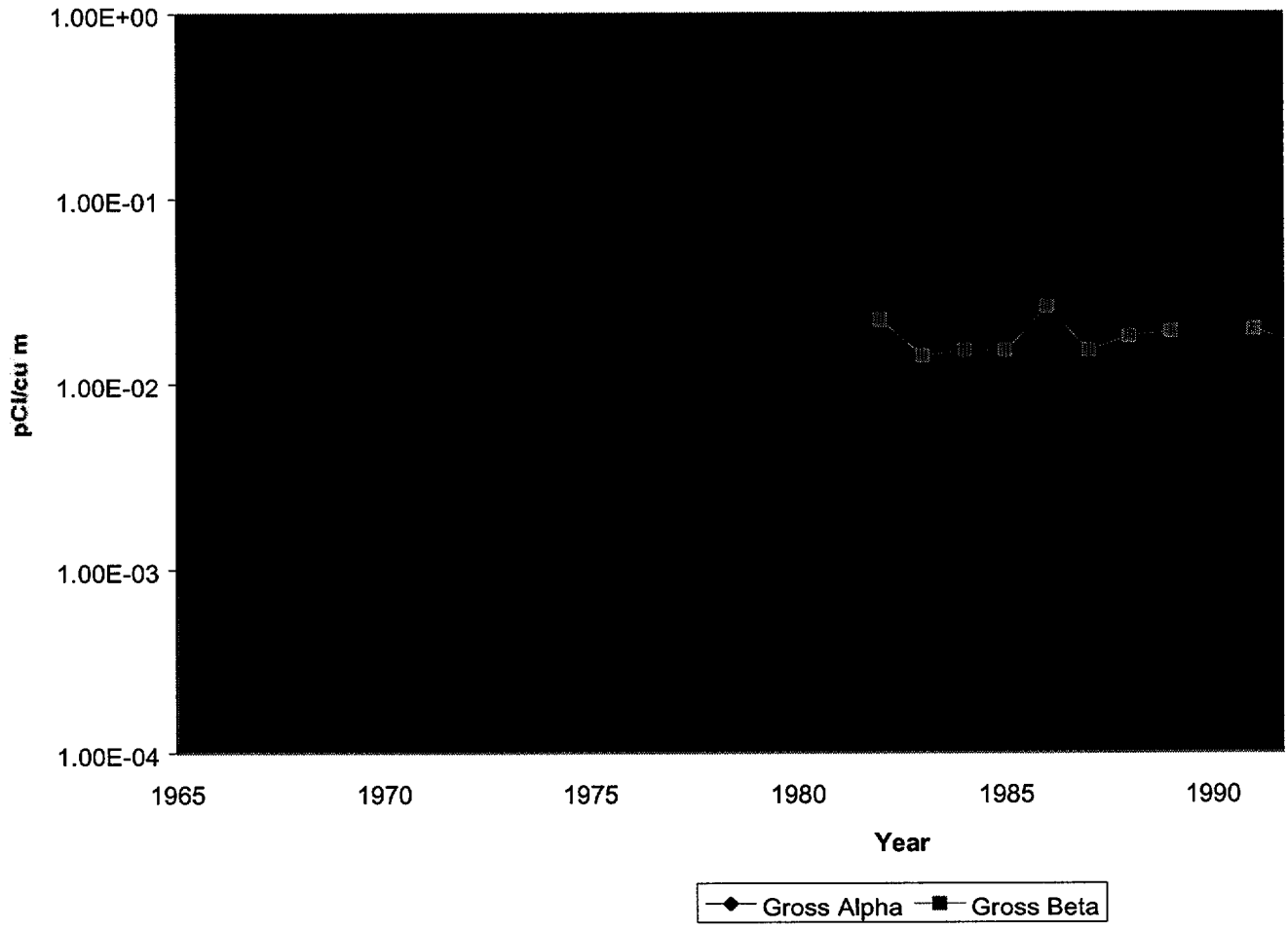


**Figure 11**
**Gross Alpha and Gross Beta Concentrations**
**at U.S. Highway 301**

**Figure 12**
**F-Area Filter Paper Co-60 (Weekly Sample)**

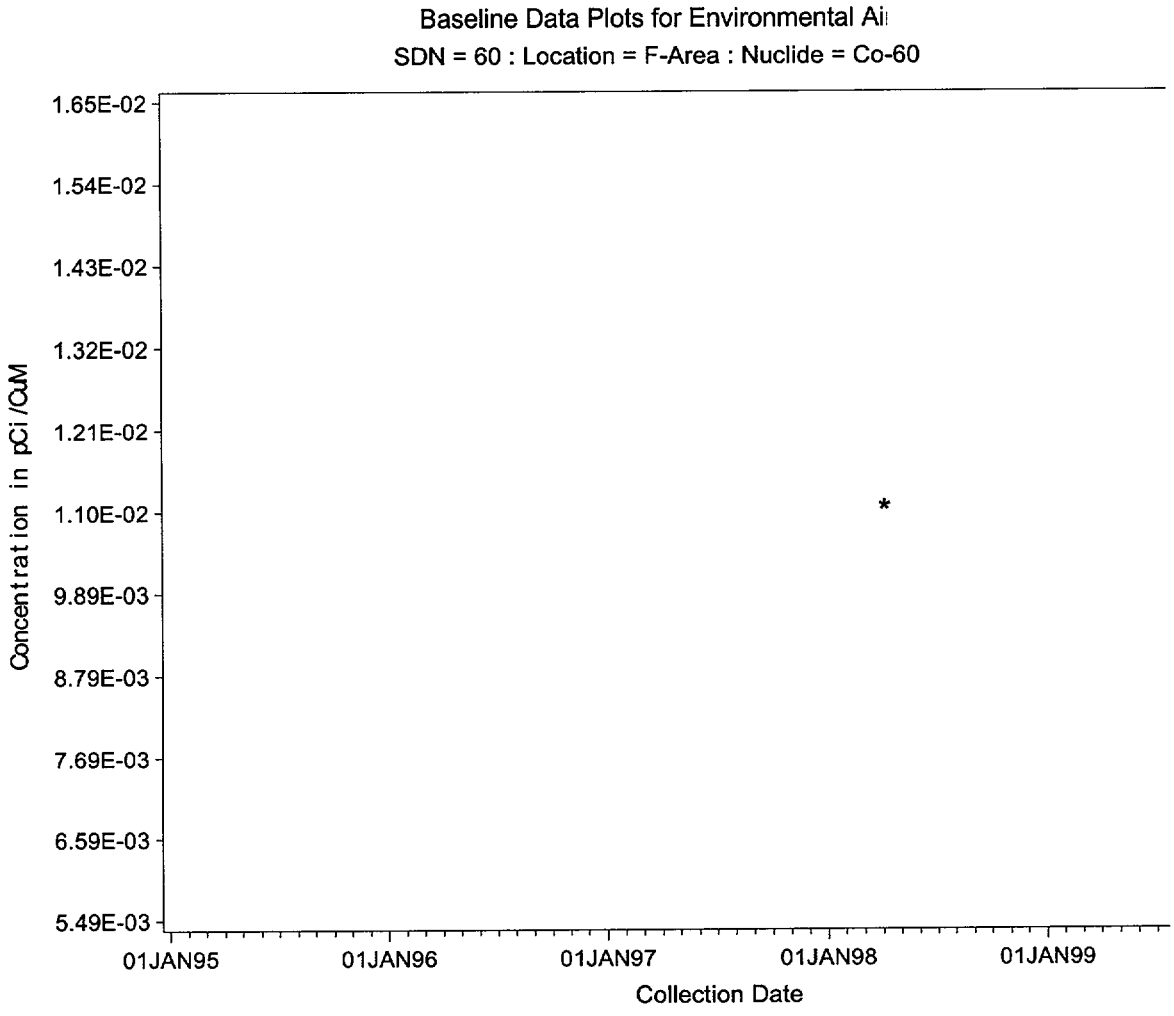


**Figure 13**
**F-Area Filter Paper Cs-137 (Weekly Sample)**

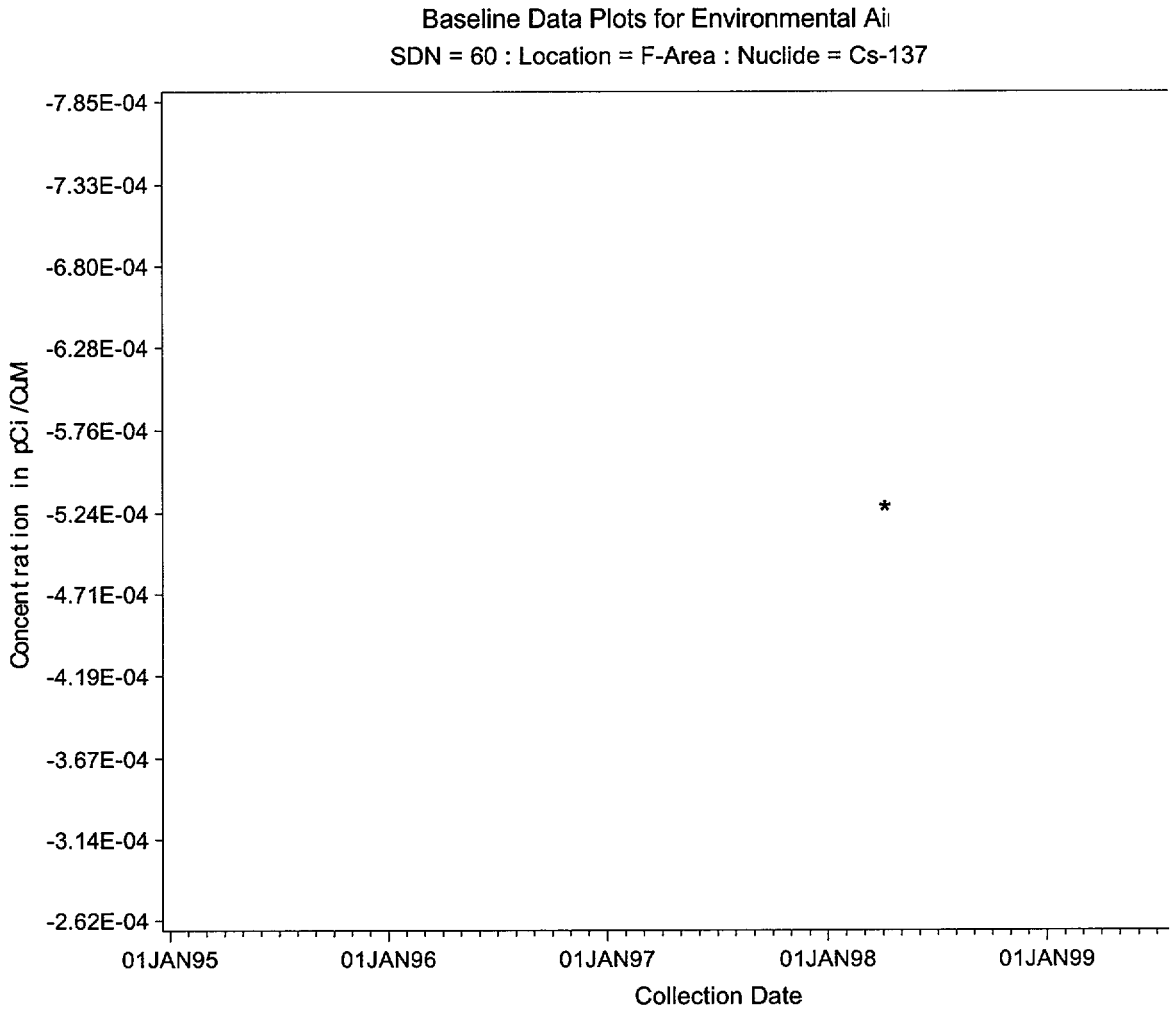


**Figure 14**
**F-Area Filter Paper Gross Beta (Weekly Sample)**

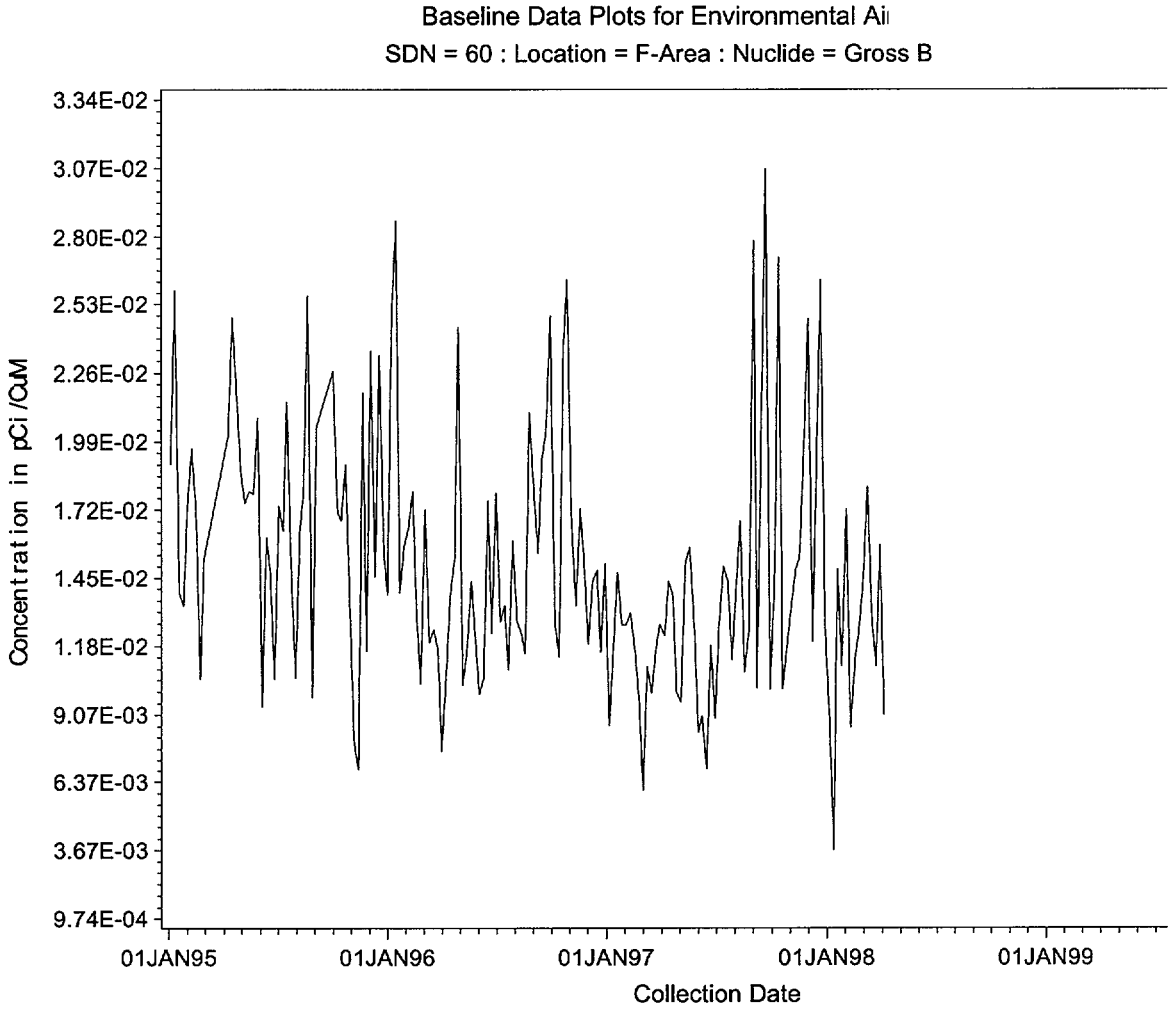


**Figure 15**
**F-Area Filter Paper Gross Alpha (Weekly Sample)**

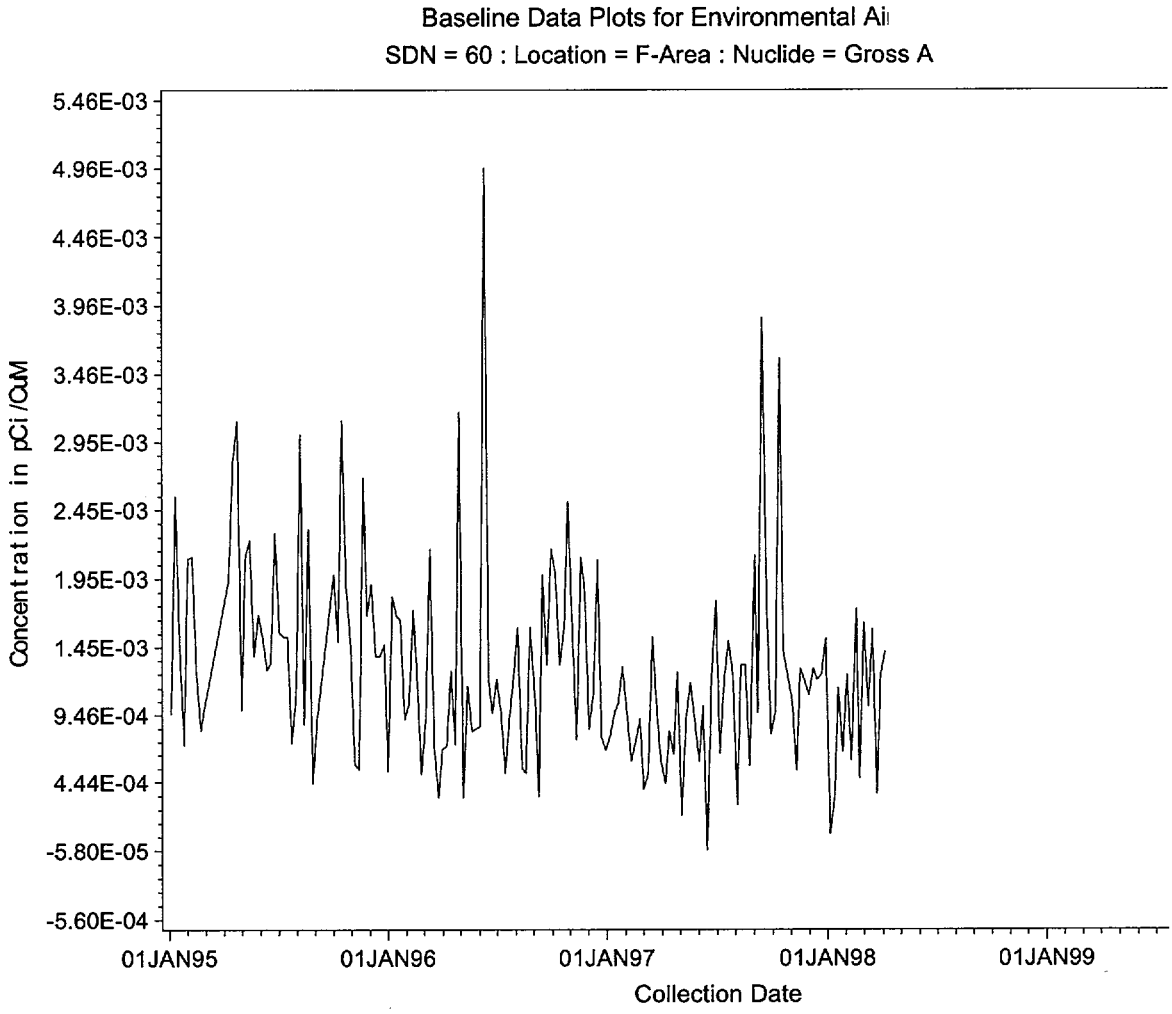


**Figure 16**
**F-Area Filter Paper Co-60 (Monthly Composite)**

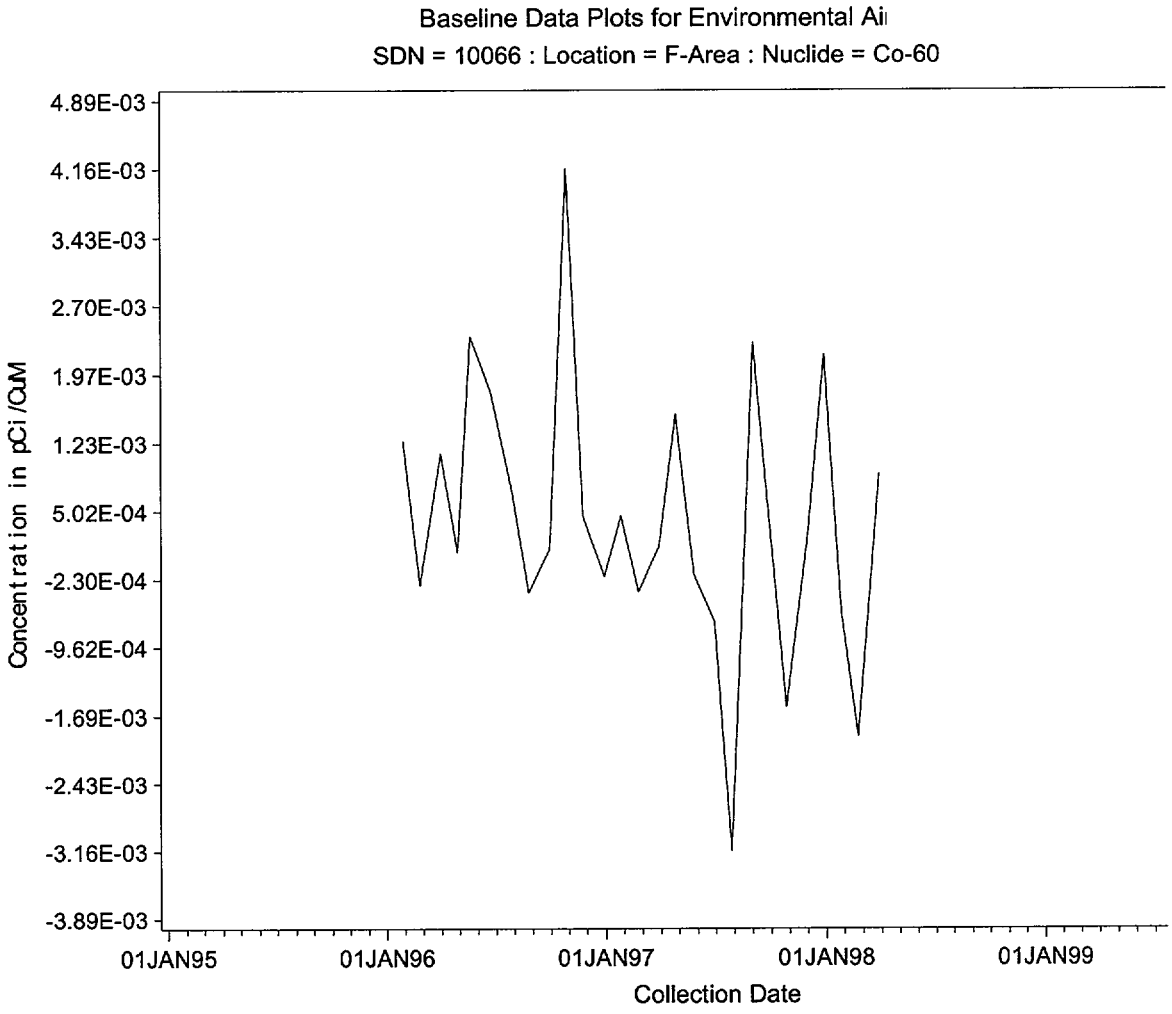


**Figure 17**
**F-Area Filter Paper Cs-137 (Monthly Composite)**

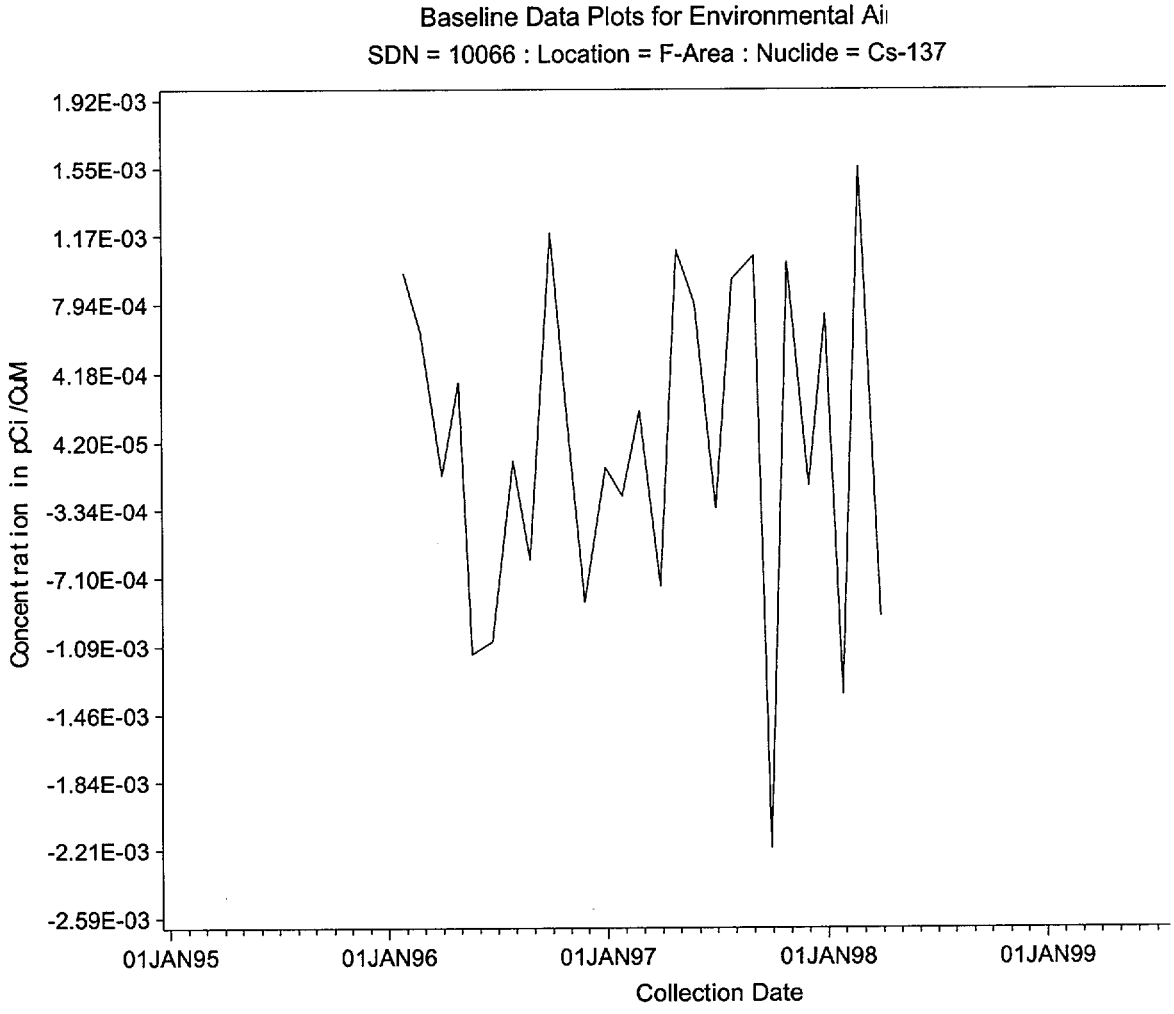


**Figure 18**
**F-Area Filter Paper Pu-238 (Monthly Composite)**

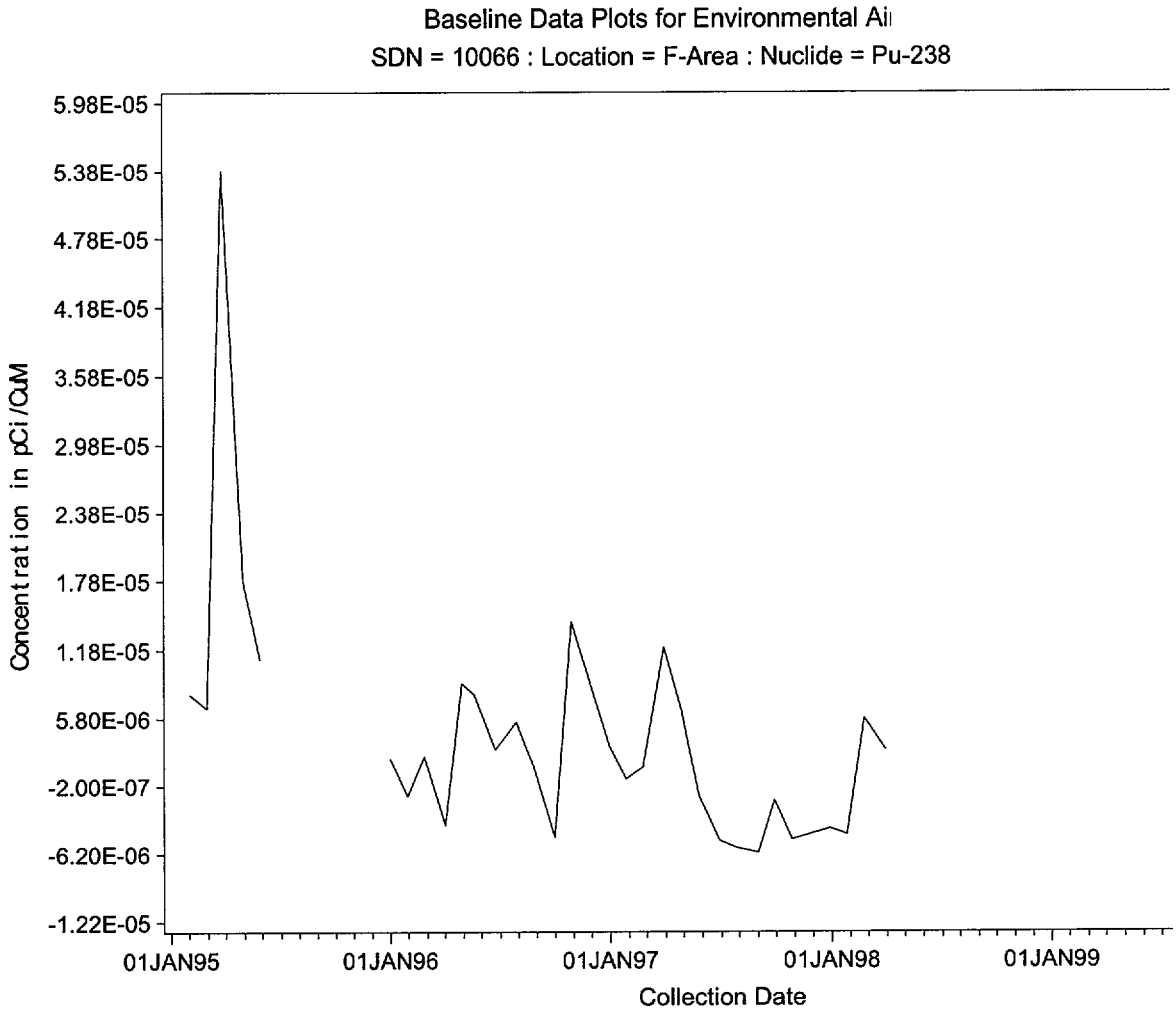


**Figure 19**
**F-Area Filter Paper Pu-239 (Monthly Composite)**

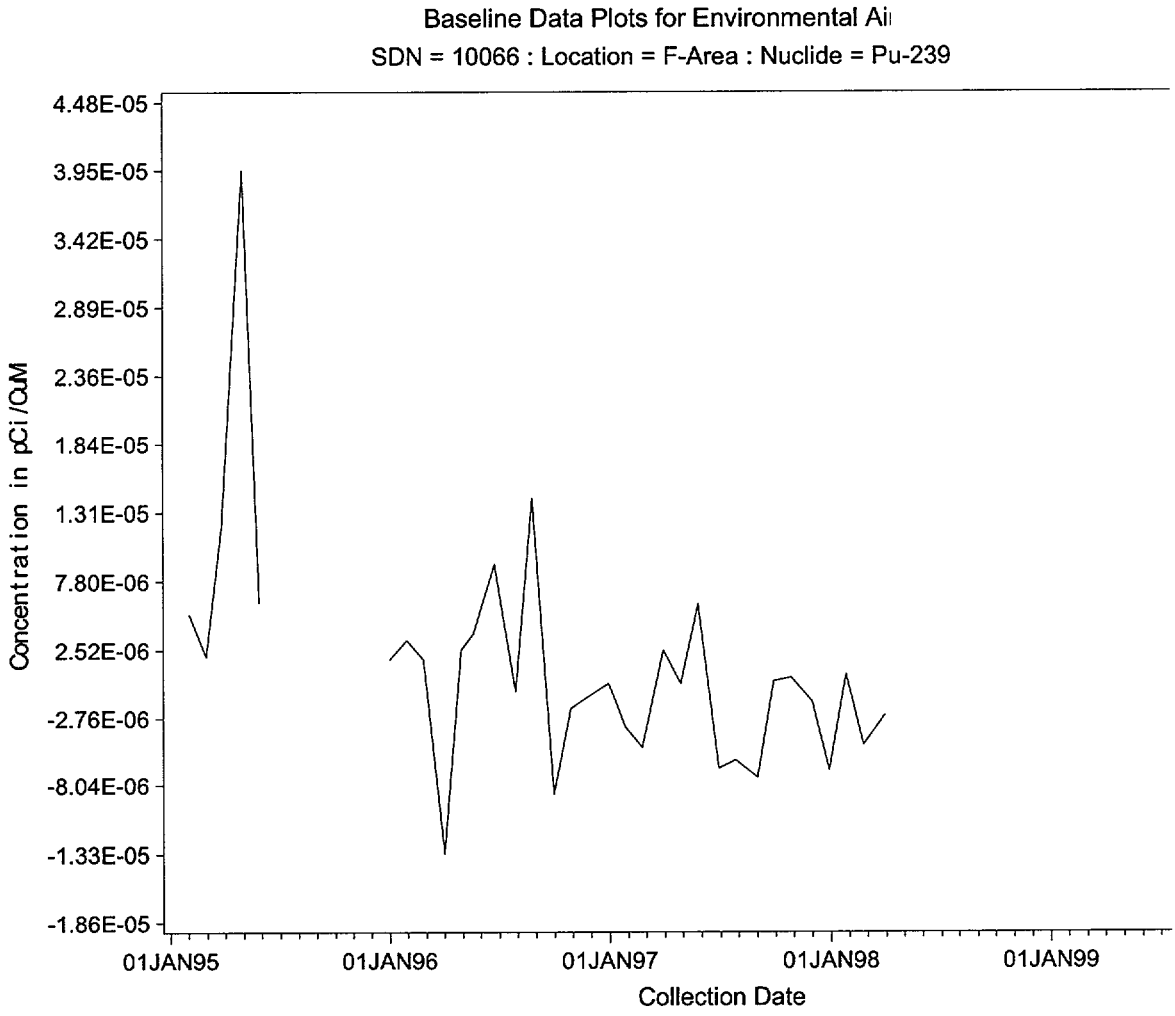


**Figure 20**
**F-Area Filter Paper Sr-89,90 (Monthly Composite)**

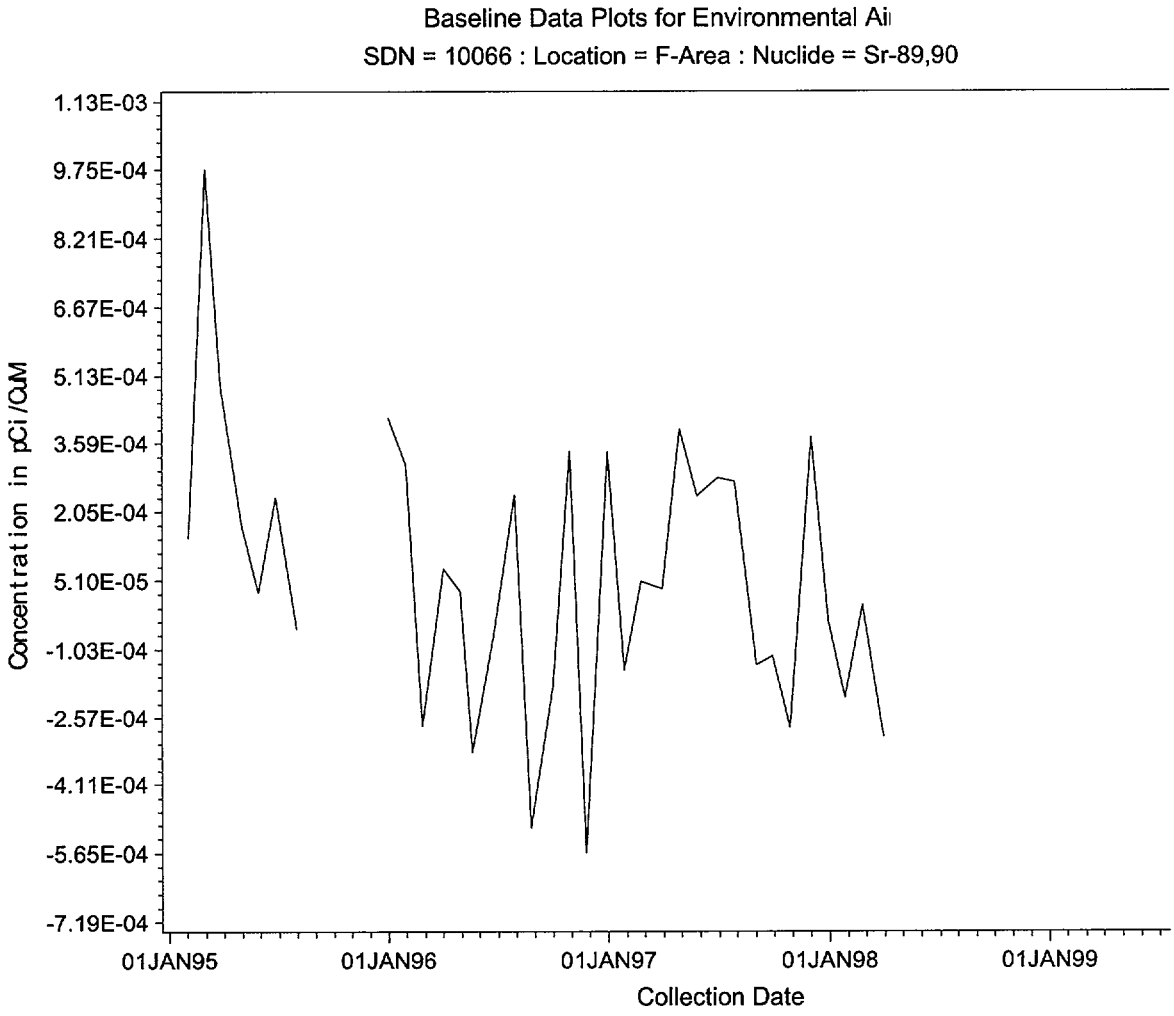


**Figure 21**
**F-Area Charcoal Canister Co-60 (Weekly Sample)**

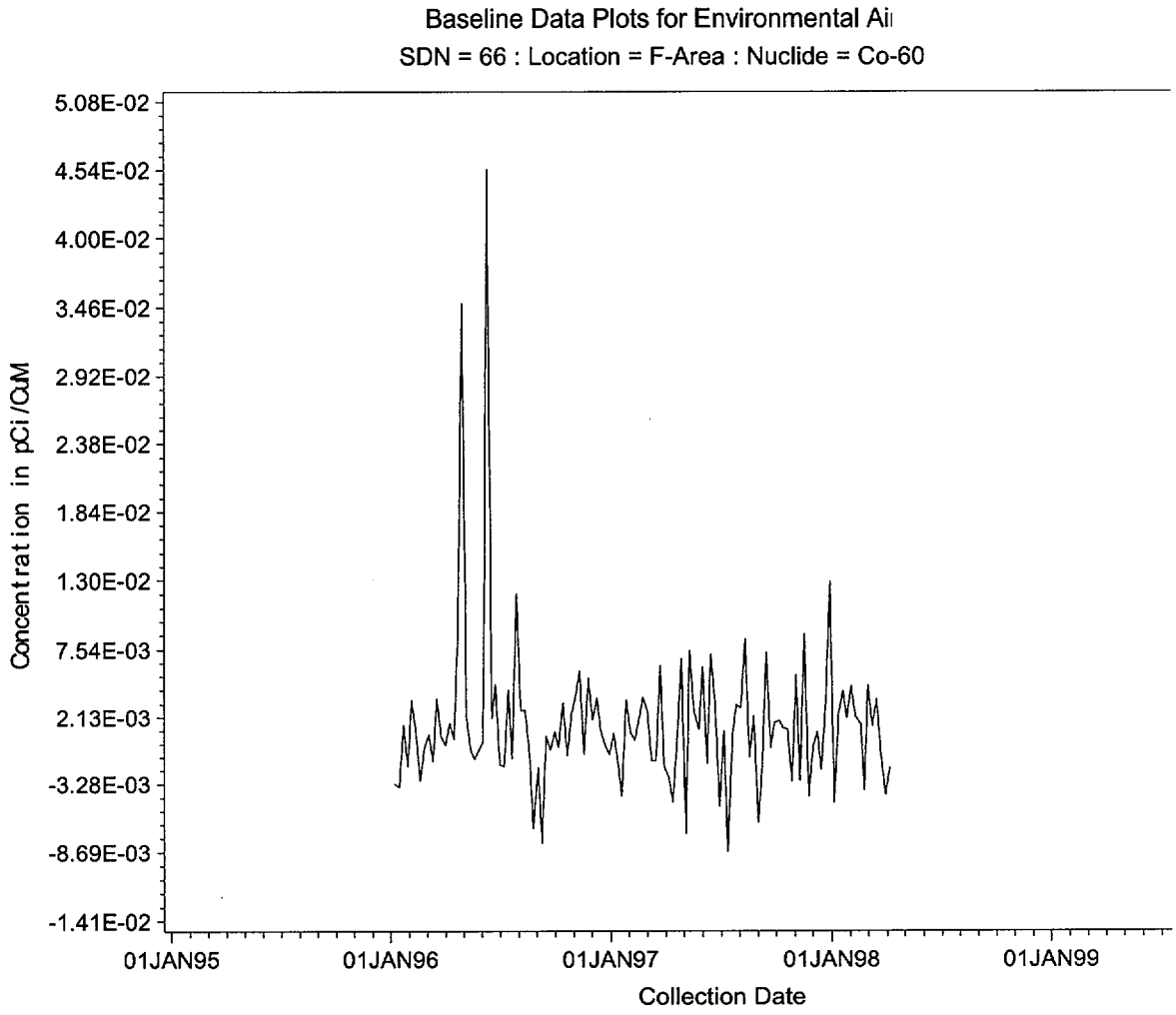


**Figure 22**
**F-Area Charcoal Canister Cs-137 (Weekly Sample)**

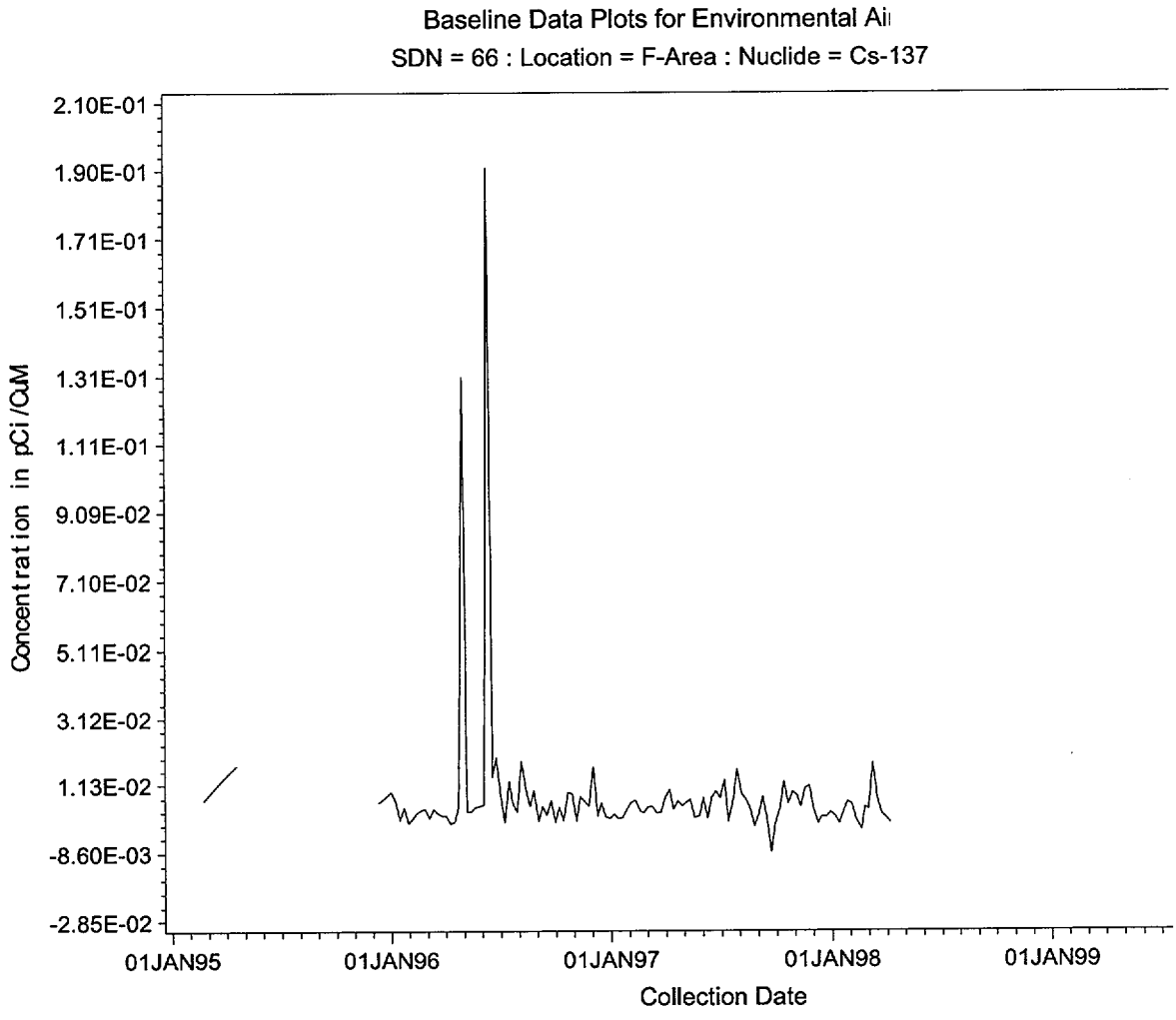


**Figure 23**
**F-Area Silica Gel H-3 (Biweekly Sample)**

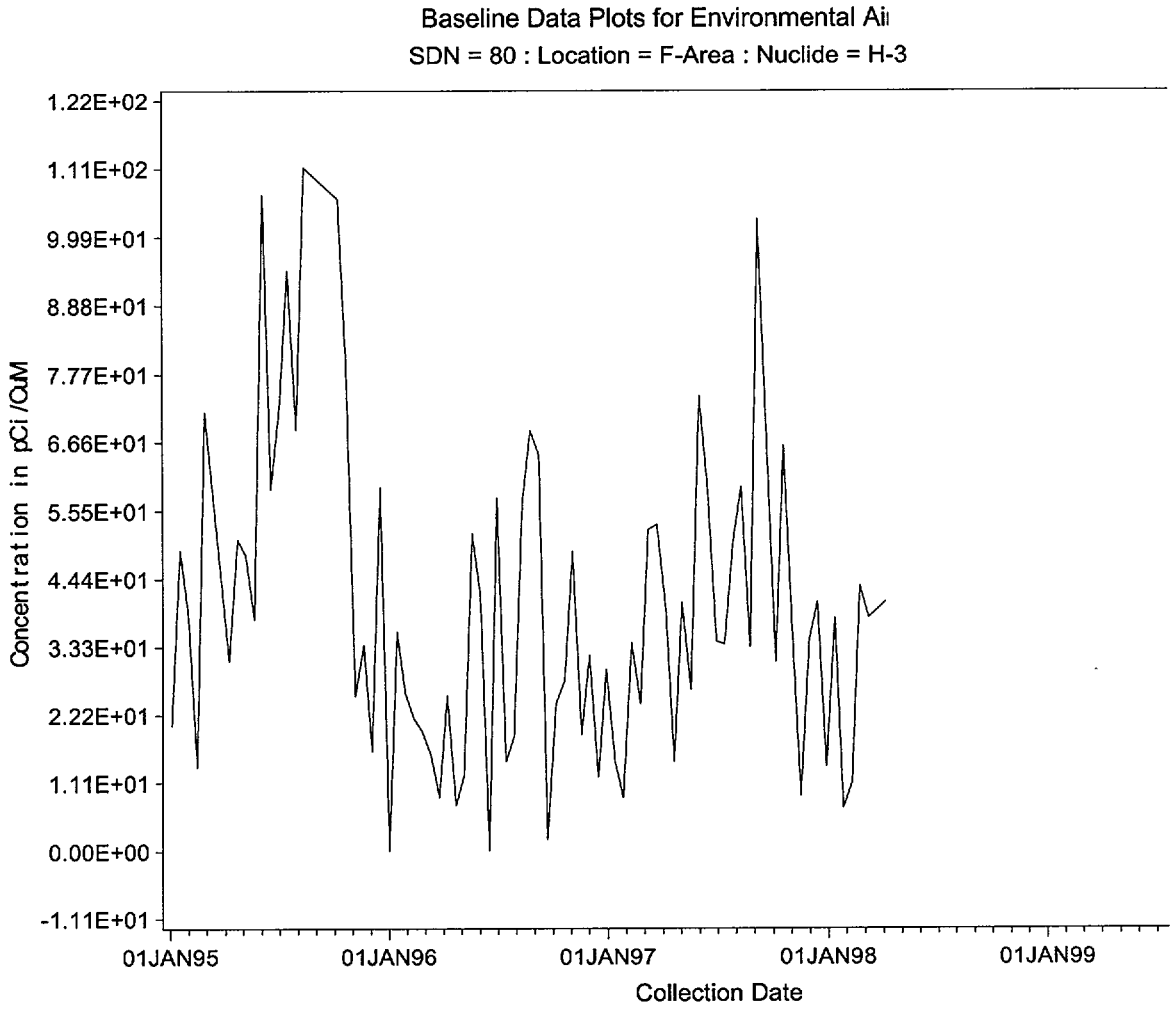


**Figure 24**
**F-Area Rainwater H-3 (Biweekly Sample)**

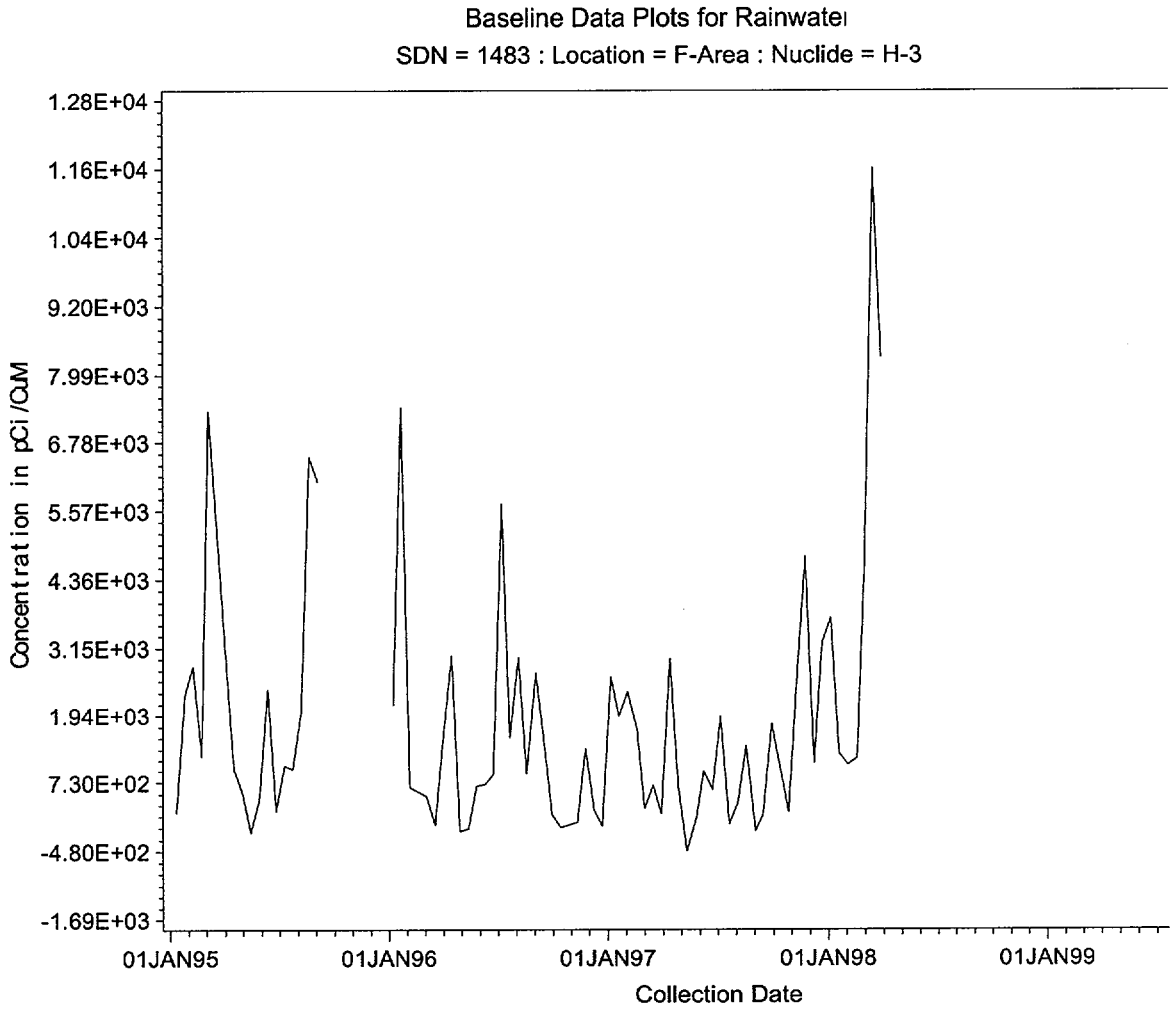


**Figure 25**
**Burial Ground North Filter Paper Co-60 (Weekly Sample)**

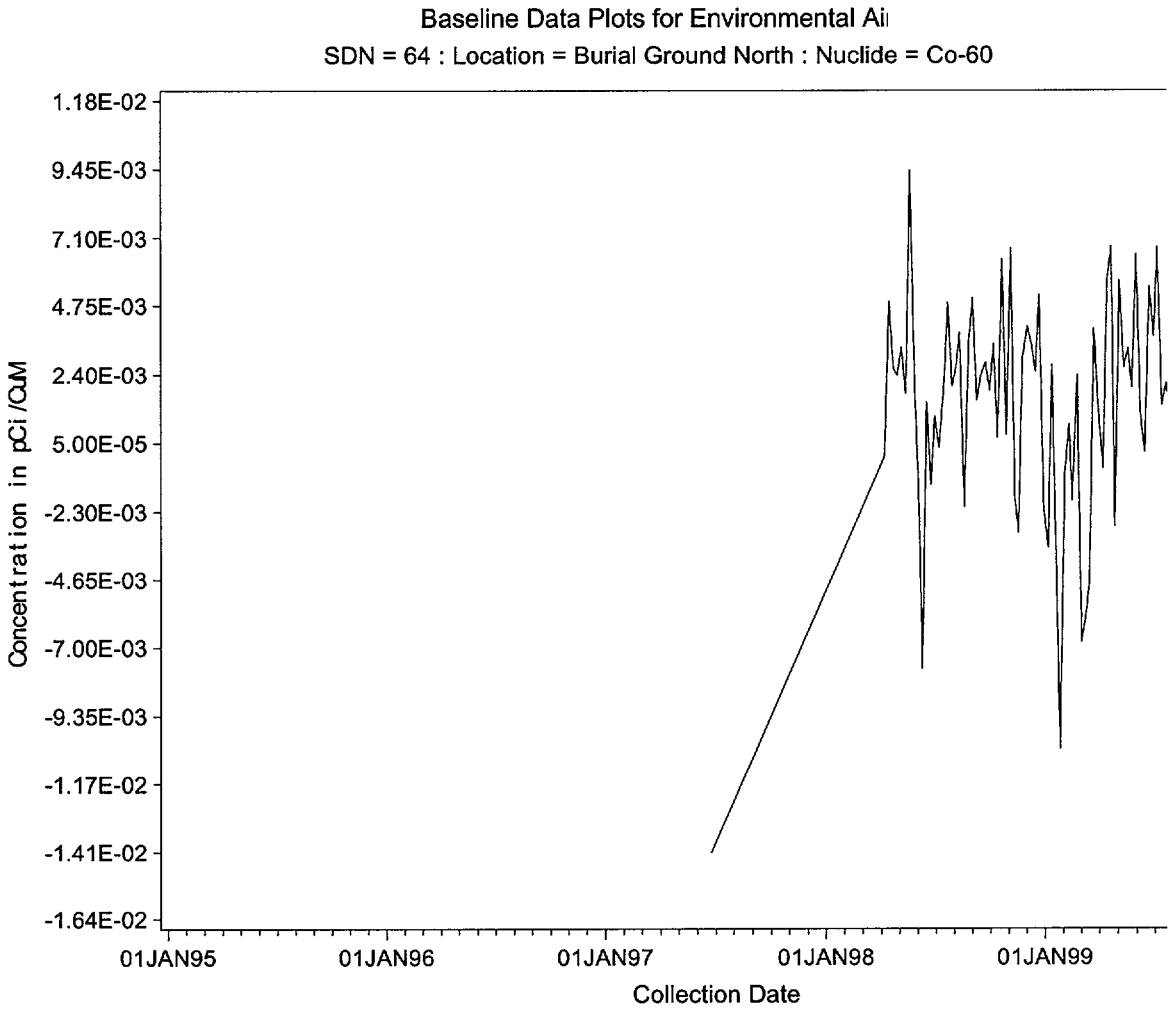


**Figure 26**
**Burial Ground North Filter Paper Cs-137 (Weekly Sample)**

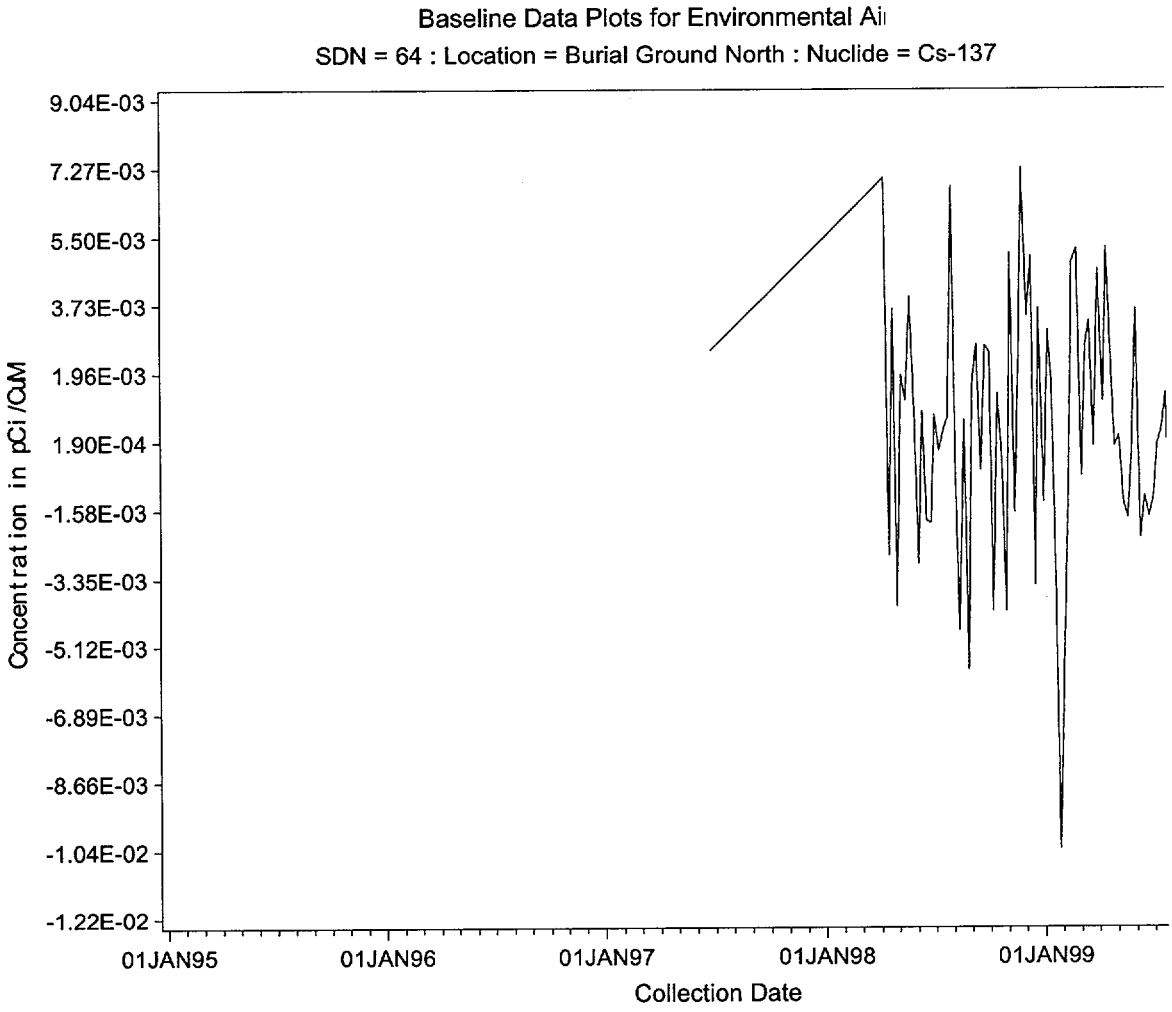


**Figure 27**
**Burial Ground North Filter Paper U-234 (Annual Sample)**

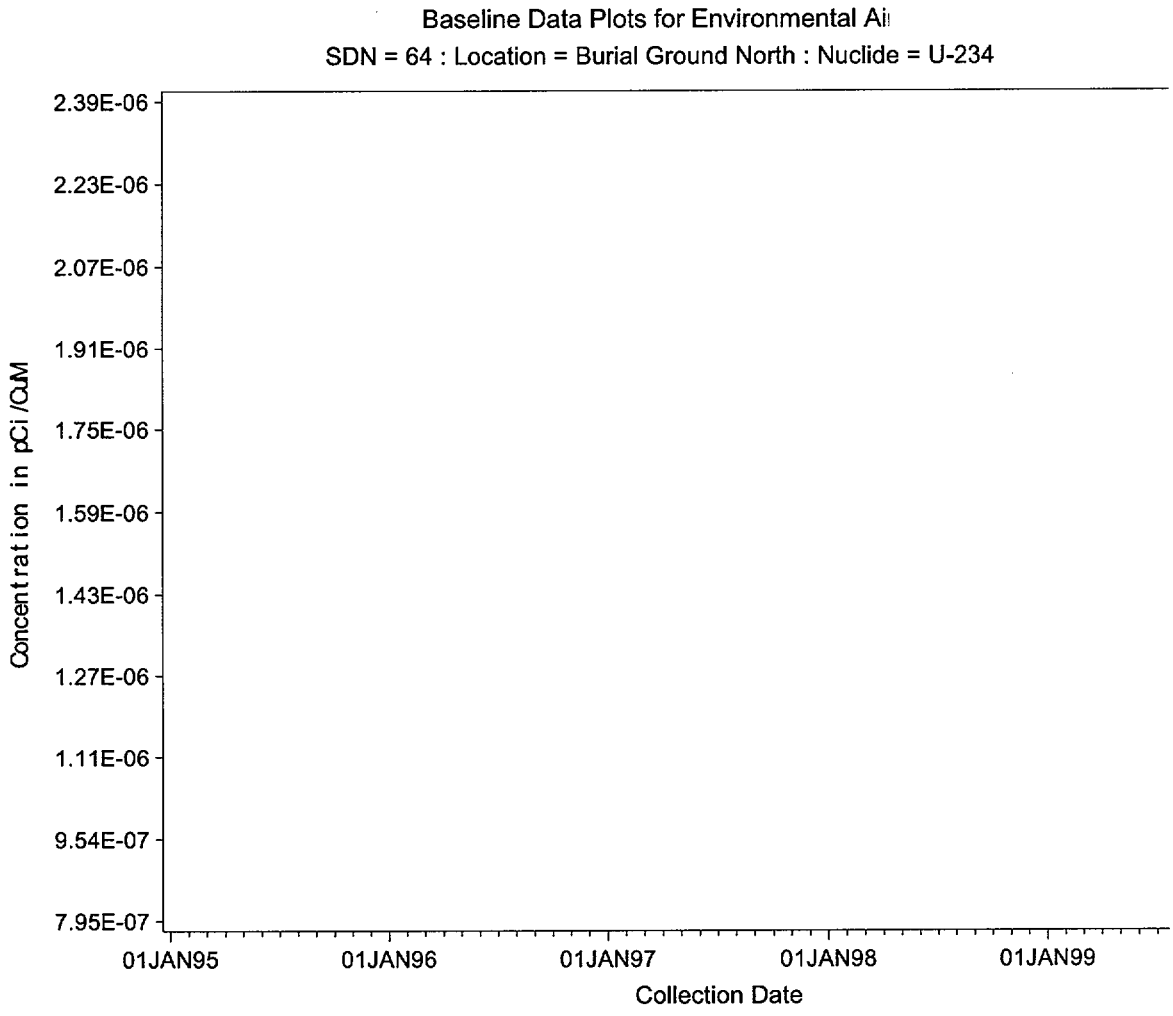


**Figure 28**
**Burial Ground North Filter Paper U-235 (Annual Sample)**

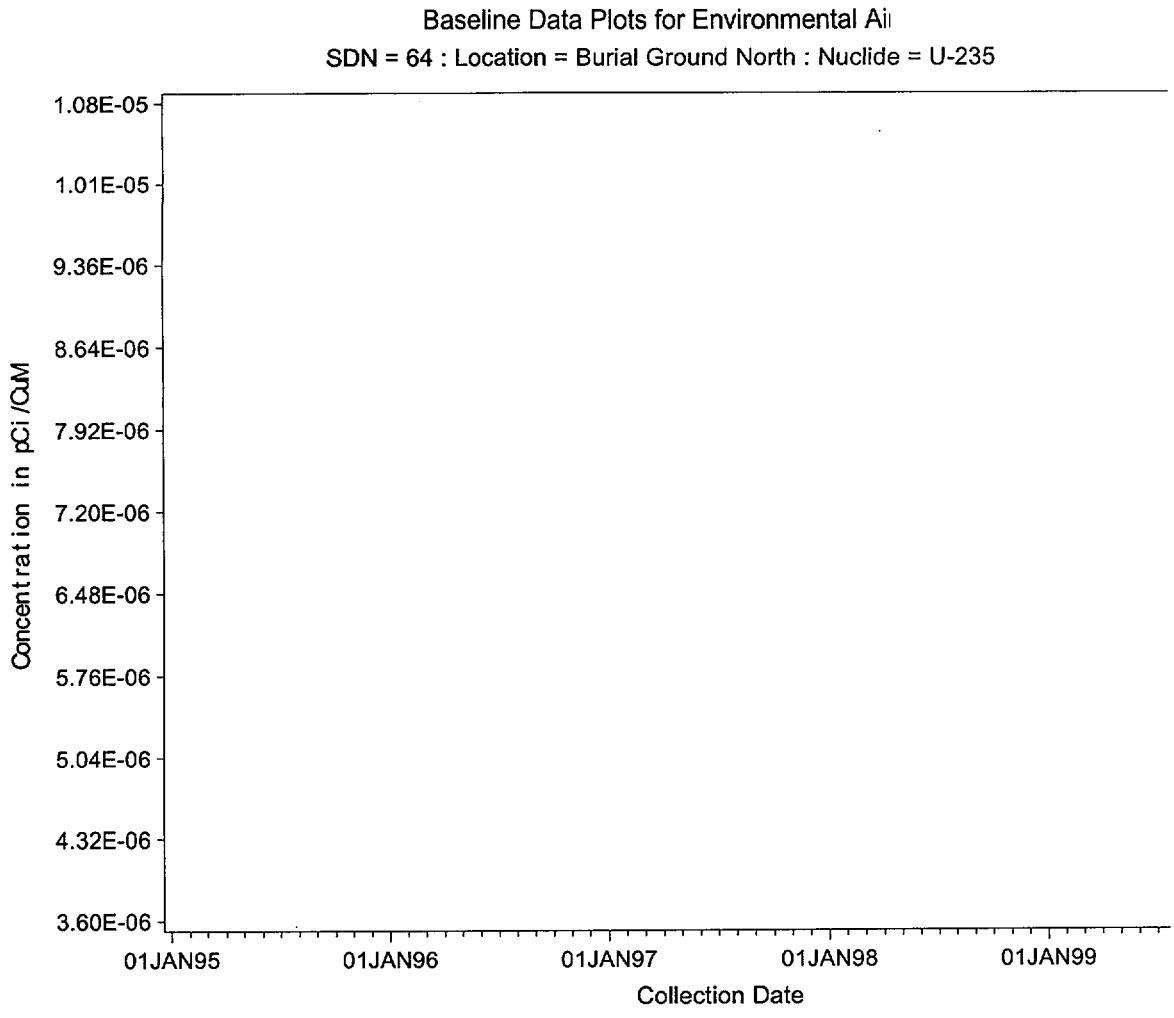


**Figure 29**
**Burial Ground North Filter Paper U-238 (Annual Sample)**

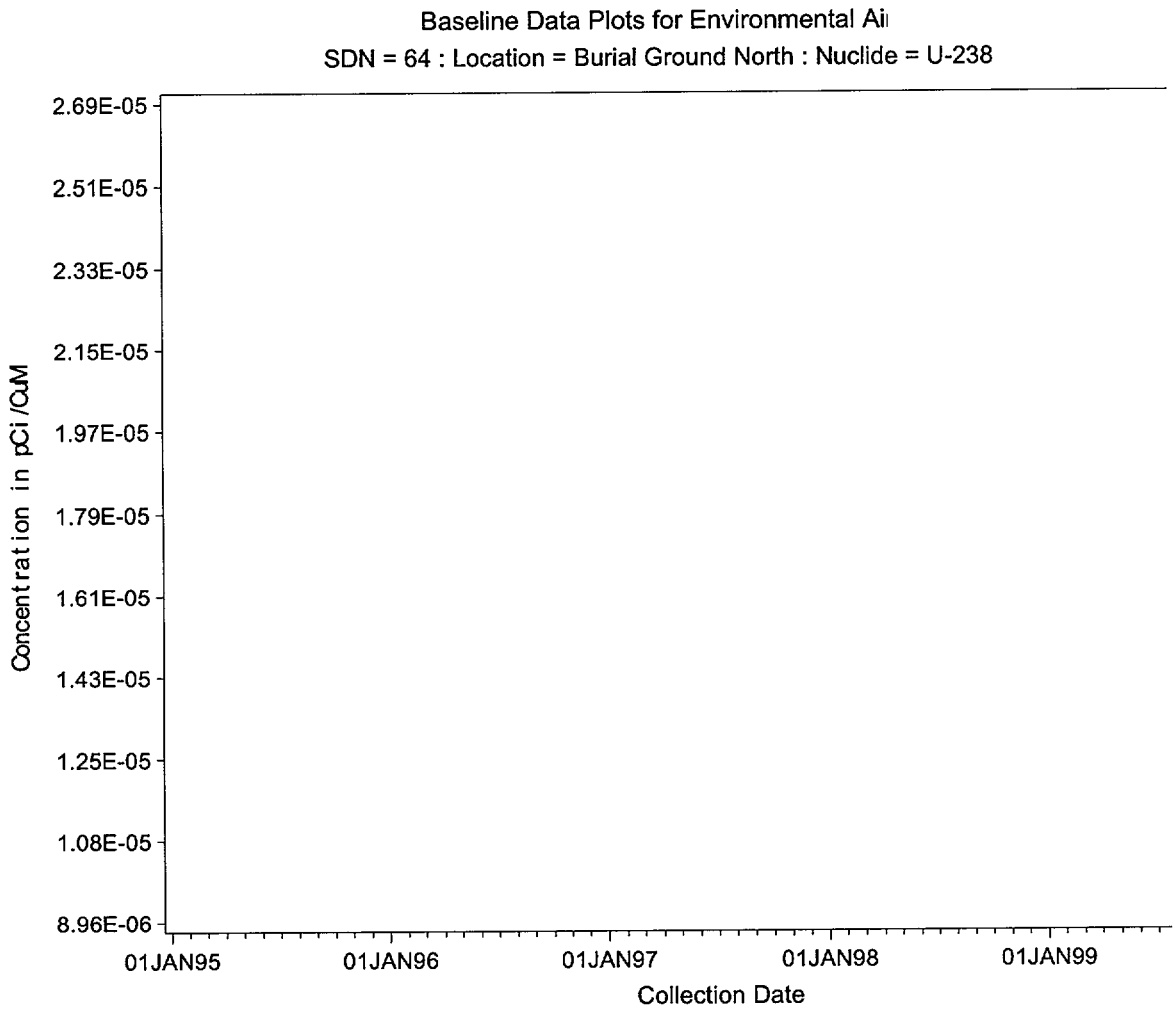


**Figure 30**
**Burial Ground North Filter Paper Pu-238 (Annual Sample)**

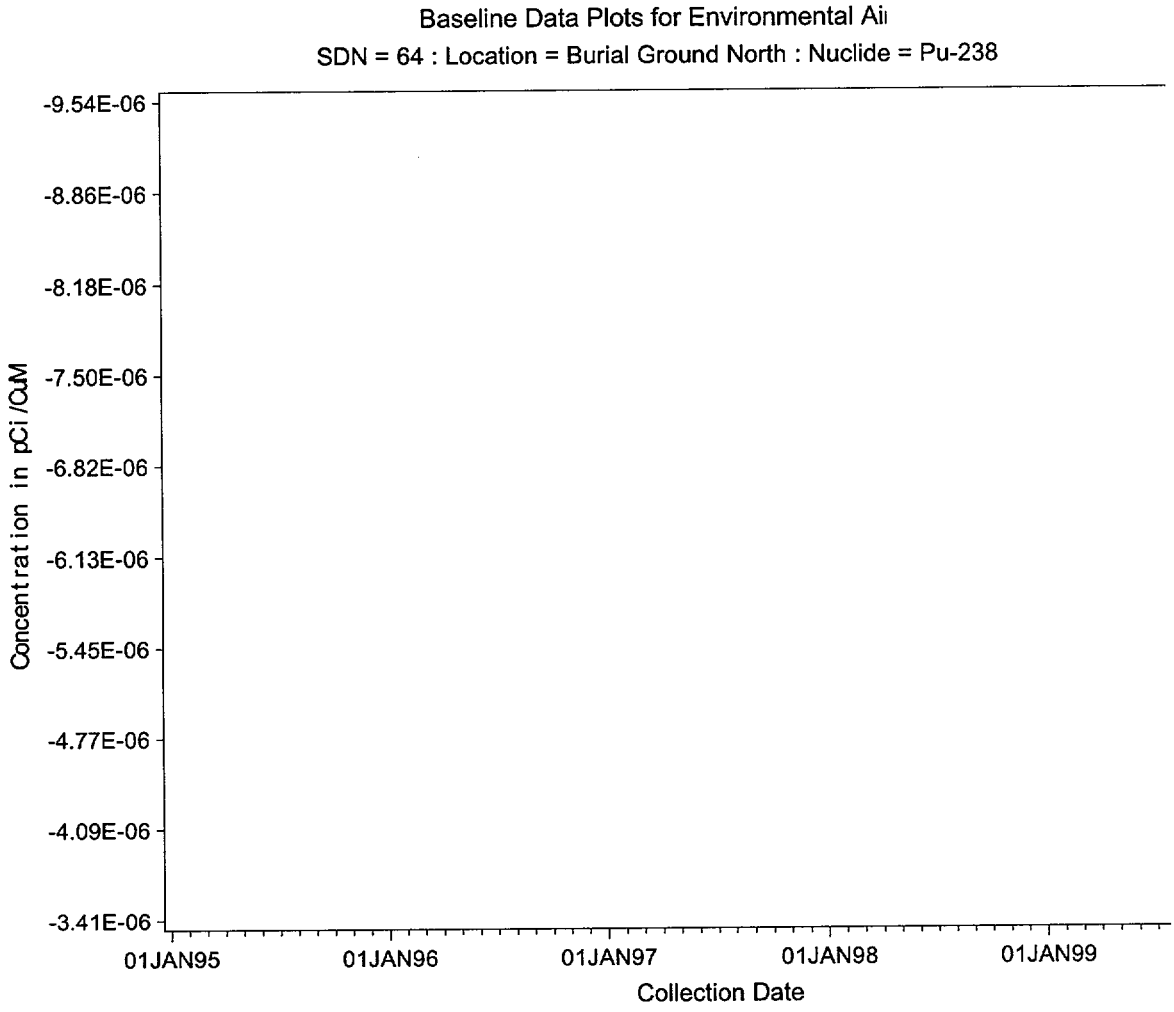


**Figure 31**
**Burial Ground North Filter Paper Pu-239 (Annual Sample)**

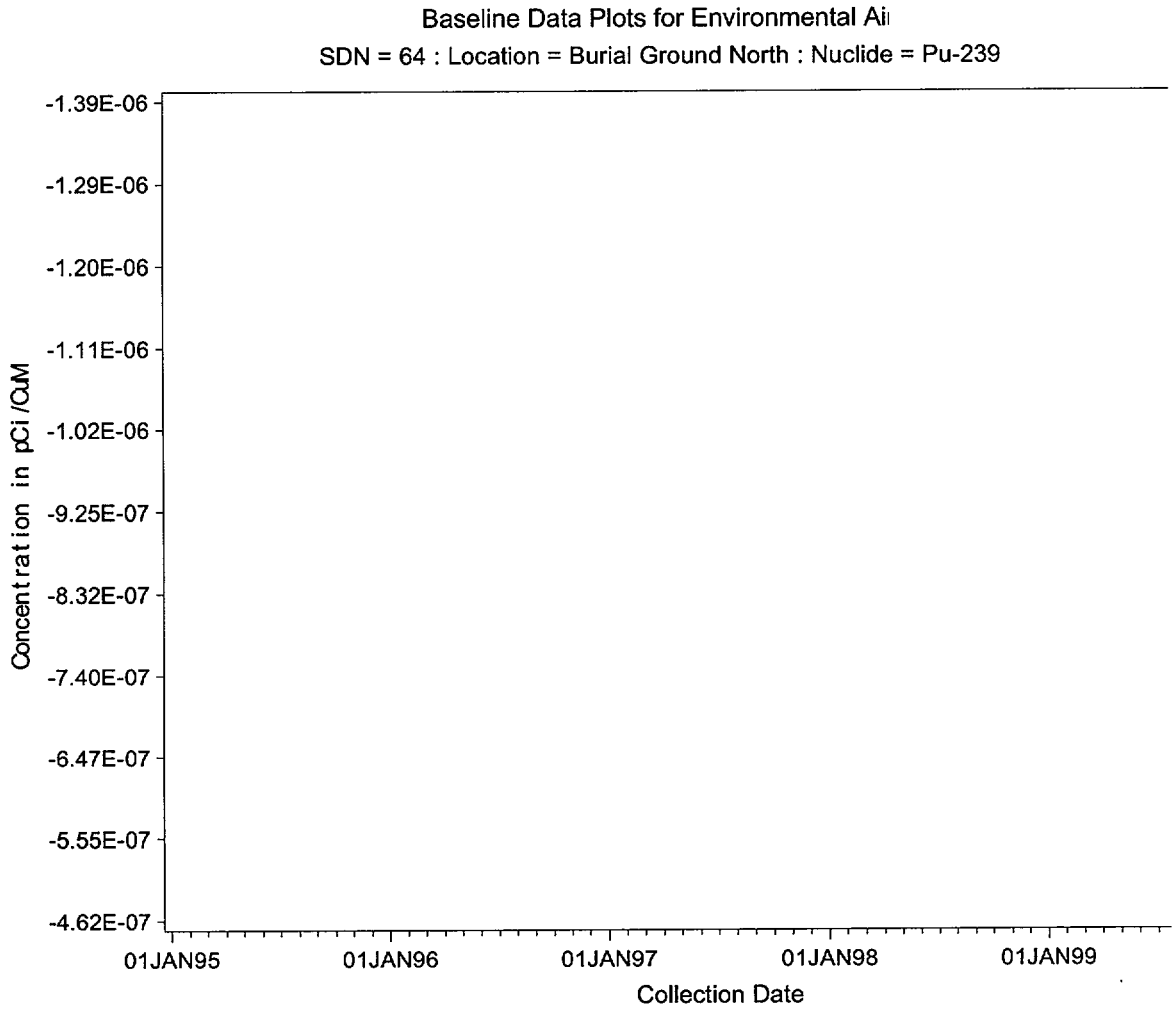


**Figure 32**
**Burial Ground North Filter Paper Am-241 (Annual Sample)**

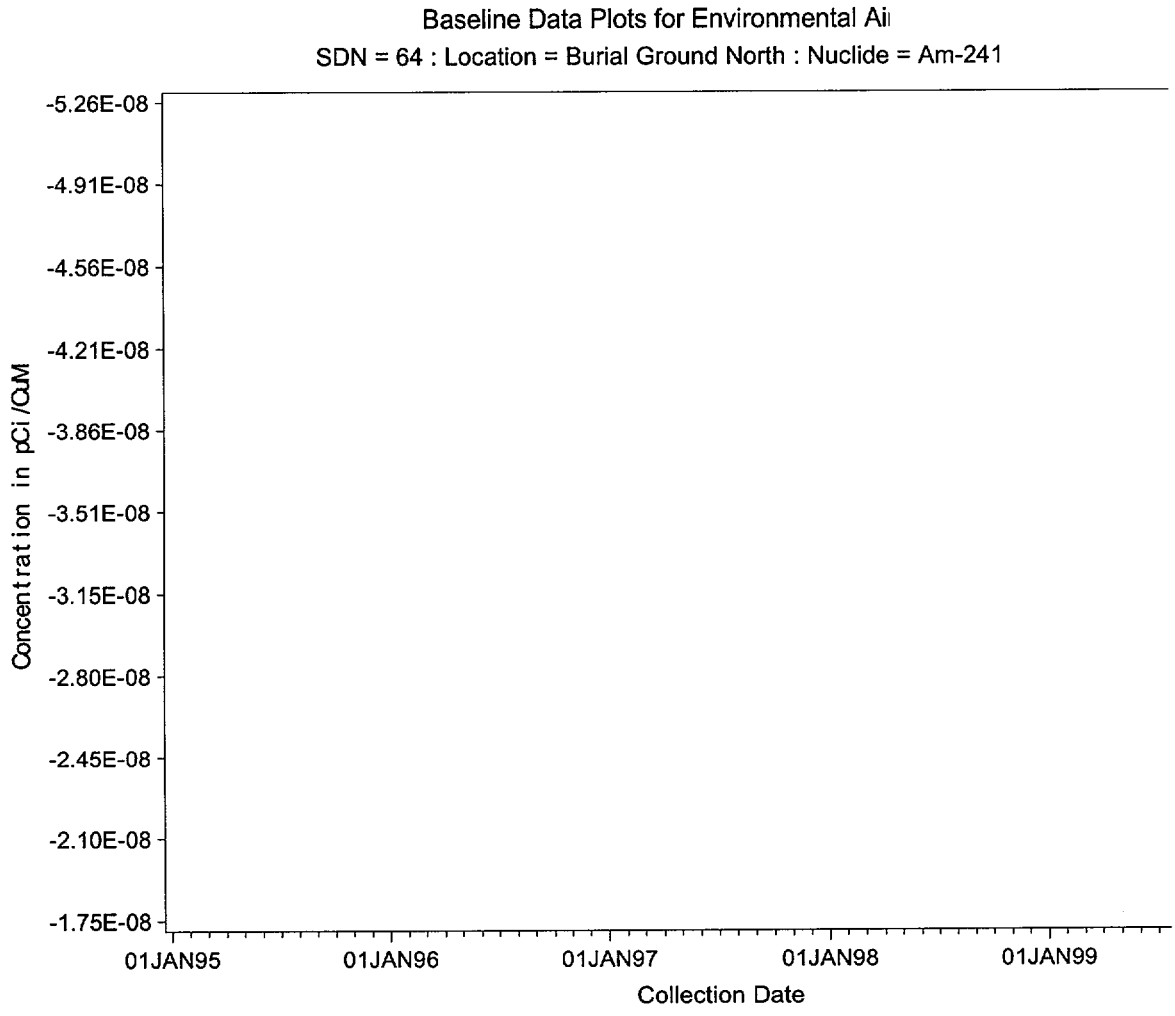


**Figure 33**
**Burial Ground North Filter Paper Cm-244 (Annual Sample)**

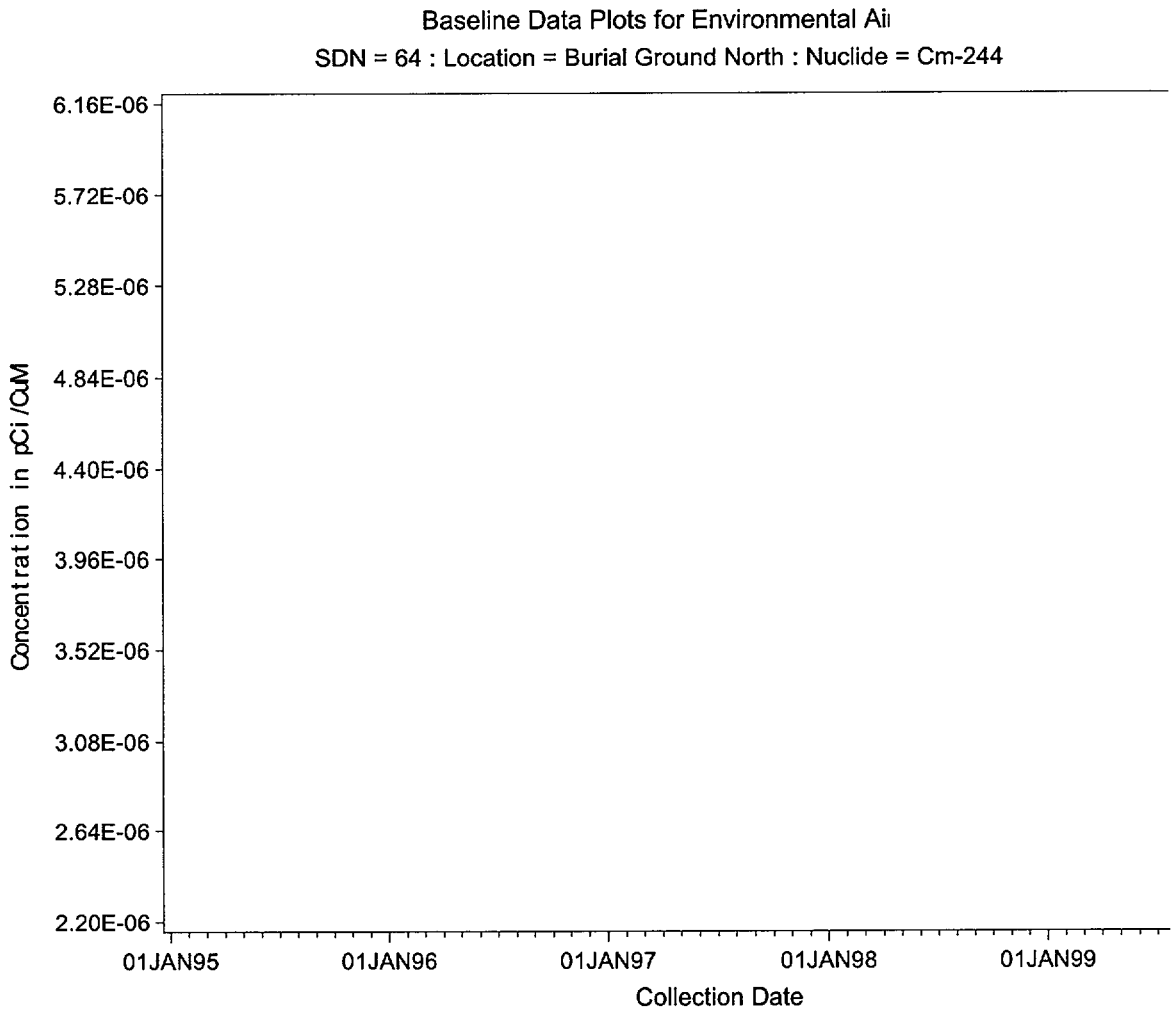


**Figure 34**
**Burial Ground North Filter Paper Sr-89,90 (Annual Sample)**

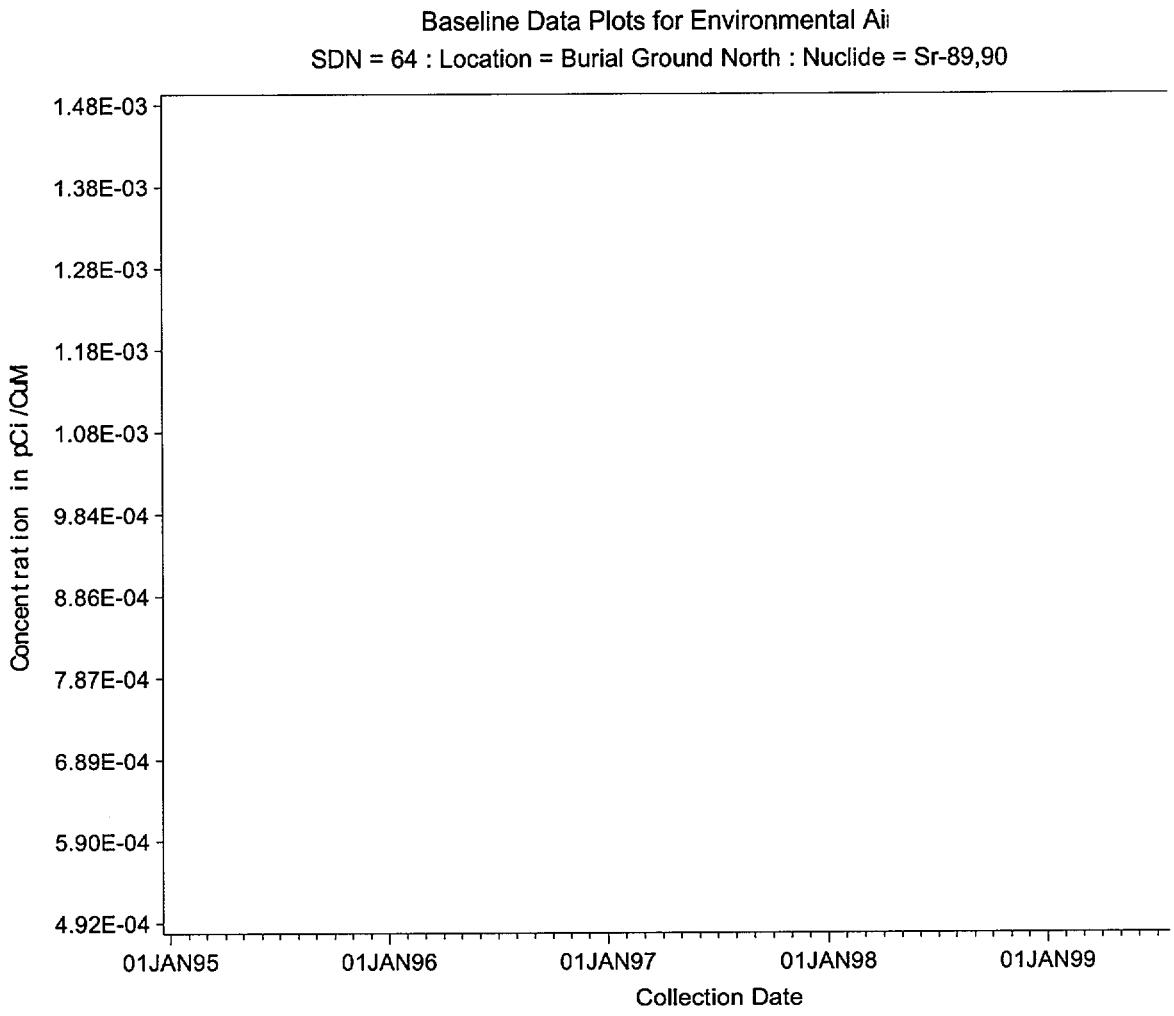


**Figure 35**
**Burial Ground North Filter Paper Gross Beta (Weekly Sample)**

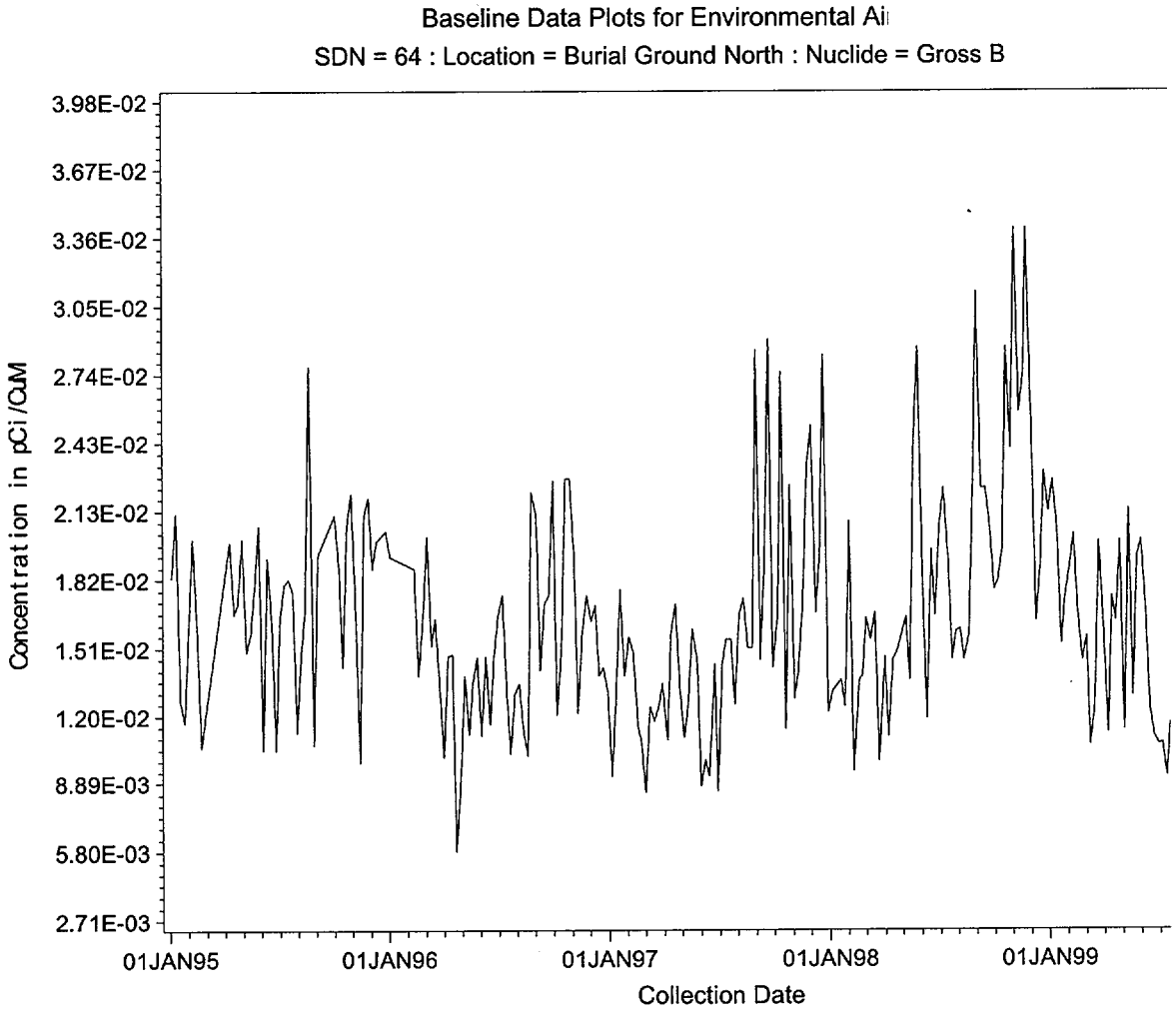


**Figure 36**
**Burial Ground North Filter Paper Gross Alpha (Weekly Sample)**

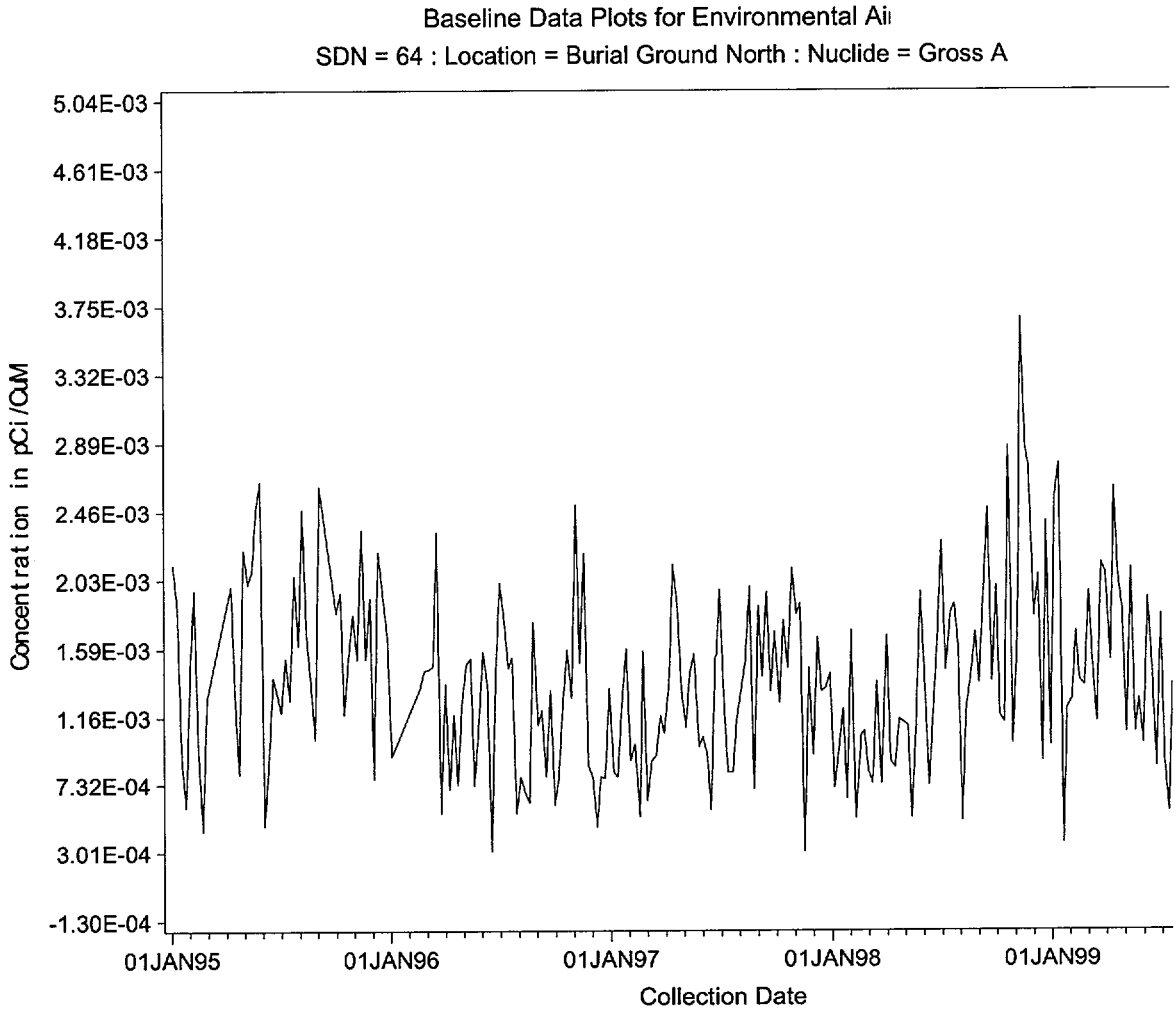


**Figure 37**
**Burial Ground North Filter Paper Co-60 (Monthly Composite)**

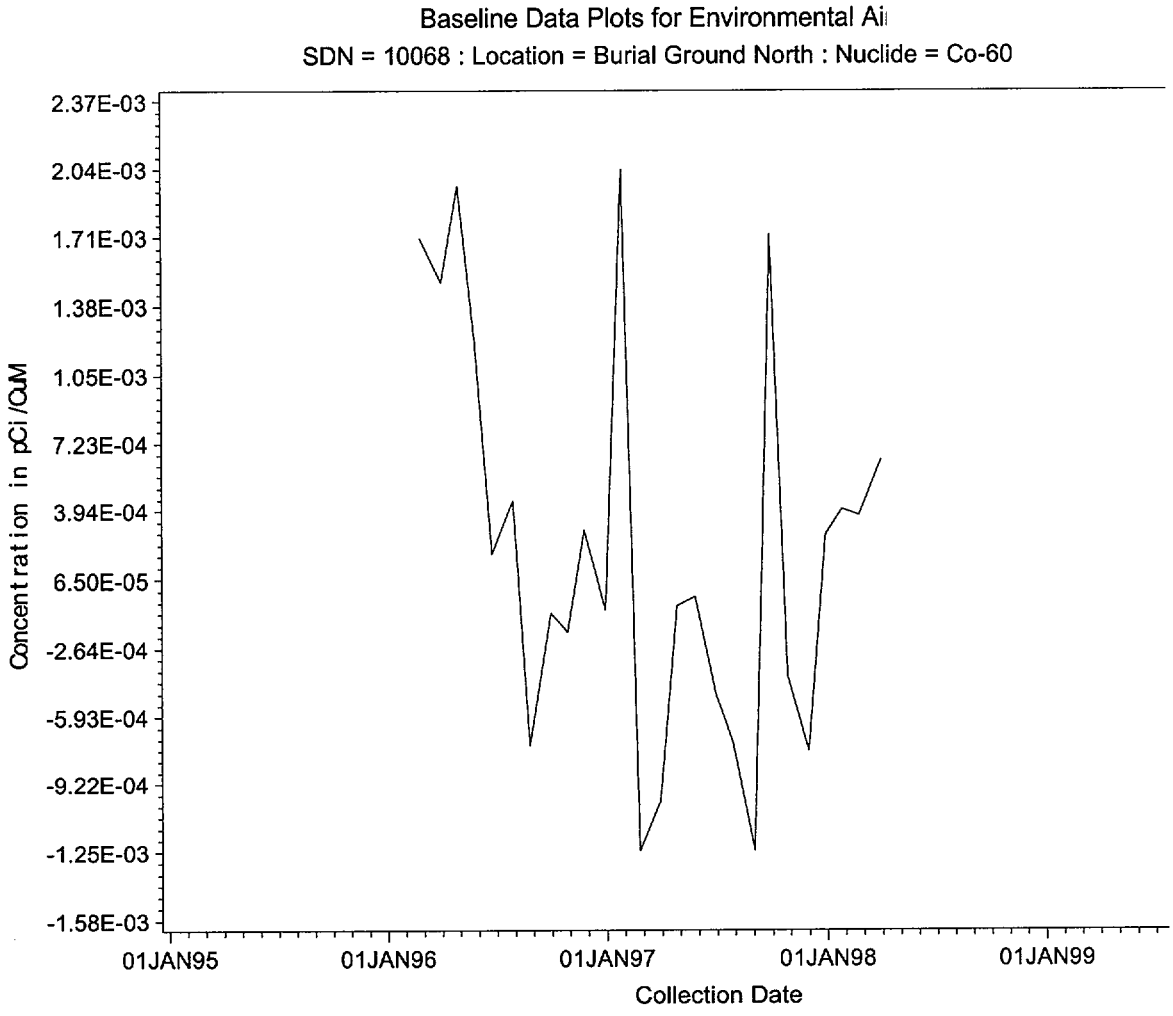


**Figure 38**
**Burial Ground North Filter Paper Cs-137 (Monthly Composite)**

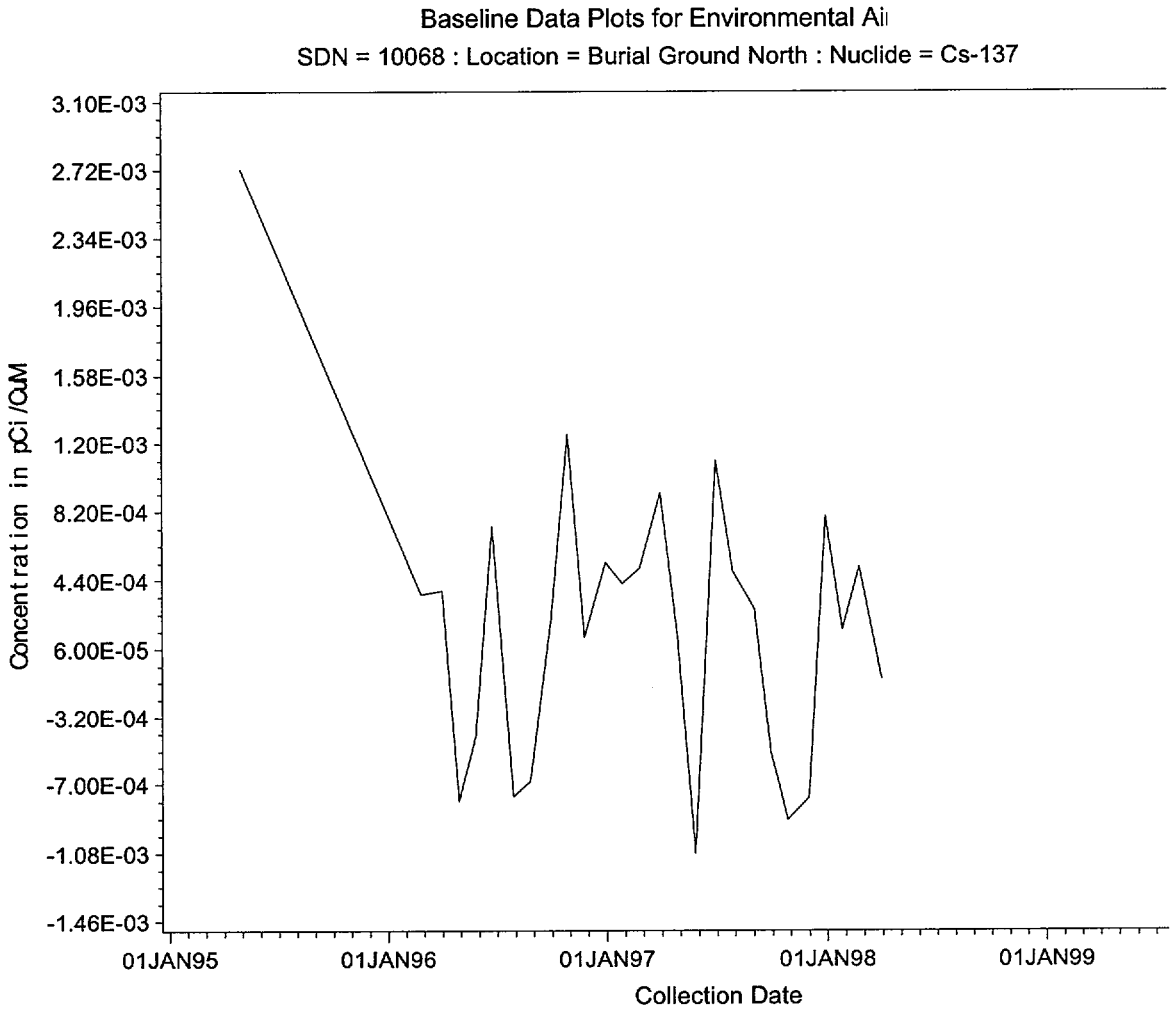


**Figure 39**
**Burial Ground North Filter Paper Pu-238 (Monthly Composite)**

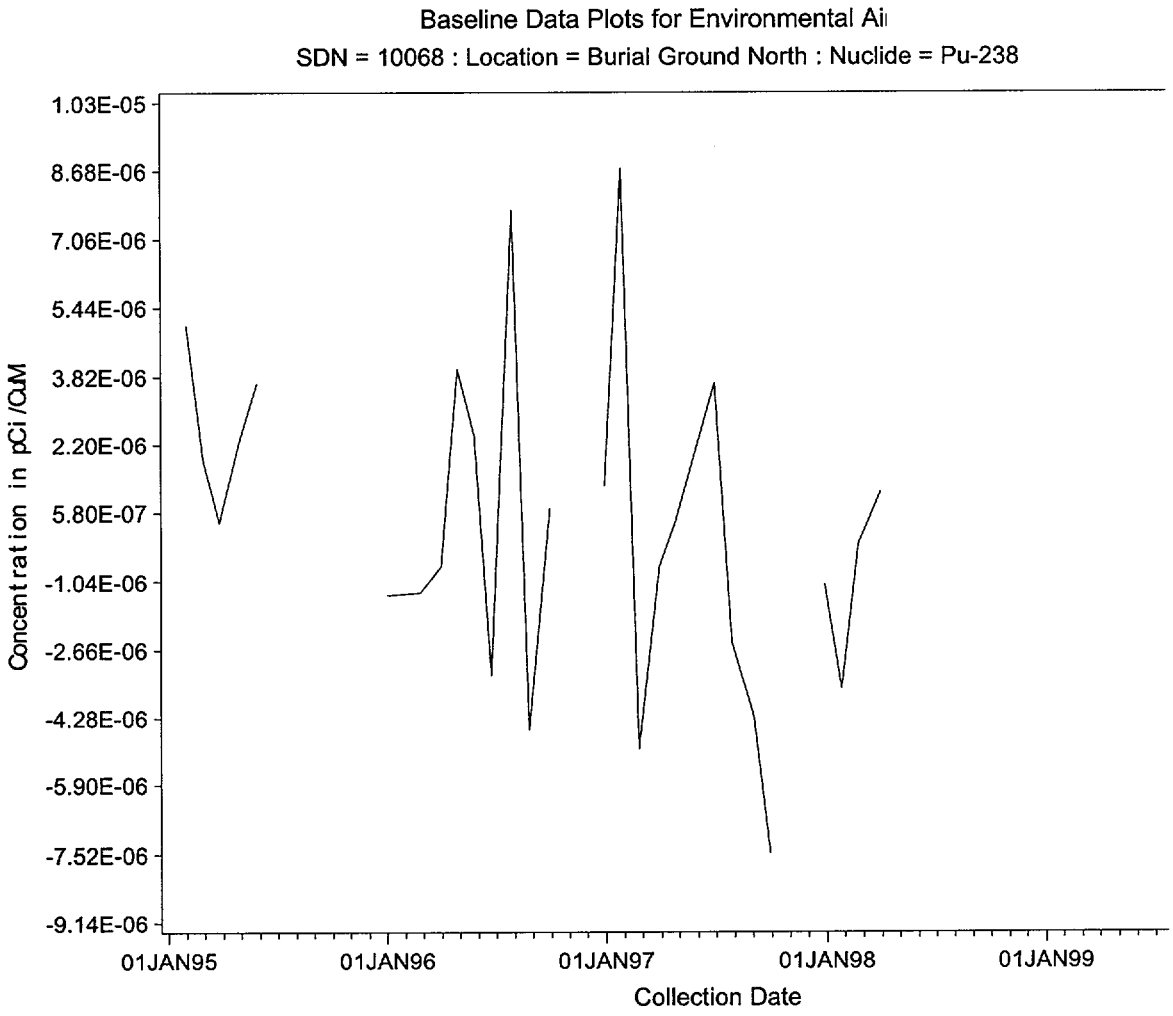


**Figure 40**
**Burial Ground North Filter Paper Pu-239 (Monthly Composite)**

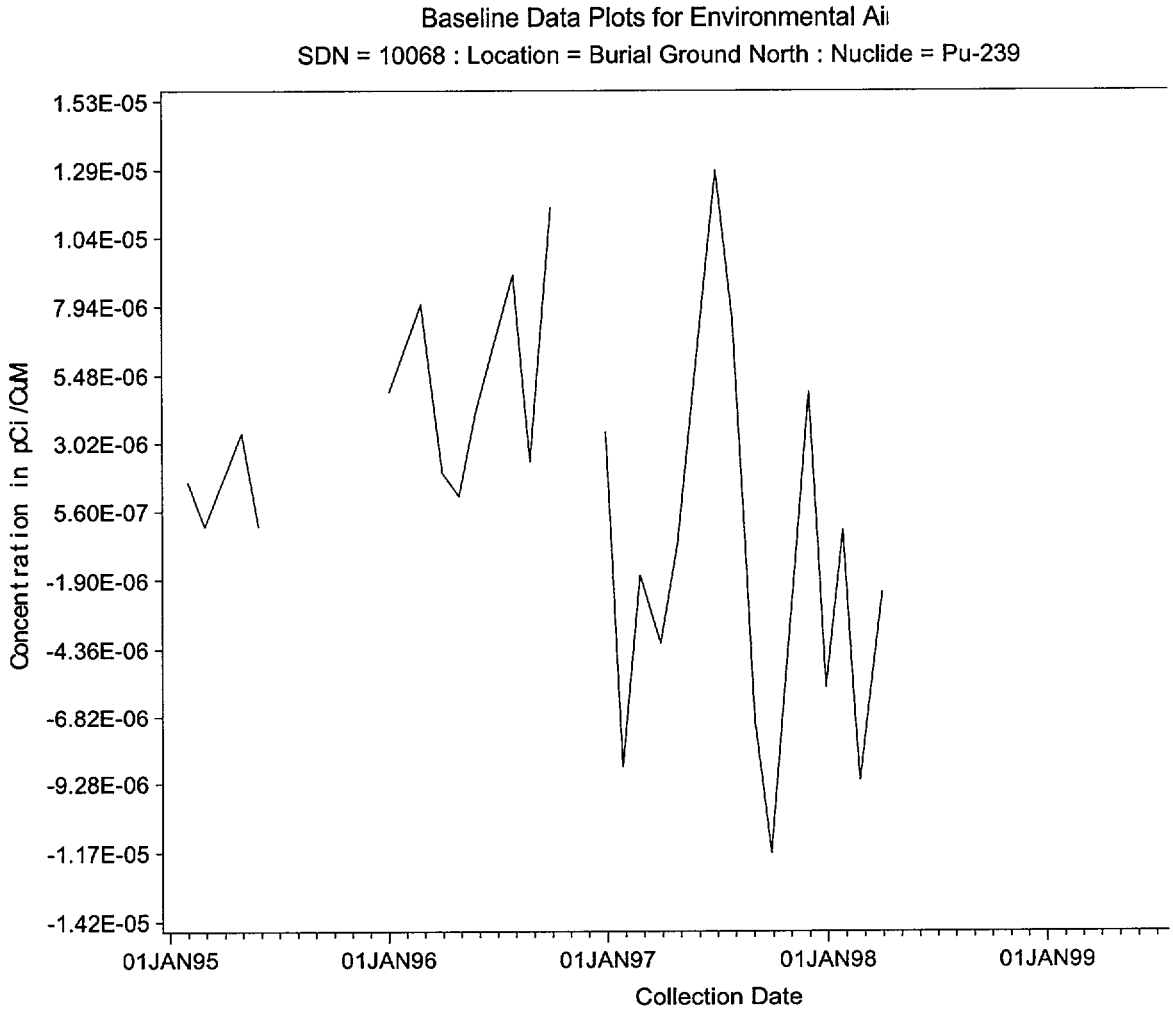


**Figure 41**
**Burial Ground North Filter Paper Sr-89,90 (Monthly Composite)**

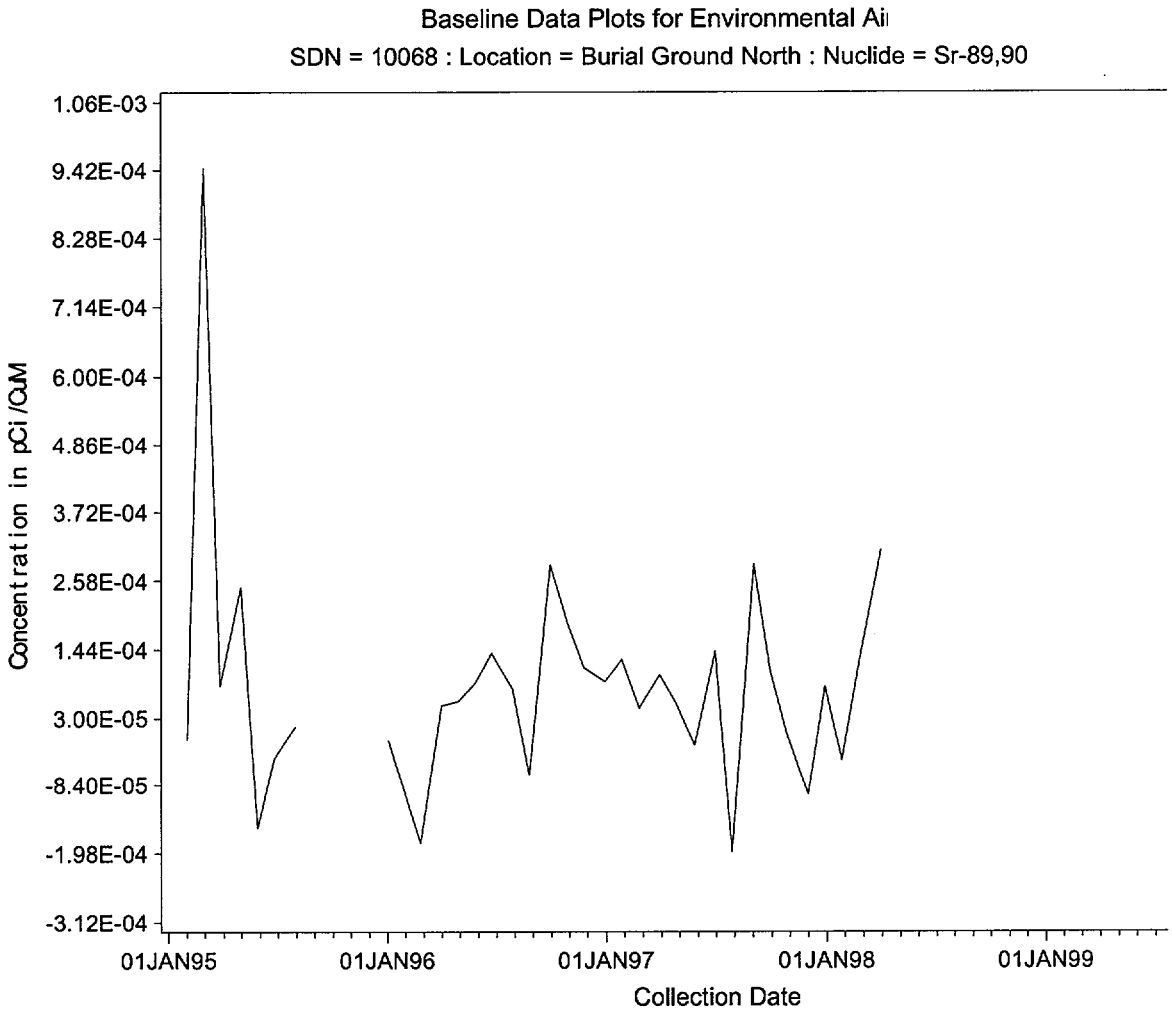


**Figure 42**
**Burial Ground North Charcoal Canister Co-60 (Weekly Sample)**

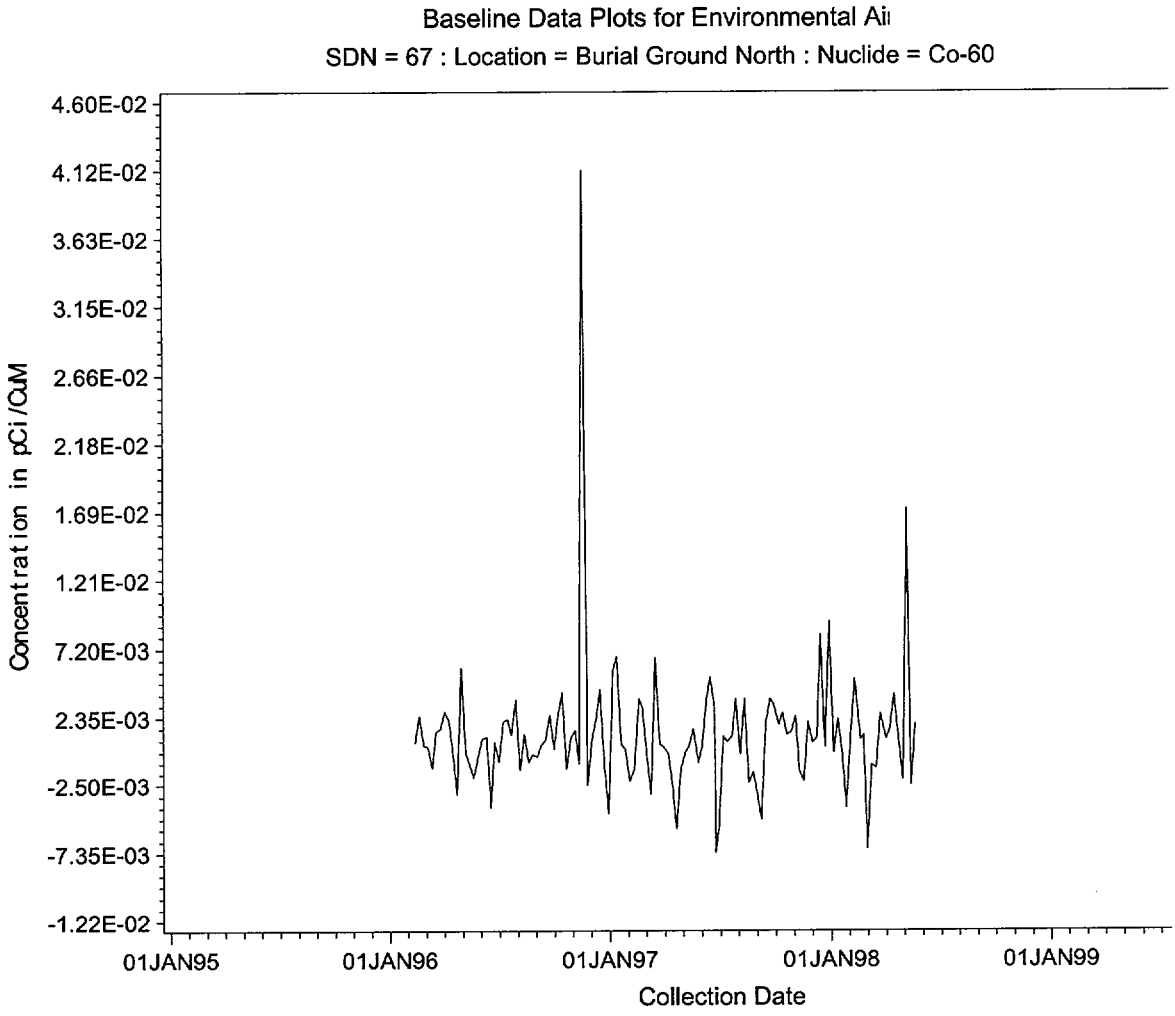


**Figure 43**
**Burial Ground North Charcoal Canister Co-137 (Weekly Sample)**

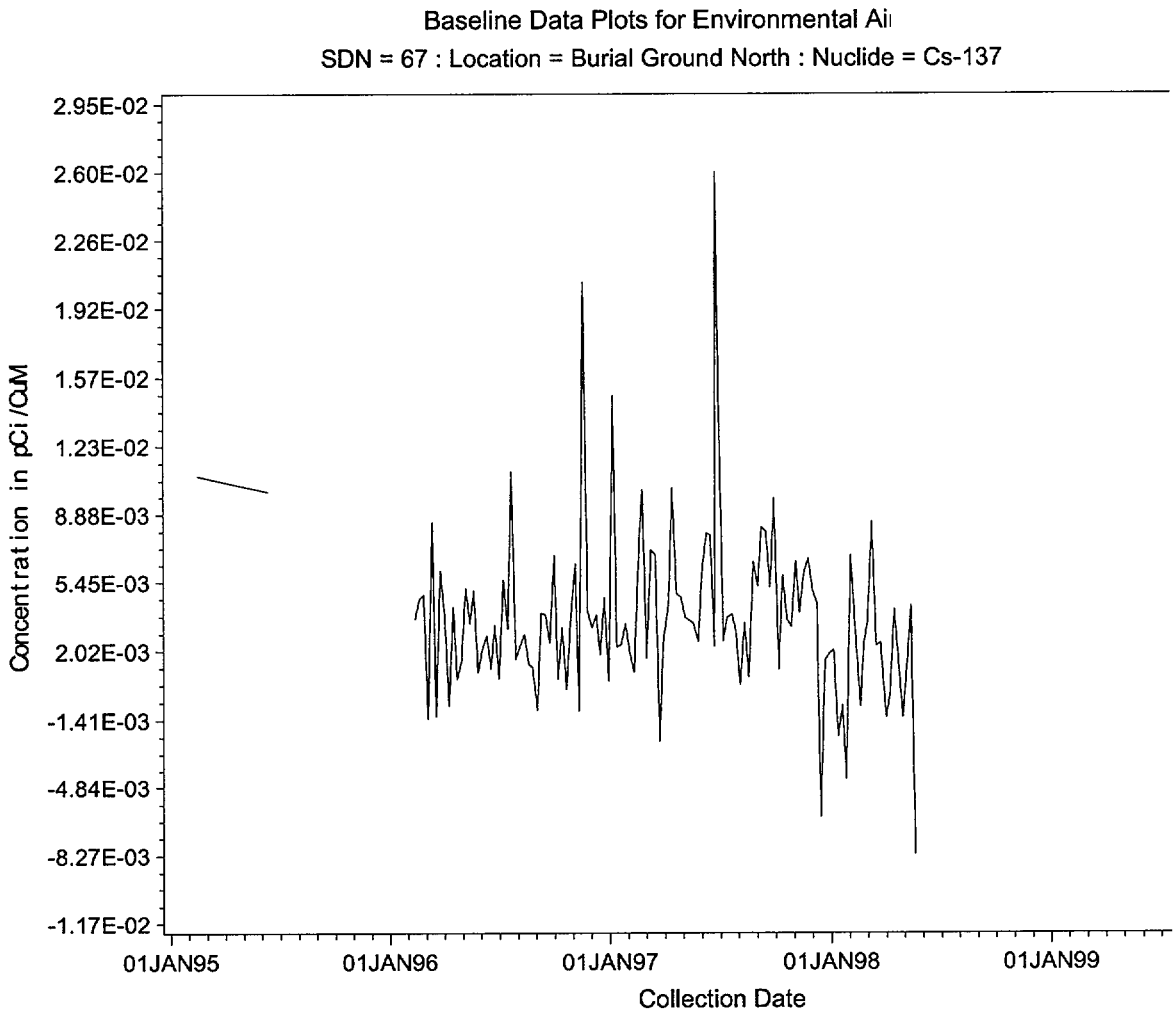


**Figure 44**
**Burial Ground North Silica Gel H-3 (Biweekly Sample)**

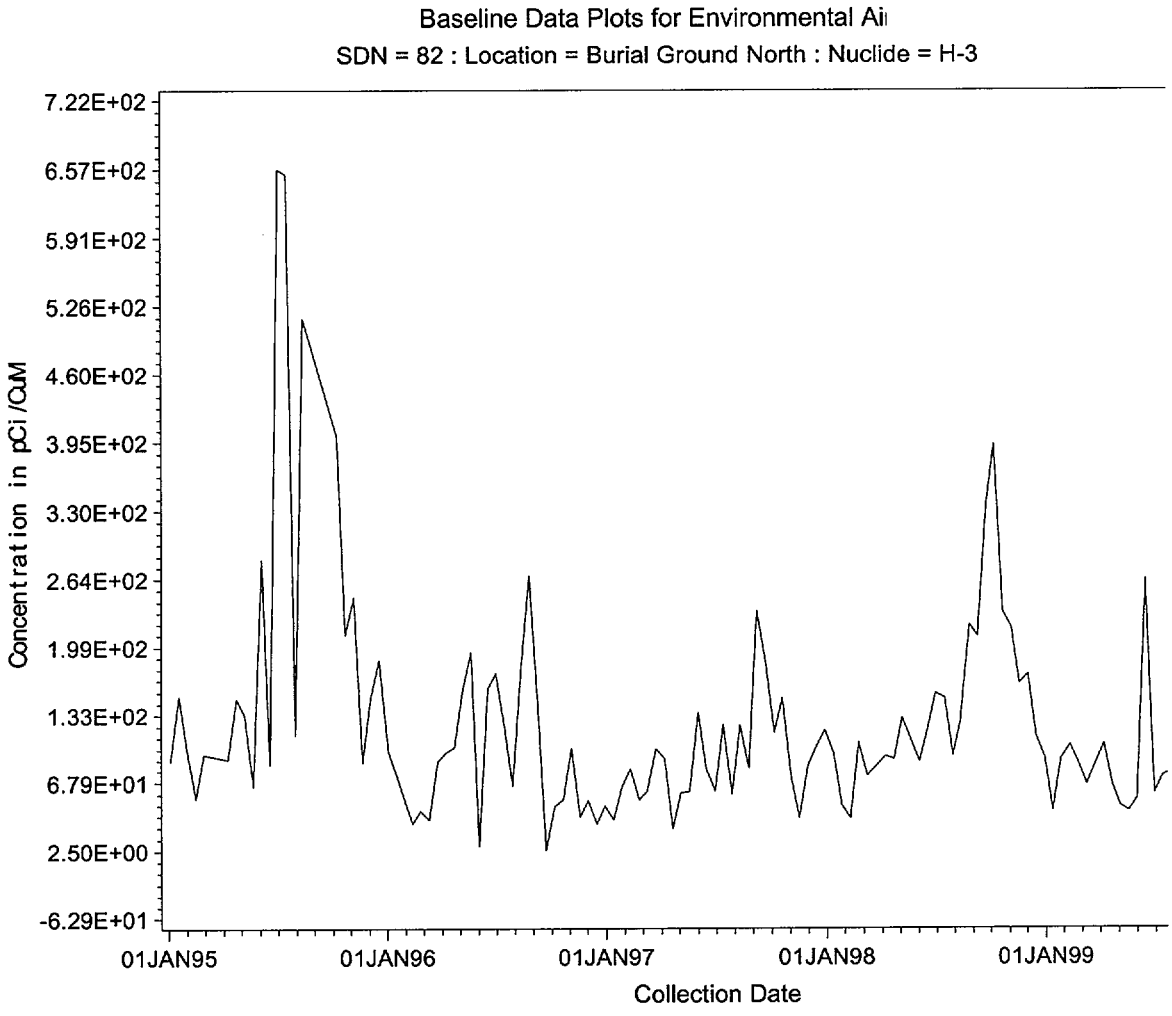


**Figure 45**
**Burial Ground North Rain Water H-3 (Biweekly Sample)**

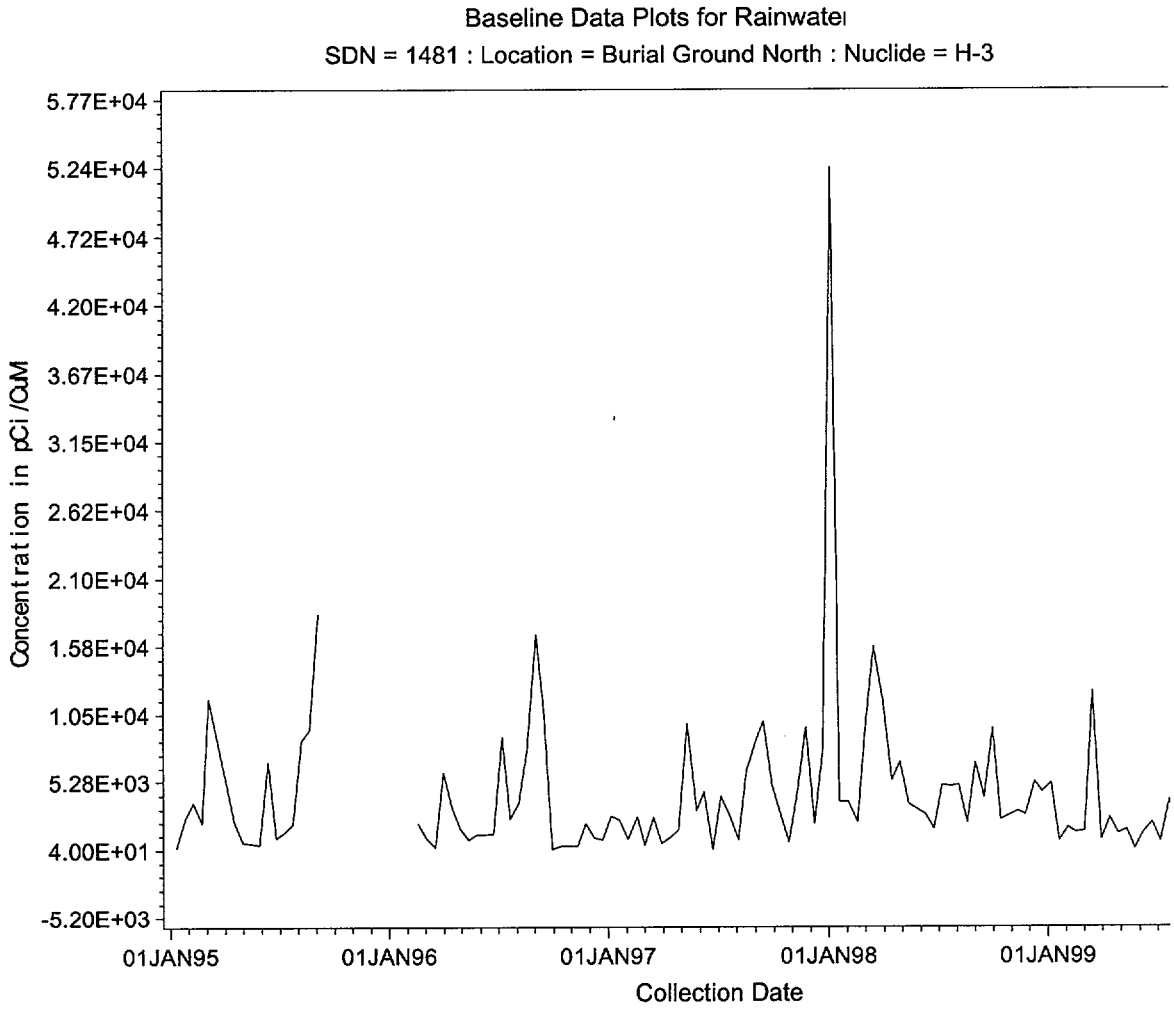


**Figure 46**
**U.S. Highway 301 Filter Paper Co-60 (Weekly Sample)**

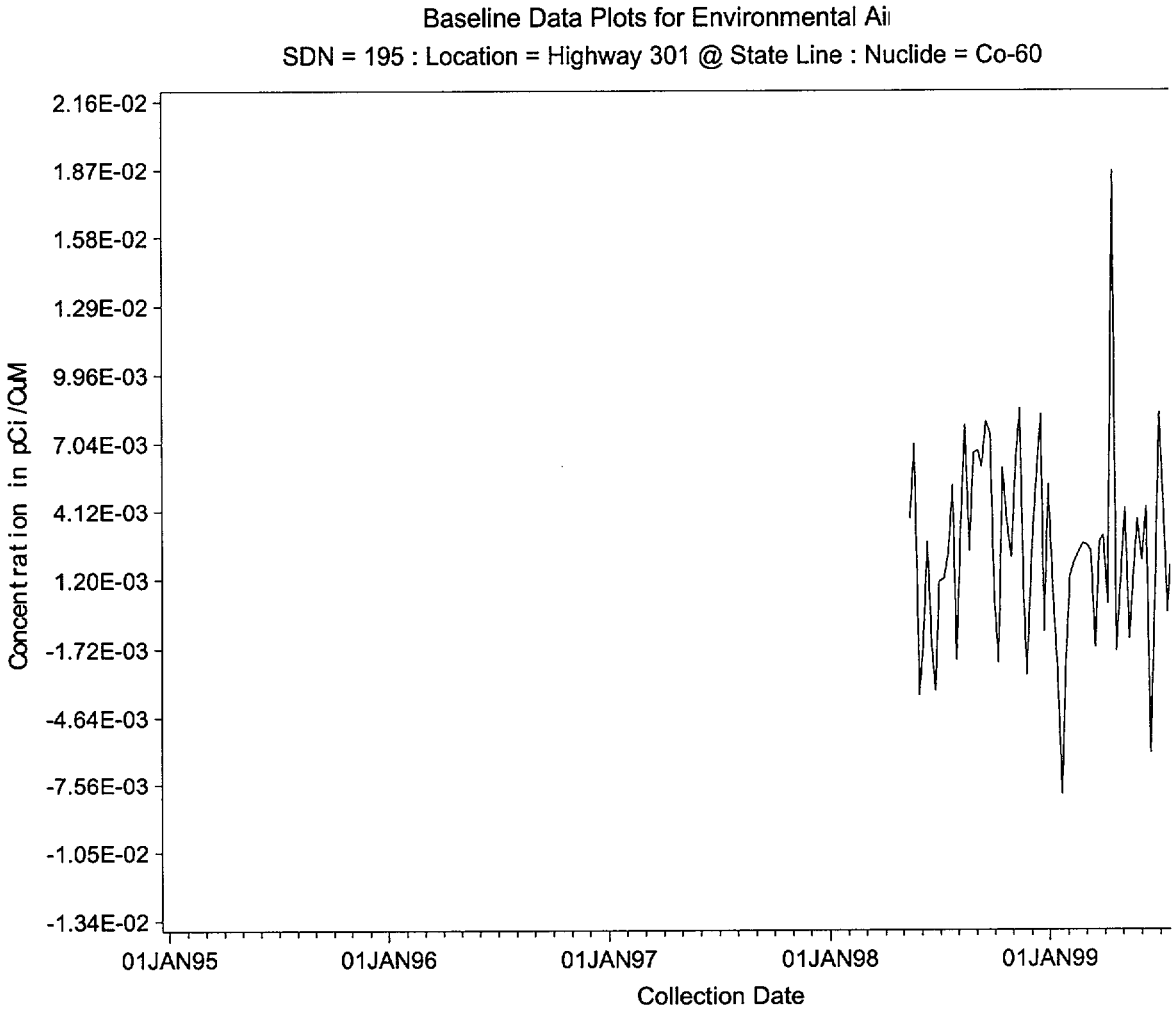


**Figure 47**
**U.S. Highway 301 Filter Paper Co-137 (Weekly Sample)**

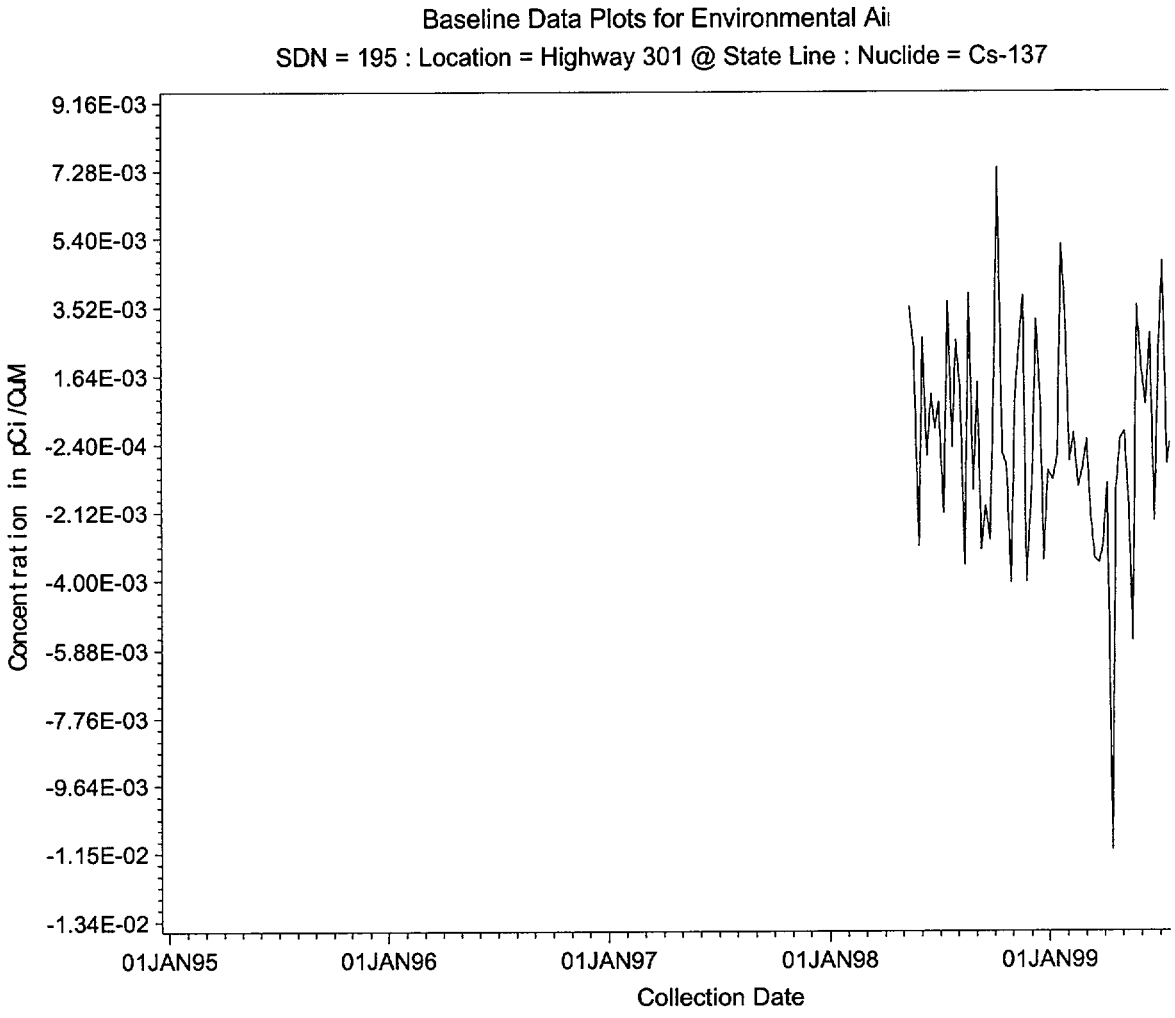


**Figure 47**
**U.S. Highway 301 Filter Paper Co-137 (Weekly Sample)**

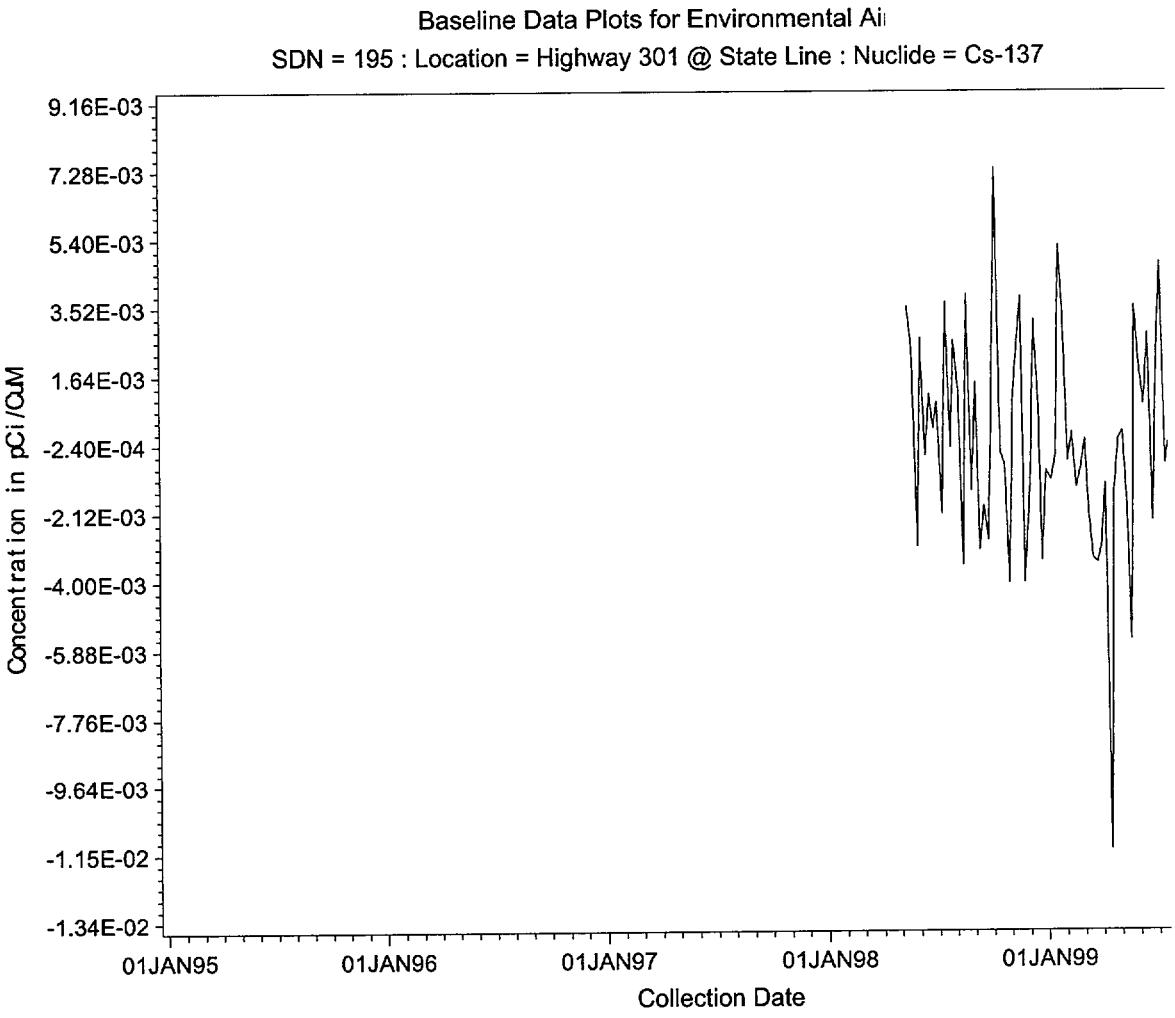


**Figure 48**
**U.S. Highway 301 Filter Paper U-234 (Annual Sample)**

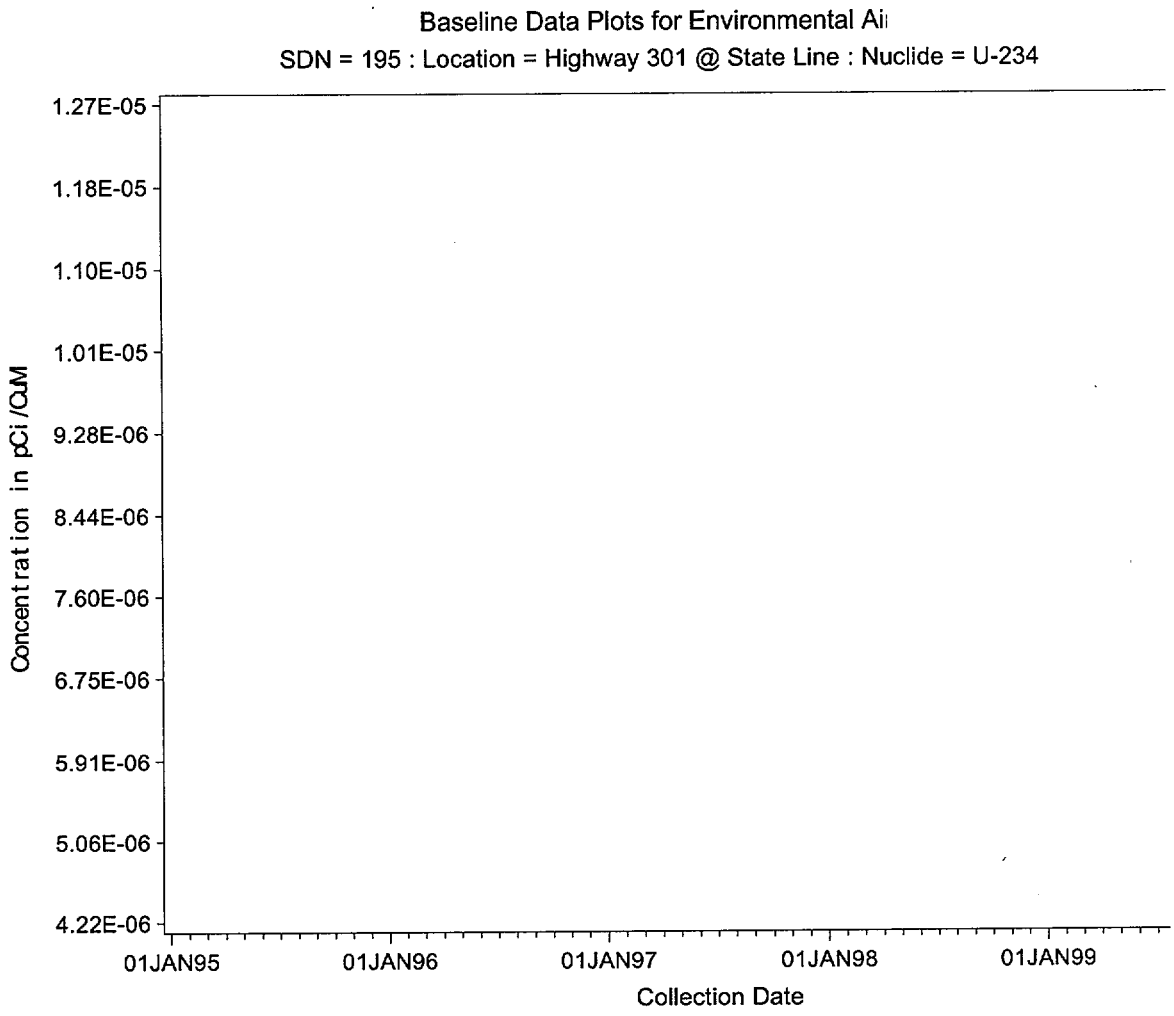


**Figure 49**
**U.S. Highway 301 Filter Paper U-235 (Annual Sample)**

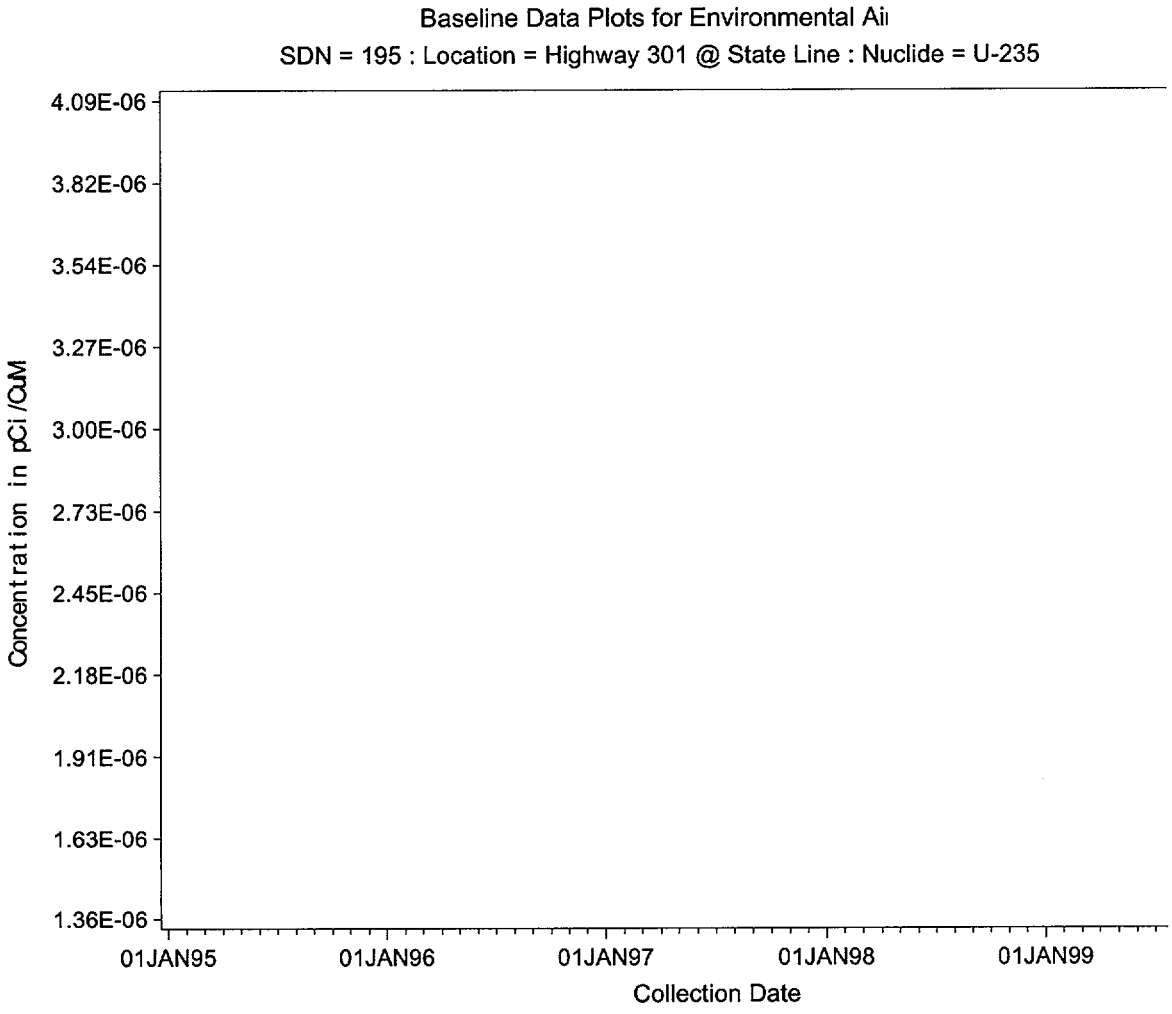


**Figure 50**
**U.S. Highway 301 Filter Paper U-238 (Annual Sample)**

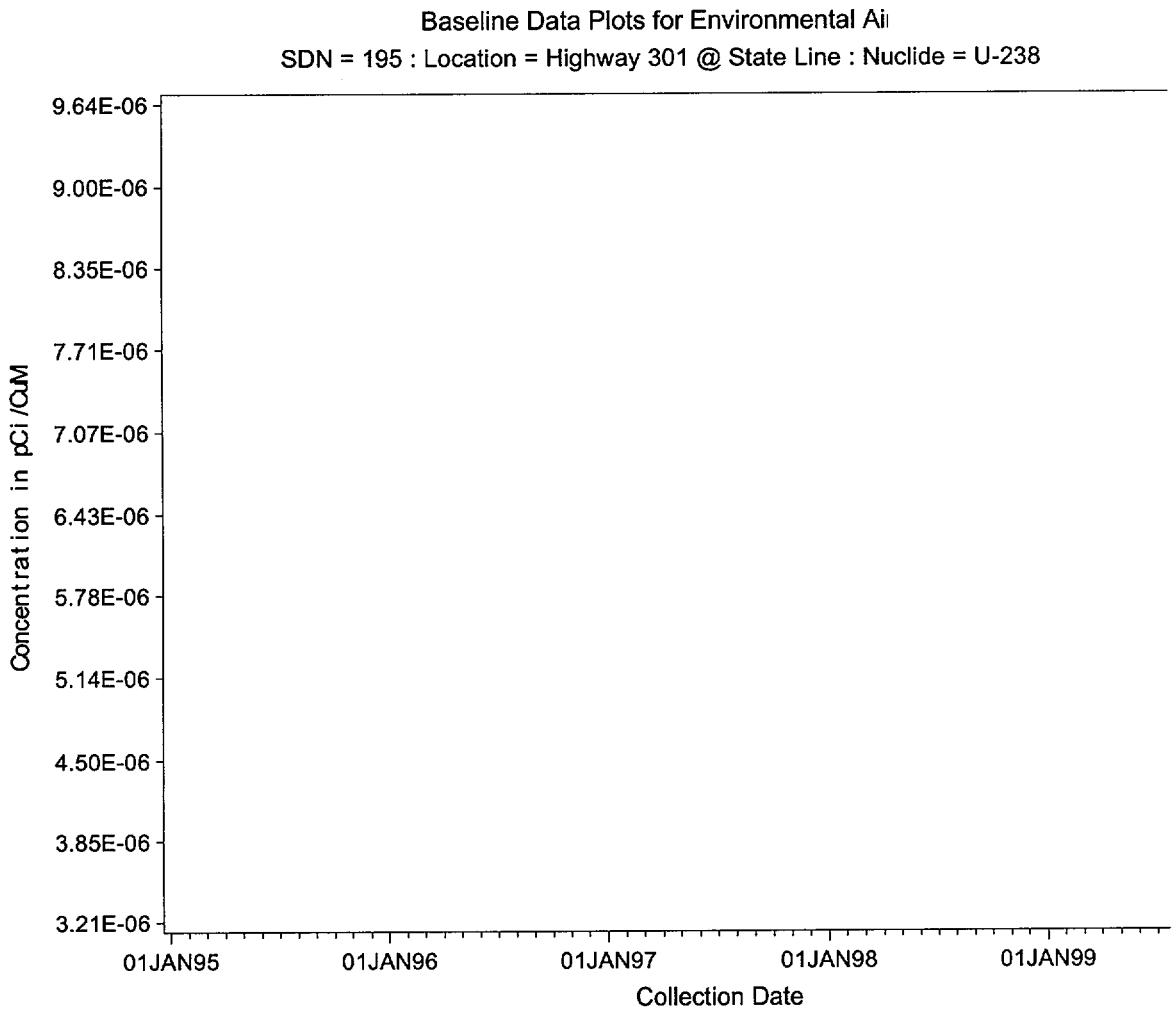


**Figure 51**
**U.S. Highway 301 Filter Paper Pu-238 (Annual Sample)**

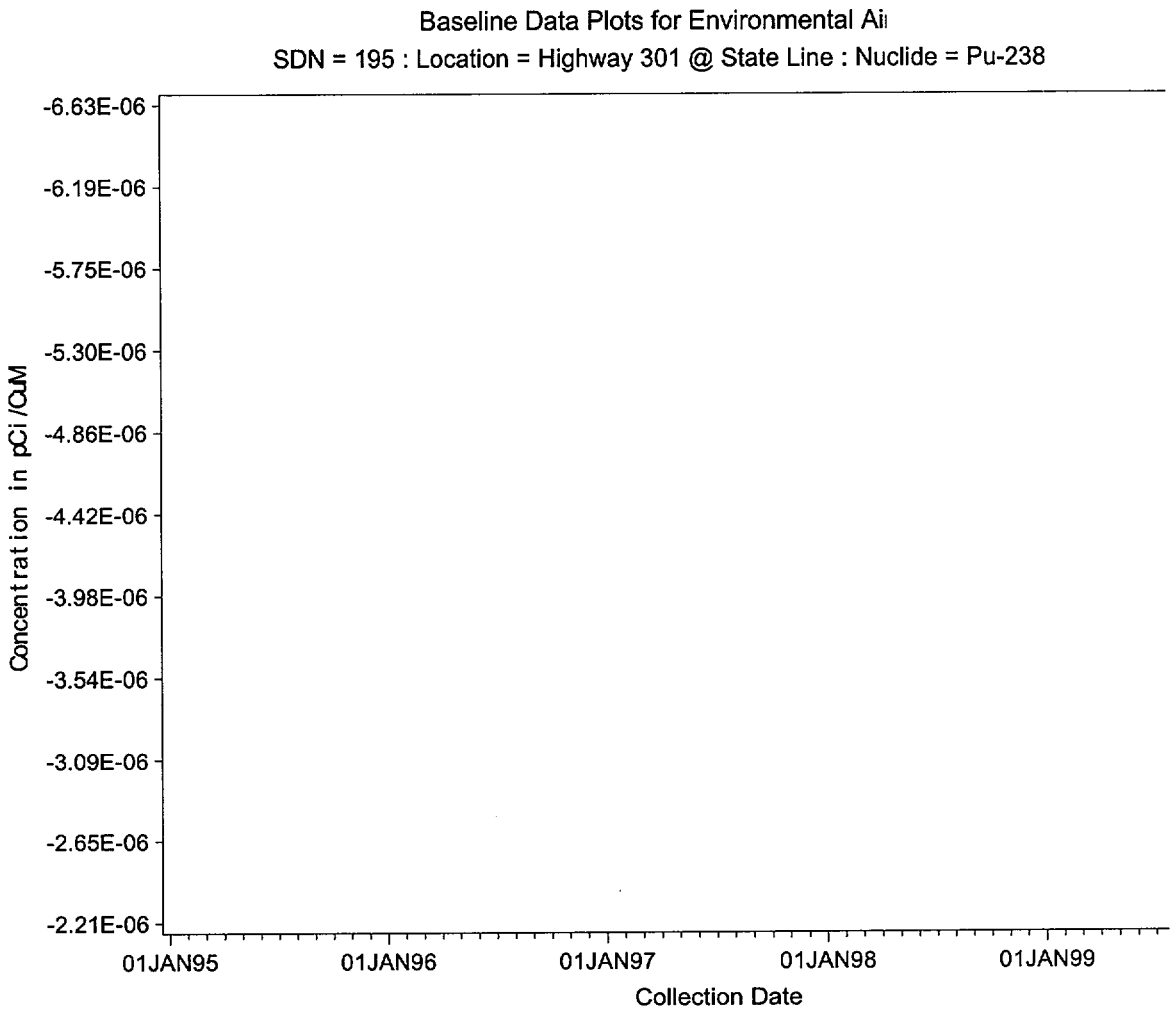


**Figure 52**
**U.S. Highway 301 Filter Paper Pu-239 (Annual Sample)**

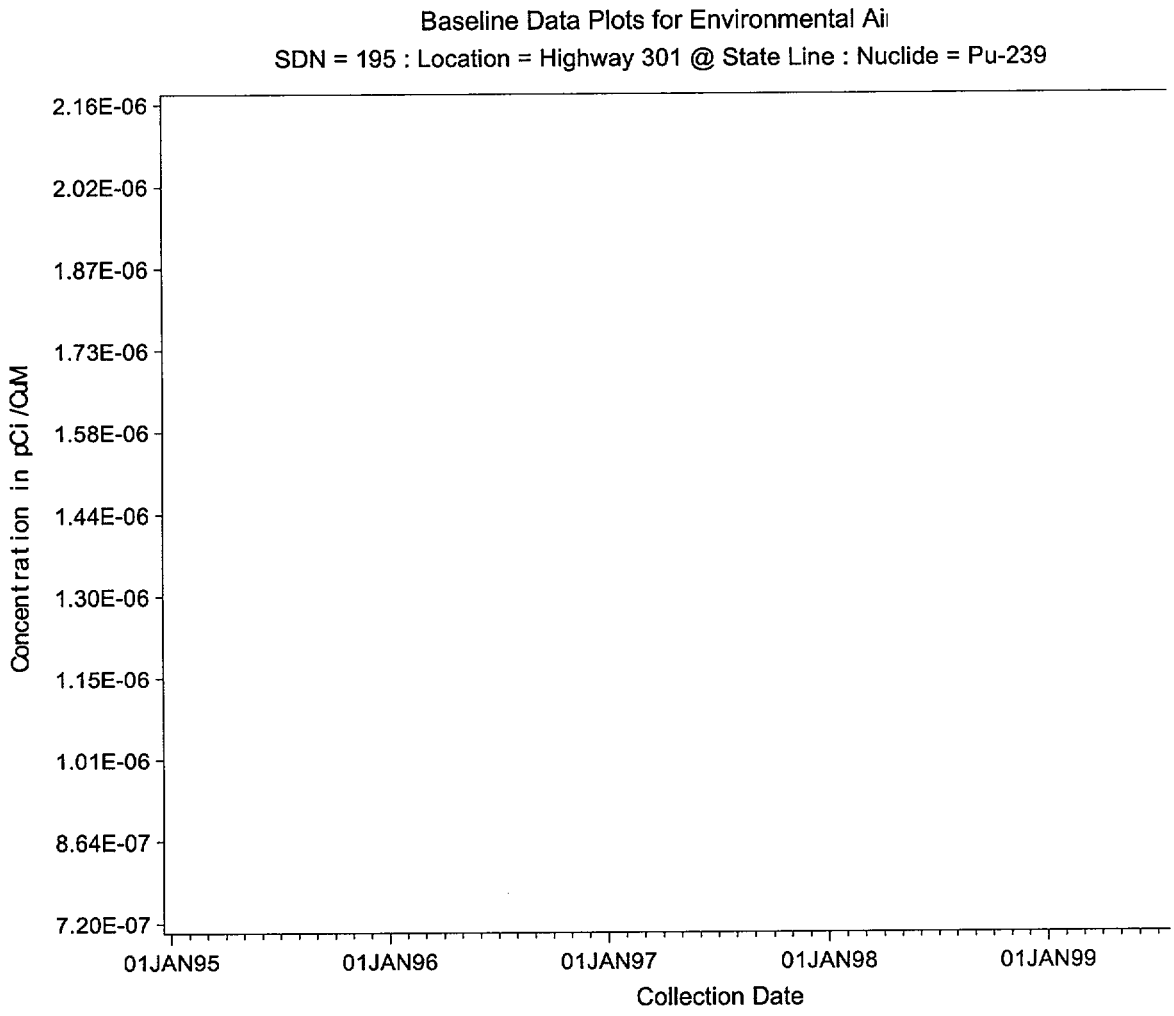


**Figure 53**
**U.S. Highway 301 Filter Paper Am-241 (Annual Sample)**

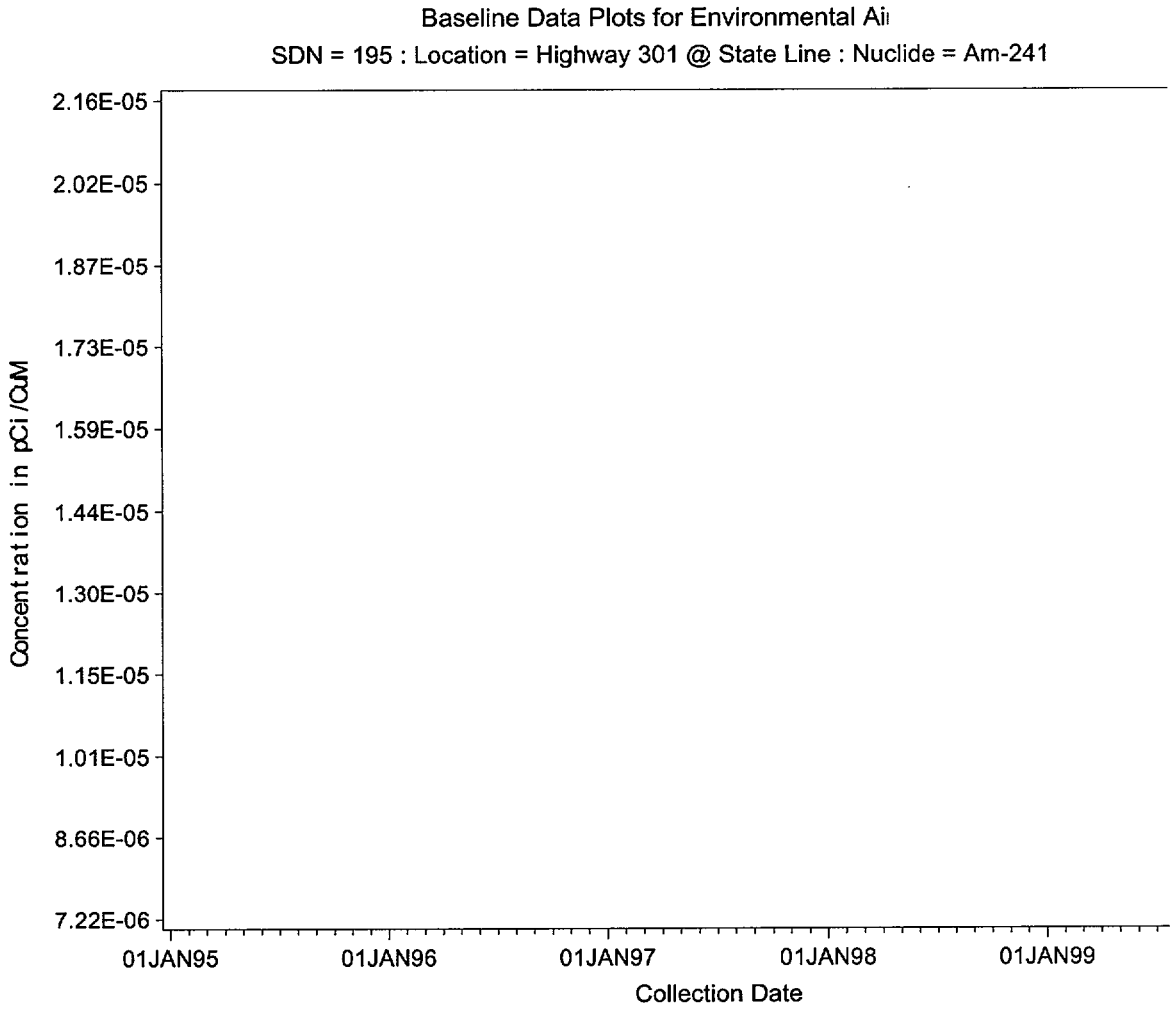


**Figure 54**
**U.S. Highway 301 Filter Paper Cm-244 (Annual Sample)**

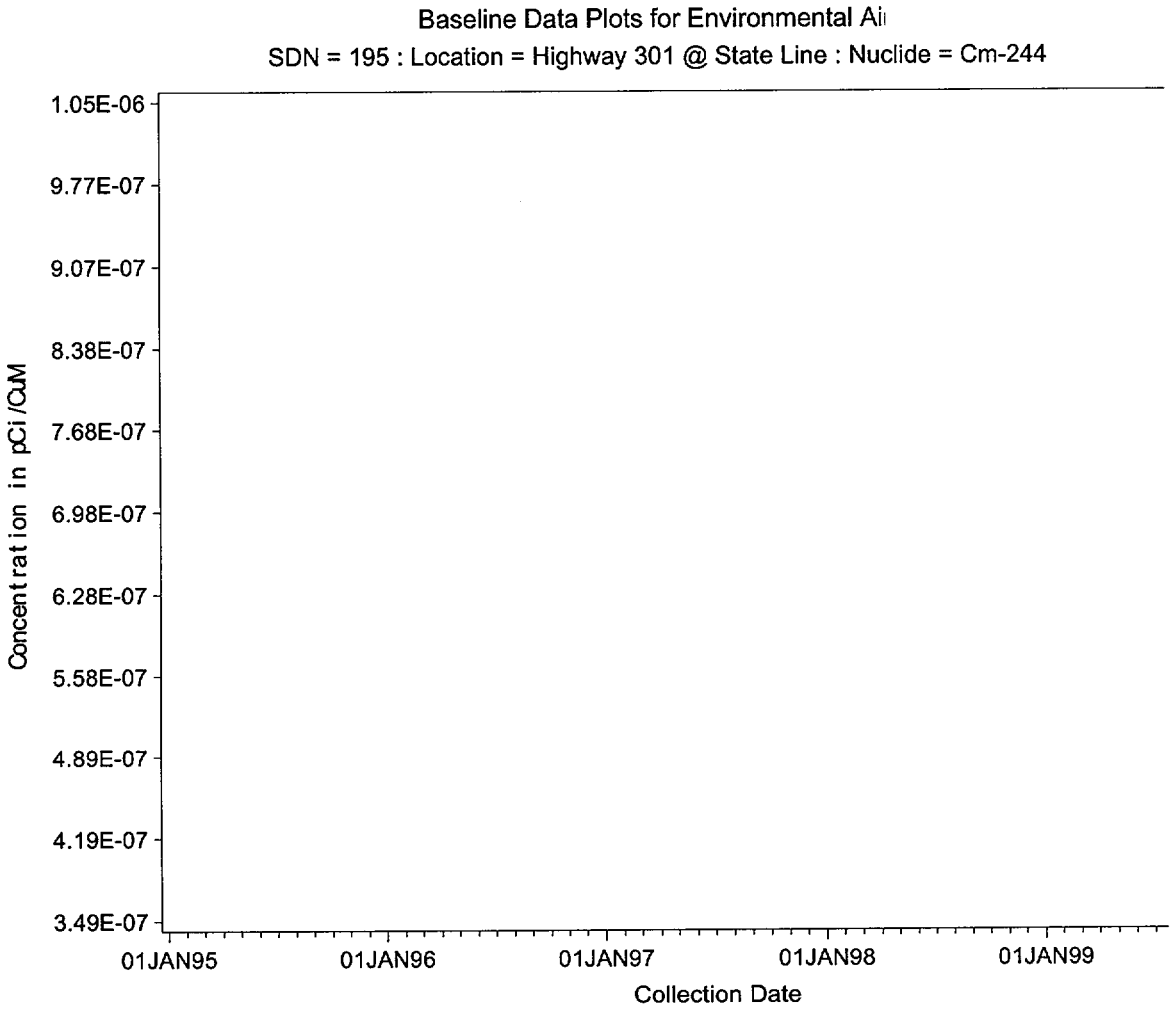


**Figure 55**
**U.S. Highway 301 Filter Paper Sr-89,90 (Annual Sample)**

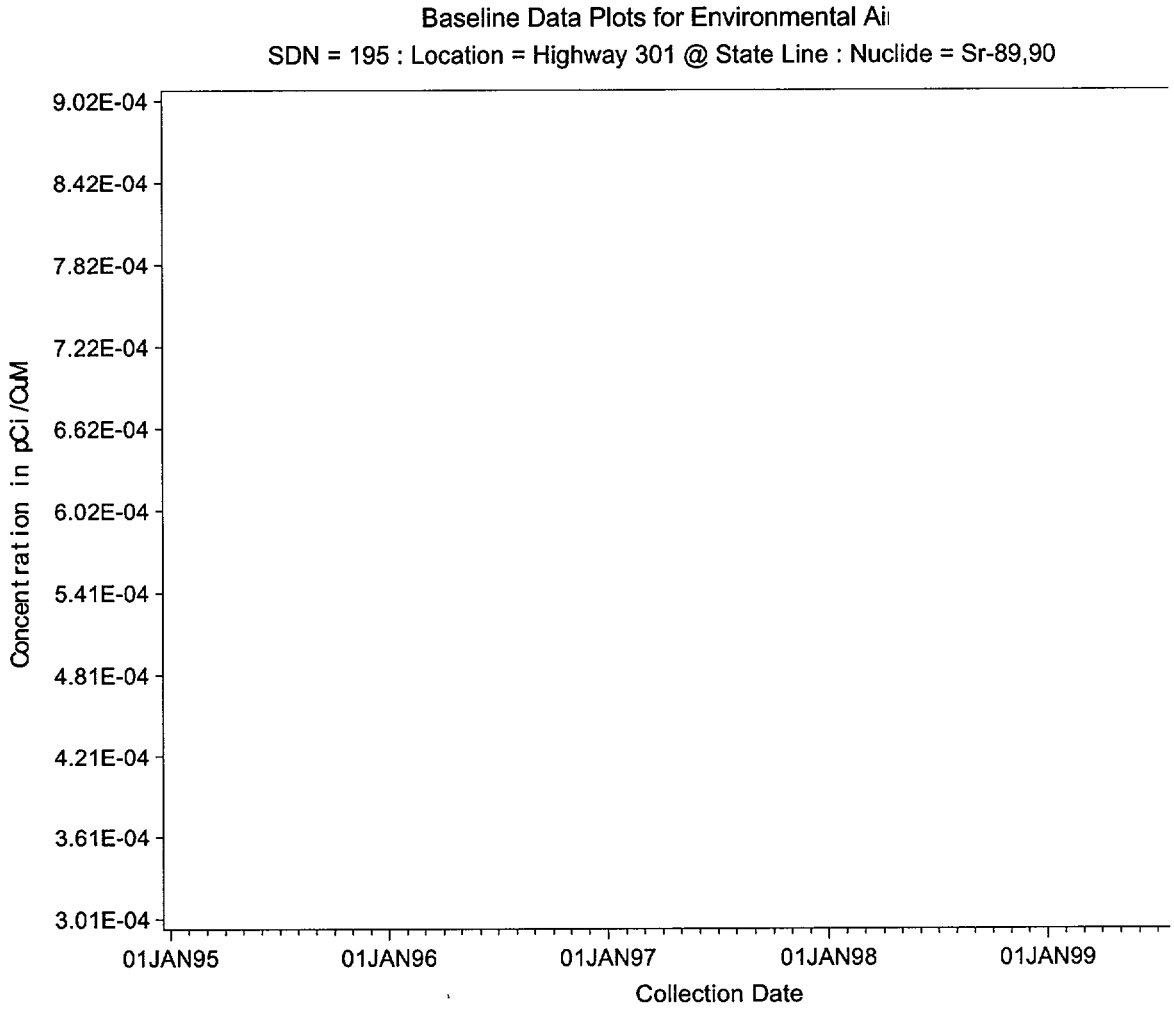


**Figure 56**
**U.S. Highway 301 Filter Paper Gross Beta (Weekly Sample)**

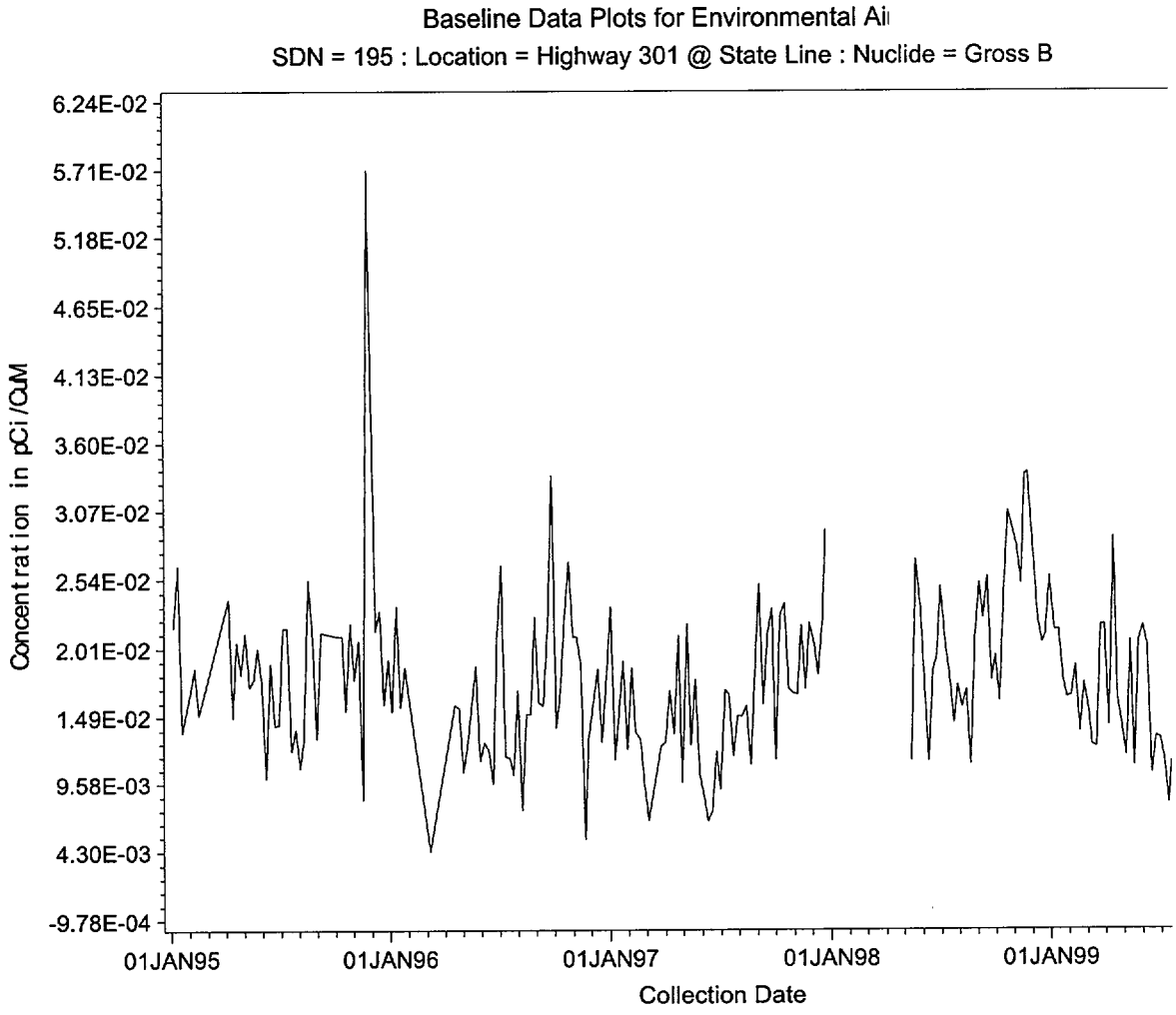


**Figure 57**
**U.S. Highway 301 Filter Paper Gross Alpha (Weekly Sample)**

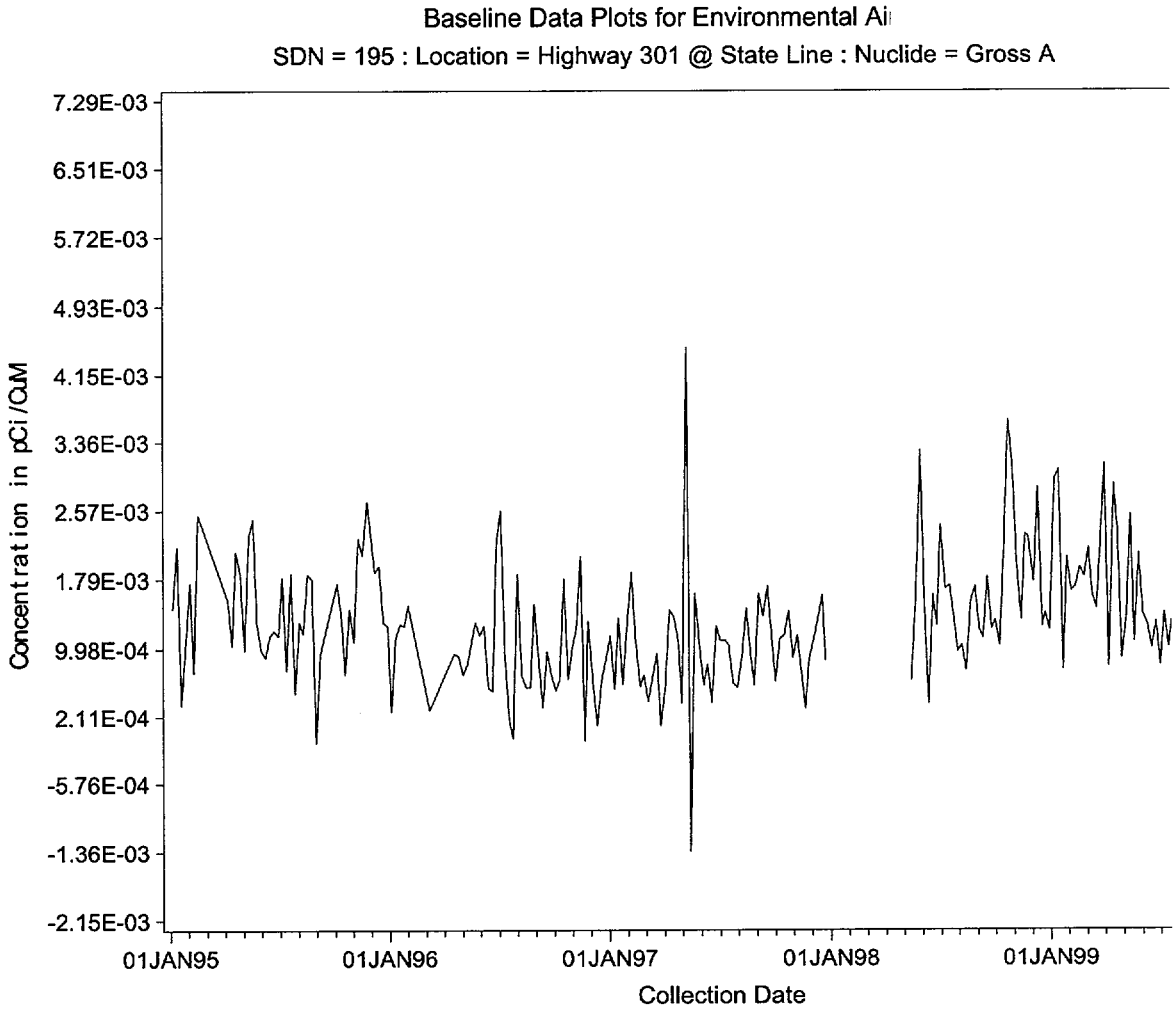


**Figure 58**
**U.S. Highway 301 Charcoal Canister Co-60 (Weekly Sample)**

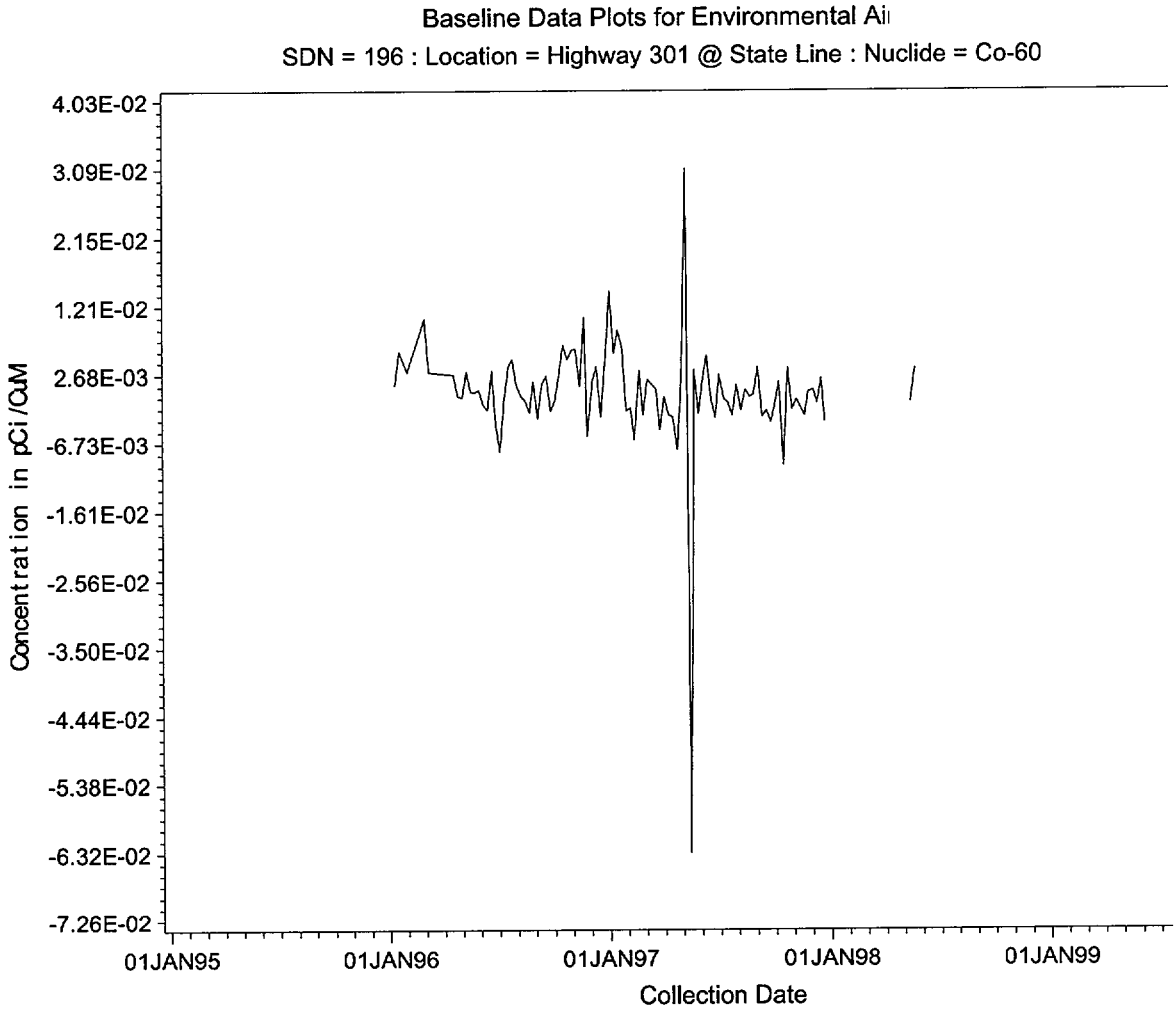


**Figure 59**
**U.S. Highway 301 Charcoal Canister Cs-137 (Weekly Sample)**

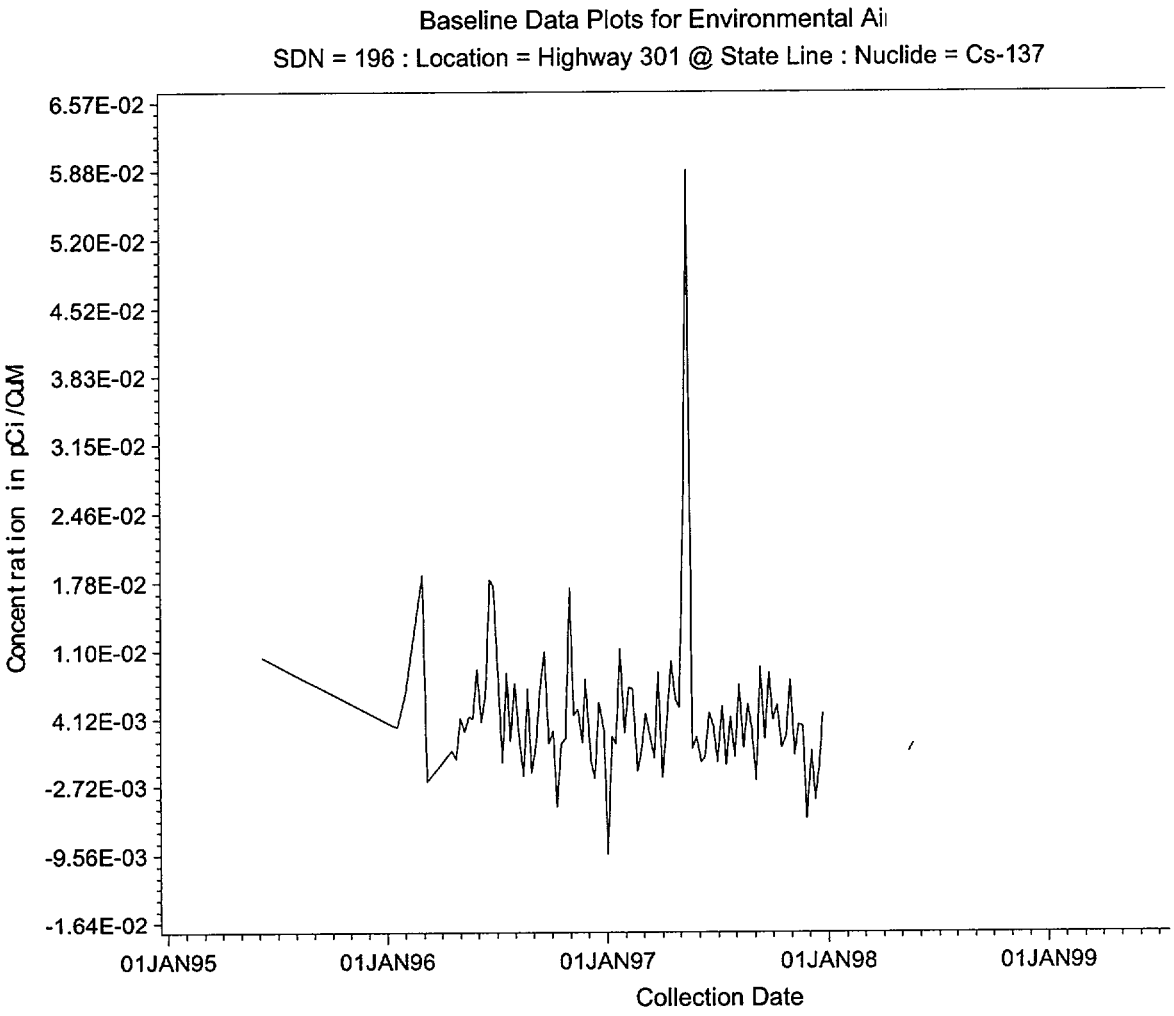


**Figure 60**
**U.S. Highway 301 Silica Gel H-3 (Biweekly Sample)**

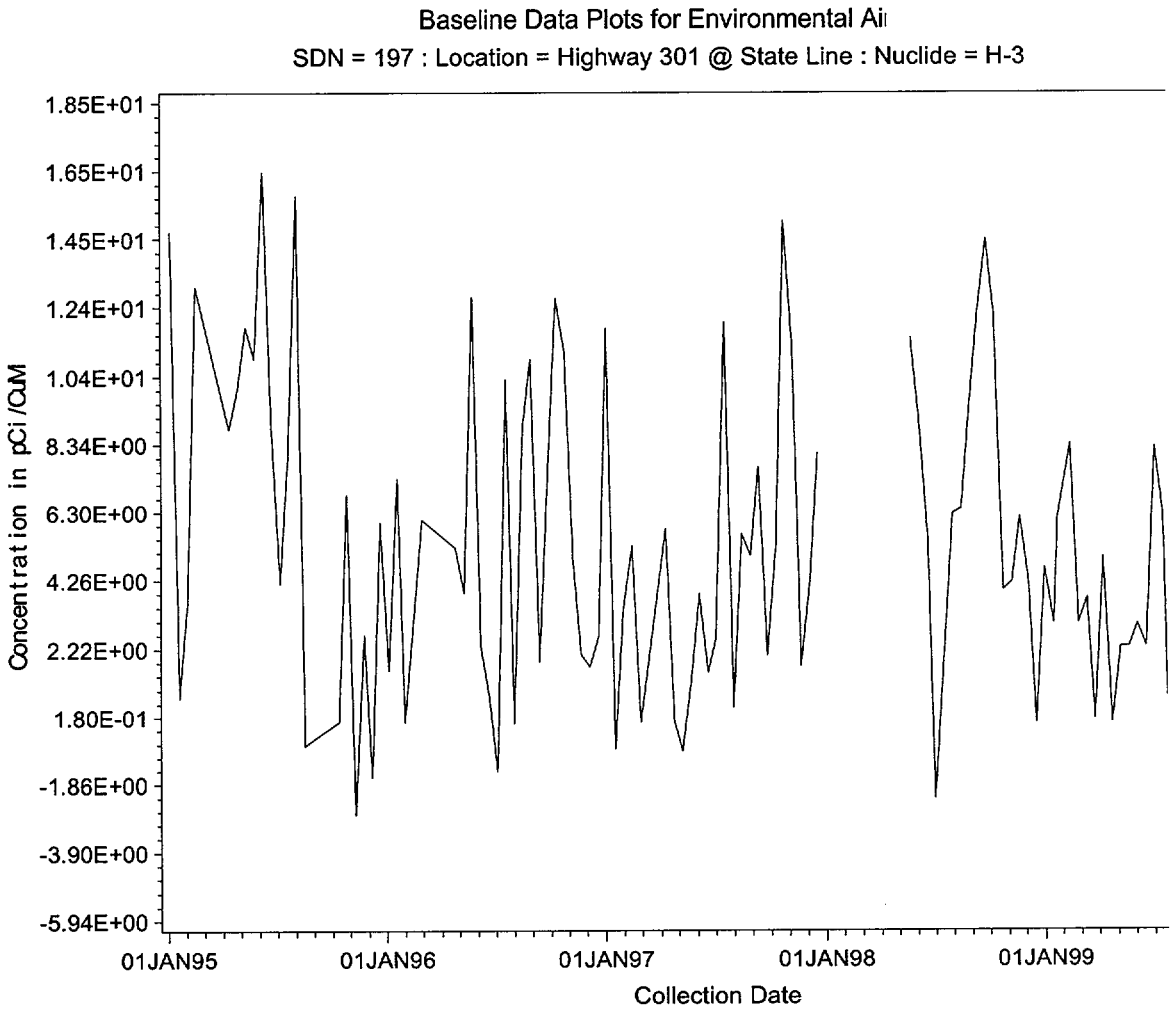


**Figure 61**
**U.S. Highway 301 Rain Water H-3 (Biweekly Sample)**

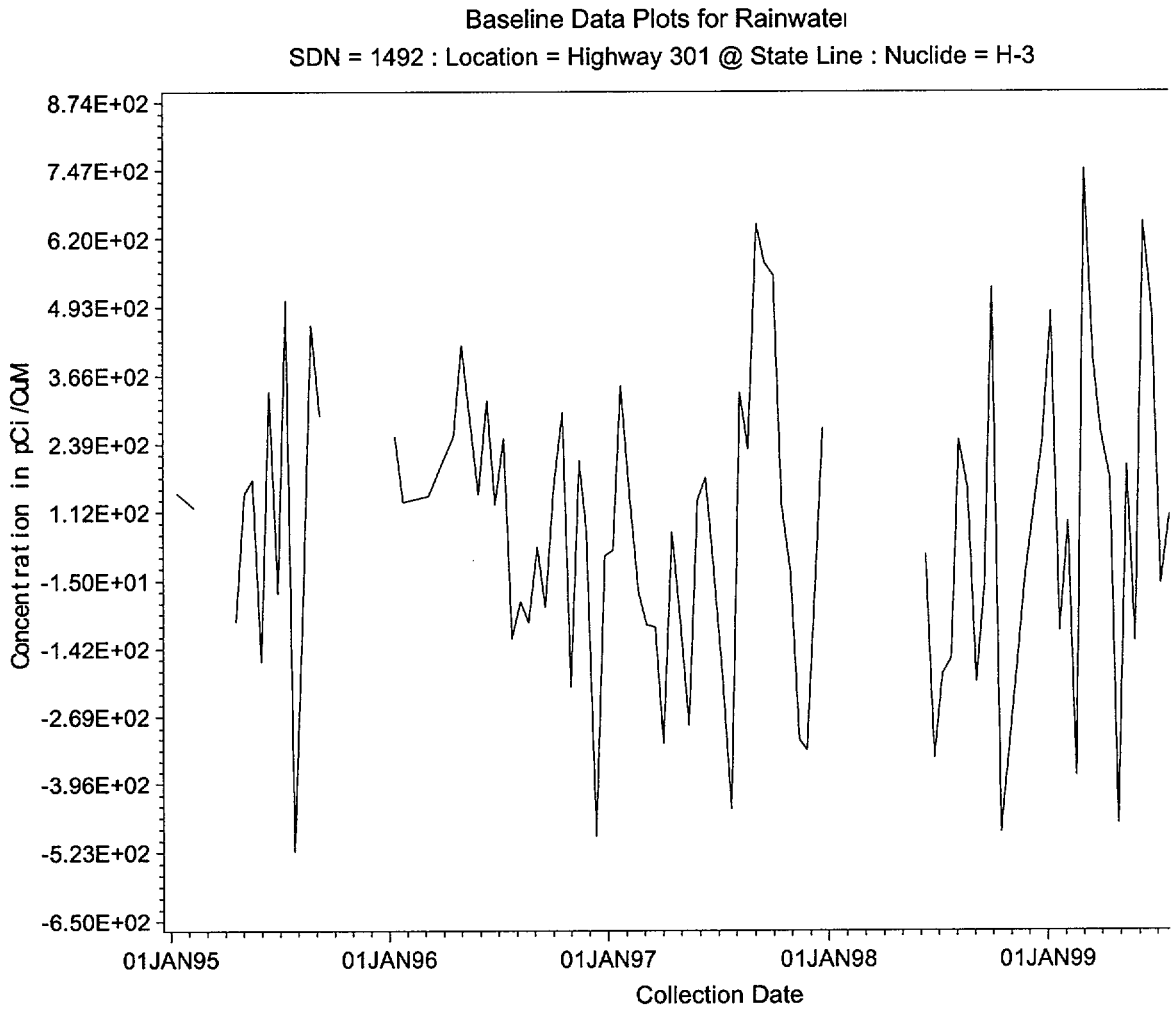


**Figure 62**
**Cs-137 Concentration in Soil**
**Near F-Area**

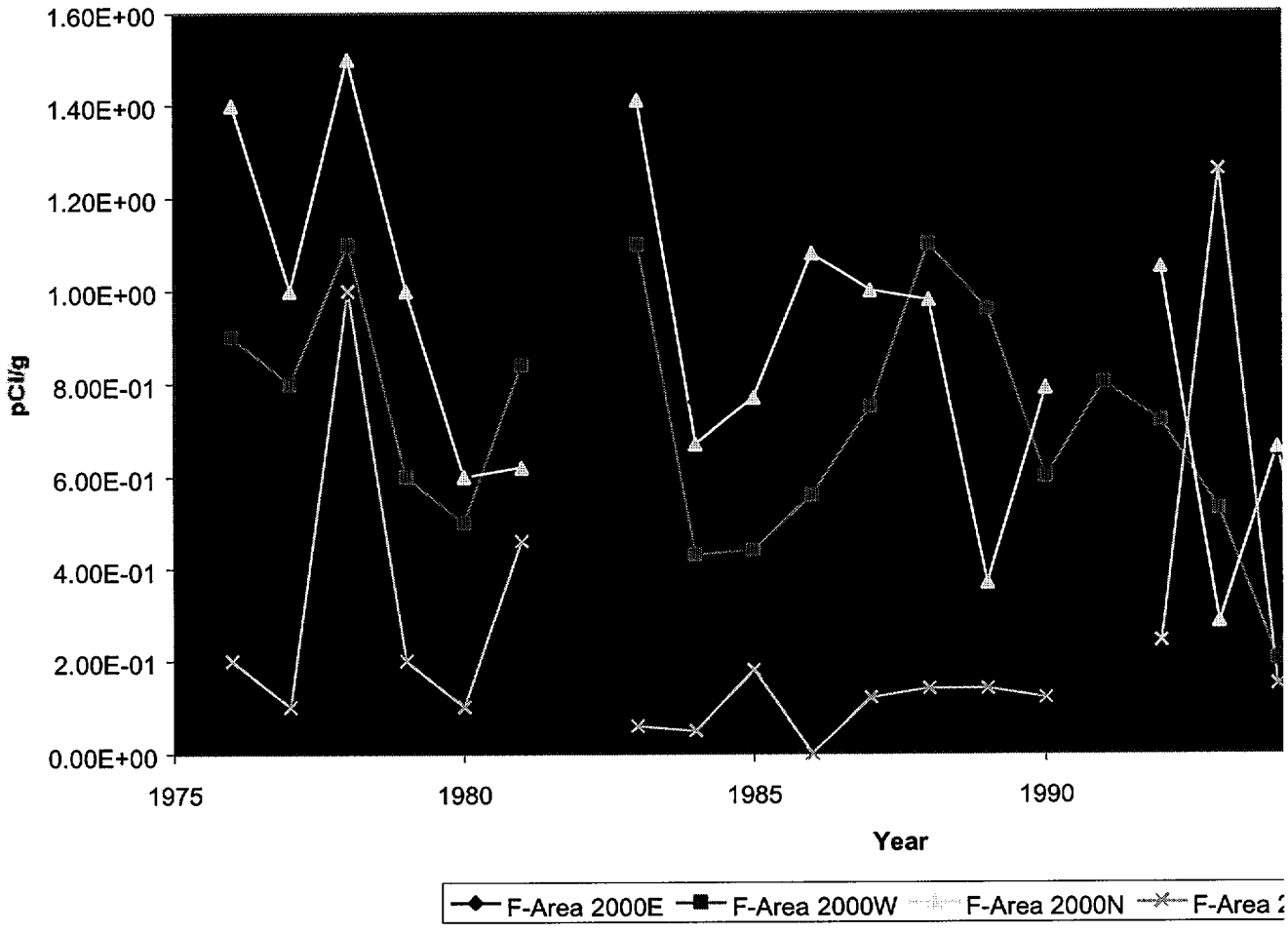


**Figure 63**
**Sr-89,90 Concentration in Soil**
**Near F-Area**

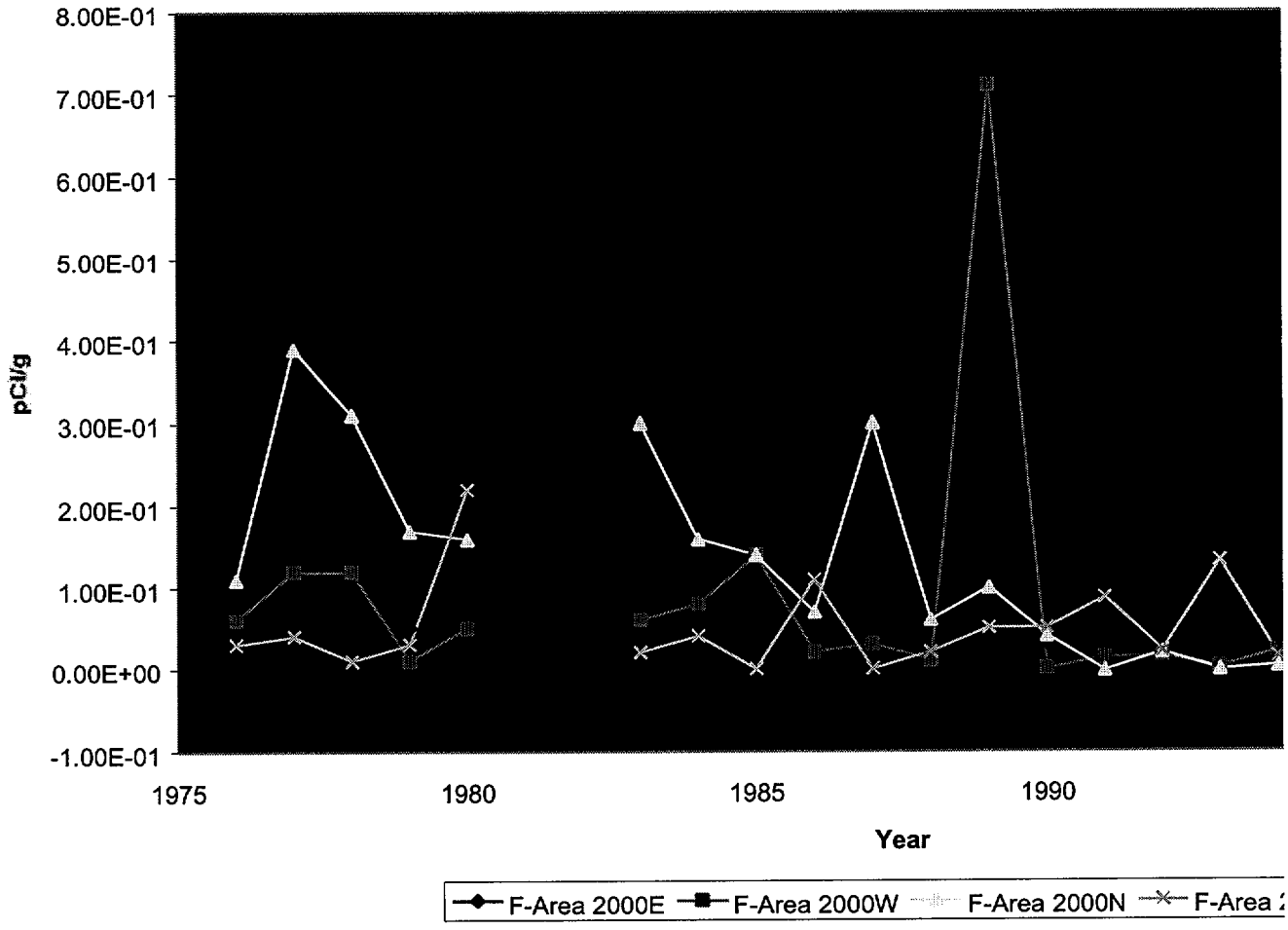


**Figure 64**
**Pu-238 Concentration in Soil**
**Near F-Area**

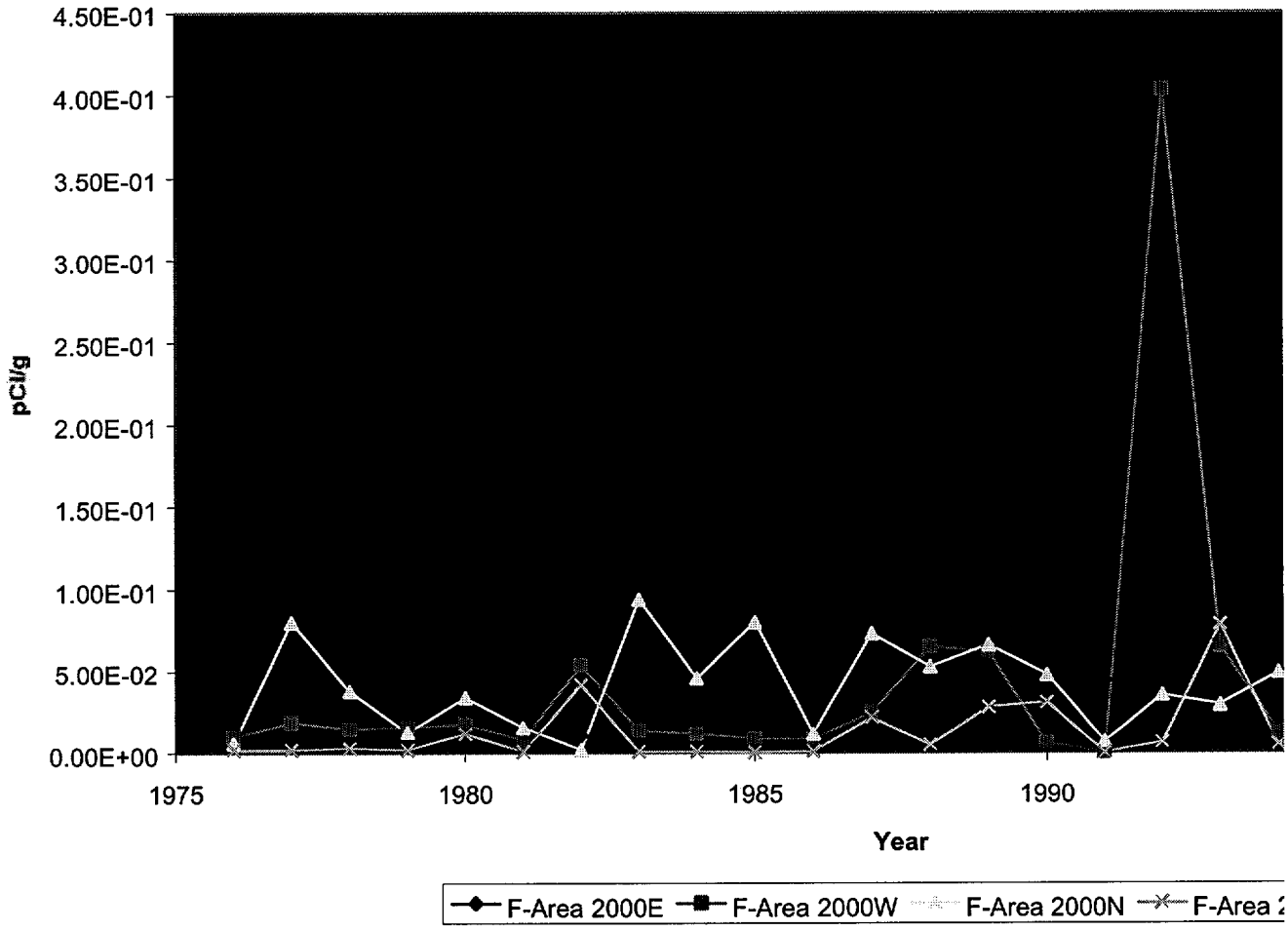
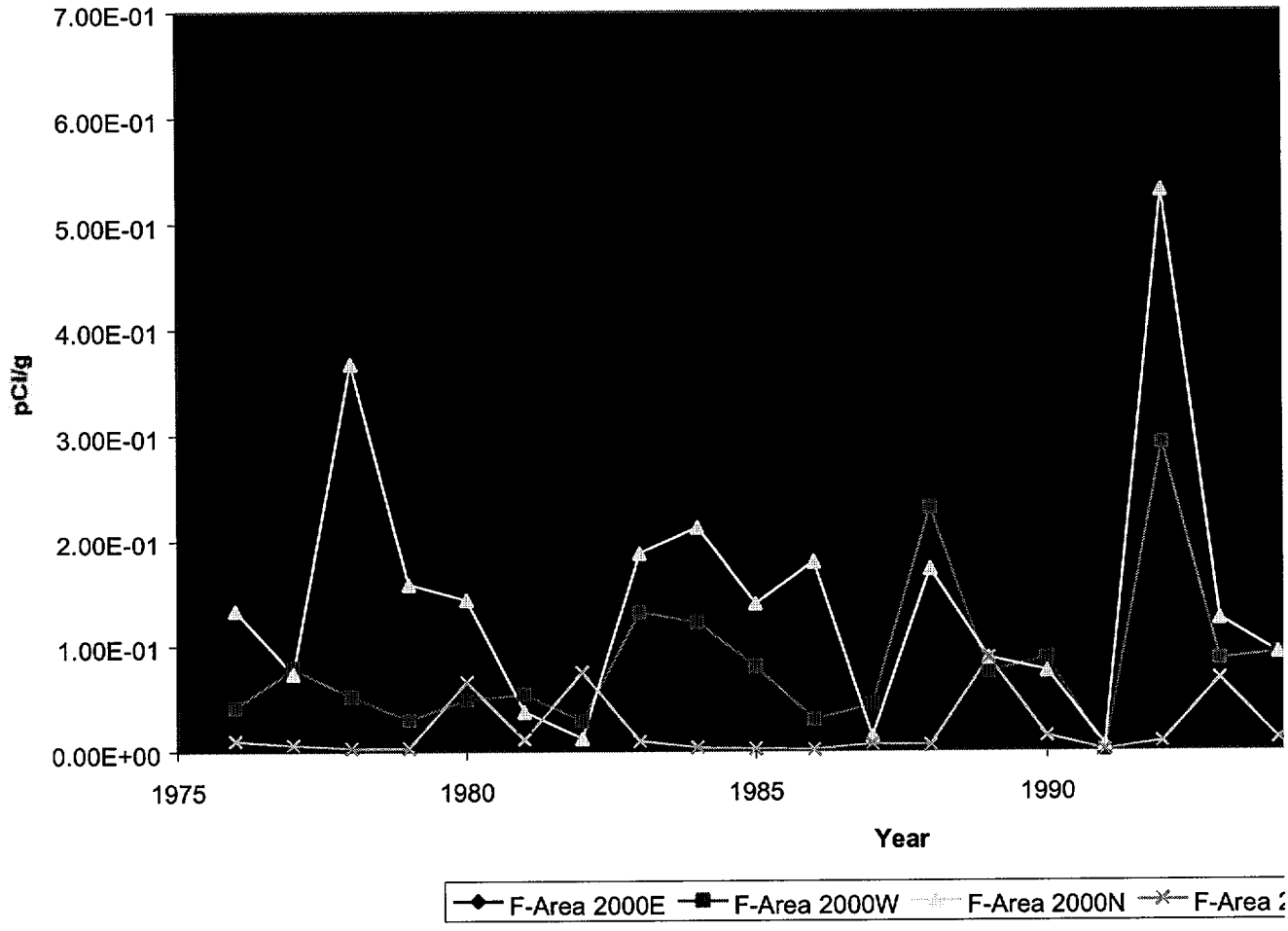


**Figure 65**
**Pu-239 Concentration in Soil**
**Near F-Area**



24-1

Output a assumptions used in the MOBILE5b and PART5 code runs

**ATTACHMENT 24-1**

**MOBILE5b Output**

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.

Cal. Year: 2005 I/M Program: No Ambient Temp: 49.1 / 49.1 / 49.1 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Jan Minimum Temp: 32. (F) Maximum Temp: 56. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VOC HC: | 0.99 | 1.32 | 1.84 | 1.48 | 1.28 | 0.25 | 0.33 | 1.01 | 1.75 | 1.140 |
| Exhaust HC: | 0.86 | 1.17 | 1.67 | 1.33 | 0.82 | 0.25 | 0.33 | 1.01 | 1.26 | 1.001 |
| Evaporat HC: | 0.08 | 0.10 | 0.11 | 0.10 | 0.37 | | | 0.33 | | 0.088 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.000 | |
| Runing L HC: | 0.04 | 0.04 | 0.05 | 0.04 | 0.07 | | | | | 0.036 |
| Rsting L HC: | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | | | 0.15 | | 0.014 |
| Exhaust CO: | 8.73 | 12.09 | 16.56 | 13.46 | 18.06 | 0.68 | 0.75 | 5.33 | 10.15 | 10.086 |
| Exhaust NOX: | 1.73 | 1.99 | 2.74 | 2.22 | 5.60 | 1.18 | 1.31 | 9.37 | 1.40 | 2.558 |

Evaporative Emissions by Component Weathered RVP: 8.7 Hot Soak Temp: 53.1 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 54.1 (F)
Resting Loss Temp: 45.6 (F)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hot Soak | 0.15 | 0.14 | 0.16 | 0.15 | 0.52 | | | 0.87 | | |
| WtDiurnal | 1.42 | 2.07 | 2.51 | 2.20 | 13.58 | | | 2.17 | | |
| Multiple | 2.53 | 2.77 | 3.30 | 2.92 | 17.88 | | | | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | | 0.00 | | |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| Resting | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | | | 0.06 | | |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 52.8 / 52.8 / 52.8 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Feb Minimum Temp: 35. (F) Maximum Temp: 60. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VOC HC: | 0.96 | 1.28 | 1.77 | 1.43 | 1.33 | 0.25 | 0.33 | 1.01 | 1.85 | 1.110 |
| Exhaust HC: | 0.81 | 1.11 | 1.58 | 1.25 | 0.79 | 0.25 | 0.33 | 1.01 | 1.23 | 0.952 |
| Evaporat HC: | 0.09 | 0.10 | 0.11 | 0.11 | 0.43 | | | | 0.46 | 0.097 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | 0.000 |
| Runing L HC: | 0.05 | 0.05 | 0.06 | 0.05 | 0.08 | | | | | 0.045 |
| Rsting L HC: | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | | | | 0.16 | 0.016 |
| Exhaust CO: | 8.32 | 11.47 | 15.75 | 12.78 | 17.75 | 0.68 | 0.75 | 5.33 | 9.78 | 9.635 |
| Exhaust NOX: | 1.69 | 1.94 | 2.68 | 2.17 | 5.56 | 1.18 | 1.31 | 9.37 | 1.38 | 2.519 |

Evaporative Emissions by Component Weathered RVP: 8.7 Hot Soak Temp: 56.9 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 57.9 (F)
Resting Loss Temp: 49.2 (F)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hot Soak | 0.22 | 0.21 | 0.25 | 0.22 | 0.72 | | | | | 1.12 |
| WtDiurnal | 1.43 | 2.09 | 2.53 | 2.22 | 13.94 | | | | | 3.10 |
| Multiple | 2.53 | 2.78 | 3.31 | 2.93 | 18.76 | | | | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | | | | 0.00 |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| Resting | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | | | | | 0.07 |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 61.5 / 61.5 / 61.5 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Mar Minimum Temp: 42. (F) Maximum Temp: 69. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 0.91 | 1.19 | 1.64 | 1.33 | 1.49 | 0.25 | 0.33 | 1.01 | 2.17 | 1.060 |
| Exhaust HC: | 0.72 | 0.97 | 1.38 | 1.10 | 0.73 | 0.25 | 0.33 | 1.01 | 1.15 | 0.849 |
| Evaporat HC: | 0.11 | 0.13 | 0.14 | 0.13 | 0.60 | | | 0.81 | | 0.126 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.000 | |
| Runing L HC: | 0.07 | 0.07 | 0.09 | 0.08 | 0.12 | | | | | 0.065 |
| Rsting L HC: | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | | | 0.21 | | 0.020 |
| Exhaust CO: | 7.41 | 10.10 | 13.97 | 11.29 | 17.05 | 0.68 | 0.75 | 5.33 | 8.99 | 8.640 |
| Exhaust NOX: | 1.60 | 1.83 | 2.53 | 2.05 | 5.47 | 1.18 | 1.31 | 9.37 | 1.32 | 2.429 |

Evaporative Emissions by Component Weathered RVP: 8.7 Hot Soak Temp: 65.4 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 66.5 (F)
Resting Loss Temp: 57.5 (F)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hot Soak | 0.45 | 0.45 | 0.54 | 0.47 | 1.35 | | | 1.69 | | |
| WtDiurnal | 1.46 | 2.14 | 2.58 | 2.27 | 15.02 | | | 5.86 | | |
| Multiple | 2.52 | 2.80 | 3.33 | 2.95 | 21.34 | | | | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | | 0.00 | | |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| Resting | 0.02 | 0.02 | 0.03 | 0.03 | 0.04 | | | 0.09 | | |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 69.5 / 69.5 / 69.5 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Apr Minimum Temp: 49. (F) Maximum Temp: 77. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| VOC HC: | 0.90 | 1.14 | 1.56 | 1.27 | 1.78 | 0.25 | 0.33 | 1.01 | 2.79 | 1.048 |
|---|---|---|---|---|---|---|---|---|---|---|
| Exhaust HC: | 0.65 | 0.86 | 1.23 | 0.97 | 0.68 | 0.25 | 0.33 | 1.01 | 1.09 | 0.769 |
| Evaporat HC: | 0.15 | 0.17 | 0.18 | 0.17 | 0.90 | | | 1.44 | | 0.174 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.000 | |
| Runing L HC: | 0.08 | 0.09 | 0.12 | 0.10 | 0.16 | | | | | 0.081 |
| Rsting L HC: | 0.02 | 0.03 | 0.03 | 0.03 | 0.05 | | | 0.26 | | 0.025 |
| Exhaust CO: | 6.65 | 8.94 | 12.48 | 10.03 | 16.43 | 0.68 | 0.75 | 5.33 | 8.36 | 7.798 |
| Exhaust NOX: | 1.53 | 1.74 | 2.40 | 1.94 | 5.39 | 1.18 | 1.31 | 9.37 | 1.27 | 2.352 |

Evaporative Emissions by Component Weathered RVP: 8.7 Hot Soak Temp: 73.0 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 74.0 (F)
Resting Loss Temp: 65.1 (F)

| | | | | | | |
|---|---|---|---|---|---|---|
| Hot Soak | 0.73 | 0.76 | 0.91 | 0.81 | 2.64 | 3.75 |
| WtDiurnal | 1.65 | 2.38 | 2.86 | 2.52 | 16.36 | 9.32 |
| Multiple | 3.32 | 3.35 | 3.89 | 3.51 | 24.51 | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Resting | 0.03 | 0.03 | 0.03 | 0.03 | 0.05 | 0.11 |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 77.4 / 77.4 / 77.4 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS May Minimum Temp: 58. (F) Maximum Temp: 84. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| VOC HC: | 0.91 | 1.14 | 1.55 | 1.27 | 2.16 | 0.25 | 0.33 | 1.01 | 3.66 | 1.074 |
|---|---|---|---|---|---|---|---|---|---|---|
| Exhaust HC: | 0.60 | 0.80 | 1.14 | 0.90 | 0.65 | 0.25 | 0.33 | 1.01 | 1.05 | 0.720 |
| Evaporat HC: | 0.19 | 0.22 | 0.23 | 0.22 | 1.27 | | | 2.29 | | 0.228 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.000 | |
| Runing L HC: | 0.09 | 0.10 | 0.14 | 0.11 | 0.19 | | | | | 0.095 |
| Rsting L HC: | 0.03 | 0.03 | 0.03 | 0.03 | 0.06 | | | 0.32 | | 0.031 |
| Exhaust CO: | 6.15 | 8.20 | 11.52 | 9.22 | 16.36 | 0.68 | 0.75 | 5.33 | 8.22 | 7.269 |
| Exhaust NOX: | 1.47 | 1.68 | 2.31 | 1.87 | 5.40 | 1.18 | 1.31 | 9.37 | 1.21 | 2.299 |

Evaporative Emissions by Component Weathered RVP: 8.6 Hot Soak Temp: 79.9 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 80.9 (F)
Resting Loss Temp: 72.7 (F)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hot Soak | 0.94 | 1.02 | 1.22 | 1.08 | 4.49 | | 7.97 |
| WtDiurnal | 1.95 | 2.76 | 3.29 | 2.91 | 17.46 | | 12.17 |
| Multiple | 5.03 | 5.34 | 5.86 | 5.49 | 27.19 | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | 0.00 |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Resting | 0.04 | 0.04 | 0.04 | 0.04 | 0.06 | | 0.13 |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 83.6 / 83.6 / 83.6 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Jun Minimum Temp: 66. (F) Maximum Temp: 89. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| VOC HC: | 0.97 | 1.21 | 1.63 | 1.34 | 2.52 | 0.25 | 0.33 | 1.01 | 4.31 | 1.145 |
|---|---|---|---|---|---|---|---|---|---|---|
| Exhaust HC: | 0.60 | 0.80 | 1.14 | 0.90 | 0.67 | 0.25 | 0.33 | 1.01 | 1.04 | 0.721 |
| Evaporat HC: | 0.21 | 0.25 | 0.27 | 0.25 | 1.54 | | | 2.89 | | 0.265 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.000 | |
| Runing L HC: | 0.12 | 0.13 | 0.18 | 0.15 | 0.24 | | | | | 0.122 |
| Rsting L HC: | 0.04 | 0.04 | 0.04 | 0.04 | 0.07 | | | 0.38 | | 0.036 |
| Exhaust CO: | 6.17 | 8.23 | 11.57 | 9.25 | 17.78 | 0.68 | 0.75 | 5.33 | 9.00 | 7.336 |
| Exhaust NOX: | 1.49 | 1.69 | 2.33 | 1.89 | 5.40 | 1.18 | 1.31 | 9.37 | 1.16 | 2.309 |

Evaporative Emissions by Component Weathered RVP: 8.4 Hot Soak Temp: 85.2 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 86.0 (F)
Resting Loss Temp: 78.5 (F)

| Hot Soak | 1.11 | 1.22 | 1.47 | 1.30 | 5.82 | | | 11.31 | |
|---|---|---|---|---|---|---|---|---|---|
| WtDiurnal | 2.12 | 2.96 | 3.52 | 3.12 | 18.30 | | | 13.66 | |
| Multiple | 5.80 | 6.45 | 7.08 | 6.63 | 28.86 | | | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | | 0.00 | |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | |
| Resting | 0.04 | 0.04 | 0.05 | 0.05 | 0.07 | | | 0.16 | |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 87.0 / 87.0 / 87.0 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Jul Minimum Temp: 70. (F) Maximum Temp: 92. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VOC HC: | 1.02 | 1.26 | 1.69 | 1.39 | 2.75 | 0.25 | 0.33 | 1.01 | 4.74 | 1.196 |
| Exhaust HC: | 0.60 | 0.80 | 1.14 | 0.90 | 0.69 | 0.25 | 0.33 | 1.01 | 1.04 | 0.722 |
| Evaporat HC: | 0.23 | 0.27 | 0.29 | 0.28 | 1.70 | | | 3.28 | | 0.291 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | 0.000 |
| Runing L HC: | 0.14 | 0.15 | 0.22 | 0.17 | 0.29 | | | | | 0.144 |
| Rsting L HC: | 0.04 | 0.04 | 0.04 | 0.04 | 0.08 | | | 0.42 | | 0.040 |
| Exhaust CO: | 6.21 | 8.29 | 11.67 | 9.33 | 18.77 | 0.68 | 0.75 | 5.33 | 9.51 | 7.414 |
| Exhaust NOX: | 1.49 | 1.70 | 2.34 | 1.89 | 5.40 | 1.18 | 1.31 | 9.37 | 1.13 | 2.315 |

Evaporative Emissions by Component Weathered RVP: 8.3 Hot Soak Temp: 88.2 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 89.0 (F)
Resting Loss Temp: 81.8 (F)

| | | | | | | |
|---|---|---|---|---|---|---|
| Hot Soak | 1.22 | 1.35 | 1.63 | 1.43 | 6.58 | 13.25 |
| WtDiurnal | 2.28 | 3.16 | 3.74 | 3.32 | 19.08 | 14.97 |
| Multiple | 6.35 | 7.32 | 8.09 | 7.54 | 30.33 | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Resting | 0.05 | 0.05 | 0.05 | 0.05 | 0.08 | 0.17 |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Aug Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VOC HC: | 0.98 | 1.22 | 1.64 | 1.35 | 2.60 | 0.25 | 0.33 | 1.01 | 4.40 | 1.156 |
| Exhaust HC: | 0.60 | 0.80 | 1.14 | 0.90 | 0.68 | 0.25 | 0.33 | 1.01 | 1.04 | 0.721 |
| Evaporat HC: | 0.22 | 0.25 | 0.27 | 0.26 | 1.59 | | | 2.95 | | 0.269 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | 0.000 |
| Runing L HC: | 0.13 | 0.14 | 0.19 | 0.15 | 0.26 | | | | | 0.127 |
| Rsting L HC: | 0.04 | 0.04 | 0.04 | 0.04 | 0.07 | | | 0.40 | | 0.038 |
| Exhaust CO: | 6.18 | 8.26 | 11.62 | 9.29 | 18.25 | 0.68 | 0.75 | 5.33 | 9.23 | 7.372 |
| Exhaust NOX: | 1.49 | 1.69 | 2.33 | 1.89 | 5.40 | 1.18 | 1.31 | 9.37 | 1.15 | 2.312 |

Evaporative Emissions by Component Weathered RVP: 8.3 Hot Soak Temp: 86.4 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.1 (F)
Resting Loss Temp: 80.2 (F)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hot Soak | 1.15 | 1.28 | 1.53 | 1.35 | 6.12 | | | 12.08 | | |
| WtDiurnal | 2.07 | 2.91 | 3.46 | 3.07 | 18.09 | | | 13.29 | | |
| Multiple | 5.64 | 6.24 | 6.84 | 6.42 | 28.46 | | | | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | | 0.00 | | |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| Resting | 0.04 | 0.05 | 0.05 | 0.05 | 0.08 | | | 0.17 | | |

Exhaust emissions for gasoline fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 80.5 / 80.5 / 80.5 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Sep Minimum Temp: 63. (F) Maximum Temp: 86. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VOC HC: | 0.94 | 1.17 | 1.58 | 1.29 | 2.31 | 0.25 | 0.33 | 1.01 | 3.87 | 1.100 |
| Exhaust HC: | 0.60 | 0.80 | 1.14 | 0.90 | 0.66 | 0.25 | 0.33 | 1.01 | 1.05 | 0.721 |
| Evaporat HC: | 0.19 | 0.22 | 0.24 | 0.23 | 1.37 | | | 2.47 | | 0.239 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.000 | |
| Runing L HC: | 0.11 | 0.11 | 0.16 | 0.13 | 0.21 | | | | | 0.107 |
| Rsting L HC: | 0.03 | 0.03 | 0.04 | 0.03 | 0.06 | | | 0.35 | | 0.033 |
| Exhaust CO: | 6.15 | 8.20 | 11.53 | 9.22 | 16.94 | 0.68 | 0.75 | 5.33 | 8.59 | 7.290 |
| Exhaust NOX: | 1.48 | 1.68 | 2.32 | 1.88 | 5.40 | 1.18 | 1.31 | 9.37 | 1.19 | 2.304 |

Evaporative Emissions by Component Weathered RVP: 8.5 Hot Soak Temp: 82.2 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 83.1 (F)
Resting Loss Temp: 75.6 (F)

| | | | | | | |
|---|---|---|---|---|---|---|
| Hot Soak | 1.01 | 1.10 | 1.32 | 1.17 | 5.07 | 9.41 |
| WtDiurnal | 1.93 | 2.74 | 3.26 | 2.89 | 17.42 | 12.07 |
| Multiple | 5.01 | 5.32 | 5.84 | 5.47 | 27.13 | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Resting | 0.04 | 0.04 | 0.05 | 0.04 | 0.07 | 0.15 |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 69.8 / 69.8 / 69.8 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Oct Minimum Temp: 50. (F) Maximum Temp: 77. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VOC HC: | 0.90 | 1.14 | 1.55 | 1.26 | 1.78 | 0.25 | 0.33 | 1.01 | 2.77 | 1.045 |
| Exhaust HC: | 0.64 | 0.86 | 1.23 | 0.97 | 0.68 | 0.25 | 0.33 | 1.01 | 1.09 | 0.766 |
| Evaporat HC: | 0.15 | 0.17 | 0.18 | 0.17 | 0.90 | | | 1.42 | | 0.173 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.000 | |
| Runing L HC: | 0.08 | 0.09 | 0.12 | 0.10 | 0.16 | | | | | 0.081 |
| Rsting L HC: | 0.02 | 0.03 | 0.03 | 0.03 | 0.05 | | | 0.26 | | 0.025 |
| Exhaust CO: | 6.62 | 8.90 | 12.42 | 9.98 | 16.41 | 0.68 | 0.75 | 5.33 | 8.34 | 7.768 |
| Exhaust NOX: | 1.53 | 1.74 | 2.40 | 1.94 | 5.39 | 1.18 | 1.31 | 9.37 | 1.27 | 2.349 |

Evaporative Emissions by Component Weathered RVP: 8.7 Hot Soak Temp: 73.1 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 74.1 (F)
Resting Loss Temp: 65.4 (F)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hot Soak | 0.73 | 0.77 | 0.92 | 0.81 | 2.67 | | | 3.81 | | |
| WtDiurnal | 1.62 | 2.35 | 2.83 | 2.49 | 16.26 | | | 9.08 | | |
| Multiple | 3.22 | 3.28 | 3.81 | 3.43 | 24.30 | | | | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | | 0.00 | | |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| Resting | 0.03 | 0.03 | 0.03 | 0.03 | 0.05 | | | 0.11 | | |

Exhaust emissions for gasoline fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 60.8 / 60.8 / 60.8 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Nov Minimum Temp: 42. (F) Maximum Temp: 68. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 0.91 | 1.19 | 1.65 | 1.33 | 1.46 | 0.25 | 0.33 | 1.01 | 2.11 | 1.061 |
| Exhaust HC: | 0.73 | 0.98 | 1.40 | 1.11 | 0.74 | 0.25 | 0.33 | 1.01 | 1.15 | 0.857 |
| Evaporat HC: | 0.11 | 0.12 | 0.14 | 0.13 | 0.57 | | | 0.75 | | 0.122 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | 0.000 |
| Runing L HC: | 0.06 | 0.07 | 0.09 | 0.07 | 0.12 | | | | | 0.063 |
| Rsting L HC: | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | | | 0.21 | | 0.020 |
| Exhaust CO: | 7.48 | 10.21 | 14.11 | 11.40 | 17.10 | 0.68 | 0.75 | 5.33 | 9.05 | 8.716 |
| Exhaust NOX: | 1.61 | 1.84 | 2.54 | 2.06 | 5.48 | 1.18 | 1.31 | 9.37 | 1.32 | 2.436 |

Evaporative Emissions by Component Weathered RVP: 8.7 Hot Soak Temp: 64.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 65.5 (F)
Resting Loss Temp: 56.8 (F)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hot Soak | 0.41 | 0.42 | 0.50 | 0.44 | 1.27 | | 1.63 |
| WtDiurnal | 1.45 | 2.13 | 2.57 | 2.26 | 14.82 | | 5.36 |
| Multiple | 2.52 | 2.80 | 3.32 | 2.95 | 20.87 | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | | 0.00 |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Resting | 0.02 | 0.02 | 0.03 | 0.02 | 0.04 | | 0.09 |

Exhaust emissions for gasoline-fueled vehicles beginning in 1995 have been reduced as a result of Gasoline Detergent Additive Regulations (1994).

Emission factors are as of Jan. 1st of the indicated calendar year.
Cal. Year: 2005 I/M Program: No Ambient Temp: 52.8 / 52.8 / 52.8 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
SRS Dec Minimum Temp: 35. (F) Maximum Temp: 60. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | | |
| VMT Mix: | 0.601 | 0.196 | 0.087 | 0.031 | 0.002 | 0.002 | 0.075 | 0.006 | | |

Composite Emission Factors (Gm/Mile)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VOC HC: | 0.96 | 1.28 | 1.77 | 1.43 | 1.33 | 0.25 | 0.33 | 1.01 | 1.85 | 1.110 |
| Exhaust HC: | 0.81 | 1.11 | 1.58 | 1.25 | 0.79 | 0.25 | 0.33 | 1.01 | 1.23 | 0.952 |
| Evaporat HC: | 0.09 | 0.10 | 0.11 | 0.11 | 0.43 | | | 0.46 | | 0.097 |
| Refuel L HC: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | 0.000 |
| Runing L HC: | 0.05 | 0.05 | 0.06 | 0.05 | 0.08 | | | | | 0.045 |
| Rsting L HC: | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | | | 0.16 | | 0.016 |
| Exhaust CO: | 8.32 | 11.47 | 15.75 | 12.78 | 17.75 | 0.68 | 0.75 | 5.33 | 9.78 | 9.635 |
| Exhaust NOX: | 1.69 | 1.94 | 2.68 | 2.17 | 5.56 | 1.18 | 1.31 | 9.37 | 1.38 | 2.519 |

Evaporative Emissions by Component Weathered RVP: 8.7 Hot Soak Temp: 56.9 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 57.9 (F)
Resting Loss Temp: 49.2 (F)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hot Soak | 0.22 | 0.21 | 0.25 | 0.22 | 0.72 | 1.12 | |
| WtDiurnal | 1.43 | 2.09 | 2.53 | 2.22 | 13.94 | 3.10 | |
| Multiple | 2.53 | 2.78 | 3.31 | 2.93 | 18.76 | | |
| Crankcase | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | |
| Refuel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Resting | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.07 | |

ENVIRONMENTAL SCIENCE
AND TECHNOLOGY

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# MAXIMALLY EXPOSED OFFSITE INDIVIDUAL LOCATION DETERMINATION FOR NESHAPS COMPLIANCE

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30 - 1

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January 2000

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

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Key Words Atmospheric Dispersion
Dose Determination
Atmospheric Releases

**Retention: Lifetime**

# MAXIMALLY EXPOSED OFFSITE INDIVIDUAL LOCATION DETERMINATION FOR NESHAPS COMPLIANCE

**A. A. Simpkins**

**Issued: January 2000**

*SRTC*

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**AIKEN, SC 29808**
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**PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC09-96SR18500**

## ABSTRACT

The Environmental Protection Agency (EPA) requires the use of the computer program CAP88 for demonstrating compliance with the National Emission Standard for Hazardous Air Pollutants (NESHAPS.) One of the inputs required for CAP88 is the location of the maximally exposed individual (MEI) by sector and distance. Distances to the MEI have been determined for 15 different potential release locations at SRS. These locations were compared with previous work and differences were analyzed. Additionally, SREL Conference Center was included as a potential 'offsite' location since in the future it may be used as a dormitory. Worst sectors were then determined based on the distances.

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# MAXIMALLY EXPOSED OFFSITE INDIVIDUAL LOCATION DETERMINATION FOR NESHAPS COMPLIANCE

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## 1. INTRODUCTION

The Environmental Protection Agency (EPA) requires the use of the computer code CAP88 (Beres 1990) for demonstrating compliance with the National Emission Standard for Hazardous Air Pollutants (NESHAPS). To demonstrate compliance, the location of the maximally exposed individual (MEI) is needed as input to CAP88. This location is entered as sector and distance to the receptor. These distances and sectors were originally determined in 1990 with virtually no documentation and are determined now with strict documentation.

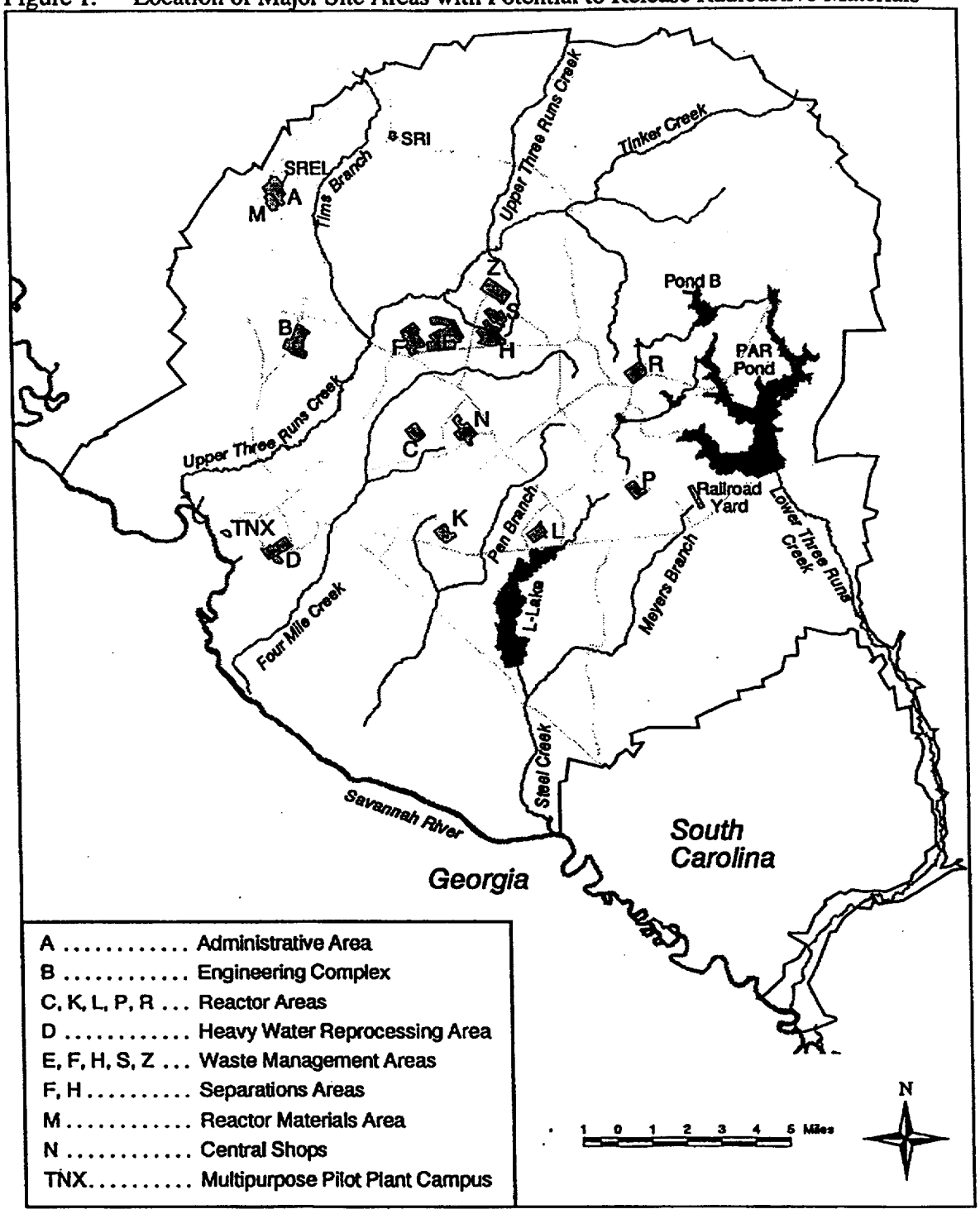
## 2. METHODOLOGY

To determine the location of the MEI, the nearest offsite individual is identified for each of the sixteen compass point sectors surrounding each potential release point. Next, CAP88 is executed to determine which sector would result in the highest dose (referred to as the worst sector.) A listing of each of the potential release points is shown in Table 1 and is graphically depicted in Figure 1. Table 1 also shows the location of each of the potential release points using the site coordinate system.

Table 1. Potential Release Points for NESHAPS Compliance

| Location | Easting Coordinate | Northing Coordinate |
|---|---|---|
| A-Area | 51860 | 106670 |
| APT | 75000 | 75000 |
| C-Area | 46230 | 67630 |
| Center | 58000 | 62000 |
| D-Area | 20940 | 65280 |
| E-Area | 58000 | 75000 |
| F-Area | 53970 | 78020 |
| H-Area | 63380 | 71900 |
| K-Area | 40740 | 54130 |
| L-Area | 50460 | 45910 |
| M-Area | 50040 | 104830 |
| N-Area | 51000 | 65000 |
| P-Area | 64800 | 43800 |
| S/Z-Area | 64010 | 73750 |
| T-Area | 17500 | 71500 |

Figure 1. Location of Major Site Areas with Potential to Release Radioactive Materials



## 2.1. Determination of MEI Location

NESHAPS calculations are performed in accordance with 40CFR61 (EPA 1989). In reference to determining the location of the MEI, Section 92 states:

> 'Compliance with this standard shall be determined by calculating the highest effective dose equivalent to any member of the public at any offsite point where there is a residence, school, business or office. .....Distances from the points of release to the nearest residence, school, business or office and the nearest farms producing vegetables, milk, and meat.'

The E&GIS Group was contacted to determine the location of the nearest offsite individual in each of the sixteen compass sectors for each potential release location. Appendix A contains a complete copy of the results of this study (Mackey 1999). Site wide photography taken in 1998 was examined to pinpoint the location of buildings or farms. For conservatism, all cultivated fields were assumed to be vegetable-producing farms.

The Savannah River Ecology Lab (SREL) Conference Center, which is located onsite along Highway 278, may be used as a dormitory in the future. This location was also considered as a potential residence location. Table 2 shows the distance to the nearest offsite individual for each of the sixteen sectors for each release location and Table 3 contains similar results with the inclusion of the SREL Conference Center. Appendix B shows the distances that were determined in the previous study performed in 1990.

Table 4 shows the ratio of distances determined in 1999 to those determined in 1990. Looking at Table 4, the only areas that show considerable differences are A Area and D Area, both of which are close to the site boundary. One reason for the differences may be that the photography in 1998 has greater detail. Another reason may be that some of the buildings/farms that were selected using the 1998 photography may not have existed in 1990.

Independent review of the photography for A Area and D Area validated that correct methods were used with the current study. For A Area, the north-northwest sector was looked at closely because this was the location of the worst sector during the previous analysis. To ensure proper selection of nearest building/farm a field verification was preformed for questionable sectors for the A Area release location. This field verification determined that there is a habitable structure at the questionable location.

There may be differences when comparing this study to the previous study because of how the sectors were defined. Current methods utilized computer models to overlay exact 22.5 degree sectors centered upon true North. Previous studies might not have used such sophisticated methods to define sectors.

## 2.2. Determination of Worst Sector

Now that distances have been determined as shown in Tables 2 and 3, CAP88 is executed for each of these distances and corresponding sectors to determine which sector would provide the highest dose to the offsite individual. The relative air concentrations, which are directly proportional to dose, are shown in Tables 5 and 6 both without and with considering the

Table 2. Distance to the Nearest Residence, School, Business, or Farm for Demonstrating NESHAP Compliance

| Sector | Release Area – Distance (m) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | APT | C | Center | D | E | F | H | K | L | M | N | P | S/Z | T |
| S | 20575 | 20750 | 15102 | 15033 | 7329 | 19235 | 19026 | 18466 | 13401 | 9621 | 19788 | 17874 | 10928 | 19054 | 5628 |
| SSW | 7758 | 23038 | 13477 | 16784 | 5355 | 17637 | 16135 | 19398 | 11102 | 12970 | 7077 | 15119 | 11828 | 19795 | 4613 |
| SW | 4761 | 21743 | 12751 | 16203 | 4996 | 16564 | 15328 | 18080 | 10986 | 12513 | 4815 | 14134 | 16535 | 18359 | 4450 |
| WSW | 2639 | 15574 | 13236 | 17004 | 5792 | 13316 | 10229 | 15194 | 10957 | 14074 | 3137 | 14786 | 18419 | 13893 | 4551 |
| W | 2141 | 14625 | 10481 | 13839 | 6390 | 10967 | 9442 | 12817 | 13296 | 16377 | 2440 | 11832 | 20514 | 12603 | 4816 |
| WNW | 1173 | 12396 | 10150 | 13690 | 7810 | 11557 | 9996 | 12346 | 12912 | 16446 | 2203 | 11634 | 19459 | 11259 | 5670 |
| NW | 699 | 10193 | 11904 | 14434 | 8180 | 10525 | 9450 | 11820 | 13212 | 17200 | 1538 | 13389 | 20252 | 11027 | 6221 |
| NNW | 973 | 9932 | 12693 | 15032 | 8291 | 11007 | 9948 | 11623 | 17025 | 19539 | 1342 | 13723 | 19772 | 11828 | 6394 |
| N | 1159 | 9478 | 14475 | 15813 | 14868 | 11478 | 10933 | 12380 | 19027 | 21069 | 1932 | 15188 | 19021 | 11795 | 9117 |
| NNE | 2626 | 9580 | 17761 | 15987 | 21224 | 13534 | 14180 | 12723 | 21491 | 21372 | 3390 | 16996 | 16182 | 12225 | 18430 |
| NE | 3770 | 11461 | 20048 | 17228 | 27066 | 15598 | 16290 | 14682 | 22663 | 17868 | 5200 | 19334 | 13493 | 14319 | 25253 |
| ENE | 13725 | 12540 | 20209 | 16283 | 23297 | 17575 | 18973 | 15792 | 16431 | 12843 | 14176 | 18584 | 8468 | 15703 | 28951 |
| E | 21107 | 13408 | 16904 | 13012 | 21689 | 17761 | 19279 | 15872 | 17341 | 13483 | 22659 | 15260 | 9662 | 15974 | 25043 |
| ESE | 24872 | 13106 | 17939 | 15233 | 16802 | 15806 | 17303 | 14046 | 13847 | 11386 | 24661 | 16644 | 9845 | 14389 | 18494 |
| SE | 28548 | 16035 | 16414 | 15131 | 15032 | 19002 | 19820 | 17815 | 12227 | 10054 | 27997 | 15855 | 9268 | 18351 | 16808 |
| SSE | 27453 | 18700 | 15450 | 15025 | 10533 | 18650 | 19115 | 18078 | 11098 | 9906 | 26800 | 15059 | 9617 | 18656 | 10478 |

Table 3. Distance to the Nearest Residence, School, Business or Farm for Demonstrating NESHAP Compliance (SREL Conference Center Included – Italics show distances that change as a result of Conference Center Included)

| Sector | Release Area – Distance (m) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | APT | C | Center | D | E | F | H | K | L | M | N | P | S/Z | T |
| S | 20575 | 20750 | 15102 | 15033 | 7329 | 19235 | 19026 | 18466 | 13401 | 9621 | 19788 | 17874 | 10928 | 19054 | 5628 |
| SSW | 7758 | 23038 | 13477 | 16784 | 5355 | 17637 | 16135 | 19398 | 11102 | 12970 | 7077 | 15119 | 11828 | 19795 | 4613 |
| SW | 4761 | 21743 | 12751 | 16203 | 4996 | 16564 | 15328 | 18080 | 10986 | 12513 | 4815 | 14134 | 16535 | 18359 | 4450 |
| WSW | 2639 | 15574 | 13236 | 17004 | 5792 | 13316 | 10229 | 15194 | 10957 | 14074 | 3137 | 14786 | 18419 | 13893 | 4551 |
| W | 2141 | 14625 | 10481 | 13839 | 6390 | 10967 | 9442 | 12817 | 13296 | 16377 | 2440 | 11832 | 20514 | 12603 | 4816 |
| WNW | 1173 | 12396 | 10150 | 13690 | 7810 | 11557 | 9996 | 12346 | 12912 | 16446 | 2203 | 11634 | 19459 | 11259 | 5670 |
| NW | 699 | 10193 | 11904 | 14434 | 8180 | 10525 | 9450 | 11820 | 13212 | 17200 | 1538 | 13389 | 20252 | 11027 | 6221 |
| NNW | 973 | 9932 | 12693 | 15032 | 8291 | 11007 | 9948 | 11623 | 17025 | 19539 | 1342 | 13723 | 19772 | 11828 | 6394 |
| N | 1159 | *8370* | 14475 | *14740* | 14868 | 11478 | 10933 | 12380 | 19027 | *19960* | 1932 | 15188 | *18150* | *10940* | 9117 |
| NNE | 2626 | 9580 | *16390* | 15987 | 21224* | *12160* | *12750* | *11460* | *20210* | 21372 | 3390 | *15690* | 16182 | 12225 | 18430 |
| NE | 3770 | 11461 | 20048 | 17228 | 27066 | 15598 | 16290 | 14682 | 22663 | 17868 | 5200 | 19334 | 13493 | 14319 | *23770* |
| ENE | *12320* | 12540 | 20209 | 16283 | 23297 | 17575 | 18973 | 15792 | 16431 | 12843 | *12740* | 18584 | 8468 | 15703 | 28951 |
| E | 21107 | 13408 | 16904 | 13012 | 21689 | 17761 | 19279 | 15872 | 17341 | 13483 | 22659 | 15260 | 9662 | 15974 | 25043 |
| ESE | 24872 | 13106 | 17939 | 15233 | 16802 | 15806 | 17303 | 14046 | 13847 | 11386 | 24661 | 16644 | 9845 | 14389 | 18494 |
| SE | 28548 | 16035 | 16414 | 15131 | 15032 | 19002 | 19820 | 17815 | 12227 | 10054 | 27997 | 15855 | 9268 | 18351 | 16808 |
| SSE | 27453 | 18700 | 15450 | 15025 | 10533 | 18650 | 19115 | 18078 | 11098 | 9906 | 26800 | 15059 | 9617 | 18656 | 10478 |

* No Change – Distance to SREL Conference Center greater than distance to the nearest offsite individual so original distance used.

Table 4. Ratio of MEI distance for 1999 to MEI distance for 1990

| Sector | A | APT | C | Center | D | E | F | H | K | L | M | P | S/Z | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 1.0 | 1.0 | 0.9 | 1.0 | 0.7 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 |
| SSW | 1.1 | 1.0 | 0.9 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 0.9 | 0.7 |
| SW | 0.9 | 1.0 | 1.0 | 1.0 | 0.7 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| WSW | 0.8 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.1 |
| W | 0.8 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.8 |
| WNW | 0.5 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| NW | 0.4 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 |
| NNW | 0.7 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 |
| N | 0.6 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 0.7 |
| NNE | 0.6 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.8 | 1.0 | 1.1 | 0.9 |
| NE | 0.5 | 1.0 | 1.1 | 1.0 | 1.0 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 0.7 | 1.0 | 1.0 | 0.9 |
| ENE | 1.0 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| E | 0.9 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| ESE | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |
| SE | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| SSE | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |

Table 5. Relative Air Concentrations At Offsite Locations Corresponding To Table 2 (Highest Highlighted)

| | A-Area | APT | C-Area | Center | D-Area | E-Area | F-Area | H-Area | K-Area | L-Area | M-Area | N-Area | P-Area | S/Z-Area | T-Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 1.54E-09 | 1.78E-09 | 2.23E-09 | 2.32E-09 | 7.97E-09 | 1.74E-09 | 1.31E-09 | 1.84E-09 | 2.81E-09 | 3.63E-09 | 1.61E-09 | 1.83E-09 | 3.53E-09 | 1.75E-09 | 1.14E-08 |
| SSW | 1.33E-08 | 5.72E-09 | 7.14E-09 | 6.14E-09 | 2.23E-08 | 5.79E-09 | 6.77E-09 | 5.13E-09 | 9.67E-09 | 5.97E-09 | 1.49E-08 | 6.27E-09 | 8.86E-09 | 5.01E-09 | 2.66E-08 |
| SW | 5.78E-08 | 9.70E-09 | **1.78E-08** | **1.15E-08** | **4.65E-08** | 1.11E-08 | 2.01E-08 | 1.00E-08 | **2.03E-08** | **1.58E-08** | 5.74E-08 | **1.57E-08** | 1.42E-08 | 9.82E-09 | **5.35E-08** |
| WSW | 8.84E-08 | 9.69E-09 | 1.33E-08 | 7.32E-09 | 3.73E-08 | 9.85E-09 | **2.25E-08** | 8.39E-09 | 1.62E-08 | 1.23E-08 | 7.28E-08 | 1.17E-08 | 1.03E-08 | 9.36E-09 | 4.96E-08 |
| W | 8.59E-08 | 8.43E-09 | 1.30E-08 | 7.49E-09 | **2.59E-08** | 9.94E-09 | 1.40E-08 | 8.22E-09 | 1.05E-08 | 8.04E-09 | 7.46E-08 | 1.13E-08 | 6.32E-09 | 8.40E-09 | 3.62E-08 |
| WNW | 1.10E-07 | 1.12E-08 | 1.12E-08 | 7.44E-09 | 1.98E-08 | 9.10E-09 | 1.15E-08 | 8.41E-09 | 9.89E-09 | 6.29E-09 | 6.26E-08 | 9.59E-09 | 4.92E-09 | 9.38E-09 | 2.89E-08 |
| NW | 1.38E-07 | 1.58E-08 | 1.08E-08 | 7.74E-09 | 2.81E-08 | 1.13E-08 | 1.46E-08 | 9.83E-09 | 1.29E-08 | 7.30E-09 | 8.70E-08 | 9.44E-09 | 5.73E-09 | 1.07E-08 | 3.86E-08 |
| NNW | **1.55E-07** | 1.98E-08 | 1.44E-08 | 9.13E-09 | 3.22E-08 | 1.33E-08 | 1.84E-08 | 1.25E-08 | 1.10E-08 | 8.07E-09 | **1.32E-07** | 1.32E-08 | 7.35E-09 | 1.22E-08 | 4.41E-08 |
| N | 1.51E-07 | **2.52E-08** | 1.26E-08 | 1.01E-08 | **9.76E-09** | **1.49E-08** | 1.75E-08 | **1.36E-08** | 9.53E-09 | 8.52E-09 | 1.06E-07 | 1.19E-08 | 9.91E-09 | **1.44E-08** | 1.84E-08 |
| NNE | 7.50E-08 | 2.23E-08 | 9.48E-09 | 9.18E-09 | 6.96E-09 | 1.12E-08 | 1.18E-08 | 1.21E-08 | 8.17E-09 | 9.30E-09 | 5.81E-08 | 9.96E-09 | 1.20E-08 | 1.27E-08 | 8.32E-09 |
| NE | 6.69E-08 | 1.84E-08 | 9.80E-09 | 8.79E-09 | 4.99E-09 | 9.90E-09 | 1.24E-08 | 1.06E-08 | 7.01E-09 | 9.96E-09 | 4.67E-08 | 1.02E-08 | 1.42E-08 | 1.10E-08 | 5.41E-09 |
| ENE | 1.49E-08 | 1.84E-08 | 9.40E-09 | 1.02E-08 | 6.17E-09 | 9.28E-09 | 1.08E-08 | 1.05E-08 | 1.04E-08 | 1.54E-08 | 1.43E-08 | 1.04E-08 | **2.33E-08** | 1.06E-08 | 4.82E-09 |
| E | 8.04E-09 | 1.03E-08 | 1.05E-08 | 8.99E-09 | 7.47E-09 | 6.14E-09 | 9.66E-09 | 7.05E-09 | 9.67E-09 | 1.28E-08 | 7.41E-09 | 1.19E-08 | 1.85E-08 | 6.99E-09 | 6.34E-09 |
| ESE | 4.83E-09 | 8.98E-09 | 7.02E-09 | 6.25E-09 | 9.81E-09 | 5.97E-09 | 7.64E-09 | 6.91E-09 | 1.06E-08 | 1.22E-08 | 4.88E-09 | 7.66E-09 | 1.35E-08 | 6.71E-09 | 8.77E-09 |
| SE | 2.58E-09 | 5.15E-09 | 4.77E-09 | 4.51E-09 | 9.06E-09 | 3.40E-09 | 3.87E-09 | 3.70E-09 | 8.85E-09 | 8.37E-09 | 2.64E-09 | 4.96E-09 | 1.03E-08 | 3.57E-09 | 7.98E-09 |
| SSE | 2.00E-09 | 3.88E-09 | 3.80E-09 | 3.83E-09 | 1.07E-08 | 2.98E-09 | 2.73E-09 | 3.09E-09 | 6.53E-09 | 6.11E-09 | 2.05E-09 | 3.91E-09 | 6.45E-09 | 2.98E-09 | 1.08E-08 |

Table 6. Relative Air Concentrations At Offsite Locations Corresponding To Table 3 – (Highest Highlighted)

| | A-Area | APT | C-Area | Center | D-Area | E-Area | F-Area | H-Area | K-Area | L-Area | M-Area | N-Area | P-Area | S/Z-Area | T-Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 1.54E-09 | 1.78E-09 | 2.24E-09 | 2.32E-09 | 7.97E-09 | 1.74E-09 | 1.31E-09 | 1.84E-09 | 2.81E-09 | 3.63E-09 | 1.61E-09 | 1.83E-09 | 3.53E-09 | 1.75E-09 | 1.14E-08 |
| SSW | 1.33E-08 | 5.72E-09 | 7.14E-09 | 6.14E-09 | 2.23E-08 | 5.79E-09 | 6.77E-09 | 5.13E-09 | 9.67E-09 | 5.97E-09 | 1.49E-08 | 6.27E-09 | 8.86E-09 | 5.01E-09 | 2.66E-08 |
| SW | 5.78E-08 | 9.70E-09 | **1.78E-08** | **1.15E-08** | **4.65E-08** | 1.11E-08 | 2.01E-08 | 1.00E-08 | **2.03E-08** | **1.58E-08** | 5.74E-08 | **1.57E-08** | 1.42E-08 | 9.82E-09 | **5.35E-08** |
| WSW | 8.84E-08 | 9.69E-09 | 1.33E-08 | 7.32E-09 | 3.73E-08 | 9.85E-09 | **2.25E-08** | 8.39E-09 | 1.62E-08 | 1.23E-08 | 7.28E-08 | 1.17E-08 | 1.03E-08 | 9.36E-09 | 4.96E-08 |
| W | 8.59E-08 | 8.43E-09 | 1.30E-08 | 7.49E-09 | 2.59E-08 | 9.94E-09 | 1.40E-08 | 8.22E-09 | 1.05E-08 | 8.04E-09 | 7.46E-08 | 1.13E-08 | 6.32E-09 | 8.40E-09 | 3.62E-08 |
| WNW | 1.10E-07 | 1.12E-08 | 1.12E-08 | 7.44E-09 | 1.98E-08 | 9.10E-09 | 1.15E-08 | 8.41E-09 | 9.89E-09 | 6.29E-09 | 6.26E-08 | 9.59E-09 | 4.92E-09 | 9.38E-09 | 2.89E-08 |
| NW | 1.38E-07 | 1.58E-08 | 1.08E-08 | 7.74E-09 | 2.81E-08 | 1.13E-08 | 1.46E-08 | 9.83E-09 | 1.29E-08 | 7.30E-09 | 8.70E-08 | 9.44E-09 | 5.73E-09 | 1.07E-08 | 3.86E-08 |
| NNW | **1.55E-07** | 1.98E-08 | 1.44E-08 | 9.13E-09 | 3.22E-08 | 1.33E-08 | 1.84E-08 | 1.25E-08 | 1.10E-08 | 8.07E-09 | **1.32E-07** | 1.32E-08 | 7.35E-09 | 1.22E-08 | 4.41E-08 |
| N | 1.51E-07 | **3.01E-08** | 1.26E-08 | 1.10E-08 | 9.76E-09 | **1.49E-08** | 1.75E-08 | 1.36E-08 | 9.53E-09 | 9.06E-09 | 1.06E-07 | 1.19E-08 | 1.05E-08 | **1.58E-08** | 1.84E-08 |
| NNE | 7.50E-08 | 2.23E-08 | 1.04E-08 | 9.18E-09 | 6.16E-09 | 1.27E-08 | 1.33E-08 | **1.37E-08** | 8.74E-09 | 9.30E-09 | 5.81E-08 | 1.09E-08 | 1.20E-08 | 1.27E-08 | 8.32E-09 |
| NE | 6.69E-08 | 1.84E-08 | 9.80E-09 | 8.79E-09 | 4.99E-09 | 9.90E-09 | 1.24E-08 | 1.06E-08 | 7.01E-09 | 9.96E-09 | 4.67E-08 | 1.02E-08 | 1.42E-08 | 1.10E-08 | 5.81E-09 |
| ENE | 1.69E-08 | 1.84E-08 | 9.40E-09 | 1.02E-08 | 6.17E-09 | 9.28E-09 | 1.08E-08 | 1.05E-08 | 1.04E-08 | 1.54E-08 | 1.62E-08 | 1.04E-08 | **2.33E-08** | 1.06E-08 | 4.82E-09 |
| E | 8.04E-09 | 1.03E-08 | 1.05E-08 | 8.99E-09 | 7.47E-09 | 6.14E-09 | 9.66E-09 | 7.05E-09 | 9.67E-09 | 1.28E-08 | 7.41E-09 | 1.19E-08 | 1.85E-08 | 6.99E-09 | 6.34E-09 |
| ESE | 4.83E-09 | 8.98E-09 | 7.02E-09 | 6.25E-09 | 9.81E-09 | 5.97E-09 | 7.64E-09 | 6.91E-09 | 1.06E-08 | 1.22E-08 | 4.88E-09 | 7.66E-09 | 1.35E-08 | 6.71E-09 | 8.77E-09 |
| SE | 2.58E-09 | 5.15E-09 | 4.77E-09 | 4.51E-09 | 9.06E-09 | 3.40E-09 | 3.87E-09 | 3.70E-09 | 8.85E-09 | 8.37E-09 | 2.64E-09 | 4.96E-09 | 1.03E-08 | 3.57E-09 | 7.98E-09 |
| SSE | 2.00E-09 | 3.88E-09 | 3.80E-09 | 3.83E-09 | 1.07E-08 | 2.98E-09 | 2.73E-09 | 3.09E-09 | 6.53E-09 | 6.11E-09 | 2.05E-09 | 3.91E-09 | 6.45E-09 | 2.98E-09 | 1.08E-08 |

SREL Conference Center, respectively. Since relative air concentration is directly proportional to dose, the concentrations for each sector and distance are compared to determine which is the highest. The maximum concentration has been highlighted. Table 7 shows a summary of the worst sector and distance for each of the potential release locations both considering and not considering the SREL Conference Center. The numbers in parentheses refer to input required for CAP88.

Table 7. Location of MEI for NESHAPS Calculations

| | Offsite MEI 1999 | | SREL Included 1999 | | Offsite MEI 1990 | |
|---|---|---|---|---|---|---|
| Area | Sector | Distance | Sector | Distance | Sector | Distance |
| A-Area | NNW(2) | 970 | NNW(2) | 970 | NNW(2) | 1360 |
| APT | N(1) | 9480 | N(1) | 8370 | N(1) | 9350 |
| C-Area | SW(7) | 12750 | SW(7) | 12750 | SW(7) | 13100 |
| Center | SW(7) | 16200 | SW(7) | 16200 | SW(7) | 16420 |
| D-Area | SW(7) | 5000 | SW(7) | 5000 | WSW(6) | 6640 |
| E-Area | N(1) | 11480 | N(1) | 11480 | N(1) | 11050 |
| F-Area | WSW(6) | 10230 | WSW(6) | 10230 | SW(7) | 15230 |
| H-Area | N(1) | 12380 | NNE(16) | 11460 | N(1) | 12370 |
| K-Area | SW(7) | 10990 | SW(7) | 10990 | SW(7) | 11920 |
| L-Area | SW(7) | 12510 | SW(7) | 12510 | ENE(14) | 12670 |
| M-Area | NNW(2) | 1340 | NNW(2) | 1340 | NNW(2) | 1370 |
| N-Area | SW(7) | 14130 | SW(7) | 14130 | SW(7) | 14320 |
| P-Area | ENE(14) | 8470 | ENE(14) | 8470 | ENE(14) | 8450 |
| S/Z-Area | N(1) | 11800 | N(1) | 10940 | N(1) | 10970 |
| T-Area | SW(7) | 4450 | SW(7) | 4450 | WSW(6) | 4270 |

## 3. ANALYSIS OF RESULTS

Table 8 shows the ratio of distances determined in this study to distances determined in 1990. Looking at Table 8, noticeable differences are seen for the following locations: A Area, D Area, and F Area. If the ratio shown in the last column of Table 8 is less than one, the resulting dose could increase since the MEI is now closer to the release location. Calculations were performed for each of the areas to demonstrate the magnitude of the differences.

Table 9 shows the comparison of relative air concentrations using 1990 distances versus 1999 distances. Relative air concentration is directly proportional to dose so this table represents potential dose differences that would be seen using the new distances. The largest difference is seen in D Area. This is due to the fact that not only did the distance between the MEI and the release location decrease, but the worst sector changed.

Table 8. Comparison of Distances Determined in 1999 and 1990

| | Offsite MEI 1999 | | Offsite MEI 1990 | | Ratio Dist 1999/1990 |
|---|---|---|---|---|---|
| Area | Sector | Distance | Sector | Distance | |
| A-Area | NNW(2) | 970 | NNW(2) | 1360 | 0.7 |
| APT | N(1) | 9480 | N(1) | 9350 | 1.0 |
| C-Area | SW(7) | 12750 | SW(7) | 13100 | 1.0 |
| Center | SW(7) | 16200 | SW(7) | 16420 | 1.0 |
| D-Area | SW(7) | 5000 | WSW(6) | 6640 | 0.8 |
| E-Area | N(1) | 11480 | N(1) | 11050 | 1.0 |
| F-Area | WSW(6) | 10230 | SW(7) | 15230 | 0.7 |
| H-Area | N(1) | 12380 | N(1) | 12370 | 1.0 |
| K-Area | SW(7) | 10990 | SW(7) | 11920 | 0.9 |
| L-Area | SW(7) | 12510 | ENE(14) | 12670 | 1.0 |
| M-Area | NNW(2) | 1340 | NNW(2) | 1370 | 1.0 |
| N-Area | SW(7) | 14130 | SW(7) | 14320 | 1.0 |
| P-Area | ENE(14) | 8470 | ENE(14) | 8450 | 1.0 |
| S/Z-Area | N(1) | 11800 | N(1) | 10970 | 1.1 |
| T-Area | SW(7) | 4450 | WSW(6) | 4270 | 1.0 |

Table 9. Comparison of Relative Air Concentrations using 1999 and 1990 Distances

| | 1999 Distance | 1990 Distance | % Difference |
|---|---|---|---|
| AREA | Chi/Q | Chi/Q | |
| A | 1.55E-07 | 1.31E-07 | 18% |
| APT | 2.52E-08 | 2.57E-08 | -2% |
| C | 1.78E-08 | 1.72E-08 | 3% |
| CENTER | 1.15E-08 | 1.13E-08 | 2% |
| D | 4.65E-08 | 3.16E-08 | 47% |
| E | 1.49E-08 | 1.56E-08 | -4% |
| F | 2.25E-08 | 2.03E-08 | 11% |
| H | 1.36E-08 | 1.36E-08 | 0% |
| K | 2.03E-08 | 1.84E-08 | 10% |
| L | 1.58E-08 | 1.56E-08 | 1% |
| M | 1.32E-07 | 1.30E-07 | 2% |
| P | 2.33E-08 | 2.33E-08 | 0% |
| S | 1.44E-08 | 1.57E-08 | -8% |
| T | 5.35E-08 | 5.36E-08 | 0% |

## 4. CONCLUSIONS

Distances to the maximally exposed offsite individual have been determined for demonstrating NESHAPS compliance. Should the SREL Conference Center become a potential offsite location, distances also have been included for this facility. Three release locations (APT, H, S/Z) would show increases in dose predictions if the SREL Conference Center were considered.

## 5. REFERENCES

Beres, Deborah A. 'The Clean Air Act Assessment Package – 1988 (CAP88) A Dose and Risk Assessment Methodology For Radionuclide Emissions To Air, Volume 1, User's Manual,' U.S. Environmental Protection Agency, Washington, D.C. 1990.

EPA 1989 U.S. Environmental Protection Agency, 1989, "National Emission Standards for Hazardous Air Pollutants; Radionuclides," Title 40 Code of Federal Regulations, Part 61, Voluime 54, No 240, Washington, D.C.

Mackey, Hal. " NESHAPS Distances Summary Memo, Tables, and Figures (U)" Westinghouse Inter-Office Memorandum: PECD-EGIS-99-0035, September 13, 1999, Westinghouse Savannah River Company, Aiken, SC.

# APPENDIX A. Mackey's NESHAPS Distance Memo

PECD-EGIS-99-0035

September 13, 1999

To: Ali Simpkins, SRTC, 773-42A, RM228

From: Hal Mackey, E&GIS, 730-2B, RM 1109

NESHAPS Distances Summary Memo, Tables, and Figures (U)

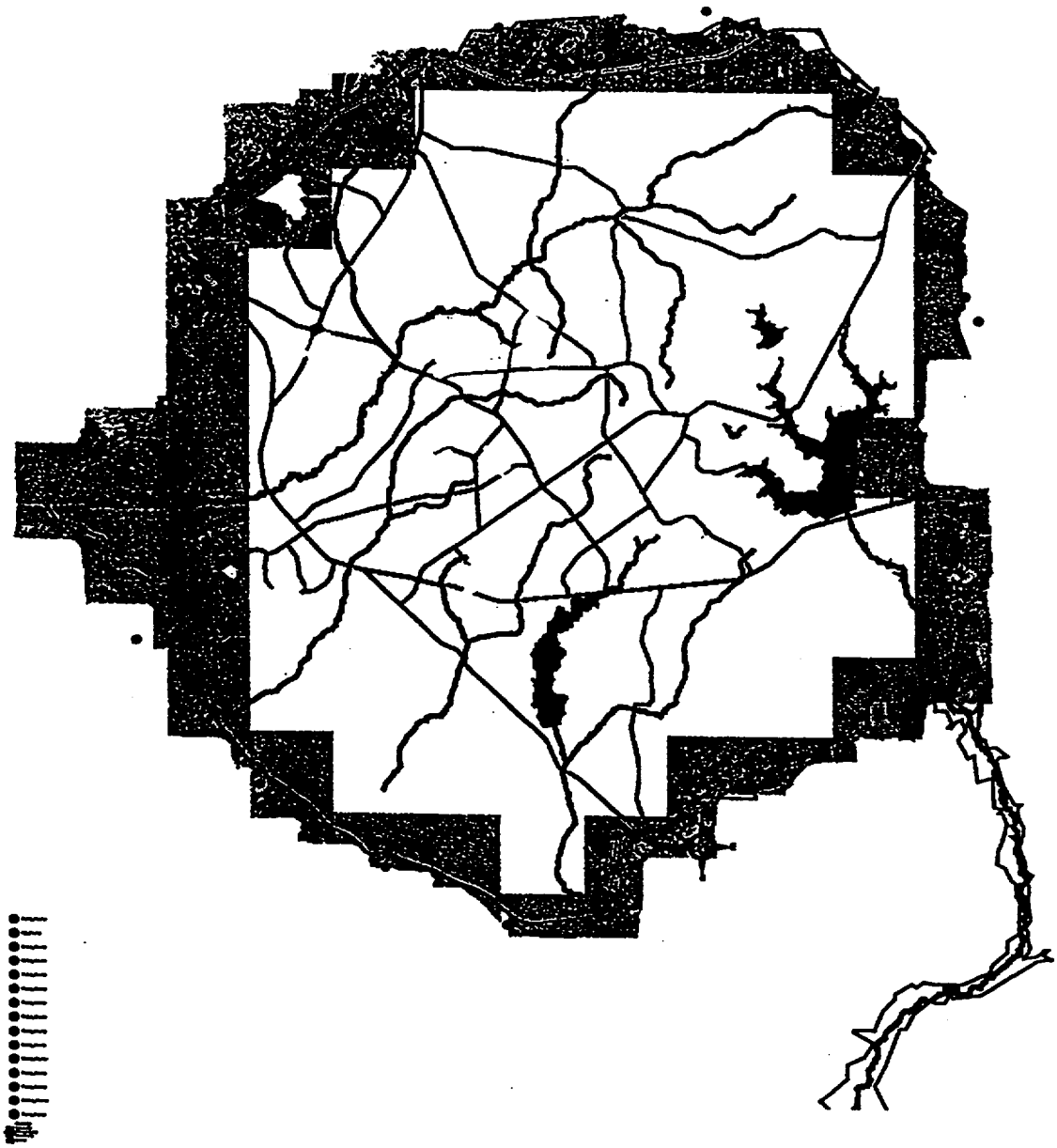
Attached are Tables and Figures which summarize our efforts to date for estimating the distances from 15 points (source locations-- A, APT, C, Center of SRS, D, E, F, H, K, L, M, N, P, SZ, T) on the SRS to the nearest offsite feature of interest, i.e., buildings, fields, etc., for the 16 directional sectors from each center point, plus an estimate to the SREL Conference Center. Distances are in meters and coordinates for the off-site locations are in UTMs. In the summary table, we also provide information on the 1996 SRS ortho-photographic tile which was used to identify the off-site feature, its direction, and the type of feature. Site-wide SRS photography from the summer of 1998, taken by Bechtel Nevada, was also reviewed to verify the off-site features, thus some minor changes were made based on off-site changes from 1996 to 1998. Figures are provided to show the general location of each feature for each center and sector. Note, a number of the off-site features are used several times for a number of the sectors. At this point in time, we have not conducted off-site visits to verify the identity of the off-site features. Thus, feature selection is based entirely on photographic interpretation. In addition, the final two columns in the summary table are a comparison of the distances from 1989 versus the distances for 1999 (units are kilometers), for those source locations in common for the two years. There is general agreement for most points (a few tenths of a kilometer). However, there are several distances of a few kilometers different. No, attempt has been made to determine if in these latter cases if there were a change in landuse, criteria for off-site feature location, or technical difference in determination of off-site features between our determination in 1999 and in the selections in 1989.

The entire effort has been save as a GIS project, thus both the data base (1996 photography, sectors, etc.) can be review independently, or we would be happy to review the effort and every point selection with you if needed.

This completes the effort at this time. I would recommend that field visits and verification be conducted for at least a sub-set of the off-site points to test the accuracy of the photo interpretation. In addition, a support document to provide QA/QC verification would be in order, so that future updates would be easy and defensible for any NESHAPS based calculation for existing and/or future dose calculations.

CC: EGIS File
John Gladden, SRTC
Russ Beckmeyer, E&GIS
Larry Koffman, E&GIS
Cheryl Hardy, E&GIS

A1



**Nearest Offsite Points of Interest**
**Hal Mackey, Cheryl Hardy, and Larry Koffman**
**-draft-example-9/13/99**

| AREA | UTM_E | UTM_N | SECTOR | DISTANCE | AZIMUTH | TYPE-COMMENTS | 89Distance | 99distance |
|---|---|---|---|---|---|---|---|---|
| A-Area | 431264.0 | 3690881.8 | N | 1158.8 | 354.21 | Field, D-2 | 1.8 | 1.159 |
| A-Area | 431890.9 | 3692303.1 | NNE | 2626.3 | 11.00 | Field, D-2 | 1.93 | 2.26 |
| A-Area | 433533.7 | 3692818.3 | NE | 3770.0 | 34.60 | Field, E-2 | 3.59 | 3.77 |
| A-Area | 443826.5 | 3695499.1 | ENE | 13724.8 | 64.79 | Field, 9-6468 | 7.93 | 13.725 |
| A-Area | 452104.2 | 3693695.3 | E | 21106.5 | 78.82 | Building, K-1 | 18.56 | 21.106 |
| A-Area | 453892.7 | 3679167.0 | ESE | 24872.4 | 114.78 | Building, K-6 | 24.73 | 24.872 |
| A-Area | 448365.2 | 3666787.3 | SE | 28548.0 | 143.12 | Field, I-10 | 26.64 | 28.548 |
| A-Area | 443219.0 | 3664962.5 | SSE | 27452.6 | 154.09 | Field, H-11 | 22.14 | 27.453 |
| A-Area | 427401.7 | 3669540.4 | S | 20575.0 | 190.78 | Building, C-9 | 13.48 | 20.575 |
| A-Area | 427082.9 | 3683265.0 | SSW | 7758.0 | 213.23 | Field, C-5 | 5.64 | 7.758 |
| A-Area | 427458.0 | 3687021.2 | SW | 4760.6 | 234.99 | Building, C-4 | 3.89 | 4.761 |
| A-Area | 428786.2 | 3689210.0 | WSW | 2639.1 | 258.33 | Field, C-3 | 2.59 | 2.639 |
| A-Area | 429235.6 | 3689828.3 | W | 2140.6 | 272.33 | Building, C-3 | 2.15 | 2.141 |
| A-Area | 430265.7 | 3690111.6 | WNW | 1172.7 | 288.73 | Field, D-2,BN1998 | 1.49 | 1.173 |
| A-Area | 430904.3 | 3690245.4 | NW | 698.6 | 317.41 | Field, D-2 | 1.47 | 0.699 |
| A-Area | 430912.4 | 3690584.5 | NNW | 972.8 | 331.32 | Building, D-2 | 1.3 | 0.973 |
| A-Area | 442748.0 | 3694450.7 | ENE | 12315.5 | 67.10 | Conference, H-1 | | |
| APT | 443837.7 | 3695491.9 | N | 9478.1 | 6.22 | Field, photo number | 15.14 | 9.478 |
| APT | 445001.3 | 3695388.8 | NNE | 9580.3 | 13.22 | Field, H-1 | 16.13 | 9.58 |
| APT | 449712.7 | 3695182.6 | NE | 11461.2 | 37.04 | Field, J-1 | 16.56 | 11.461 |
| APT | 454548.0 | 3690337.1 | ENE | 12540.4 | 69.79 | Building, L-2 | 15.14 | 12.54 |
| APT | 456150.2 | 3685518.7 | E | 13407.9 | 92.03 | Building, L-4 | 14.72 | 13.408 |
| APT | 453893.4 | 3679170.2 | ESE | 13106.4 | 121.45 | Building, K-6 | 14.72 | 12.106 |
| APT | 455886.3 | 3676875.6 | SE | 16034.6 | 124.66 | Field, L-7 | 14.35 | 16.035 |
| APT | 452524.0 | 3670131.6 | SSE | 18699.6 | 148.15 | Field, K-9 | 14.33 | 18.7 |
| APT | 446387.1 | 3665646.4 | S | 20750.0 | 169.57 | Field, I-11 | 14.33 | 20.75 |
| APT | 430270.5 | 3666713.1 | SSW | 23038.0 | 212.46 | Building, D-10 | 15.86 | 23.038 |
| APT | 424792.0 | 3673822.9 | SW | 21743.1 | 235.35 | Field, B-8 | 12.81 | 21.743 |
| APT | 427531.4 | 3682787.0 | WSW | 15573.6 | 257.46 | Field, C-5 | 12.81 | 15.573 |
| APT | 428351.8 | 3688616.6 | W | 14624.5 | 279.65 | Field, C-3 | 12.96 | 14.624 |
| APT | 431479.5 | 3691228.9 | WNW | 12396.2 | 294.21 | Field, D-2 | 13.2 | 12.396 |
| APT | 437088.9 | 3694550.2 | NW | 10193.4 | 325.89 | Building, F-1 | 14.45 | 10.193 |
| APT | 437408.7 | 3694446.3 | NNW | 9931.5 | 327.09 | Building, F-1 | 14.45 | 9.931 |
| APT | 442747.9 | 3694450.3 | N | 8374.4 | 359.61 | Conference, H-1 | | |
| C-Area | 434174.3 | 3693299.5 | N | 14474.6 | 348.44 | Field, Photo Number | | |
| C-Area | 443825.8 | 3695493.4 | NNE | 17761.4 | 22.29 | Field, I-1 | | |
| C-Area | 448711.8 | 3695363.2 | NE | 20047.6 | 35.44 | Building, J-1 | | |
| C-Area | 456151.3 | 3685518.7 | ENE | 20209.4 | 71.13 | Building, L-4 | | |
| C-Area | 453892.2 | 3679168.6 | E | 16904.4 | 89.42 | Building, K-6 | | |
| C-Area | 452523.4 | 3670132.1 | ESE | 17938.5 | 119.65 | Field, K-9 | | |
| C-Area | 446387.1 | 3665644.7 | SE | 16413.8 | 144.72 | Field, I-11 | | |
| C-Area | 443219.5 | 3664963.6 | SSE | 15449.8 | 155.86 | Field, H-11 | | |
| C-Area | 434920.2 | 3664141.2 | S | 15102.0 | 187.52 | Building, E-11 | | |
| C-Area | 429505.9 | 3667892.4 | SSW | 13476.5 | 213.37 | Building, D-10 | | |
| C-Area | 427484.4 | 3670599.8 | SW | 12751.0 | 227.84 | Building, C-9 | | |
| C-Area | 425727.6 | 3672145.0 | WSW | 13235.7 | 237.94 | Field, B-8 | | |
| C-Area | 426668.1 | 3680933.5 | W | 10481.4 | 279.72 | Field, B-6 | | |
| C-Area | 427531.0 | 3682786.1 | WNW | 10149.6 | 290.94 | Field, C-5 | | |
| C-Area | 427092.0 | 3685717.5 | NW | 11904.2 | 303.42 | Field, C-4 | | |
| C-Area | 430903.6 | 3690240.3 | NNW | 12692.7 | 331.01 | Field, D-2? | | |
| C-Area | 442747.0 | 3694451.1 | NNE | 16394.9 | 20.22 | Conference, H-1 | | |
| Center | 439050.1 | 3695529.9 | N | 15813.3 | 352.94 | Building, H-1 | 16.1 | 15.813 |
| Center | 444021.6 | 3695503.8 | NNE | 15987.4 | 10.92 | Field, H-1 | 16.26 | 15.987 |
| Center | 454548.1 | 3690334.9 | NE | 17228.2 | 52.06 | Building, L-2 | 17.55 | 17.228 |
| Center | 456152.0 | 3685519.0 | ENE | 16282.9 | 69.18 | Building, L-4 | 16.58 | 16.283 |
| Center | 453892.4 | 3679167.4 | E | 13011.8 | 92.55 | Building, K-6 | 13.2 | 13.012 |
| Center | 455392.4 | 3675142.9 | ESE | 15232.6 | 107.55 | Field, L-7 | 15.3 | 15.233 |
| Center | 452518.8 | 3670135.0 | SE | 15131.2 | 129.47 | Field, K-9 | 15.3 | 15.131 |
| Center | 448362.0 | 3666785.9 | SSE | 15024.5 | 149.86 | Field, J-10 | 15.3 | 15.024 |
| Center | 443328.6 | 3664990.1 | S | 15032.5 | 170.34 | Field, H-11 | 15.13 | 15.032 |
| Center | 434920.5 | 3664141.1 | SSW | 16783.9 | 200.51 | Building, E-11 | 17.23 | 16.784 |
| Center | 428567.9 | 3669311.4 | SW | 16203.2 | 229.20 | Building, C-9 | 16.42 | 16.203 |
| Center | 425728.1 | 3672142.5 | WSW | 17003.5 | 242.79 | Field, B-8 | 17.23 | 17.004 |

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|---|---|---|---|---|---|---|
| Center | 427323.7 | 3682521.1 W | 13838.7 | 280.89 Field, C-5 | 14.17 | 13.839 |
| Center | 427531.4 | 3682787.1 WNW | 13690.1 | 282.15 Field, C-5 | 13.85 | 13.69 |
| Center | 430904.2 | 3690240.2 NW | 14434.0 | 315.84 Field, D-2 | 14.65 | 14.434 |
| Center | 437408.4 | 3694446.0 NNW | 15031.7 | 346.23 Building, photo number | 15.3 | 15.032 |
| Center | 442747.0 | 3694450.2 N | 14741.9 | 6.86 Conference, H-1 | | |
| D-Area | 428321.2 | 3688577.4 N | 14867.9 | 348.57 Building, C-3 | 9.52 | 14.868 |
| D-Area | 436279.4 | 3694588.7 NNE | 21223.9 | 13.55 Field, photo number | 16.92 | 21.224 |
| D-Area | 446623.9 | 3696213.4 NE | 27065.9 | 34.44 Building, photo number | 23.87 | 27.066 |
| D-Area | 453892.8 | 3679167.0 ENE | 23296.9 | 76.80 Building, K-6 | 24.3 | 23.297 |
| D-Area | 452522.9 | 3670132.6 E | 21688.9 | 99.89 Field, K-9 | 18.63 | 21.689 |
| D-Area | 445173.9 | 3664688.5 ESE | 16802.0 | 123.25 Field, I-11 | 14.87 | 16.802 |
| D-Area | 443192.4 | 3664951.1 SE | 15032.0 | 126.60 Field, H-11 | 10.38 | 15.032 |
| D-Area | 434920.9 | 3664140.4 SSE | 10533.3 | 158.84 Building, E-11 | 6.97 | 10.533 |
| D-Area | 430269.9 | 3666714.2 S | 7329.1 | 186.78 Building, D-10 | 5.34 | 7.329 |
| D-Area | 428567.9 | 3669311.5 SSW | 5355.0 | 208.84 Building, C-9 | 3.39 | 5.355 |
| D-Area | 427480.7 | 3670627.8 SW | 4996.1 | 227.41 Building, C-9 | 2.79 | 4.996 |
| D-Area | 425692.2 | 3672131.6 WSW | 5792.0 | 250.97 Field, B-8? | 1.66 | 5.792 |
| D-Area | 424791.7 | 3673822.5 W | 6389.6 | 268.18 Field, B-8 | 1.66 | 6.389 |
| D-Area | 423726.5 | 3676322.2 WNW | 7810.0 | 287.05 Field, A-7 | 2.64 | 7.81 |
| D-Area | 425582.7 | 3679953.2 NW | 8180.4 | 316.48 Field, B-6 | 3.76 | 8.18 |
| D-Area | 426652.3 | 3680933.1 NNW | 8291.3 | 326.56 Field, B-6 | 8.01 | 8.291 |
| D-Area | 442747.2 | 3694450.2 NNE | 23506.9 | 29.13 Conference, H-1 | | |
| E-Area | 437408.8 | 3694446.9 N | 11478.1 | 353.86 Building, Photo Number | | |
| E-Area | 443831.3 | 3695495.3 NNE | 13534.2 | 22.55 Field, H-1 | | |
| E-Area | 447651.7 | 3695705.4 NE | 15597.6 | 35.28 Field, I-1 | | |
| E-Area | 454549.3 | 3690334.8 ENE | 17574.6 | 65.08 Building, L-2 | | |
| E-Area | 456151.3 | 3685518.0 E | 17761.0 | 81.59 Building, L-4 | | |
| E-Area | 453892.7 | 3679165.8 ESE | 15805.7 | 103.79 Building, K-6 | | |
| E-Area | 452522.3 | 3670132.0 SE | 19001.8 | 132.39 Field, K-9 | | |
| E-Area | 443210.4 | 3664964.8 SSE | 18650.1 | 165.23 Field, H-11 | | |
| E-Area | 434920.5 | 3664140.5 S | 19235.3 | 190.57 Building, E-11 | | |
| E-Area | 429504.4 | 3667895.7 SSW | 17637.3 | 210.57 Building, C-10 | | |
| E-Area | 424797.9 | 3673817.9 SW | 16564.1 | 235.87 Field, B-8 | | |
| E-Area | 425605.4 | 3679970.2 WSW | 13316.1 | 256.38 Field, B-6 | | |
| E-Area | 427678.7 | 3684345.6 W | 10966.7 | 276.55 Field, C-4 | | |
| E-Area | 428834.7 | 3689261.2 WNW | 11556.7 | 302.29 Field, C-3 | | |
| E-Area | 430906.0 | 3690245.9 NW | 10525.3 | 312.95 Field, D-2 | | |
| E-Area | 433535.4 | 3692817.8 NNW | 11007.3 | 332.46 Field, E-2 | | |
| E-Area | 442747.0 | 3694450.8 NNE | 12164.7 | 19.75 Conference, H-1 | | |
| F-Area | 434974.0 | 3693786.6 N | 10933.3 | 348.80 Field, Photo Number | 10.29 | 10.933 |
| F-Area | 443830.3 | 3695492.1 NNE | 14179.7 | 28.30 Field, H-1 | 11.35 | 14.18 |
| F-Area | 446619.5 | 3696218.1 NE | 16290.0 | 35.71 Building, Photo Number | 14 | 16.29 |
| F-Area | 454549.1 | 3690336.1 ENE | 18973.0 | 67.06 Building, L-2 | 17.49 | 18.973 |
| F-Area | 456151.9 | 3685519.0 E | 19279.4 | 82.29 Building, L-4 | 18.8 | 19.279 |
| F-Area | 453892.8 | 3679166.4 ESE | 17302.5 | 102.62 Building, K-6 | 18.8 | 17.302 |
| F-Area | 448364.8 | 3666788.1 SE | 19820.4 | 144.77 Field, J-10 | 18.98 | 19.82 |
| F-Area | 443212.1 | 3664960.6 SSE | 19114.8 | 160.78 Field, H-11 | 18.96 | 19.115 |
| F-Area | 434921.0 | 3664140.2 S | 19025.9 | 186.02 Building, E-11 | 16.93 | 19.026 |
| F-Area | 428567.3 | 3669312.0 SSW | 16135.0 | 211.29 Building, C-9 | 11.85 | 16.135 |
| F-Area | 424793.0 | 3673820.2 SW | 15327.9 | 232.63 Field, B-8 | 11.49 | 15.328 |
| F-Area | 427016.3 | 3680970.7 WSW | 10228.5 | 257.93 Field, C-6 | 9.39 | 10.228 |
| F-Area | 427678.8 | 3684344.0 W | 9441.9 | 277.54 Field, C-4 | 9.39 | 9.442 |
| F-Area | 427227.9 | 3685002.6 WNW | 9996.4 | 280.92 Field, C-4 | 9.4 | 9.996 |
| F-Area | 430904.7 | 3690242.9 NW | 9449.6 | 319.23 Field, D-2 | 9.43 | 9.45 |
| F-Area | 431510.1 | 3691323.4 NNW | 9947.8 | 325.94 Field, E-2 | 9.43 | 9.948 |
| F-Area | 442746.8 | 3694450.4 NNE | 12754.0 | 26.27 Conference, H-1 | | |
| H-Area | 439049.6 | 3695529.0 N | 12379.7 | 353.17 Building, Photo Number | 11.54 | 12.38 |
| H-Area | 443830.6 | 3695492.9 NNE | 12722.6 | 15.07 Field, H-1 | 12.59 | 12.723 |
| H-Area | 448711.5 | 3695363.3 NE | 14681.8 | 33.91 Building, J-1 | 13.08 | 14.682 |
| H-Area | 454549.0 | 3690335.9 ENE | 15791.7 | 62.90 Building, L-2 | 15.35 | 15.792 |
| H-Area | 456152.7 | 3685517.2 E | 15871.5 | 81.36 Building, L-4 | 15.47 | 15.872 |
| H-Area | 453893.2 | 3679166.6 ESE | 14046.2 | 106.46 Building, K-6 | 15.52 | 14.046 |
| H-Area | 452524.0 | 3670131.9 SE | 17814.8 | 136.97 Field, K-9 | 16.44 | 17.815 |
| H-Area | 450086.1 | 3667934.0 SSE | 18078.4 | 147.43 Field, J-10 | 17.71 | 18.078 |

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|---|---|---|---|---|---|---|
| H-Area | 443321.0 | 3664987.8 S | 18465.6 | 170.70 Field, H-11 | 17.85 | 18.466 |
| H-Area | 430270.6 | 3666714.0 SSW | 19398.2 | 211.29 Building, D-10 | 16.67 | 19.398 |
| H-Area | 427480.3 | 3670628.3 SW | 18080.4 | 225.47 Building, C-9 | 14.34 | 18.08 |
| H-Area | 425606.7 | 3679968.9 WSW | 15194.2 | 257.26 Field, B-6 | 12.81 | 15.194 |
| H-Area | 427678.8 | 3684344.0 W | 12817.0 | 274.64 Field, C-4 | 12.79 | 12.817 |
| H-Area | 430108.5 | 3689975.5 WNW | 12345.5 | 302.78 Field, D-3 | 11.83 | 12.345 |
| H-Area | 433535.4 | 3692817.3 NW | 11820.2 | 323.87 Field, E-2 | 11.74 | 11.82 |
| H-Area | 437408.9 | 3694447.3 NNW | 11623.0 | 344.50 Building, F-1 | 11.54 | 11.623 |
| H-Area | 442747.2 | 3694450.5 NNE | 11455.4 | 11.23 Conference, H-1 | | |
| K-Area | 434671.0 | 3693514.0 N | 19026.9 | 349.40 Field, Photo Number | 17.9 | 19.027 |
| K-Area | 443825.5 | 3695493.2 NNE | 21491.3 | 15.22 Field, H-1 | 20.57 | 21.491 |
| K-Area | 454548.6 | 3690335.3 NE | 22663.2 | 46.34 Building, L-2 | 19.36 | 22.663 |
| K-Area | 453893.4 | 3679167.7 ENE | 16430.6 | 74.20 Building, K-6 | 17.1 | 16.431 |
| K-Area | 455393.9 | 3675145.2 E | 17341.0 | 88.48 Field, L-7 | 14.78 | 17.341 |
| K-Area | 450086.1 | 3667933.0 ESE | 13847.0 | 119.34 Field, J-10 | 11.64 | 13.847 |
| K-Area | 445969.7 | 3665469.5 SE | 12227.1 | 139.32 Field, I-11 | 10.76 | 12.227 |
| K-Area | 443202.7 | 3664958.5 SSE | 11097.6 | 152.02 Field, H-11? | 10.76 | 11.098 |
| K-Area | 439284.3 | 3661446.1 S | 13401.0 | 174.39 Field, G-12 | 10.95 | 13.401 |
| K-Area | 434920.3 | 3664140.7 SSW | 11102.1 | 196.06 Building, E-11 | 10.58 | 11.102 |
| K-Area | 429505.2 | 3667893.7 SW | 10986.1 | 230.76 Building, C-10 | 10.58 | 10.986 |
| K-Area | 428567.8 | 3669311.8 WSW | 10957.0 | 239.65 Building, C-9 | 8.86 | 10.957 |
| K-Area | 424795.8 | 3673819.6 W | 13296.2 | 265.46 Field, B-8 | 8.86 | 13.296 |
| K-Area | 426607.9 | 3680760.6 WNW | 12911.7 | 297.19 Field, Photo Number | 9.64 | 12.912 |
| K-Area | 427458.6 | 3682680.3 NW | 13212.2 | 306.32 Field, C-5 | 12.42 | 13.212 |
| K-Area | 430905.0 | 3690240.5 NNW | 17024.7 | 334.81 Field, D-2 | 15.81 | 17.025 |
| K-Area | 442747.2 | 3694450.3 NNE | 20211.5 | 13.07 Conference, H-1 | | |
| L-Area | 443841.3 | 3695490.3 N | 21068.8 | 4.87 Field, H-1 | 20.34 | 21.069 |
| L-Area | 453653.4 | 3692375.4 NNE | 21372.1 | 32.93 Building, K-2 | 19.92 | 21.372 |
| L-Area | 456641.2 | 3684642.5 NE | 17867.6 | 55.10 Building, L-4 | 15.27 | 17.868 |
| L-Area | 453893.6 | 3679167.5 ENE | 12843.2 | 68.38 Building, K-6 | 13.42 | 12.843 |
| L-Area | 455392.7 | 3675145.9 E | 13482.5 | 86.94 Field, Photo Number | 11.42 | 13.482 |
| L-Area | 452020.7 | 3669242.9 ESE | 11386.4 | 117.20 Building, K-9 | 10.25 | 11.386 |
| L-Area | 448364.4 | 3666787.8 SE | 10053.8 | 139.82 Field, J-10 | 9.16 | 10.054 |
| L-Area | 443992.4 | 3664820.6 SSE | 9906.3 | 167.61 Building, H-11 | 9.16 | 9.906 |
| L-Area | 443323.1 | 3664990.4 S | 9620.5 | 171.29 Field, H-11 | 9.5 | 9.62 |
| L-Area | 434844.4 | 3663641.9 SSW | 12970.3 | 212.74 Field, E-11 | 12.09 | 12.97 |
| L-Area | 434921.4 | 3664140.0 SW | 12512.6 | 213.69 Building, E-11 | 12.09 | 12.513 |
| L-Area | 429502.4 | 3667895.0 WSW | 14073.7 | 241.62 Building, C-10 | 12.5 | 14.074 |
| L-Area | 425721.2 | 3672137.3 W | 16376.6 | 261.32 Field, B-8 | 12.5 | 16.377 |
| L-Area | 426984.7 | 3681382.2 WNW | 16445.7 | 294.35 Field, C-5 | 13.24 | 16.446 |
| L-Area | 427648.8 | 3684101.1 NW | 17199.6 | 303.55 Field, C-4 | 15.77 | 17.2 |
| L-Area | 431264.9 | 3690883.4 NNW | 19538.9 | 326.58 Field, D-2 | 19.18 | 19.539 |
| L-Area | 442747.0 | 3694450.6 N | 19958.7 | 2.01 Conference, H-1 | | |
| M-Area | 431261.0 | 3690881.0 N | 1932.4 | -0.19 Field, D-2 | 1.8 | 1.932 |
| M-Area | 431924.3 | 3692272.0 NNE | 3390.1 | 11.03 Field, E-2 | 1.93 | 3.39 |
| M-Area | 434146.5 | 3693270.9 NE | 5200.0 | 33.43 Field, Photo Number | 3.59 | 5.2 |
| M-Area | 443830.4 | 3695492.6 ENE | 14175.7 | 62.16 Field, H-1 | 7.98 | 14.176 |
| M-Area | 453653.6 | 3692373.9 E | 22658.5 | 80.96 Building, K-2 | 18.56 | 22.658 |
| M-Area | 453894.4 | 3679167.6 ESE | 24661.4 | 113.02 Building, K-6 | 24.73 | 24.661 |
| M-Area | 448364.1 | 3666786.8 SE | 27997.3 | 141.98 Field, J-10 | 26.64 | 27.997 |
| M-Area | 443209.5 | 3664961.9 SSE | 26800.4 | 153.16 Field, H-11 | 22.14 | 26.8 |
| M-Area | 427401.6 | 3669539.1 S | 19788.4 | 190.88 Building, C-9 | 13.48 | 19.788 |
| M-Area | 427329.4 | 3683060.7 SSW | 7076.9 | 213.35 Field, C-5 | 5.64 | 7.077 |
| M-Area | 427256.6 | 3686266.3 SW | 4815.2 | 235.80 Field, C-4 | 3.89 | 4.815 |
| M-Area | 428180.8 | 3688329.3 WSW | 3136.5 | 258.26 Field, C-3 | 2.59 | 3.136 |
| M-Area | 428836.7 | 3689267.4 W | 2439.8 | 277.16 Field, C-3 | 2.15 | 2.44 |
| M-Area | 429236.1 | 3689828.3 WNW | 2202.8 | 293.19 Building, C-3 | 1.49 | 2.203 |
| M-Area | 430098.8 | 3689961.5 NW | 1537.6 | 310.86 Field, D-3 | 1.47 | 1.538 |
| M-Area | 430904.8 | 3690244.1 NNW | 1342.2 | 344.50 Field, D-2 | 1.3 | 1.342 |
| M-Area | 442747.1 | 3694450.4 ENE | 12740.7 | 64.07 Conference, H-1 | | |
| N-Area | 437408.4 | 3694446.6 N | 15187.7 | 355.02 Building, Photo Number | | |
| N-Area | 443824.4 | 3695493.2 NNE | 16996.4 | 17.43 Field, H-1 | | |
| N-Area | 449869.0 | 3695043.5 NE | 19333.9 | 35.18 Field, J-1 | | |
| N-Area | 456151.1 | 3685517.8 ENE | 18584.4 | 70.13 Building, L-4 | | |

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|---|---|---|---|---|---|---|
| N-Area | 453893.6 | 3679166.6 E | 15259.5 | 90.18 Building, K-6 | | |
| N-Area | 452521.4 | 3670133.2 ESE | 16644.0 | 123.10 Field, K-9 | | |
| N-Area | 448362.5 | 3666788.3 SE | 15855.1 | 141.80 Field, J-10 | | |
| N-Area | 443230.6 | 3664968.3 SSE | 15058.6 | 161.88 Field, H-11 | | |
| N-Area | 439286.0 | 3661446.4 S | 17874.0 | 177.56 Field, G-12 | | |
| N-Area | 430270.1 | 3666713.8 SSW | 15119.3 | 213.24 Building, D-10 | | |
| N-Area | 427480.0 | 3670627.9 SW | 14134.4 | 231.76 Building, C-9 | | |
| N-Area | 425708.4 | 3672130.1 WSW | 14785.8 | 240.61 Field, B-8 | | |
| N-Area | 426986.1 | 3681385.0 W | 11832.2 | 279.76 Field, C-5 | | |
| N-Area | 427532.1 | 3682784.4 WNW | 11634.0 | 287.03 Field, C-5 | | |
| N-Area | 430903.6 | 3690239.5 NW | 13388.7 | 324.38 Field, Photo Number | | |
| N-Area | 431263.9 | 3690884.5 NNW | 13723.4 | 327.16 Field, Photo Number | | |
| N-Area | 442747.0 | 3694450.3 NNE | 15690.3 | 14.84 Conference, H-1 | | |
| P-Area | 448712.0 | 3695363.1 N | 19021.0 | 8.35 Building, J-1 | 17.88 | 19.021 |
| P-Area | 454682.5 | 3690111.1 NNE | 16182.4 | 32.79 Field, L-2 | 14.52 | 16.182 |
| P-Area | 456640.6 | 3684642.5 NE | 13492.6 | 52.85 Building, L-4 | 11.04 | 13.493 |
| P-Area | 453892.9 | 3679167.1 ENE | 8467.8 | 71.72 Building, K-6 | 9.71 | 8.468 |
| P-Area | 455395.0 | 3675149.8 E | 9662.4 | 98.05 Field, L-7 | 9.59 | 9.662 |
| P-Area | 455482.7 | 3674592.1 ESE | 9845.3 | 101.18 Field, L-8 | 9.21 | 9.845 |
| P-Area | 452516.5 | 3670136.1 SE | 9268.3 | 133.53 Field, K-9 | 9.21 | 9.268 |
| P-Area | 450085.3 | 3667933.4 SSE | 9616.9 | 153.43 Field, J-10 | 9.47 | 9.617 |
| P-Area | 446386.7 | 3665646.5 S | 10928.0 | 176.76 Field, I-11 | 9.87 | 10.928 |
| P-Area | 443379.9 | 3664990.8 SSW | 11827.8 | 191.64 Field, H-11 | 10.42 | 11.828 |
| P-Area | 434921.4 | 3664140.4 SW | 16534.6 | 220.96 Building, E-11 | 15.68 | 16.535 |
| P-Area | 430270.2 | 3666713.6 WSW | 18419.2 | 237.33 Building, D-10 | 16.68 | 18.419 |
| P-Area | 425607.1 | 3679969.5 W | 20514.3 | 279.22 Field, B-6 | 16.68 | 20.514 |
| P-Area | 426984.8 | 3681384.1 WNW | 19458.6 | 284.00 Field, C-6 | 18.8 | 19.459 |
| P-Area | 430904.5 | 3690241.7 NW | 20251.5 | 312.15 Field, D-2 | 19.67 | 20.251 |
| P-Area | 437408.8 | 3694446.7 NNW | 19772.0 | 334.42 Building, Photo Number | 18.72 | 19.772 |
| P-Area | 442747.6 | 3694450.6 N | 18154.6 | 349.85 Conference, H-1 | | |
| SZ-Area | 439049.8 | 3695528.7 N | 11794.9 | 353.71 Building, Photo Number | | |
| SZ-Area | 443840.2 | 3695489.1 NNE | 12224.7 | 16.63 Field, H-1 | | |
| SZ-Area | 448711.5 | 3695363.5 NE | 14318.9 | 35.77 Building, J-1 | | |
| SZ-Area | 454548.5 | 3690334.3 ENE | 15703.2 | 65.05 Building, L-2 | | |
| SZ-Area | 456151.3 | 3685518.2 E | 15973.7 | 83.46 Building, L-4 | | |
| SZ-Area | 453894.5 | 3679166.9 ESE | 14389.2 | 108.42 Building, K-6 | | |
| SZ-Area | 452521.0 | 3670133.8 SE | 18351.0 | 137.77 Field, K-9 | | |
| SZ-Area | 450086.5 | 3667932.6 SSE | 18655.7 | 147.90 Field, J-10 | | |
| SZ-Area | 443324.5 | 3664989.2 S | 19054.2 | 170.43 Field, H-11 | | |
| SZ-Area | 430270.1 | 3666714.0 SSW | 19795.0 | 209.99 Building, D-10 | | |
| SZ-Area | 427479.9 | 3670627.8 SW | 18358.5 | 223.81 Building, C-9 | | |
| SZ-Area | 426674.6 | 3680939.3 WSW | 13893.2 | 257.78 Field, B-6 | | |
| SZ-Area | 427679.1 | 3684345.2 W | 12603.4 | 272.14 Field, C-4 | | |
| SZ-Area | 433534.2 | 3692818.0 NW | 11258.6 | 322.90 Field, E-2 | | |
| SZ-Area | 437409.0 | 3694446.5 NNW | 11027.2 | 344.61 Building, F-1 | | |
| SZ-Area | 430273.7 | 3690117.9 WNW | 11827.5 | 301.95 Field, D-2 | | |
| SZ-Area | 442747.0 | 3694450.3 N | 10937.2 | 12.74 Conference, H-1 | | |
| T-Area | 427449.8 | 3683846.1 N | 9116.7 | 348.48 Field, C-4 | | |
| T-Area | 433536.2 | 3692818.4 NNE | 18429.7 | 13.21 Field, Photo Number | | |
| T-Area | 443831.1 | 3695496.8 NE | 25253.4 | 35.01 Field, H-1 | | |
| T-Area | 456150.5 | 3685517.7 ENE | 28950.8 | 68.14 Building, L-4 | | |
| T-Area | 453893.2 | 3679167.5 E | 25042.9 | 79.84 Building, K-6 | | |
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| T-Area | 439286.0 | 3661444.5 SE | 16807.9 | 142.84 Field, G-12 | | |
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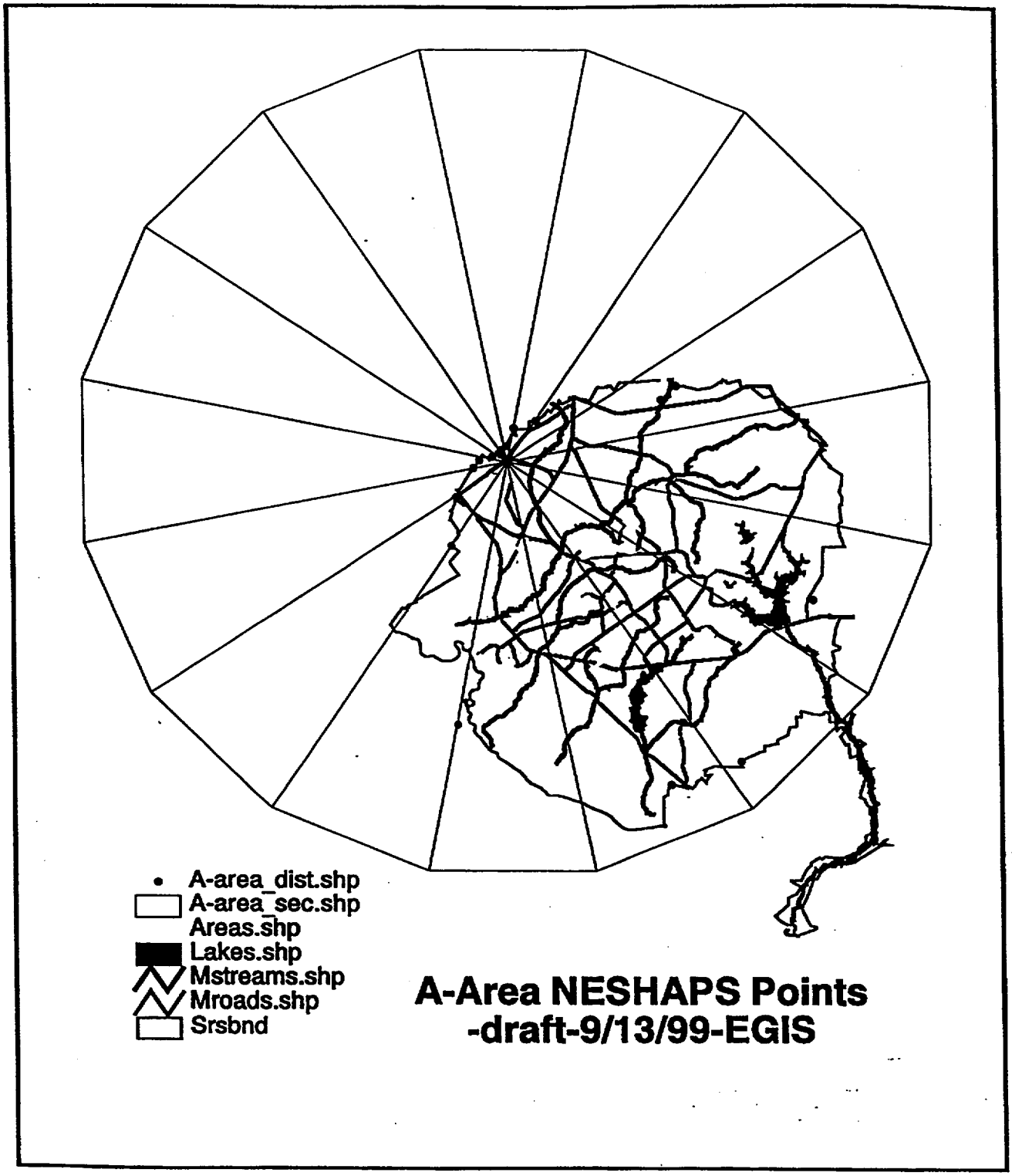
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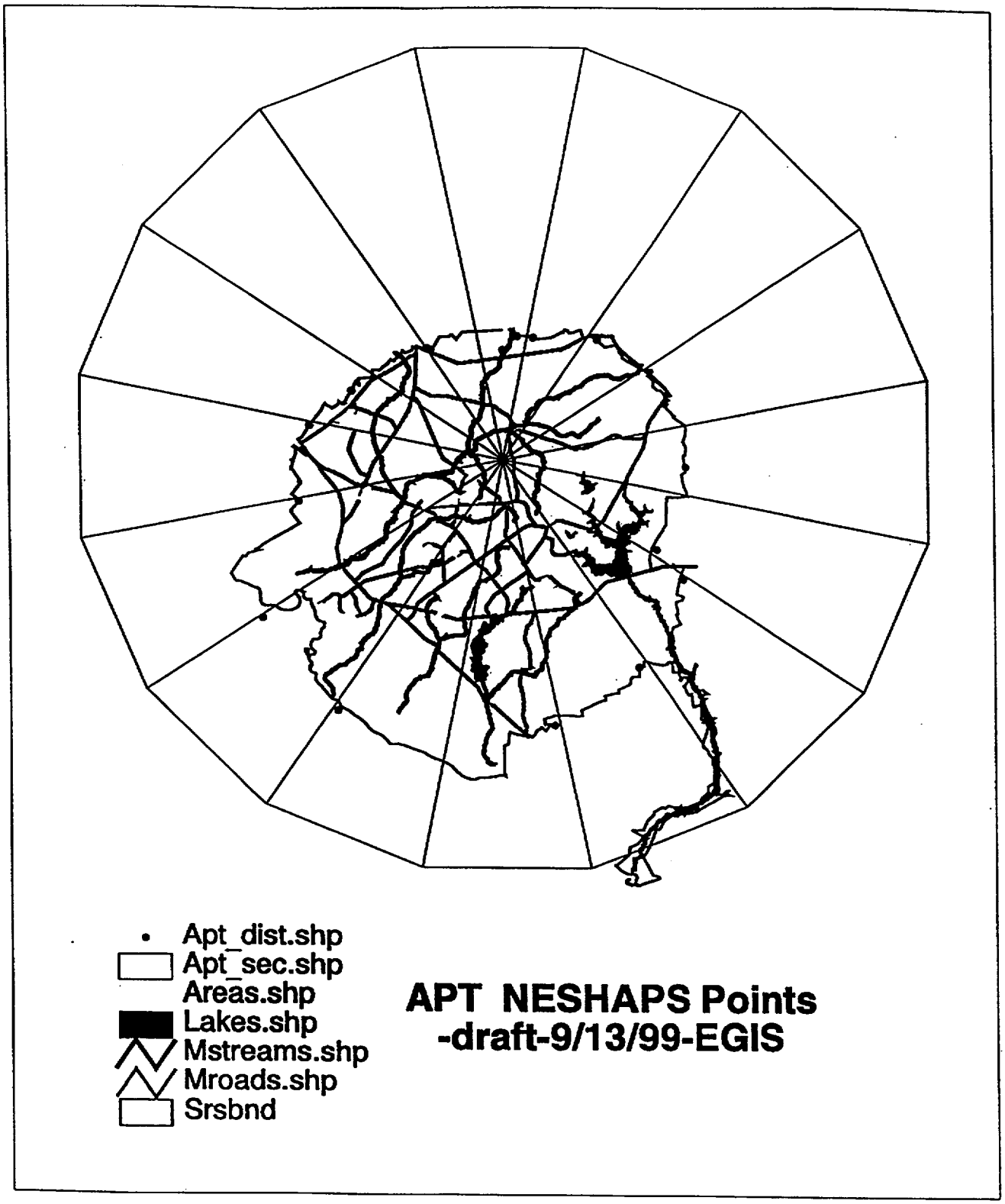
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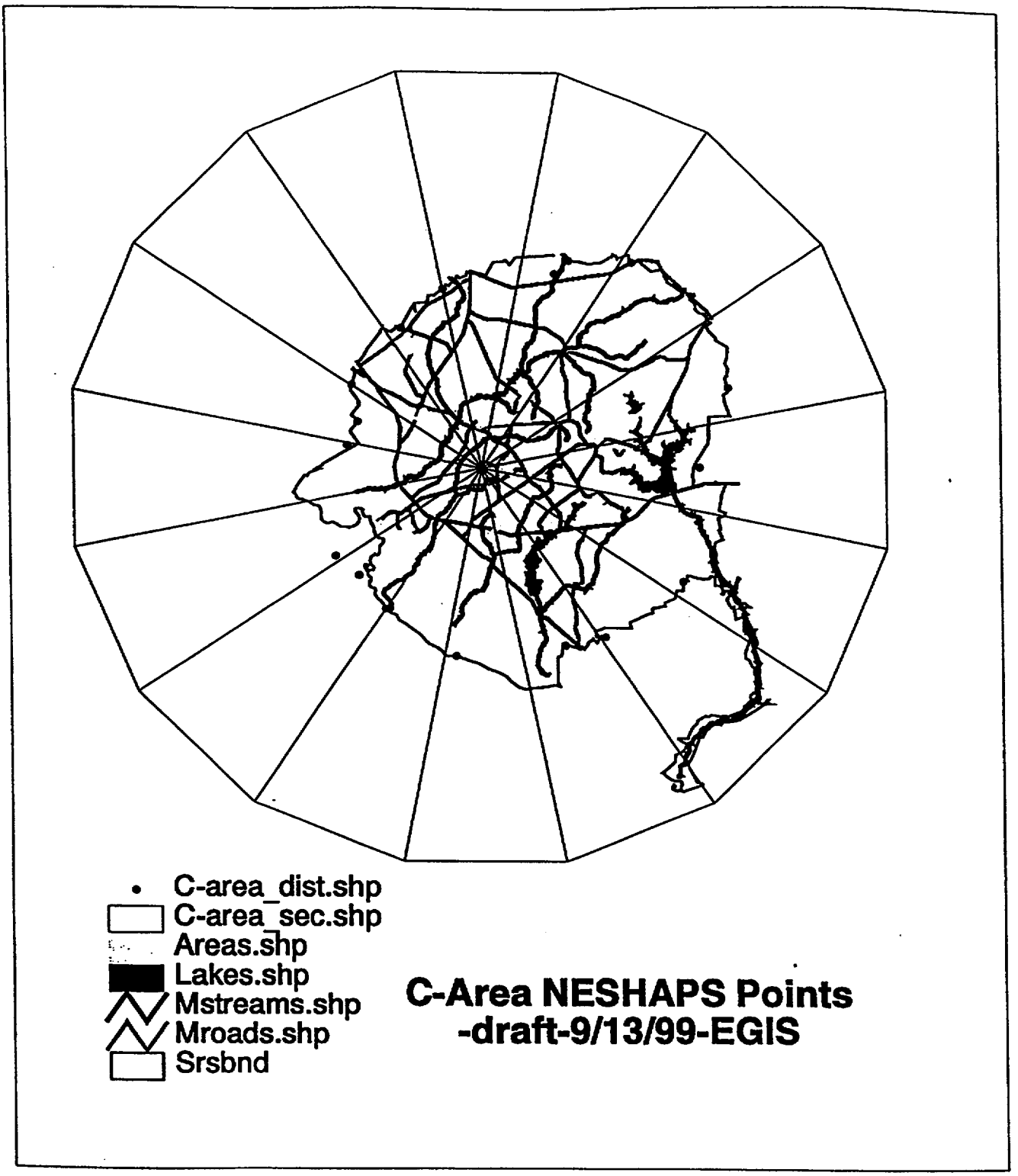
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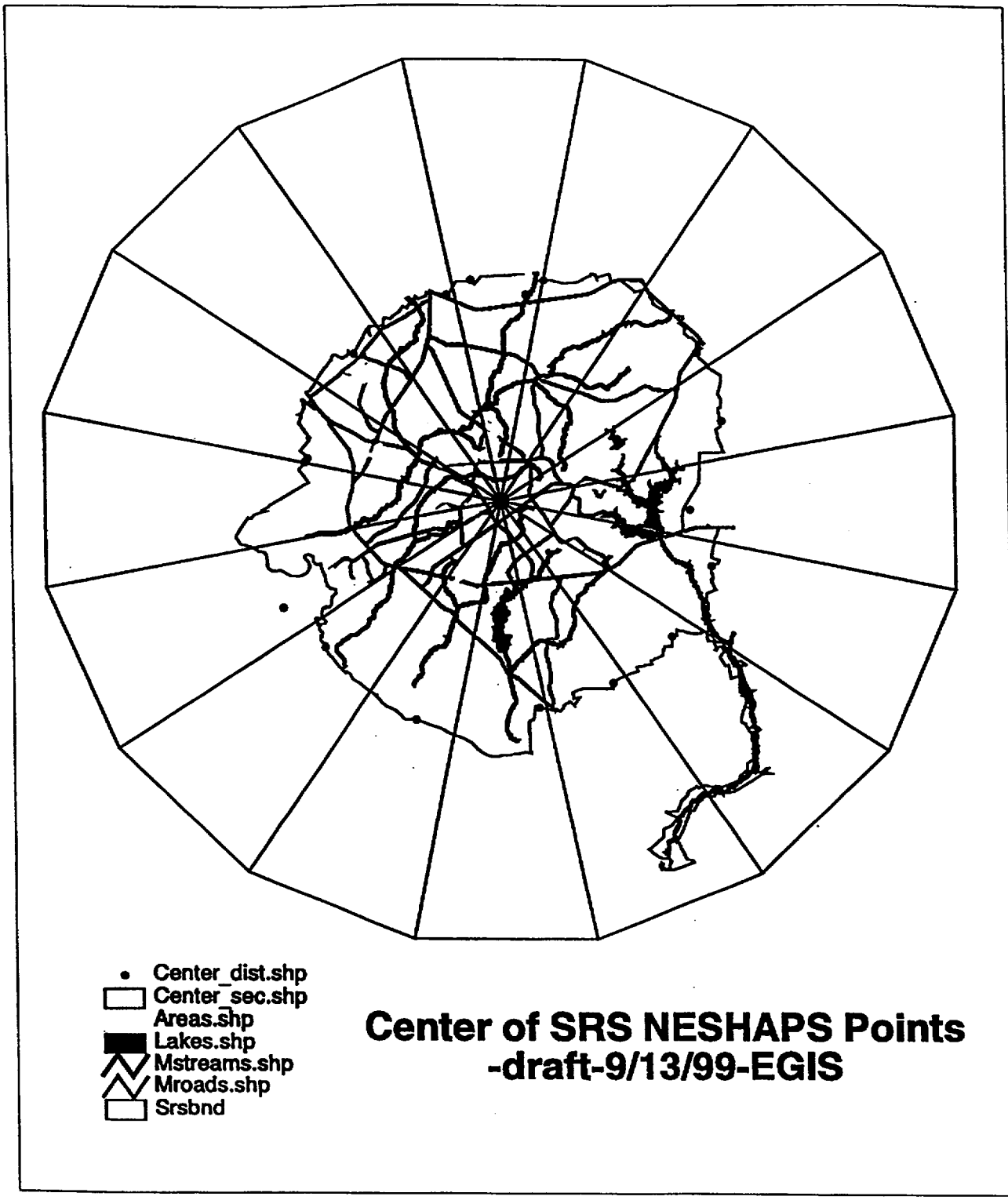
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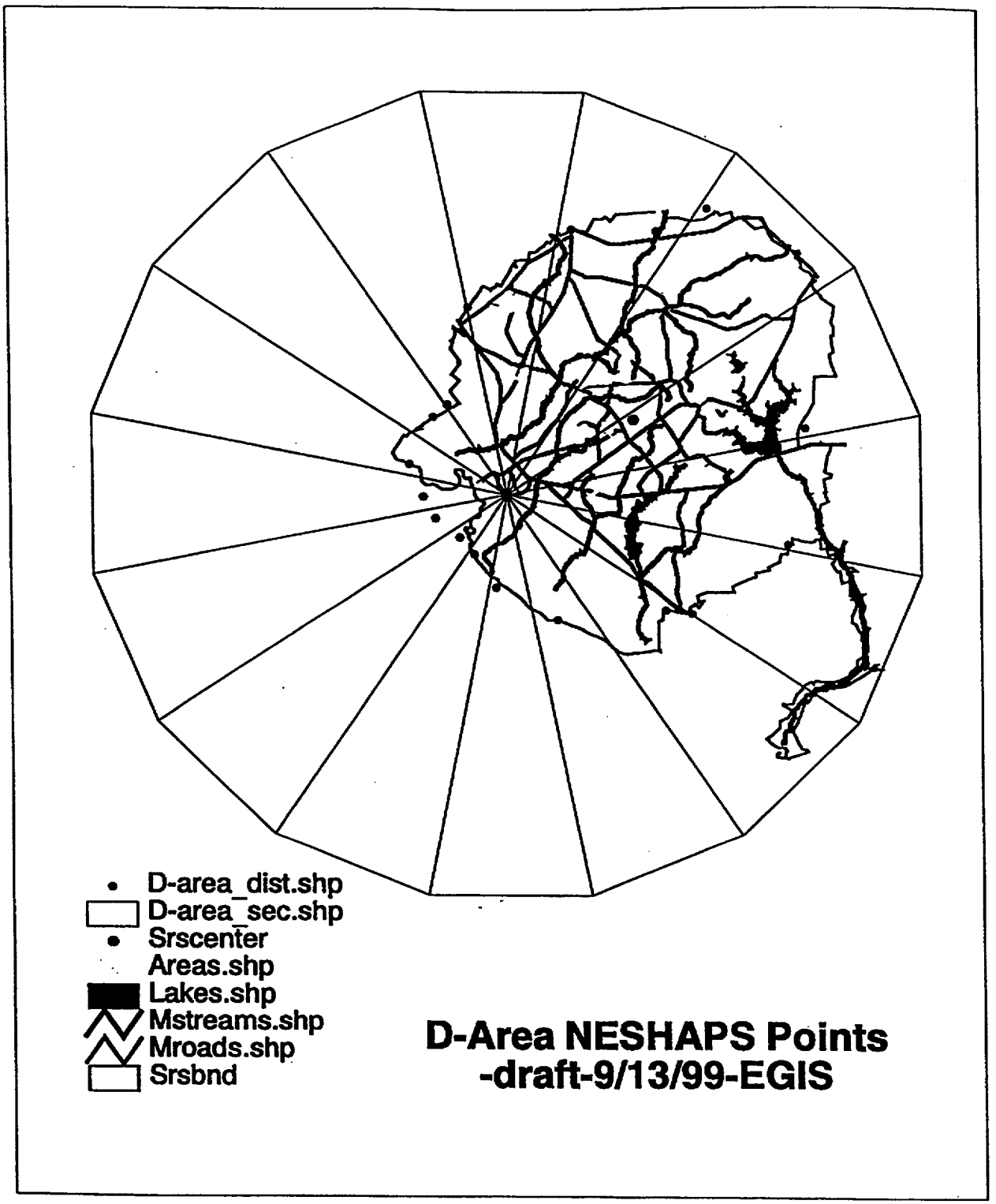
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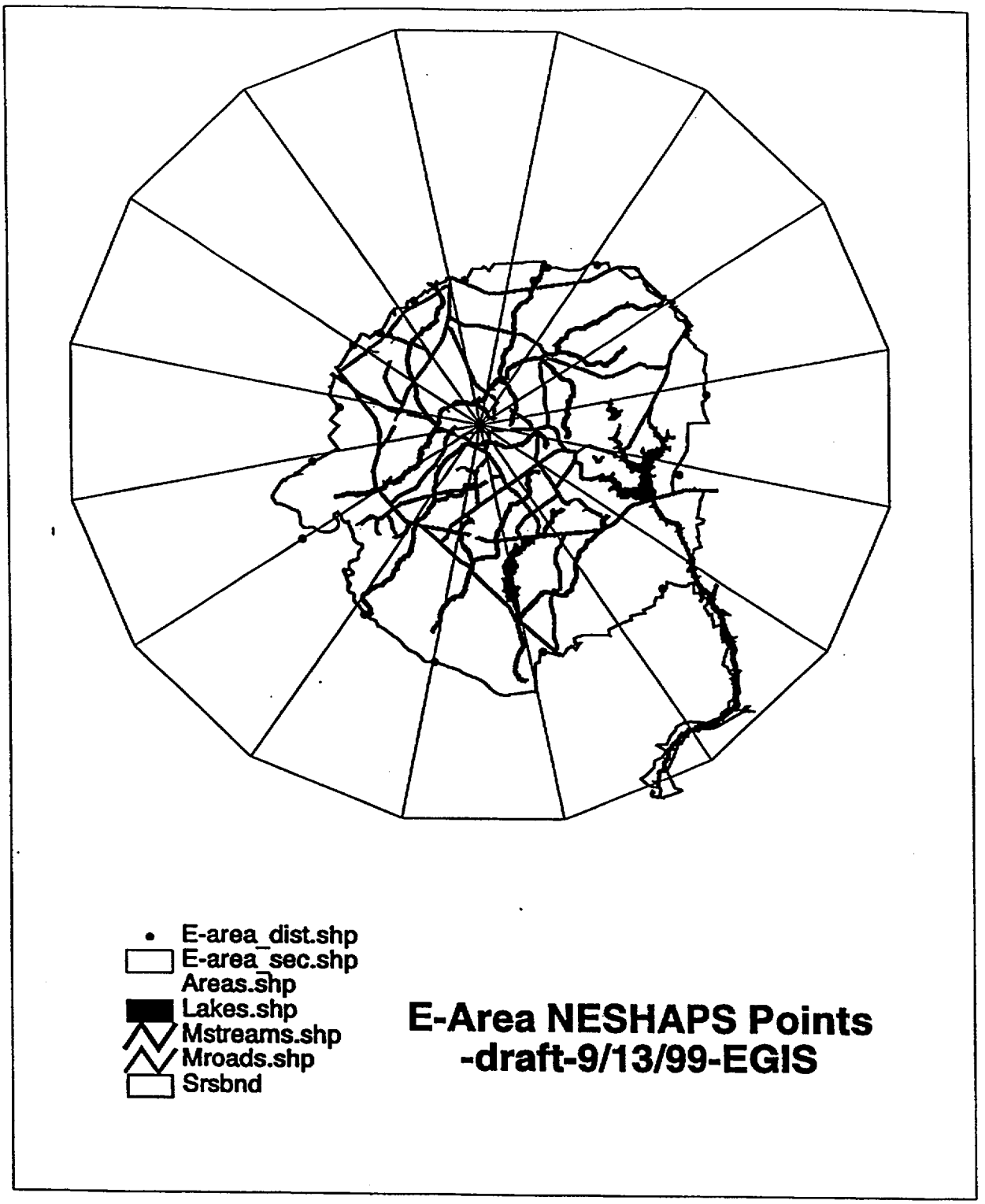
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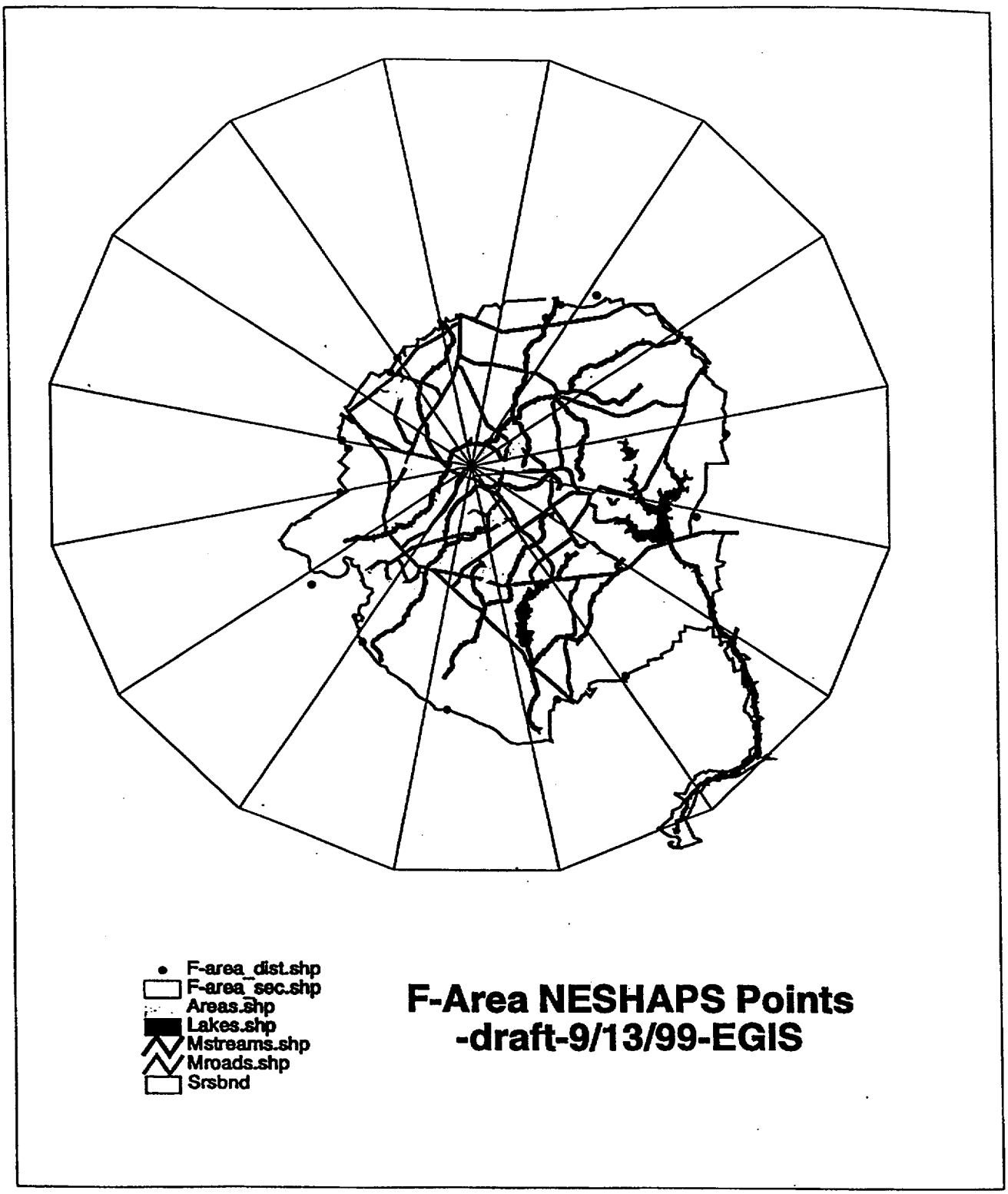
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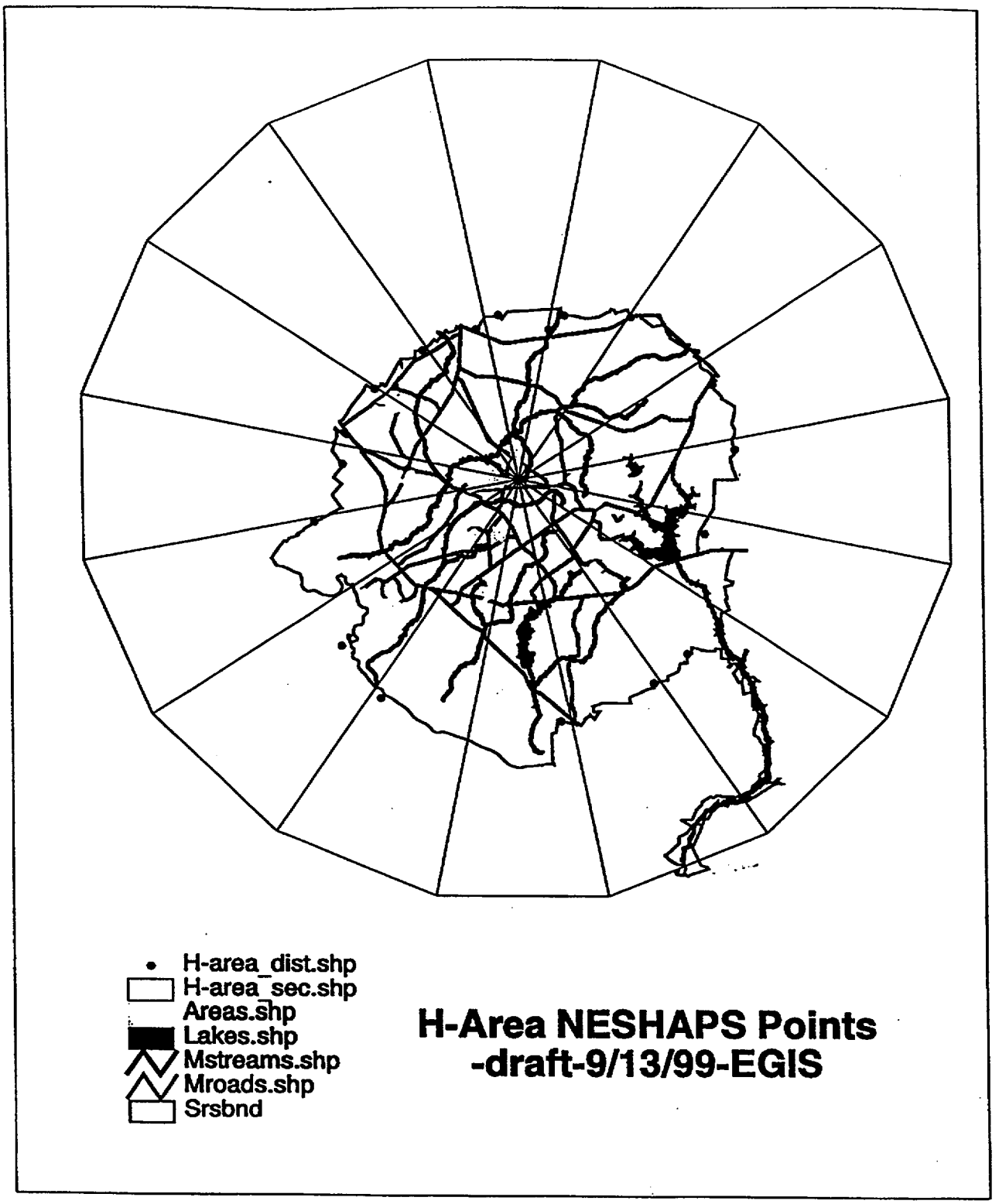
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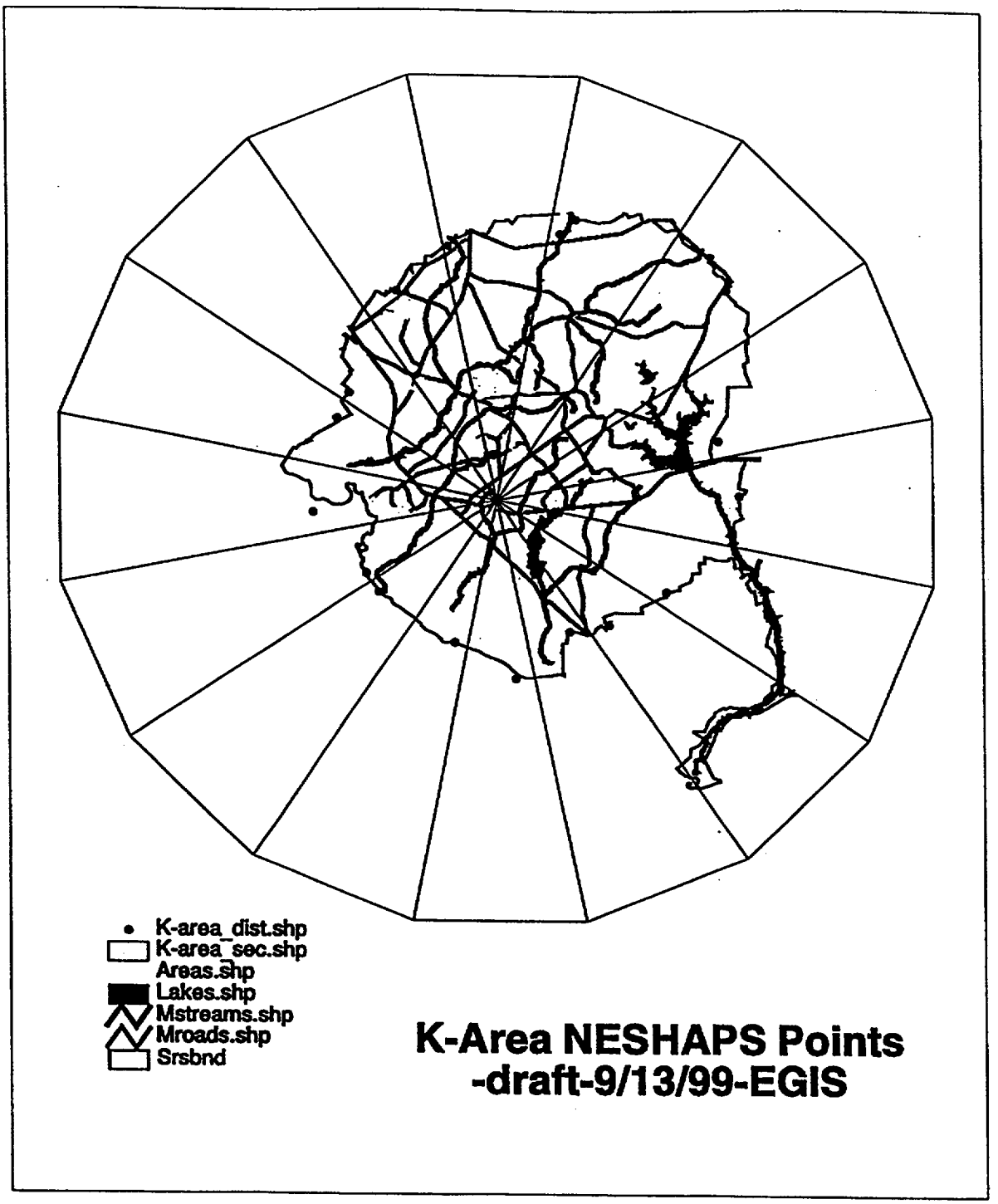
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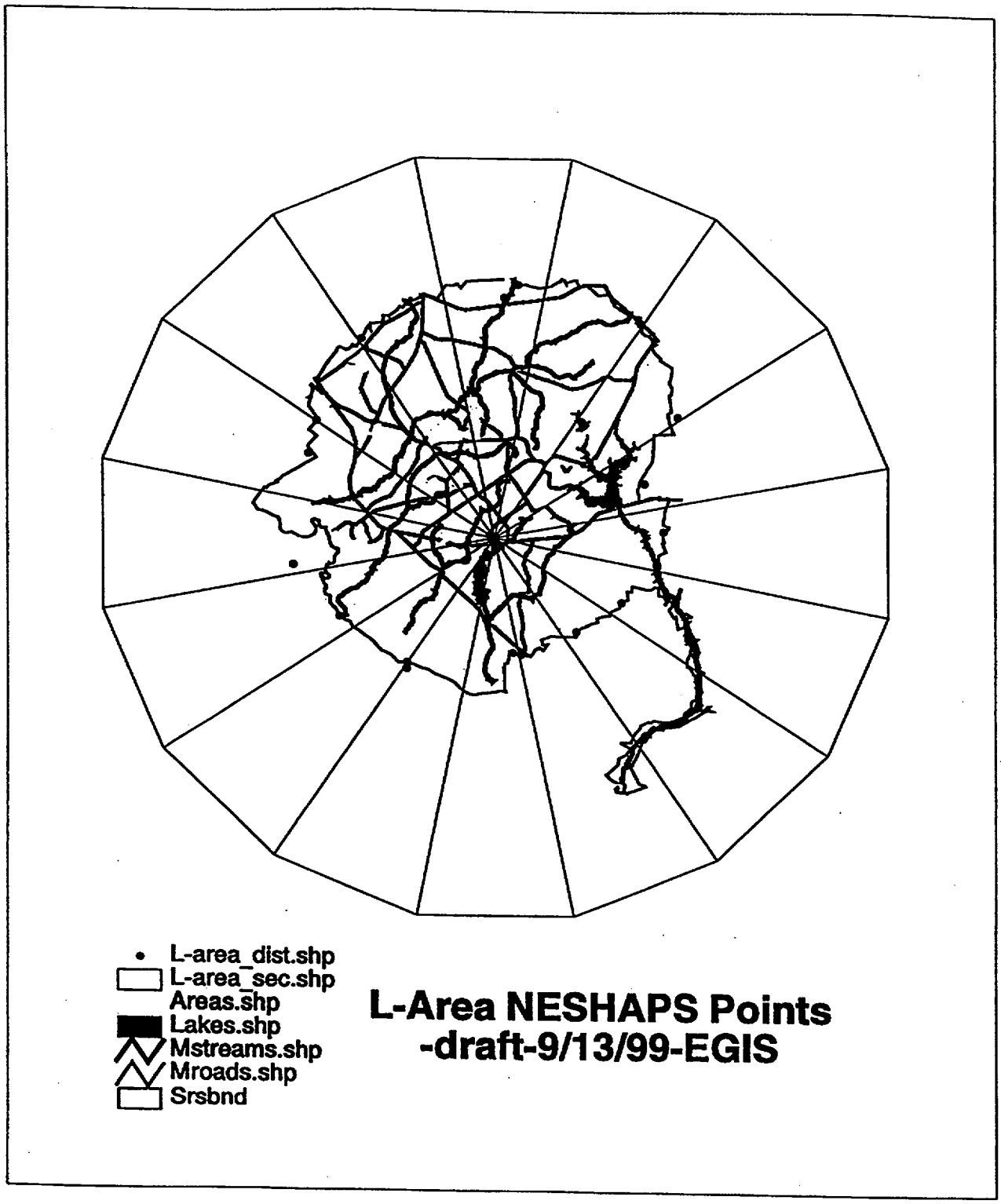
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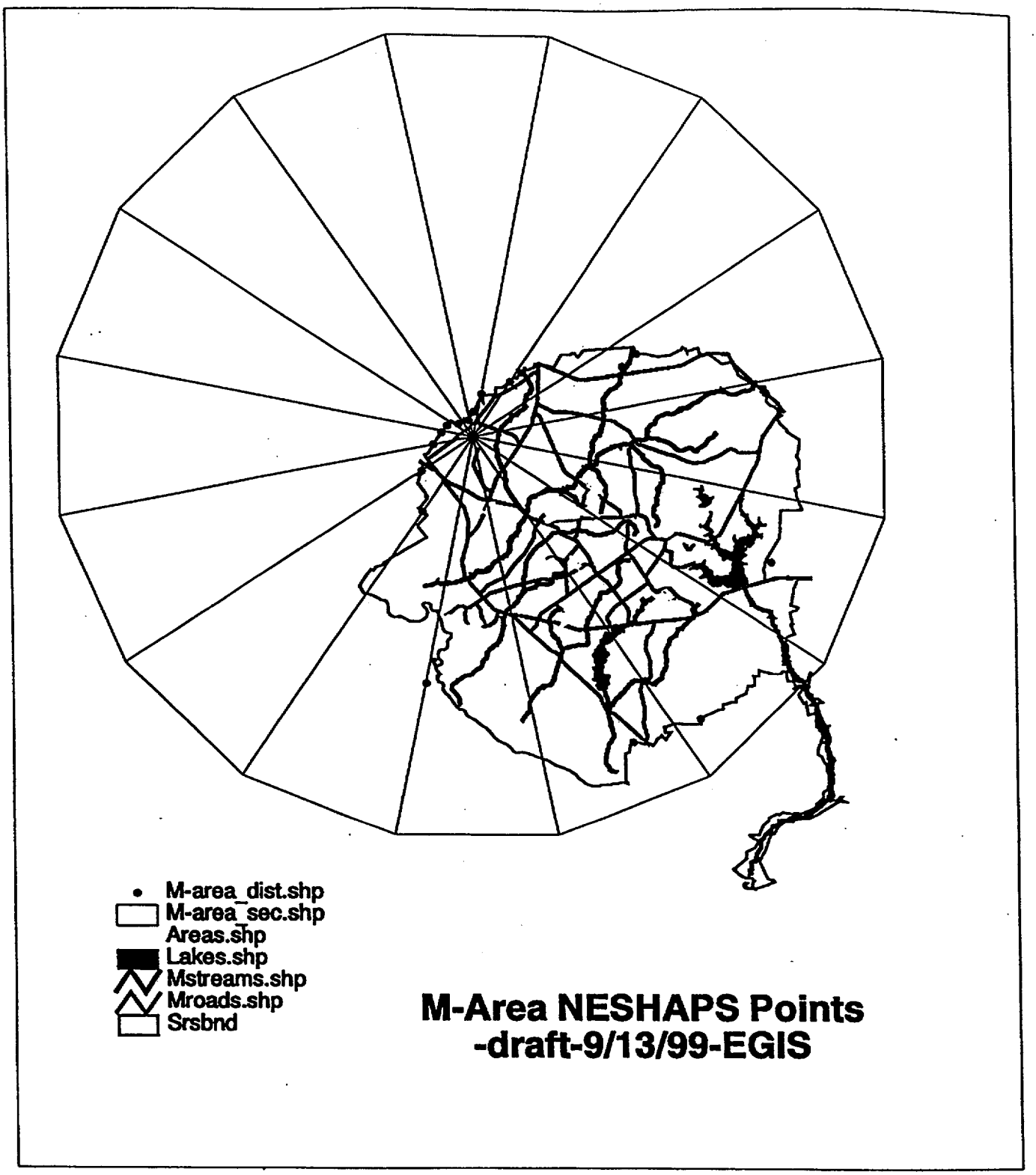
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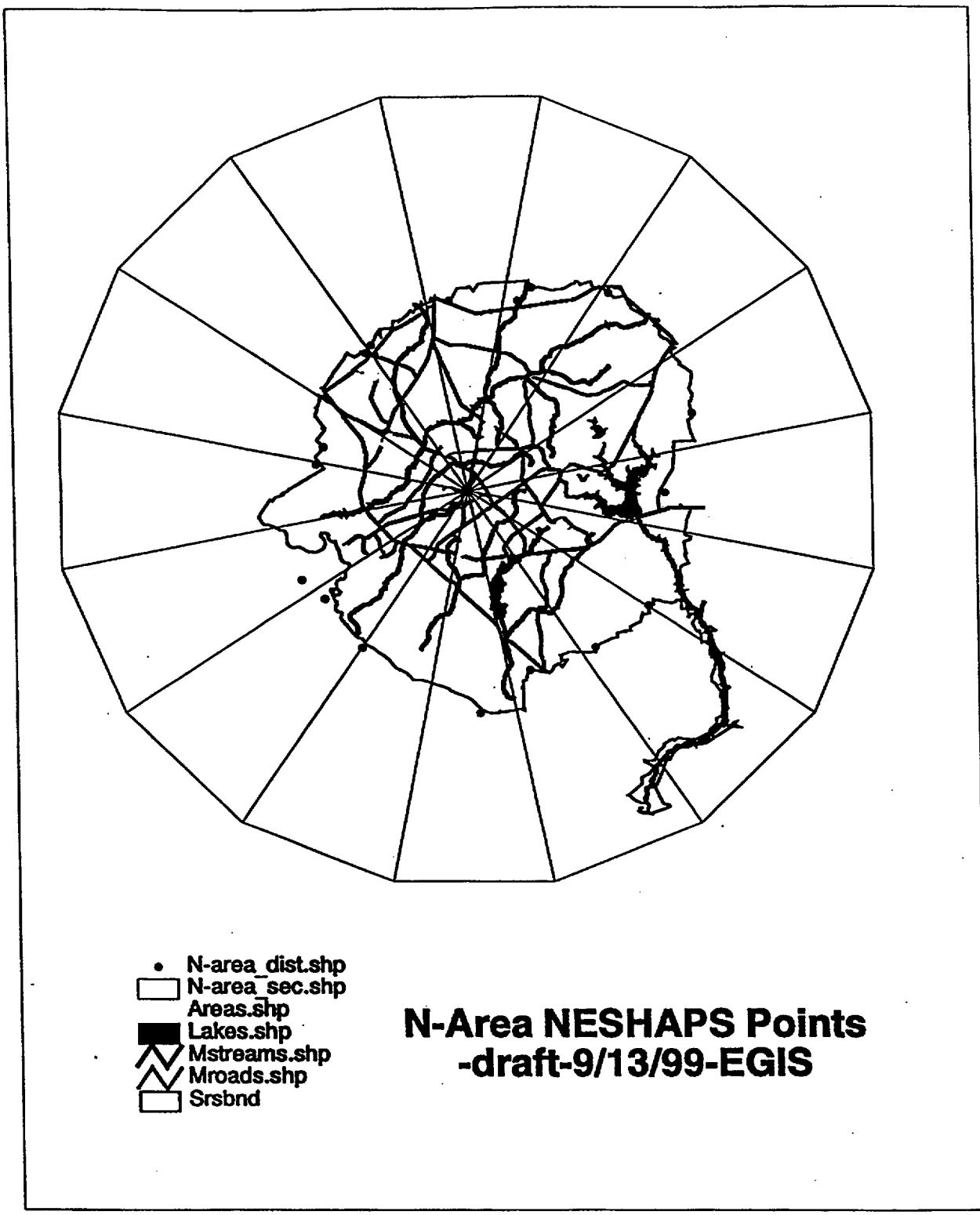
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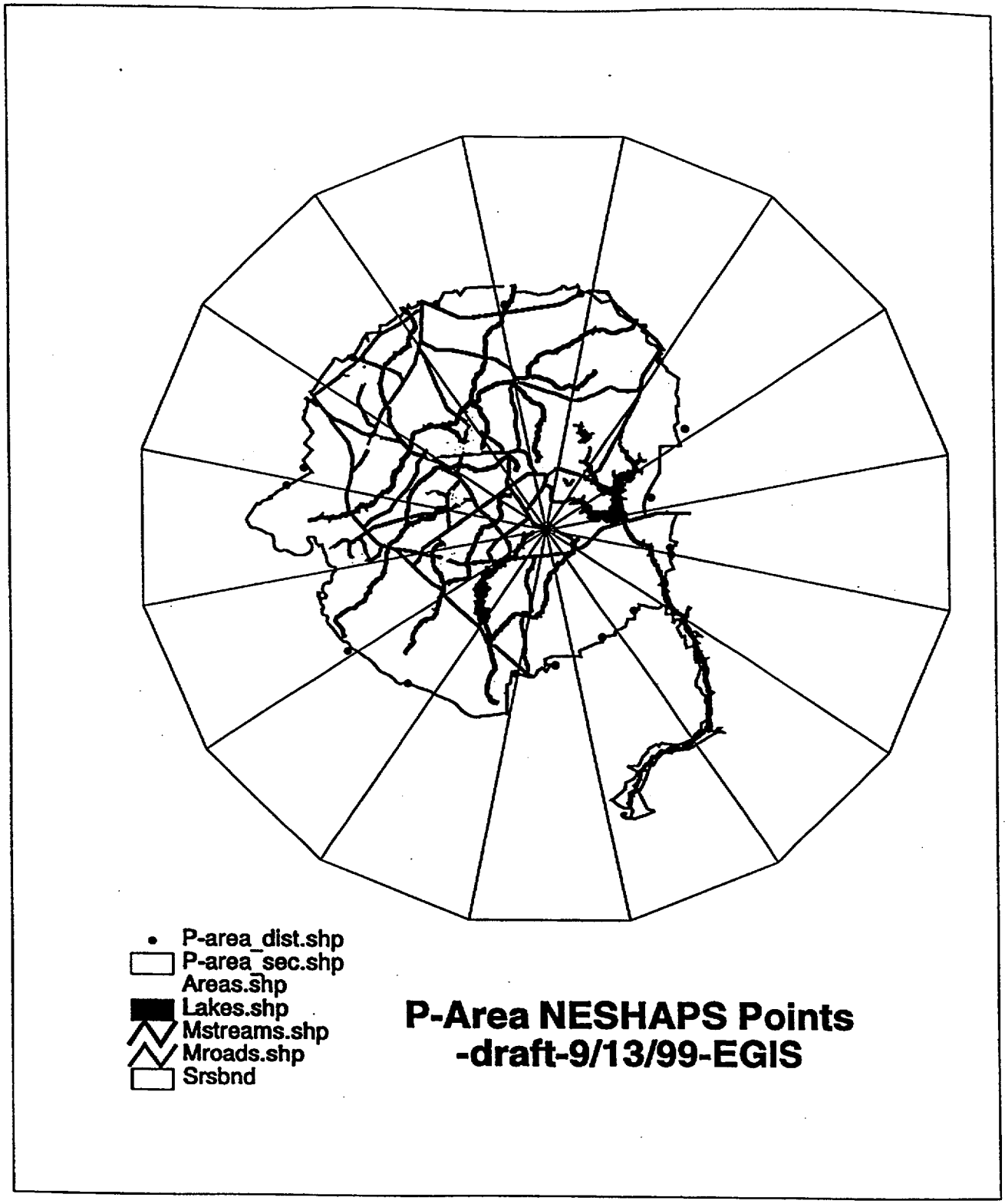
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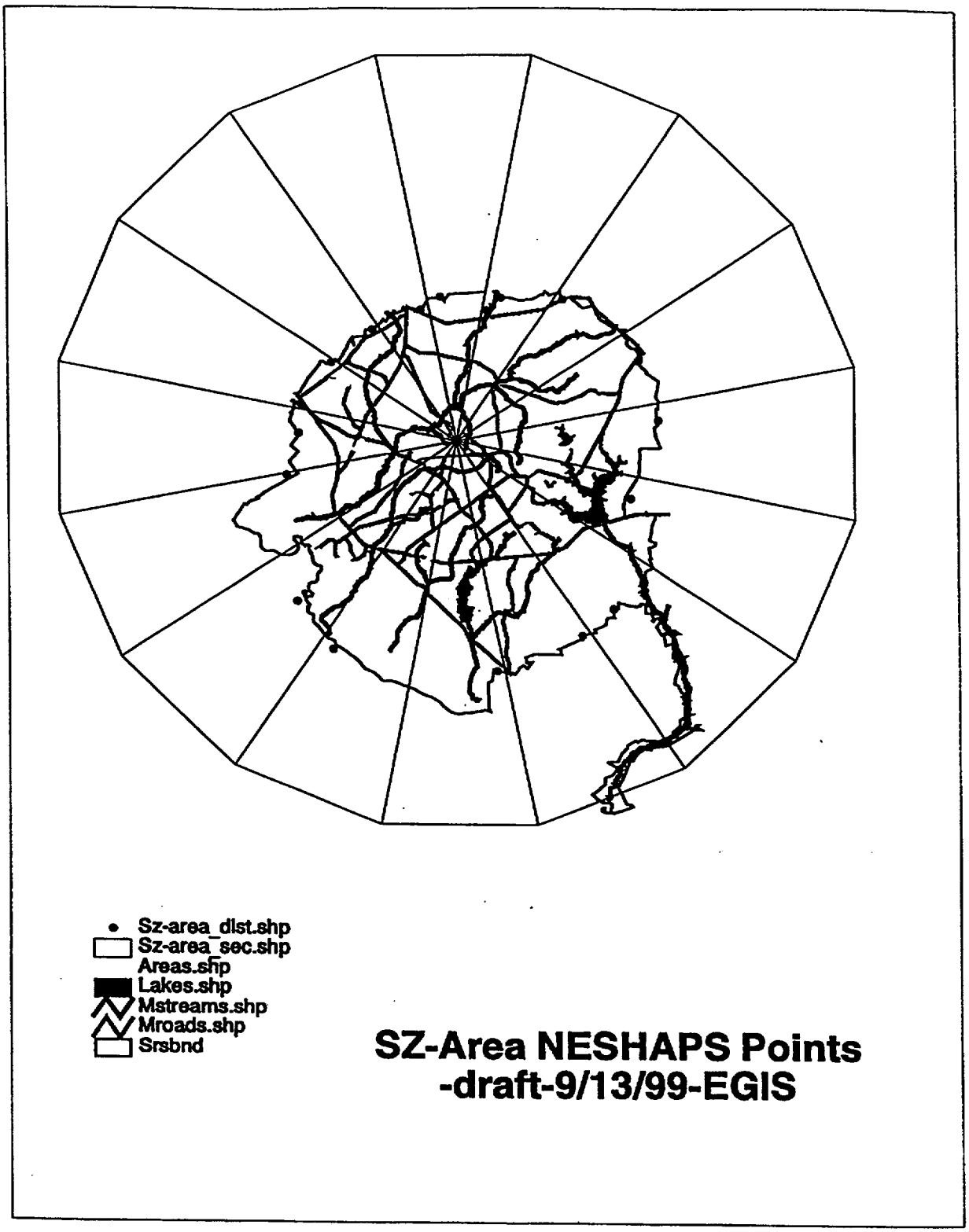
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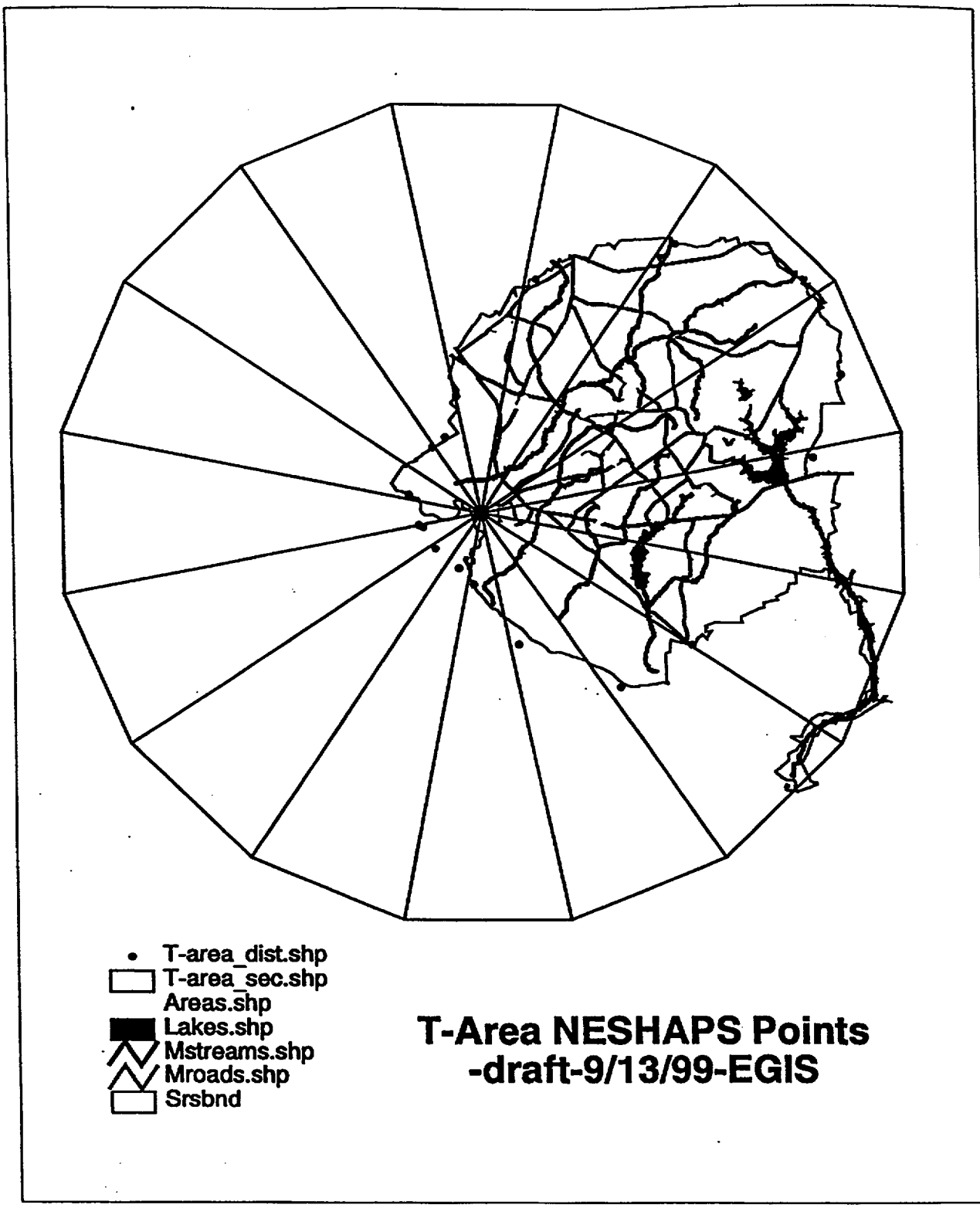
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# APPENDIX B. Offsite MEI Locations for 1990

Table B1. Distance to Nearest Residence, School, Business, or Farm from 1990 Study (Bold shows worst sector)

| Sector | A-Area | APT | C-Area | Center | D-Area | E-Area | F-Area | H-Area | K-Area | L-Area | M-Area | P-Area | S/Z-Area | T-Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 1,960 | **9,350** | 15,540 | 16,100 | 15,080 | **11,050** | 11,310 | **12,370** | 19,460 | 20,970 | 1,980 | 19,010 | **10,970** | 12,340 |
| NNE | 4,230 | 10,600 | 18,130 | 16,260 | 20,970 | 13,790 | 14,180 | 12,820 | 21,420 | 21,720 | 4,300 | 16,140 | 11,430 | 21,030 |
| NE | 6,940 | 11,460 | 18,440 | 17,550 | 27,760 | 16,690 | 17,500 | 14,930 | 22,320 | 17,800 | 7,160 | 13,580 | 14,170 | 28,190 |
| ENE | 14,190 | 12,370 | 17,980 | 16,580 | 22,930 | 17,830 | 18,700 | 15,540 | 16,140 | **12,670** | 14,480 | **8,450** | 15,240 | 25,290 |
| E | 22,340 | 13,270 | 16,910 | 13,200 | 23,980 | 18,060 | 19,010 | 15,540 | 17,200 | 13,580 | 22,860 | 9,650 | 16,000 | 24,080 |
| ESE | 24,300 | 12,970 | 18,060 | 15,300 | 17,050 | 16,080 | 17,040 | 13,730 | 13,730 | 11,610 | 24,680 | 10,260 | 14,630 | 19,500 |
| SE | 27,920 | 15,990 | 16,300 | 15,300 | 14,930 | 19,280 | 19,760 | 17,500 | 12,140 | 10,560 | 28,190 | 9,350 | 18,890 | 17,370 |
| SSE | 26,710 | 19,310 | 15,540 | 15,300 | 11,920 | 18,890 | 19,010 | 17,650 | 11,010 | 9,960 | 26,820 | 9,500 | 19,500 | 11,120 |
| S | 20,210 | 20,670 | 16,760 | 15,130 | 9,800 | 21,180 | 19,310 | 18,180 | 13,420 | 9,650 | 20,270 | 10,860 | 20,110 | 5,940 |
| SSW | 7,240 | 23,230 | 15,240 | 17,230 | 5,730 | 17,140 | 16,290 | 20,270 | 11,540 | 14,030 | 7,160 | 11,770 | 21,640 | 6,550 |
| SW | 5,430 | 22,020 | **13,100** | **16,420** | 7,390 | 16,380 | **15,230** | 18,340 | **11,920** | 13,430 | 5,330 | 17,500 | 19,660 | 5,030 |
| WSW | 3,470 | 15,690 | 13,180 | 17,230 | **6,640** | 13,260 | 11,920 | 15,290 | 10,860 | 14,180 | 3,350 | 18,400 | 13,710 | **4,270** |
| W | 2,560 | 15,080 | 11,580 | 14,170 | 6,490 | 10,820 | 9,500 | 13,190 | 13,120 | 16,890 | 2,440 | 20,360 | 12,950 | 6,250 |
| WNW | 2,260 | 12,520 | 10,210 | 13,850 | 8,450 | 11,430 | 10,110 | 12,520 | 12,820 | 16,140 | 2,130 | 19,160 | 10,970 | 5,940 |
| NW | 1,660 | 10,260 | 12,340 | 14,650 | 8,300 | 10,360 | 9,350 | 12,070 | 13,120 | 18,550 | 1,520 | 20,060 | 10,970 | 6,400 |
| NNW | **1,360** | 9,960 | 12,880 | 15,300 | 8,450 | 11,660 | 10,260 | 11,770 | 16,890 | 19,910 | **1,370** | 19,760 | 10,360 | 6,860 |

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# Report to Congress on the Projected Life-Cycle Costs of the U.S. and Russian Fissile Materials Disposition Programs

March 30, 2001

# DISTRIBUTION DRAFT

National Nuclear Security Administration

National Nuclear Security Administration
Office of Fissile Materials Disposition

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# Executive Summary

The House of Representatives Appropriations Committee[1] directed the U.S. Department of Energy (DOE) to provide a detailed report to Congress that:

- Provides the full costs of the fissile materials disposition program, with a cost and schedule baseline by year through completion of the program;
- Provides detailed information by year on the funding to be contributed by Russia and other countries in support of this initiative; and
- Describes the process by which parity between the United States and Russia will be maintained throughout the execution of the program.

This report is the National Nuclear Security Administration's response to the Congressional directive. An overview of the Fissile Materials Disposition Program is provided in Chapter 1. Chapter 2 describes the scope of the U.S. Plutonium Disposition Program. Chapters 3 and 4 discuss current and historical life-cycle cost projections for the U.S. Plutonium Disposition Program. Current initiatives to improve the accuracy and reliability of the cost projections are presented in Chapter 5. Chapter 6 summarizes the status of the Russian Plutonium Disposition Program, while Chapter 7 discusses the process for achieving parity between the U.S. and Russian programs. The projected life-cycle cost of the U.S. Surplus Highly-Enriched Uranium (HEU) Disposition Program is presented in Chapter 8.

The life-cycle cost projections provided in this report have been developed from recent reports and contractor documents. Over the next 18 months, more detailed, validated estimates of the U.S. Plutonium Disposition Program will be available from independent cost estimates (ICEs) for the major elements of the program that are scheduled to be completed over that time. Consequently, a new baseline cost estimate was not developed for this report since the forthcoming ICEs will provide a more detailed, bottom-up review of current life-cycle estimates. These estimates are predicated on receiving the appropriations necessary to support the schedules indicated.

The projected life-cycle cost of the U.S. Fissile Materials Disposition Program is presented in Table ES-1. The current life-cycle net cost projection for the U.S. Plutonium Disposition Program is approximately $6.6 billion (in constant 2001 dollars). This includes $6.3 billion for program disposition projects and an additional $360 million for other supporting activities. The projected life-cycle cost for the U.S. HEU Disposition Program is approximately $928 million (in constant 2001 dollars). The Russian Plutonium Disposition Program is projected to cost $1.8 billion (in constant 2001 dollars). Both the U.S. and Russian Plutonium Disposition Programs are scheduled to be in the design and construction phases over the next decade. Operations and decommissioning of the facilities are scheduled through 2022.

**Table ES-1. Projected Life-Cycle Costs of the U.S. Fissile Materials Disposition Program**

| Program Area | Projected Cost (millions of constant 2001 dollars) | Location in this Document |
|---|---|---|
| U.S. Plutonium Disposition | 6,616 | Chapter 3 |
| U.S. HEU Disposition | 928 | Chapter 8 |
| Russian Plutonium Disposition | 1,760 | Chapter 6 |

[1] See House Report 106-693. June 23, 2000.

Responsibility for the cost of the Russian program is to be shared among the Group-of-Eight (G-8) member countries so that only a portion of this cost will be funded by the U.S. Government. An international financing plan for the Russian Plutonium Disposition Program is under development and will be presented at the next G-8 summit in mid-2001. Several member countries have committed to providing some funding for the Russian program including the United States ($200 million), the United Kingdom (approximately $100 million), France (approximately $60 million), and Japan (approximately $34 million). Multinational discussions about additional funding support are ongoing in preparation for the mid-2001 G-8 summit.

Maintaining parity between the United States and Russia in executing the fissile materials disposition program is a cornerstone of current U.S.-Russian agreements. The September 2000 agreement[2] specifies that U.S. weapons-grade plutonium will not be dispositioned in whole or part unless and until accompanied by a similar disposition of the Russian weapons-grade plutonium. DOE is studying the schedule of the facilities involved in U.S. plutonium disposition to determine whether schedule changes to reduce peak projected annual program costs can be implemented without jeopardizing our responsibilities under the bilateral disposition agreement. Chapter 7 outlines the specific mechanisms for ensuring parity, including bilateral monitoring of disposed plutonium, inspection of facilities, and establishment of key construction and operations milestones.

[2] *Agreement Between the Government of the United States and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as no Longer Required for Defense Purposes and Related Cooperation*, Office of Fissile Materials Disposition, Washington, DC, September 1, 2000.

# 1. Overview of the U.S. and Russian Fissile Materials Disposition Programs.

## 1.1 Basis for the Fissile Materials Disposition Program

The end of the Cold War prompted a number of reviews in the early 1990's of strategic security policy within the U.S. Government. One such review, set in motion by Presidential Decision Directive 13 (PDD 13) in September 1993, entailed an assessment of fissile materials (highly enriched uranium (HEU) and plutonium) that might no longer be required for national defense purposes and could be safely removed from the U.S. nuclear military program. This review, conducted by the U.S Departments of Defense and Energy within the framework of the U.S. Nuclear Weapons Council, concluded that some 200 metric tons (MT) of fissile materials were surplus to current and future U.S. national security requirements. Approximately 52 MT of plutonium was declared surplus, of which 35 MT is weapons-grade.

In parallel with the U.S. review, President Clinton called for intensified U.S. efforts to prevent the proliferation of weapons of mass destruction, including a comprehensive approach to the growing accumulation of fissile materials from dismantled nuclear weapons and the weapons production process. In January 1994, the Presidents of the United States and Russia announced that both countries would cooperate in matters of nuclear nonproliferation, including scientific and technical collaboration in the management and disposition of fissile materials.

A key element of U.S. efforts to reduce the global danger from proliferation of weapons of mass destruction is to eliminate inventories of surplus fissile materials usable for nuclear weapons. With the widespread availability of scientific knowledge needed to build a nuclear device available through open literature, the only thing keeping terrorists or rogue nations from building a crude nuclear device is the lack of available weapons plutonium and HEU.

The National Academy of Sciences characterized the buildup of surplus fissile materials together with the increasing threat of diversion or theft of these materials in Russia as a "clear and present danger" to national and international security. The Office of Fissile Materials Disposition was created by Congress in 1994 to address this danger. The program has focused on three key objectives: 1) dispose of surplus U.S. highly enriched uranium; 2) dispose of surplus U.S. plutonium, and 3) work with Russia to eliminate similar amounts of surplus Russian plutonium.

## 1.2 U.S. Plutonium Disposition Program Evolution

Soon after the program was formed in 1994, the Department of Energy examined a broad range of over 30 different plutonium disposition technology options. It was not until January 1997, following an extensive public scoping process, a Final Programmatic Environmental Impact Statement, and a Record of Decision, that the Department announced its intention to pursue a hybrid plutonium disposition strategy that included irradiation of mixed oxide fuel (MOX) and immobilization. The overall program would entail the construction and operation of three major facilities for plutonium disposition.

- A pit disassembly and conversion facility to convert U.S. military plutonium into an unclassified oxide form suitable for disposition and international inspection.

- A MOX fuel fabrication facility (MOX FFF) to convert oxide materials into MOX fuel for irradiation in existing U.S. commercial nuclear reactors.

- An immobilization facility to immobilize surplus non-pit plutonium in a ceramic material that is then surrounded by vitrified high-level waste.

Both technologies will effectively convert the surplus plutonium to forms meeting the Spent Fuel Standard, making it as inaccessible and unattractive for weapons as the much larger and growing inventory of plutonium that exists in spent nuclear fuel from commercial power reactors.

Still undecided at the time of the 1997 Record of Decision were the locations where plutonium disposition would take place and the amount of material to be dispositioned by each technology. Since this disposition effort was considered to be a major federal action per the National Environmental Policy Act (NEPA), detailed site-specific facility design and construction activities could not begin until completion of the appropriate NEPA reviews. As a result, it was not until March 1999 that the Department awarded a contract to a consortium of Duke Engineering & Services, COGEMA, Inc., and Stone & Webster to initiate design efforts for the MOX FFF. In August 1999, the Department awarded a contract to Raytheon Engineers and Constructors (now Washington Group International) to initiate design efforts for a pit disassembly and conversion facility. The final selection of the Savannah River Site for plutonium disposition, together with a decision that up to 33 MT of plutonium would be disposed of via MOX/irradiation and up to 17 MT of plutonium would be disposed of via immobilization, was announced in January 2000 following the completion of the *Record of Decision for the Surplus Plutonium Disposition Final Environmental Impact Statement.*

**The Spent Fuel Standard**

The National Academy of Sciences recommended the Spent Fuel Standard for managing fissile material in 1994. Meeting the Spent Fuel Standard means making a material approximately as inaccessible and unattractive for weapons use as the much larger and growing inventory of plutonium that exists in spent nuclear fuel from commercial nuclear power reactors. Spent nuclear fuel from commercial power reactors is unattractive for several reasons, including its high radiation barrier, large size, and physical and chemical composition, which make it difficult to transport, conceal, and process. The Spent Fuel Standard is a broad target area, not a single point on an imaginary graph of proliferation resistance, and can take into account any number of factors affecting accessibility and attractiveness. In the January 21, 1997, Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement (62 Federal Register 3014), DOE adopted the Spent Fuel Standard specifically for the disposition of weapons-usable fissile materials.

Approaches to making fissile material less attractive for weapons use include increasing the radiation barrier surrounding the material, isotopically diluting uranium by the addition of depleted uranium, chemically diluting uranium or plutonium so that they are present in very low concentrations, and converting the material into chemical forms from which extraction of fissile material is difficult (e.g., some ceramic forms).

## 1.3 Joint U.S.–Russian Plutonium Disposition Efforts

While the United States has been working on a path to dispose of its surplus weapons plutonium, efforts to work with Russia and its material on a similar disposition strategy also have been underway.

At the Nuclear Safety and Security Summit in Moscow in April 1996, the Group-of-Seven countries and Russia agreed that plutonium immobilization and irradiation of the plutonium as MOX fuel in commercial reactors were appropriate disposition strategies. In September 1997, President Yelstin announced that the Russian Federation, too, would withdraw in stages from Russia's nuclear military programs up to 50 MT of plutonium that was no longer required for Russia's defense purposes.

In November 1997, officials from various U.S. and Russian agencies met unofficially in Cambridge, Massachusetts, for three days of discussion about ways to proceed in the joint disposition of surplus plutonium. They agreed to pursue: (1) a scientific and technical cooperation agreement between the governments to advance the technical dimensions of plutonium disposition, especially in Russia; (2) political understandings and an agreement that would articulate mutual and reciprocal obligations for plutonium disposition; and (3) understandings and agreements that would provide international technical and funding support for Russia's disposition of surplus plutonium.

These informal meetings were the genesis for the *U.S.-Russian Agreement on Scientific and Technical Cooperation in the Management of Plutonium That Has Been Withdrawn From Nuclear Military Programs,* which was signed in July 1998. The purposes of this five-year intergovernmental agreement, renewable by the parties in five-year increments, are to provide the scientific and technical bases for decisions on the management and disposition of surplus military plutonium and to establish a framework for continued scientific and technical cooperation to these ends. In September 1998, Presidents Clinton and Yeltsin announced the intention of both countries to mutually and reciprocally disposition up to 50 MT each of surplus military plutonium and set forth agreed general principles for the disposition undertaking. The Presidents also agreed to begin negotiations as soon as possible on the details of an intergovernmental agreement of mutual commitment.

U.S.-Russian negotiations on an intergovernmental agreement for the mutual disposition of surplus military plutonium began in earnest in early 1999. The negotiations focused on weapons-grade plutonium that could be withdrawn from the two countries' nuclear military programs, and settled on an initial 34 MT of this plutonium as the basis for negotiation. A key understanding was that the costs of Russian weapons-grade plutonium disposition would be largely funded by non-Russian sources, with the Russian Federation contributing to the effort according to arrangements to be subsequently negotiated.

In September 2000, the *U.S.-Russian Agreement on the Management and Disposition of Plutonium Designated As No Longer Required for Defense Purposes and Related Cooperation* was signed by the two governments. Each is committed to disposition 34 MT of weapons-grade plutonium according to roughly parallel timetables. Milestones and schedules for the design and construction of industrial-scale disposition facilities in both countries are set forth in an annex to the agreement, with the aim of positioning both countries to begin industrial-scale disposition of weapons-grade plutonium at the same time. The agreement sets 2007 as the target date to begin operating these facilities, with a minimum disposition goal of 2 MT per year thereafter. The United States and Russia also are committed to seeking ways to at least double the annual disposition rate in a joint analysis of options in the 18 months after the agreement's signing. A monitoring and inspection regime, applicable to both countries' plutonium disposition, is also to be negotiated within 18 months of the agreement's signing.

In November 2000, a Plutonium Disposition Planning Group was established under the G-8 framework to develop the international financing plan and associated framework that were called for at the July 2000 Okinawa G-8 Summit. The U.S.-Russian and Franco-German-Russian working groups on cost analysis of Russian plutonium disposition have second-stage analyses underway, with more detailed cost estimates expected in the spring of 2001.

## 1.4 Russian Plutonium Disposition

The design and development of a comparable Russian disposition effort has been technically supported not only by the United States (through the July 1998 U.S.-Russian agreement), but also by France, Germany, Japan, Canada, the European Union, and others under various agreements and arrangements. Although not as well-defined as the U.S. program at this point in time, the Russian program's principal elements have been developed and agreed upon, and substantial research and development, experiments, and small-scale demonstrations have already taken place.

Russia will irradiate 34 MT of weapons-grade plutonium that it will withdraw from its military programs as MOX fuel in existing nuclear reactors. This will require:

- Design, construction, and operation of a conversion facility in Russia to produce plutonium oxide suitable for manufacture of MOX fuel for Russian reactors.
- Design, construction, and operation of MOX fuel fabrication facilities in Russia.
- Modification, safety upgrades, and service life extensions of existing Russian reactors and associated site infrastructure to irradiate the MOX fuel.
- Associated transportation, interim storage, and waste management.
- Attendant licensing and regulatory activities.

To reduce costs and time frames, the Russian effort is expected to rely to a considerable extent on the transfer and use of industrially proven non-Russian technologies and equipment for plutonium conversion and MOX fuel fabrication. Timetables for the design, construction, and licensing of the Russian facilities are set forth in the September 2000 U.S.-Russian agreement.

The expected capacities of existing Russian reactors to irradiate MOX fuel manufactured from weapons-grade plutonium would limit the annual Russian disposition rate, once the facilities have been constructed, to approximately 2 MT. If this remains the case, the U.S. program will operate on a comparable annual disposition rate. However, the United States and Russia also are examining options that might double the annual Russian disposition rate, and thereby both accelerate and compact the time frames of both countries' plutonium disposition. Among the options under review are technical means to increase the disposition capacities of existing Russian reactors, development of a gas turbine-modular helium reactor in Russia, and the employment of commercial reactors outside Russia to irradiate MOX fuel manufactured from Russian weapons-grade plutonium.

## 1.5 U.S. Surplus Highly Enriched Uranium (HEU) Disposition Program

In the July 1996 *Record of Decision for the Disposition of Surplus Highly Enriched Uranium Final Environmental Impact Statement,* DOE announced its intention to begin a Surplus HEU Disposition Program. This program was created to support the United States' nuclear weapons non-proliferation policy by reducing global stockpiles of excess weapons-usable fissile materials, and to recover the economic value of the materials to the extent feasible.

The Surplus HEU Disposition Program makes surplus HEU non-weapons usable by blending it down to low-enriched uranium (LEU). DOE will gradually sell the resulting LEU over time for commercial use as fuel feed for nuclear power plants to generate electricity. A small fraction of the surplus HEU will be dispositioned as spent nuclear fuel or other radioactive waste. The current program scope covers 142 MT of HEU remaining for disposition as LEU reactor fuel. The quantity of HEU designated as surplus by the United States (174 MT) includes the remaining 142 MT, 14 MT that has already been downblended, and approximately 18 MT present in spent nuclear fuel.

The Surplus HEU Disposition Program differs from the Plutonium Disposition Program in several fundamental ways. In particular, the Surplus HEU Disposition Program is less technically complex and relies on the well-established commercial marketplace for LEU. It is also being conducted without any direct linkage to the Russian HEU Disposition Program. Under the program, HEU will be transferred from DOE inventories to one of four DOE or commercial facilities for downblending to LEU. Through a variety of mechanisms, the resulting LEU will be fabricated into reactor fuel and eventually used in commercial nuclear power reactors. Spent fuel from the reactors will be disposed in a geologic repository.

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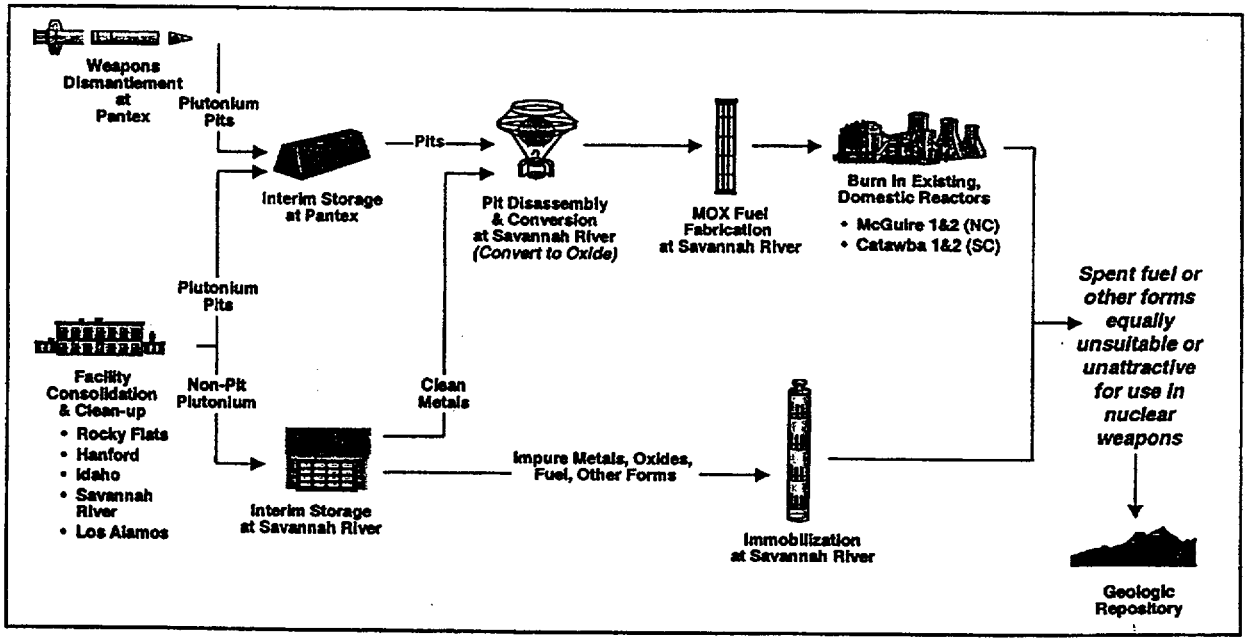
# 2. Scope of the U.S. Program

This chapter provides an overview of the scope of the four major projects of the U.S. Plutonium Disposition Program, identifies the three major disposition facilities and support services activities, and specifies the quantities of material to be processed.

In January 1997, the Department of Energy announced that it would pursue a hybrid disposition strategy for surplus U.S. plutonium. The strategy relies on two technology approaches: irradiation, in which the surplus plutonium is converted to a mixed oxide (MOX) fuel and irradiated in existing domestic reactors; and immobilization, in which surplus plutonium is incorporated in a ceramic form and then surrounded by vitrified high-level radioactive waste. Figure 2-1 illustrates the integrated approach of these two technologies.

**Figure 2-1. U.S. Plutonium Disposition Approach**




DOE has constructed and operate three government-owned facilities: a Pit Disassembly and Conversion Facility (PDCF), a MOX Fuel Fabrication Facility (MOX FFF), and a Plutonium Immobilization Project (PIP) [1] at the Savannah River Site (SRS). In addition, the Reactor Program Consortium contractor (Duke Engineering & Services, COGEMA, Stone & Webster) will fabricate initial MOX lead test assemblies (LTAs), irradiate these LTAs at a participating commercial reactor, conduct post-irradiation examination of the LTAs, and irradiate additional MOX fuel in commercial reactors.

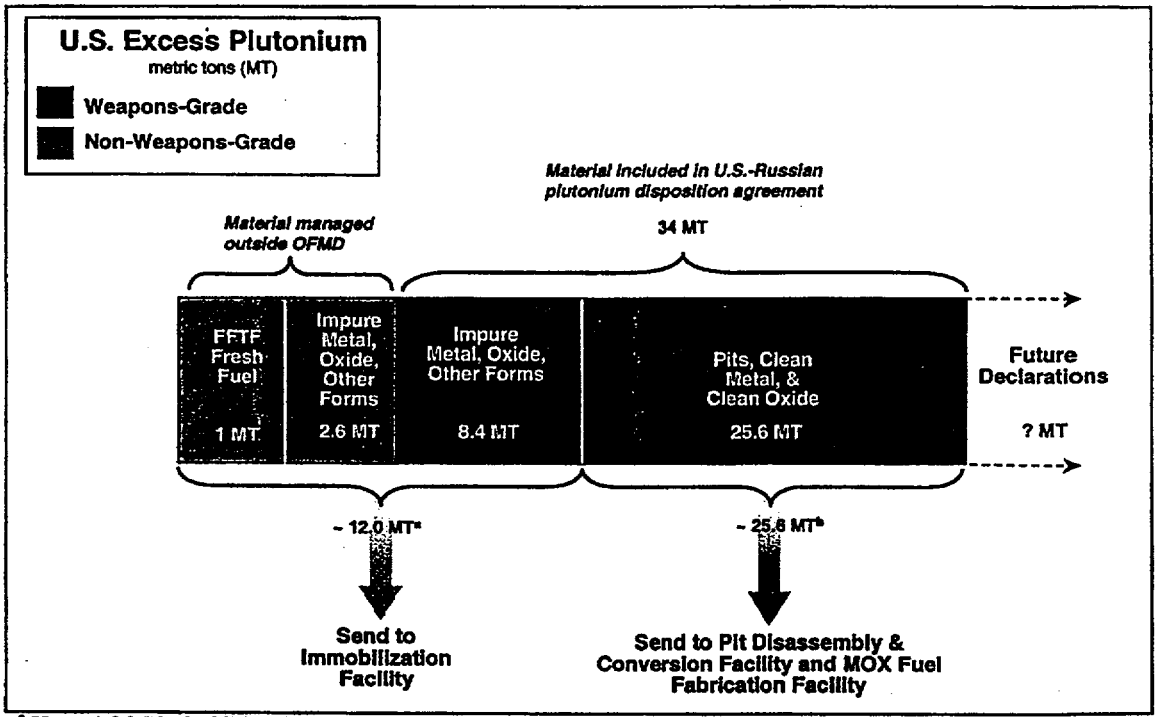
All facilities will be designed to meet applicable federal and local requirements. This includes maintaining stringent control and accountability of plutonium as well as meeting applicable worker and public safety standards. The MOX FFF will be licensed by the Nuclear Regulatory Commission (NRC). The Department's assumption is that the PDCF and PIP, while not licensed by the NRC, will be designed and constructed in accordance with applicable NRC licensing standards.

[1] This project has been previously referred to as Immobilization and Associated Processing Facility (IAPF), Plutonium Immobilization Plant, Plutonium Immobilization Facility, and Immobilization.

Until the time it meets the Spent Fuel Standard, all fissile materials within the disposition program will be transported using secure transport operated by DOE.

Figure 2-2 compares the quantities of surplus plutonium to be managed in the U.S. plutonium disposition facilities with the quantity, type, and form of surplus plutonium included in the U.S.-Russian agreement of 2000[2]. All of the U.S. material covered by this agreement (34 metric tons (MT)) is weapons-grade plutonium and is part of the inventory to be dispositioned under the U.S. program. This material includes pits, clean and impure metal and oxide, and other forms. In addition to the currently identified 34 MT, the program includes an allowance for additional weapons-grade plutonium from potential future weapons dismantlements (estimated for purposes of this cost projection at 7.4 MT), 3.6 MT of non-weapons-grade plutonium from identified inventories, and a 1.0 MT allowance for additional non-weapons-grade plutonium yet to be designated.

**Figure 2-2. Plutonium Quantities, Forms, and Disposition Pathways**




[a] Up to 1.0 MT of additional non-weapons-grade plutonium, not shown on this diagram, is considered to be immobilized under the U.S. program for the 2001 cost projection. The total amount of plutonium to be immobilized, including the 1.0 MT of additional material, is 13 MT.

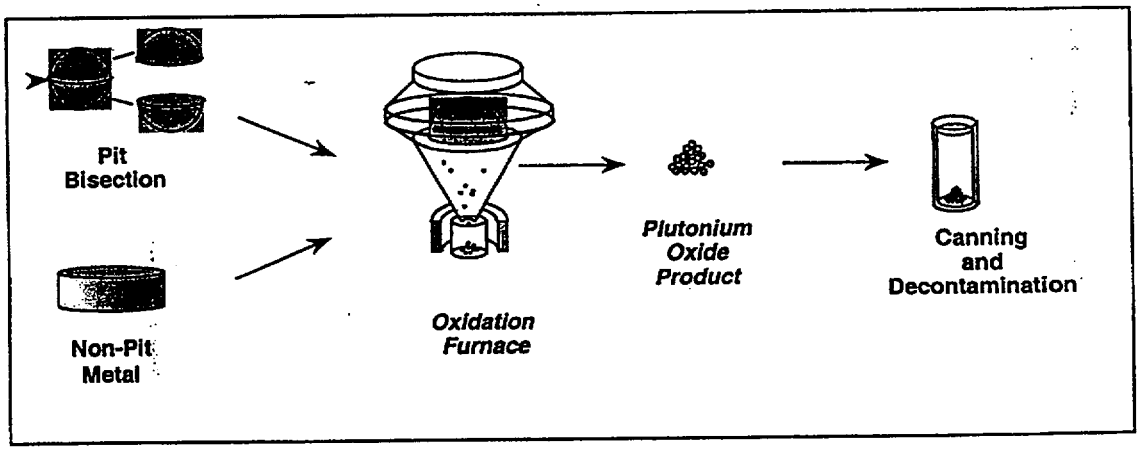
[b] An allocation of up to 7.4 MT of additional weapons-grade plutonium from future dismantlements, not shown on this diagram, is considered to be processed into MOX fuel under the U.S. program for the 2001 cost projection. The total amount of plutonium to be processed into MOX, including the 7.4 MT from potential future dismantlements, is 33 MT.

[2] DOE (U.S. Department of Energy), 2000, *Agreement Between the Government of the United States and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as no Longer Required for Defense Purposes and Related Cooperation*, Office of Fissile Materials Disposition, Washington, DC, September 1. http://www.doe-md.com/

## 2.1 Pit Disassembly and Conversion Facility (PDCF)

Under this project, DOE will contract for the design, construction, and operation of a new facility capable of converting plutonium forms suitable for use in reactors, including pits and clean metal to plutonium oxide that can then be fabricated into MOX reactor fuel. The new Pit Disassembly and Conversion Facility is a first-of-a-kind facility being designed from a laboratory prototype into an industrial-scale production facility. The 200,000 $ft^2$ facility will include areas for both processing as well as secure receipt and storage. The facility is designed to convert up to 33 MT of feed materials into a plutonium oxide powder over a ten-year period. The 33 MT quantity life-cycle throughput includes the 25.6 MT of currently identified material plus an allowance for additional material from future weapons dismantlements. As shown in Figure 2-3, the PDCF receives plutonium metal suitable for use in reactors, including pits from dismantled nuclear warheads and some non-pit plutonium. The pits are disassembled by bisection to facilitate the conversion process.

**Figure 2-3. Pit Disassembly and Conversion Process**




The plutonium metal is converted to plutonium oxide in the PDCF using a direct metal oxidation process. The plutonium oxide powder is then placed in a primary can, which is welded shut, leak tested, decontaminated, and placed into a secondary can that is also welded and leak tested. These cans are moved to a storage vault prior to shipment to the MOX FFF. The PDCF will contain storage capacity for a one-year supply of feed material and a one-year inventory of plutonium oxide product.

## 2.2 MOX Facility, Fuel Qualification / Lead Test Assemblies (LTAs), Irradiation[3]

Under this project, DOE has contracted for the design, construction, and operation of a new facility capable of converting plutonium oxide produced at the PDCF to MOX fuel suitable for irradiation in U.S. commercial power reactors. The MOX FFF includes a 320,000 $ft^2$ area for material processing and fabrication and 120,000 $ft^2$ for secure receipt, storage, and shipping. The MOX FFF design is modeled after the French Melox plant currently producing MOX fuel for irradiation in European power reactors. However, the Melox processes need to be modified to reflect U.S. environmental and safety standards. Furthermore, additional processes, as described below, are needed for feed purification and blending. The MOX fuel will be irradiated in the participating U.S. commercial reactors and the spent fuel will be

[3] This project is also known as MOX Fuel Fabrication/Irradiation and MOX Fuel Qualification, Fabrication, and Irradiation.

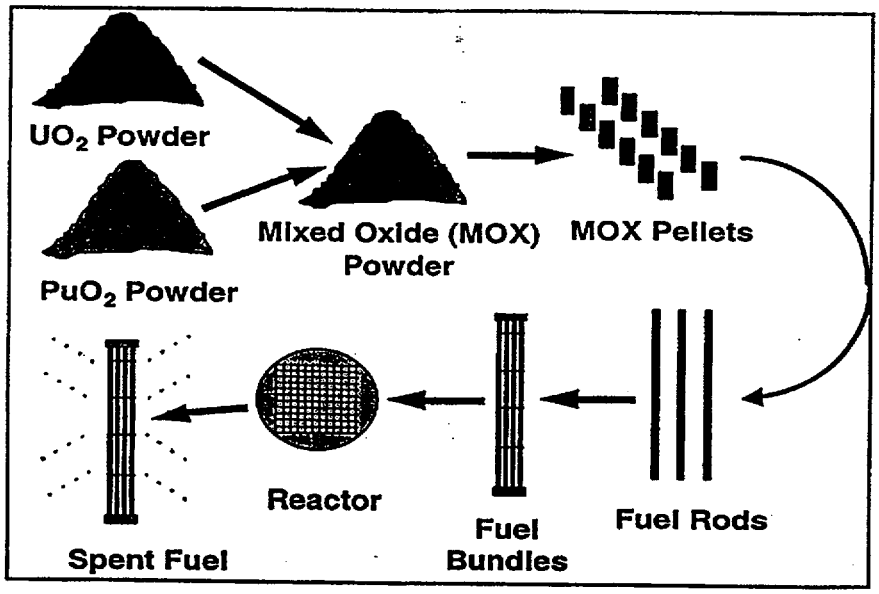
managed and disposed of in generally the same way as LEU spent reactor fuel. The MOX fuel is a mixture of depleted uranium oxide and plutonium oxide powders.

Within the processing area of the MOX FFF, plutonium oxide powder from the PDCF is processed to remove gallium and other impurities. The powder is then blended with depleted uranium oxide powder and formed into pellets by pressing the powder into cylindrical shapes. The pellets are then baked at a high temperature (sintered) and precision-ground to the proper dimensions. The finished pellets are loaded into empty tubes (rods), which are seal-welded, leak-checked, inspected, decontaminated, and bundled to form reactor fuel assemblies. The finished MOX fuel assemblies are stored in a secure storage area prior to shipment to one of several designated commercial power reactors.

This project also includes provisions for the development, fabrication, testing, and analysis of a limited number of MOX assemblies (known as lead test assemblies) prior to full-scale facility operation and provides for reactor owners to test and modify the reactors to accommodate MOX fuel.

The MOX FFF is designed to receive and process 33 MT of plutonium oxide powder from the PDCF over a 12-to-13-year period and store about two years worth of the incoming plutonium oxide. Figure 2-4 shows the basic MOX fabrication and irradiation steps.

**Figure 2-4. MOX Fabrication and Irradiation**




## 2.3 Plutonium Immobilization Project (PIP)

Under this project, DOE will contract for the design, construction, and operation of a new facility and utilize an existing high-level waste vitrification facility to convert plutonium not suitable for use in reactors into an immobilized "can-in-canister" final form which meets the Spent Fuel Standard and is suitable for geologic disposal. Immobilization consists of three primary steps, the first two of which are performed in the new immobilization facility.

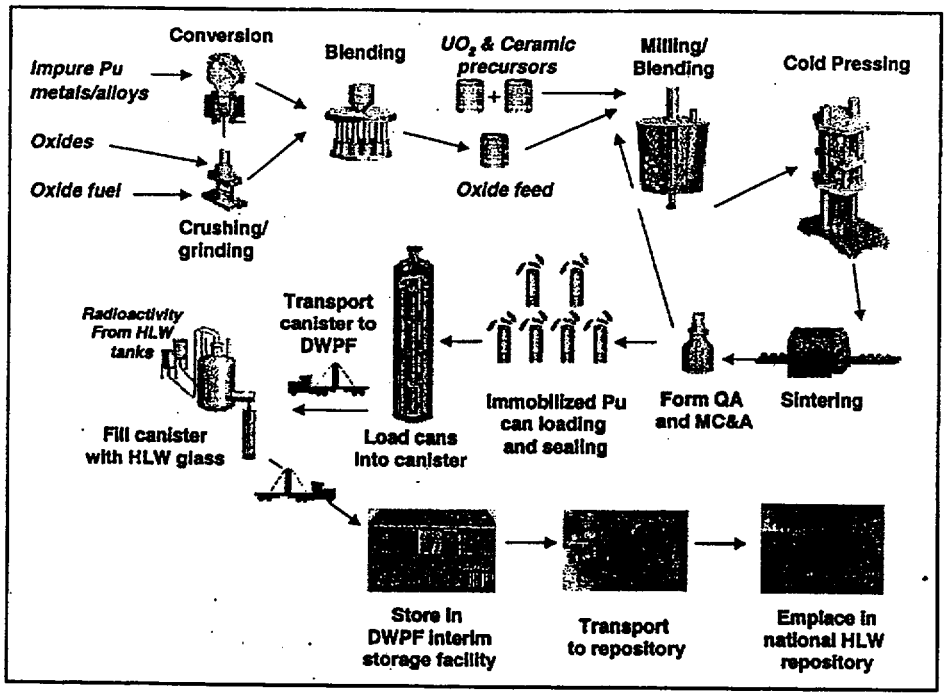
First, plutonium not suitable for use in reactors is converted into plutonium oxide suitable for immobilization. Converted feed material is blended with depleted uranium oxides and neutron absorbers to produce individual batches with consistent composition and to provide long-term safety of the

immobilized form in a geologic repository. This blended feed material is prepared for sintering by milling and blending with ceramic precursors and binder agents. The plutonium oxide is then pressed into ceramic disks (first-stage immobilization) that are stacked inside stainless steel cans. These cans are welded, leak-tested, and assayed. The cans are then loaded in racks within large canisters (hence "can-in-canister") which are subsequently filled with high-level waste glass (second-stage immobilization). The high-level waste provides a highly radioactive barrier to deter possible theft or diversion.

Second-stage immobilization will be performed at the existing Defense Waste Processing Facility (DWPF) at SRS, which is currently being used to vitrify high-level waste at the site. Since the immobilized plutonium cans displace vitrified high-level waste in the canisters, implementing this project is expected to modestly increase the total number of vitrified high-level waste canisters produced at the DWPF. The filled and sealed canisters will be placed into storage prior to ultimate disposal in a planned geologic repository pursuant to the Nuclear Waste Policy Act.

The PIP will immobilize up to 13 MT of plutonium not suitable for reactor use over a 10-year operating period. The various materials from throughout the DOE complex that will be received by the PIP include unirradiated oxide reactor fuel in pellets, plutonium alloys, plutonium metals, and plutonium oxides. Several different glovebox operations will be necessary in order to convert the various feed materials to a form suitable for immobilization. A vault will be available to store up to six months of incoming plutonium feed materials.

**Figure 2-5. Ceramic Can-in-Canister Immobilization Process**



## 2.4 Plutonium Disposition Support Systems (PDSS)

The Plutonium Disposition Support Systems Project consists of the design, construction and operation of the systems necessary to provide services to the three previously defined disposition facilities currently planned at SRS. The disposition facilities will need infrastructure support from existing SRS utilities such as water, steam, electricity, and support services such as roads, parking, laboratory analysis, during construction and operation phases.

This project was developed to allow integration of SRS infrastructure support and systems to the three plutonium disposition facilities. The plan is to reduce duplication of effort on the part of facility design engineers and have the overall area prepared to allow construction to start when required by the agreement between the United States and Russia. Due to the close proximity of the facilities and the construction schedule, a detailed plan for development of the entire site will be developed to allow for integration of all elements of support. Facilities design engineers would identify facility requirements and the PDSS would optimize the requirements. This approach will allow cost saving to be achieved by reducing separate pipe runs, utility ductbanks, and powerlines; identifying total waste streams to be dispositioned; and obtaining construction permits for in a timely manner. It will also allow for a single storm drainage plan to be developed to ensure that the entire site is properly drained. This project was identified as one of the 25 items to be accomplished by DOE in a June 2000 report to Congress, *A Strategic Approach to Integrating the Long-Term Management of Nuclear Materials*, as part of the multi-year agenda.

The PDSS Project will be accomplished in two phases. Phase I includes the design and installation of systems and services required to start construction of the three new plutonium facilities. Phase II will expand the construction systems and services and complete the design and construction of remaining systems and services required for startup and operation of the three new facilities.

# 3. Current Life-Cycle Cost Projection for the U.S. Plutonium Disposition Program

This chapter presents the projected life-cycle cost for the U.S. Plutonium Disposition Program. This program, together with the U.S. Surplus Highly Enriched Uranium (HEU) Program and the Russian Plutonium Disposition Program, are the three primary areas of responsibility of the Office of Fissile Materials Disposition (OFMD).

The projected life-cycle cost of the U.S. Plutonium Disposition Program is summarized in Table 3-1, according to its major program elements. These elements include four disposition projects and two smaller support activities.

**Table 3-1. Projected Life-Cycle Costs of the U.S. Plutonium Disposition Program**

| Cost Element | Projected Cost (millions of constant 2001 dollars) |
|---|---|
| **Disposition Projects** | |
| Pit Disassembly & Conversion Facility (PDCF) | 2,157 |
| MOX Facility, Fuel Qualification/LTAs, Irradiation | 3,246 |
| *MOX Fuel Credit* | *(552)* |
| *HEU Credit* | *(231)* |
| Plutonium Immobilization Project (PIP) | 1,535 |
| Plutonium Disposition Support Systems (PDSS) | 97 |
| **Subtotal Disposition Projects** | **6,253** |
| Other Supporting Activities | |
| Plutonium Storage | 266 |
| Other Support | 97 |
| **Total (All Cost Elements)** | **6,616** |

The remainder of this chapter addresses the projected life-cycle costs of the four disposition projects of the U.S. Plutonium Disposition Program. It describes the approach for developing the life-cycle cost projection, presents a summary of the total costs, and concludes with a discussion of the uncertainties and risks surrounding the cost projection.

Costs associated with the Other Supporting Activities have not been included in previous cost estimates of the U.S. Plutonium Disposition Program because they either were historically funded by other DOE programs (Plutonium Storage) or were not sufficiently well-defined (Other Support). However, these activities appear here as part of the projected program cost because they directly support the U.S. program and are projected to be funded under OFMD budget authority. These activities are briefly described below.

- **Plutonium Storage.** This cost element covers the storage of surplus weapons components (pits) to be dispositioned under the U.S. program. It historically has been funded by other DOE programs responsible for storage of surplus pits designated for disposition. However, the cost and corresponding budget authority for this storage was transferred to the OFMD beginning in FY 2001 by Congressional direction.

- **Other Support.** This cost element includes primarily technical analysis and support in areas common to all disposition technologies and National Environmental Policy Act supporting studies.

## 3.1 Approach for Developing the Life-Cycle Cost Projection

The June 23rd House Energy and Water Subcommittee (H.R. 106-693) report directed the Department to provide a life-cycle cost estimate of the U.S. Plutonium Disposition Program by February 15, 2001. This chapter responds to the Congressional directive with the best information available. Since the last program life-cycle cost report in November 1999[1], the Department has completed the following important studies that better define major elements of the U.S. Plutonium Disposition Program:

- The *Record of Decision for the Surplus Plutonium Disposition Final Environmental Impact Statement*, which identifies the sites for the three disposition facilities and the amounts of plutonium to be treated by the MOX Fuel Fabrication Facility (MOX FFF) and the PIP, issued in January 2000.

- A draft of the third revision of the *Design-Only Conceptual Design Report for the Plutonium Immobilization Project*, dated November 2000.

- The *MOX Fuel Fabrication Facility Final Preliminary Design Life-Cycle Cost Estimate*, released by Duke Engineering & Services, COGEMA, Stone & Webster (DCS) in December 2000.

- The *Plutonium Facility Scope Evaluation*, which addresses the PDSS Project, released by Westinghouse Savannah River Company in August 2000.

- An estimate prepared by the Washington Group International (WGI) as the present status of the PDCF design provides a limited conceptual estimate of that facility.

These reports served as the starting points for the 2001 cost projection. The 2001 cost projection was prepared by adjusting the cost data in these reports based on what is known about the program today, including more accurate assumptions regarding project contingencies and the scope of site support costs. Better, refined estimates on the program will be forthcoming from independent cost estimates (ICEs) scheduled for the major elements of the U.S. program over the next 18 months. While the annualized cost data presented in this report is the best available data derived from the recent studies and updated with the best professional judgment of DOE program managers, it does not constitute a cost baseline for the program. A formal cost baseline will be prepared after Title I preliminary designs of the facilities are completed.

All cost estimates obtained for this cost projection have been adjusted to constant Fiscal Year 2001 dollars using the U.S. Department of Energy's inflation index.[2]

## 3.2 Summary of Program Cost and Schedule

The combined projected life-cycle cost for the four U.S Plutonium Disposition Program projects is $6.253 billion. Costs for the program are presented in Table 3-2, organized according to the four major projects. The projected life-cycle costs for each project are: PDCF - $2.157 billion; MOX - $2.463 billion; PIP $1.535 billion; and PDSS - $97 million. The schedule for each project is illustrated in Figure 3-1. Annual costs for each project are illustrated in Figure 3-2 according to three primary cost categories (design and construction, operations, and other). Contingency costs for each project are presented separately because they represent a significant portion of the cost increase since the Department's previously issued cost

[1] *Plutonium Disposition Life-Cycle Costs and Cost-Related Comment Resolution Document* (DOE/MD-0013, November 1999).
[2] DOE Departmental Price Change Index - January 2000

estimate in 1999. The contingency costs distributed among the cost categories of each project are presented in Appendix A. Table 3-2 also identifies separate costs for PDCF Support, MOX Fuel Credits, and HEU Credits.

DOE is studying the schedule of these facilities to determine if schedule changes to reduce peak projected annual program costs can be implemented without jeopardizing U.S. responsibilities under the U.S.-Russian plutonium disposition agreement.

### Constant vs. Current Dollars

*Constant dollars* represent a dollar value adjusted for changes in prices. Dollars in the future are adjusted by removing inflation. Unless otherwise noted, all cost projections in this document are in constant 2001 dollars as if costs were incurred this year.

*Current dollars* represent a dollar value of goods or services in terms of prices current at the time the goods or services are purchased (in other words, inflation is factored into the estimate).

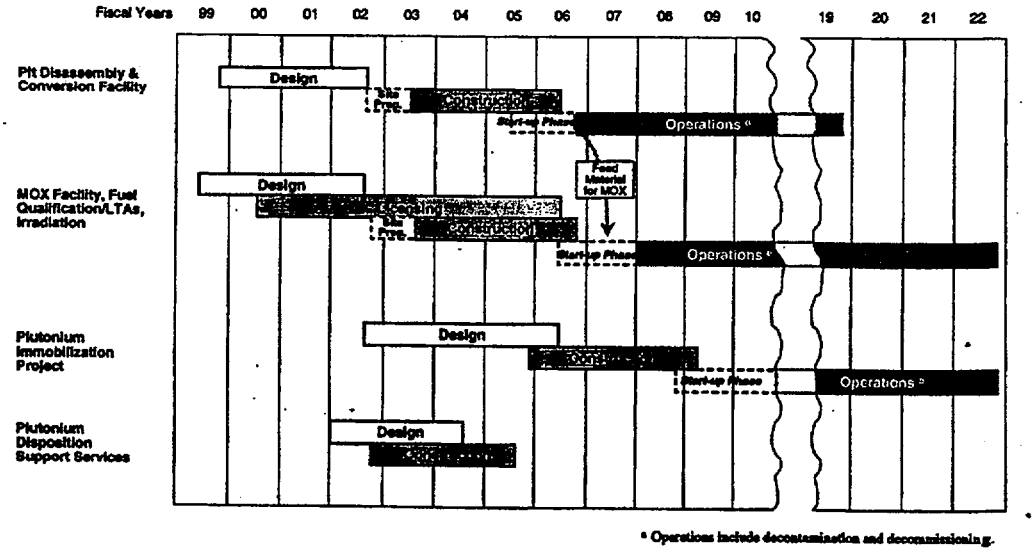
### Adjustment Credits in the MOX Project

The projected costs of the MOX project include two separate credits that partially offset the life-cycle cost of that project.

**MOX Fuel Credit.** This credit accounts for the value of the MOX fuel produced by the program. The MOX fuel value is based on two factors: (1) the projected market value of the corresponding low enriched uranium fuel that the MOX fuel would displace when the MOX is used in reactors to produce electric power; and (2) the ratio of the economic value of using MOX fuel vs. LEU fuel. The difference between the MOX fuel value and LEU fuel value is also considered an irradiation fee charged by the reactor operator. The MOX fuel credit is a credit to the government from the contractor operating the MOX fabrication facility.

**HEU Credit.** This credit accounts for government revenue resulting from HEU derived from pit dismantlement in the PDCF. This HEU will be transferred to the Surplus HEU Disposition Program, downblended to LEU, and sold on commercial markets. The funding from the sale of LEU—produced from downblending the HEU derived from PDCF pit dismantlement—will be used to partially offset operating costs of the MOX project.

**Figure 3-1. Project Schedules Based on 2001 Cost Projection**



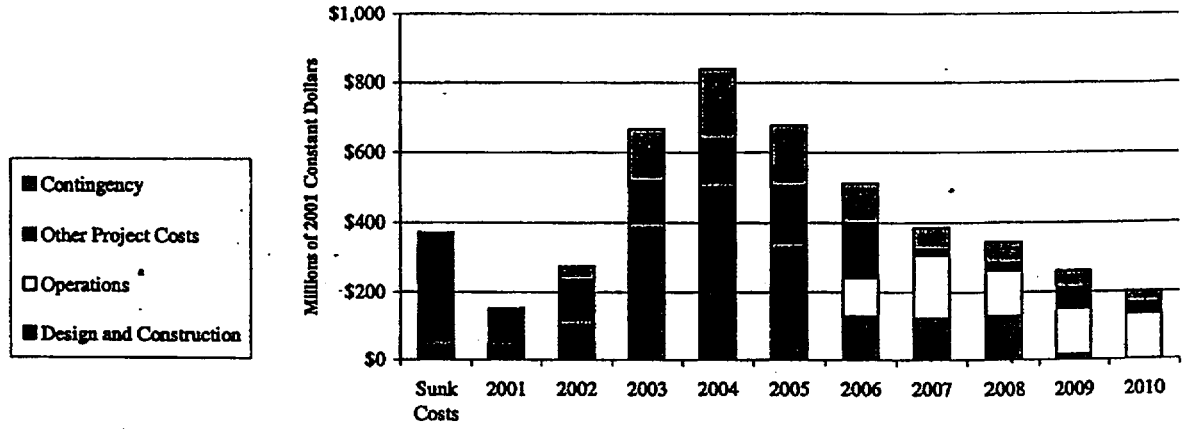

a Operations include decontamination and decommissioning.

**Table 3-2. Total Annualized Life-Cycle Cost Projections by Fiscal Year and Cost Category (millions of constant 2001 dollars)**

| Project and Cost Category | LCCE Cost Projection | Sunk Costs | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pu Disposition Facility (PDCF) | | | | | | | | | | | | |
| Design and Construction | 476.7 | 16.8 | 20.0 | 40.6 | 106.2 | 165.6 | 127.5 | - | - | - | - | - |
| Operations[a] | 797.2 | - | - | - | - | - | - | 70.3 | 70.3 | 70.3 | 70.3 | 70.3 |
| Other Project Costs | 342.7 | 90.4 | 27.0 | 36.6 | 30.3 | 49.6 | 58.1 | 49.2 | 1.5 | - | - | - |
| PDCF Support | 218.8 | 0.8 | 0.5 | - | 0.8 | 0.8 | 0.8 | 20.3 | 19.5 | 19.5 | 19.5 | 19.5 |
| Contingency | 322.0 | - | - | 14.1 | 45.2 | 77.7 | 64.0 | 27.5 | 9.5 | 9.0 | 9.0 | 9.0 |
| Total PDCF | 2,157.4 | 107.9 | 47.4 | 91.3 | 182.5 | 293.7 | 250.4 | 167.3 | 100.9 | 98.9 | 98.9 | 98.9 |
| MOX Fuel Fabrication/IAEA Facility | | | | | | | | | | | | |
| Design and Construction | 929.2 | 40.4 | 26.0 | 62.2 | 271.5 | 295.6 | 167.3 | 66.2 | - | - | - | - |
| Operations[a] | 1,257.3 | - | - | - | - | - | - | 22.3 | 93.1 | 88.6 | 90.6 | 90.6 |
| MOX Fuel Credit | (552.0) | - | - | - | - | - | - | - | - | (46.0) | (46.0) | (46.0) |
| HEU Credit | (231.0) | | - | - | - | - | - | - | - | - | - | (28.9) |
| Other Project Costs | 536.7 | 123.2 | 48.5 | 59.3 | 64.7 | 49.7 | 88.0 | 100.3 | 3.0 | - | - | - |
| Contingency | 522.7 | - | - | 19.2 | 89.5 | 102.1 | 90.1 | 64.8 | 13.0 | 12.0 | 12.0 | 12.0 |
| Total MOX | 2,462.8 | 163.6 | 74.5 | 140.7 | 425.7 | 447.4 | 345.4 | 253.6 | 109.1 | 54.6 | 56.6 | 27.7 |
| Pu Disposition Project (PIP) | | | | | | | | | | | | |
| Design and Construction | 400.0 | - | 3.0 | 1.9 | 7.3 | 21.0 | 39.6 | 61.7 | 122.2 | 128.1 | 15.2 | - |
| Operations[a] | 566.3 | - | - | - | - | - | - | - | - | - | - | 27.7 |
| Other Project Costs | 356.3 | 101.2 | 20.9 | 21.8 | 23.9 | 22.0 | 17.1 | 10.4 | 15.9 | 24.0 | 64.5 | 34.6 |
| Contingency | 212.8 | - | - | 0.7 | 4.9 | 8.7 | 13.6 | 19.3 | 37.7 | 38.9 | 23.3 | 11.9 |
| Total PIP | 1,535.4 | 101.2 | 23.9 | 24.4 | 36.1 | 51.8 | 70.4 | 91.4 | 175.8 | 191.0 | 102.9 | 74.2 |
| Pu Disposition Support Systems (PDSS) | | | | | | | | | | | | |
| Design and Construction | 68.6 | - | 4.9 | 10.6 | 14.0 | 31.8 | 7.3 | - | - | - | - | - |
| Operations[a] | - | - | - | - | - | - | - | - | - | - | - | - |
| Other Project Costs | 9.0 | - | - | 2.2 | 2.2 | 3.6 | 1.0 | - | - | - | - | - |
| Contingency | 19.4 | - | - | 3.3 | 4.1 | 9.8 | 2.3 | - | - | - | - | - |
| Total PDSS | 97.0 | - | 4.9 | 16.1 | 20.3 | 45.2 | 10.5 | - | - | - | - | - |
| Total Life-Cycle Cost Projection | 6,252.6 | 372.7 | 150.7 | 272.5 | 664.5 | 838.0 | 676.6 | 512.3 | 385.7 | 344.4 | 258.3 | 200.8 |

[a] The Operations cost category includes decontamination and decommissioning costs.

**Figure 3-2. Projected Annual Program Costs**




[a] The Operations cost category, as shown in Figure 3-2, includes life-cycle PDCF Support costs of $218.8 million, life-cycle MOX Fuel Credits of ($552 million) and life-cycle HEU Credits of ($231 million).

| 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Cost Element |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Plutonium Disposition Facility (PDCF) |
| - | - | - | - | - | - | - | - | - | - | - | - | Design and Construction |
| 70.3 | 70.3 | 70.3 | 70.3 | 70.3 | 70.3 | 7.9 | 7.9 | 7.9 | - | - | - | Operations[a] |
| - | - | - | - | - | - | - | - | - | - | - | - | Other Project Costs |
| 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | - | - | - | - | - | - | PDCF Support |
| 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 0.9 | 0.9 | 0.9 | - | - | - | Contingency |
| 98.9 | 98.9 | 98.9 | 98.9 | 98.9 | 98.9 | 8.8 | 8.8 | 8.8 | - | - | - | Total PDCF |
| | | | | | | | | | | | | MOX Fuel Fabrication Facility (MFFF) |
| - | - | - | - | - | - | - | - | - | - | - | - | Design and Construction |
| 90.6 | 90.6 | 90.6 | 90.6 | 90.6 | 90.6 | 90.6 | 90.6 | 83.8 | 24.7 | 19.7 | 19.7 | Operations[a] |
| (46.0) | (46.0) | (46.0) | (46.0) | (46.0) | (46.0) | (46.0) | (46.0) | (46.0) | - | - | - | MOX Fuel Credit |
| (28.9) | (28.9) | (28.9) | (28.9) | (28.9) | (28.9) | (28.9) | - | - | - | - | - | HEU Credit |
| - | - | - | - | - | - | - | - | - | - | - | - | Other Project Costs |
| 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | - | - | - | Contingency |
| 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 56.6 | 49.8 | 24.7 | 19.7 | 19.7 | Total MOX |
| | | | | | | | | | | | | Pit Disassembly & Conversion Facility (PDCF) |
| - | - | - | - | - | - | - | - | - | - | - | - | Design and Construction |
| 55.4 | 55.4 | 55.4 | 55.4 | 55.4 | 55.4 | 55.4 | 55.4 | 55.4 | 30.8 | 5.0 | 4.0 | Operations[a] |
| - | - | - | - | - | - | - | - | - | - | - | - | Other Project Costs |
| 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 3.1 | 0.5 | 0.4 | Contingency |
| 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 61.0 | 33.9 | 5.5 | 4.4 | Total PIP |
| | | | | | | | | | | | | Plutonium Disposition Support Systems (PDSS) |
| - | - | - | - | - | - | - | - | - | - | - | - | Design and Construction |
| - | - | - | - | - | - | - | - | - | - | - | - | Operations[a] |
| - | - | - | - | - | - | - | - | - | - | - | - | Other Project Costs |
| - | - | - | - | - | - | - | - | - | - | - | - | Contingency |
| - | - | - | - | - | - | - | - | - | - | - | - | Total PDSS |
| 187.5 | 187.5 | 187.5 | 187.5 | 187.5 | 187.5 | 97.4 | 126.3 | 119.5 | 58.6 | 25.2 | 24.1 | |

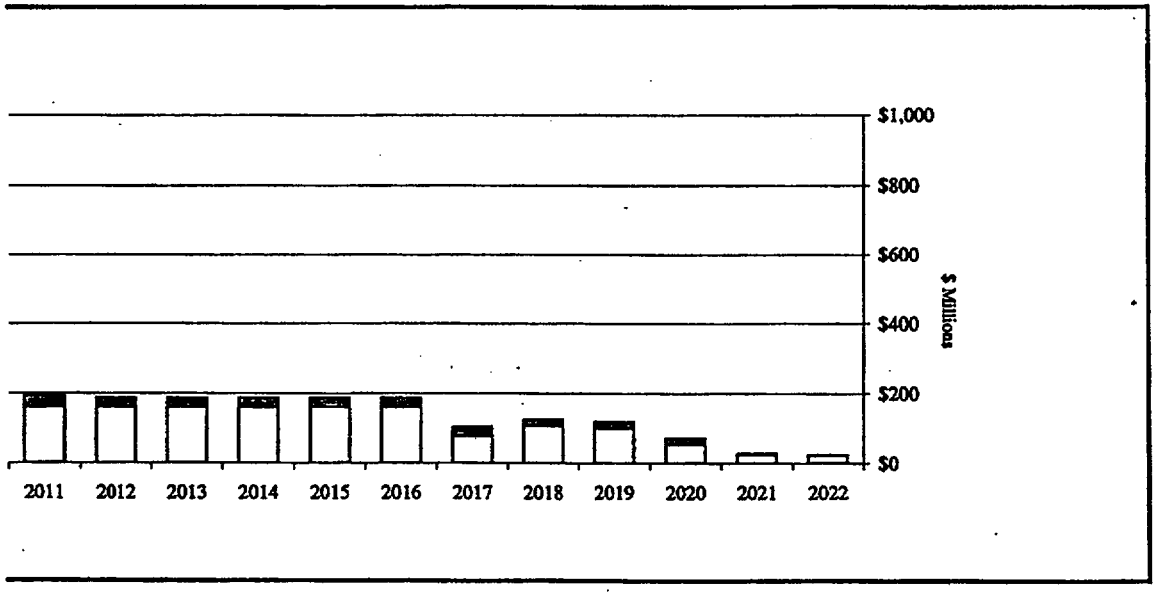


Table 3-3 presents the projected cost of the four projects in current year dollars, which includes assumptions for inflation over the 20-year-plus duration of the program.

**Table 3-3. Projected Costs in Current Year Dollars**

| Project | Projected Cost (millions of current year dollars) |
|---|---|
| PDCF | 2,465 |
| MOX | 2,731 |
| PIP | 1,801 |
| PDSS | 102 |

## 3.3 Uncertainty in the 2001 Life-Cycle Cost Projection

The projects comprising the U.S. Fissile Materials Disposition Program are in varying stages of design and development. None of the projects have been developed to the point of establishing approved baselines as defined by DOE Order 413.3, *Program and Project Management for the Acquisition of Capital Assets*. The degree of confidence in the life-cycle cost estimate is largely driven by the level of project definition and is strongly influenced by the complexity of the projects and the use of first-of-a-kind technologies. Regulatory oversight and other external issues also add a large amount of uncertainty to the program.

The purpose of this section is to describe and discuss the program's approach to mitigating project risk and uncertainty. Most of this section focuses on contingency costs included in the 2001 life-cycle cost projection. Contingency is a specific provision for unforeseeable costs **within** the defined project scope. Any unforeseen events resulting in major scope changes are **not** addressed by contingency costs included in the life-cycle cost projection. The contingency included in the current life-cycle cost projection is not provided to address a major change in the scope of the U.S. Plutonium Disposition Program due to political, technical, regulatory, or any other event. When these major events occur, the program must be "re-baselined" to reflect the major change.[3]

Table 3-4 presents the percent of contingency included in the 2001 life-cycle cost projection for both the design/construction and other project cost phase and the operations phase of the four major projects of the U.S. Plutonium Disposition Program. These percentages were determined by calculating the weighted average contingency from all individual activities and contingencies within the cost category. Contingencies vary across projects in rough proportion to their complexity. Published government and industry estimates of appropriate contingency ranges for non-conventional projects suggest that a range of 20-60% contingency is appropriate for projects in similar stages of design development.

[3] While the costs provided herein are the best available to date, the Department does not apply the term "baseline" until projects have successfully completed Title I (preliminary) design and a subsequent independent review. None of the plutonium disposition projects have yet been formally baselined.

**Table 3-4. Contingency Levels in U.S. Plutonium Disposition Project Cost Projections**

| Project | Project Phase | |
|---|---|---|
| | Design/Construction and Other Project Costs | Operations[a] |
| PDCF | 27% | 10% |
| MOX | 24% | 14% |
| PIP | 21% | 10% |
| PDSS | 25% | Not Applicable |

[a] The Operations cost category includes decontamination and decommissioning activities for each project and PDCF Support (security), but excludes MOX Fuel Credit.

The contingency percentages for PDCF, PIP, and PDSS are based on the best professional judgment of the project managers and are supported by experience with comparable projects. In the case of the MOX project, DCS explicitly identified risks associated with that facility. A detailed description of this analysis is available in the DCS December 2000 *MOX Fuel Fabrication Facility Final Preliminary Design Life-Cycle Cost Estimate*. Risks for the PIP are detailed in the *Plutonium Immobilization Risk Assessment Report*, rev. 0, issued in February 2000.

As the U.S. Plutonium Disposition Program matures, more systems are integrated, and the various technologies supporting the program are confirmed, then the contingency percentage will decrease. However, at this stage in the evolution of the program, a seemingly large contingency amount is both prudent and justifiable.

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# 4. Comparison with Previous U.S. Program Estimates

This chapter compares the 2001 life-cycle cost projection for the U.S. Plutonium Disposition Program presented in Chapter 3 with the two previous life-cycle cost estimates (LCCEs) prepared by the Office of Fissile Materials Disposition (OFMD) in 1999 and 1996. This chapter also describes the approach taken in developing the comparison, identifies the changing costs, and discusses the reasons for the changes.

Over the past six years, the OFMD has published two LCCEs on the U.S. Plutonium Disposition Program:

- **1999 LCCE.** In November 1999, the OFMD issued the *Plutonium Disposition Life-Cycle Costs and Cost-Related Comment Resolution Document* (DOE/MD-0013, November 1999) providing an updated cost estimate for the U.S. Plutonium Disposition Program of about $4.1 billion in constant 2000 dollars or $4.2 billion in constant 2001 dollars.

- **1996 LCCE.** In October 1996, the OFMD provided a rough, order-of-magnitude cost estimate for the U.S. Plutonium Disposition Program of about $2.2 billion in constant 1996 dollars or $2.4 billion in constant 2001 dollars (*Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition*, DOE/MD-0003, October 1996).

Table 4-1 provides a project-level comparison between the 2001 U.S. Plutonium Disposition Program cost projection and the two earlier cost estimates. The 2001 projected cost of the program represents a 50 percent increase over the 1999 LCCE, which in turn was a 73 percent increase over the 1996 LCCE. In this comparison, costs from the original 1999 and 1996 LCCEs were escalated to constant 2001 dollars.

**Table 4-1. Summary of U.S. Plutonium Disposition Program Cost Estimates (millions of constant 2001 dollars) [a]**

| Project | | 2001 Life-Cycle Cost Projection | 1999 LCCE | 1996 LCCE |
|---|---|---|---|---|
| Pit Disassembly and Conversion Facility (PDCF) | | 2,157 | 1,252 | 1,467 [b] |
| MOX Facility, Fuel Qualification / LTAs, Irradiation (MOX), without credits | | 3,246 | 2,009 | 1,622 |
| Plutonium Immobilization Project (PIP) | | 1,535 | 1,477 | 342 [b] |
| Plutonium Disposition Support Services (PDSS) | | 94 | Not Included | Not Included |
| **Subtotals** | | **7,036** | **4,737** | **3,432** |
| Credit Adjustments | MOX Fuel Credit | (552) | (578) | (1,027) |
| | HEU Credit | (231) | Not Included | Not Included |
| **Totals** | | **6,253** | **4,159** | **2,405** |

[a] The costs shown here for the 1999 and 1996 LCCEs have been escalated from the originally published data, which had been published in constant 2000 and constant 1996 dollars, respectively, to account for inflation over the intervening period. The initially published 1999 and 1996 LCCE cost figures were increased by about 2.2 percent and 10.4 percent, respectively.

[b] In the 1996 LCCE, the processes in the current PDCF and PIP configuration were grouped differently. Conversion and 1st-stage immobilization of plutonium destined for immobilization (now part of the PIP) were part of a "front-end" facility that also included conversion of plutonium destined for MOX. The cost of this "front-end" facility, which appears in Table 4-1 as the 1996 equivalent of the current PDCF, included these additional processes. Similarly, the cost of 2nd-stage immobilization, which appears in Table 4-1 as the 1996 equivalent of the current PIP, excluded these processes.

## 4.1 Approach

An accurate comparison between the 1996 LCCE, the 1999 LCCE, and the 2001 life-cycle cost projection is difficult due to the variation in technical assumptions, estimating methods, and project schedules. In order to compare the three estimates, the 1996 LCCE and the 1999 LCCE were analyzed using the following approach:

- Estimates were escalated to constant 2001 dollars;
- Estimates were placed in a common, summary level, work breakdown structure according to the major cost categories of each project;
- Technical bases and assumptions for the estimates were examined;
- Cost estimating methods and approaches were assessed;
- Contingencies were identified; and
- Major cost drivers were determined.

The following cautionary notes should be considered in comparing the three cost estimates:

- Two distinct process steps, non-pit conversion and first-stage immobilization, were included as part of a "front-end" for either the reactor or immobilization alternatives in the 1996 LCCE. In the 1999 and 2001 cost data, the processes comprising the "front-end" were separated. The process for conversion of pits and clean metal into oxide were incorporated into the PDCF, and the processes for conversion and ceramification of other plutonium not suitable for use in reactors were included in the PIP. This shift contributed to the PIP cost increase. Similarly, an aqueous gallium removal and purification process was shifted from the "front-end" in the 1996 LCCE to the MOX fuel fabrication facility (FFF) in the later cost data, contributing to the MOX FFF cost increase.
- The 2001 cost projections will be subject to change as the Title I and Title II designs and Independent Cost Evaluations are completed for the individual projects.
- Increases in costs are primarily the result of process equipment quantity and cost increases, seismic design requirements, and safeguards and security requirements. Facility square footage growth to accommodate the increased amount of equipment has, in turn, contributed to cost increases.
- The 1999 and 1996 LCCEs included only limited allowances for cost contingencies.

## 4.2 Comparison Between the 2001 Life-Cycle Cost Projection and the 1999 LCCE

This section of the report compares the 2001 life-cycle projection presented in Chapter 4 with the 1999 LCCE. Chapters 2 and 3 provide more detail on the technical basis and assumptions for the 2001 life-cycle cost projection. The 1999 LCCE is based on technical and cost information provided in three Design Only-Conceptual Design Reports (DO-CDRs) for the three principal plutonium disposition projects:

- PDCF DO-DCR, Rev. 0, dated December 1997;
- MOX FFF DO-DCR, Rev. 0, dated December 1997; and
- PIP DO-DCR, Rev. 1, dated January 1999.

The costs in the 1999 LCCE were developed by evaluating the technical information in DO-CDRs for completeness, reviewing the DO-CDR cost estimate, and adjusting the costs as required. The 1999 LCCE reflected a somewhat better but limited understanding of the technology requirements, individual facility size, and equipment needs than the DO-CDRs upon which it was based. However, when the 1999 LCCE was prepared, decisions regarding the scope and location of the facilities remained unresolved. While design contracts had been awarded for two of the three facilities as much as six months before the 1999 LCCE was published, the design process was in its infancy when the LCCE was prepared, and facility designers were not able to significantly contribute to the 1999 LCCE.

### 4.2.1 Comparison of Cost Data

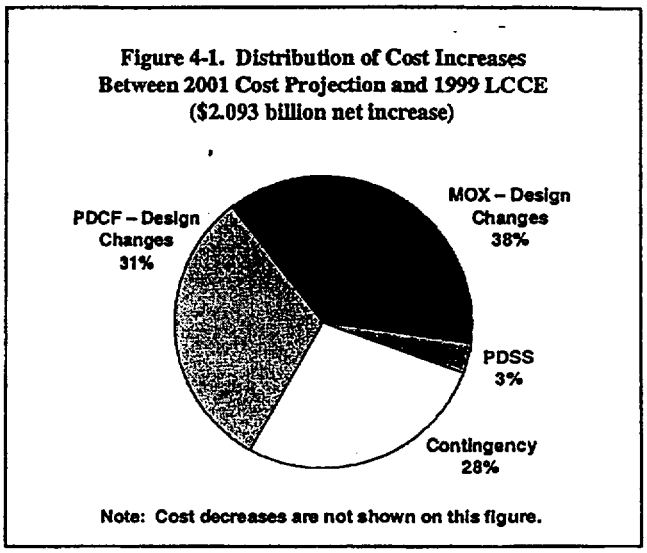
The 2001 life-cycle cost projection for the U.S. Plutonium Disposition Program of $6.253 billion represents a 50 percent increase over the 1999 life-cycle cost estimate of $4.159 billion. Table 4-2 provides a side-by-side comparison of the 2001 projection and the 1999 LCCE in a summary level work breakdown structure.

**Table 4-2. Comparison Between 2001 Projection and 1999 LCCE (millions of constant 2001dollars)**

| Project and Cost Category | 2001 Projection | 1999 LCCE | Difference |
|---|---|---|---|
| **PDCF** | | | |
| *Design and Construction and Other* | | | |
| Facility | 819 | 341 | 479 |
| Contingency | 220 | 150 | 70 |
| *Operations* | | | |
| Facility | 1,016 | 761 | 255 |
| Contingency | 102 | 0 | 102 |
| **MOX** | | | |
| *Design and Construction and Other* | | | |
| Fuel Fabrication Facility | 1,111 | 608 | 504 |
| LTAs / Fuel Qualification / Reactor Licensing & Mods | 355 | 425 | -70 |
| Contingency | 279 | 129 | 150 |
| *Operations* | | | |
| Fuel Fabrication Facility | 1,133 | 756 | 378 |
| LTAs / Fuel Qualification / Reactor Licensing & Mods | 124 | 92 | 32 |
| MOX Fuel Credit | (552) | (578) | 26 |
| HEU Credit | (231) | 0 | (231) |
| Contingency | 244 | 0 | 244 |
| **PIP** | | | |
| *Design and Construction and Other* | | | |
| Facility | 756 | 727 | 29 |
| Contingency | 156 | 152 | 4 |
| *Operations* | | | |
| Facility | 566 | 597 | -31 |
| Contingency | 57 | 0 | 57 |
| **PDSS** | | | |
| *Design and Construction and Other* | | | |
| Facilities | 78 | 0 | 78 |
| Contingency | 19 | 0 | 19 |
| **Total U.S. Plutonium Disposition Program** | **6,253** | **4,159** | **2,093** |

### 4.2.2 Reasons for Difference in the Program Estimate

The following factors account for most of the difference between the 2001 cost projection and the 1999 LCCE. Figure 4-1 and Table 4-3 summarize the major factors contributing to the $3.217 billion difference between the 2001 projection and the 1999 LCCE.




- **Design Changes.** Design changes identified in the PDCF and MOX FFF Title I design substantially increased the complexity and cost of these facilities. Many of these changes were incorporated to meet more stringent seismic, security, and safeguards standards than had been assumed in the 1999 LCCE. Changes in processes and operational requirements also substantially increased the amount of floor space in the facilities, including floor space that is "hardened" with more reinforcing steel and other features to comply with seismic, security, and safeguards requirements. Other changes involved efforts to segregate workspaces for better safety and contamination control, expansion of loading and storage areas, and consideration of how to incorporate an aqueous polishing unit into the MOX FFF.

- **Contingency.** Contingency was applied to facility operations in the 2001 cost projection, but was largely excluded from the 1999 LCCE.

Table 4-4 compares the basic assumptions and design bases that were used to prepare the 2001 cost projections and the 1999 LCCE.

**Table 4-3. Major Factors Accounting for the Difference between the 2001 Projection and the 1999 LCCE**

| Driver | Impact (millions of constant 2001 dollars) |
|---|---|
| PDCF – Changes identified in Title I design | 734 |
| MOX – Changes identified in Title I design | 881 |
| Contingency | 645 |
| PDSS – Newly identified line item | 78 |
| Other | -40 |
| Credits | -205 |
| Total | 2,093 |

**Table 4-4. Facility-Level Summary of Differences Between the 2001 Projection and the 1999 LCCE**

| Project | Assumptions and Bases | | Difference in Life-Cycle Cost (millions of constant 2001 dollars) |
|---|---|---|---|
| | 2001 Projection | 1999 LCCE | |
| PDCF | • Design updated from DO-CDR Rev. 0<br>• Estimate updated during preparation of Title I design<br>• New facility<br>• Design/construction and operations contingencies $322 million<br>• Larger secure shipping and receiving area<br>• 246,000 $ft^2$ total floor space<br>• 176,000 $ft^2$ hardened floor space | • Design based on 1997 DO-CDR Rev. 0<br>• Design costs are extracted from contract award documents<br>• New facility<br>• Design/construction contingency $150 million<br>• Secure shipping and receiving area included<br>• 190,000 $ft^2$ total floor space<br>• 140,000 $ft^2$ hardened floor space | 906 |
| MOX | • Design based on DCS (contractor) Title I (2000)<br>• New facility<br>• Design/construction and operations contingencies $523 million<br>• Application of U.S. seismic, safety, and security standards<br>• Automated design<br>• Secure shipping, receiving, and storage<br>• Aqueous polishing process requirements integrated into facility operations and support functions<br>• Increased operations staffing for aqueous polishing systems and security<br>• 440,000 $ft^2$ total floor space<br>• 370,000 $ft^2$ hardened floor space<br>• Annual production 70—100 MTHM MOX fuel [a]<br>• Lifecycle dispositioning of 33 MT of plutonium (2.0—3.5 MT Pu/year)<br>• Net MOX fuel credit included ($552 million)<br>• HEU credit included ($231 million) | • Design adapted from 1997 DO-CDR, Rev. 0<br>• New facility<br>• Design/construction contingency $129 million<br>• Limited consideration of seismic, safety, and security requirements<br>• Design based on LEU fuel fabrication<br>• No secure shipping, receiving, and storage functions<br>• Aqueous polishing process for gallium removal included but not integrated into facility systems<br>• 158,000 $ft^2$ total floor space<br>• 138,000 $ft^2$ hardened floor space<br>• Annual production 100 MTHM MOX fuel [a]<br>• Lifecycle dispositioning of 33 MT plutonium (3.5 MT Pu/year)<br>• Net MOX fuel credit included ($578 million)<br>• No HEU credit | 1,032 |
| PIP | • Design based on DO-CDR, Rev 3 (draft, 2000)<br>• New facility<br>• Design/construction and operations contingencies $213 million<br>• Design/construction and operations cost based on 13 MT throughput over 10 years<br>• ZPPR alloy fuel deleted from feed to immobilization (affected conversion equipment, plant throughput, and blending strategies)<br>• One 50% capacity ceramification and canning line<br>• 168,000 $ft^2$ total floor space<br>• 112,000 $ft^2$ hardened floor space<br>• Secure feed receipt and storage areas included<br>• Interim two-year storage of pucks in magazines included | • Design based on 1999 DO-CDR, Rev 1<br>• New facility<br>• Design/construction contingency $152 million<br>• Design/construction cost based on 50MT throughput over 10 years; operations cost based on 17MT over 10 years<br>• One 100% capacity ceramification and canning line<br>• Increased number of DWPF canisters<br>• Design for all phases of immobilization<br>• 203,000 $ft^2$ total floor space<br>• 148,000 $ft^2$ hardened floor space<br>• Feed receipt and storage area not included<br>• Storage for pucks in magazines not included | 58 |
| PDSS | • New design and construction project | • Not included | 97 |

[a] MTHM means metric tons heavy metal, which is the conventional terminology used to measure quantities of nuclear fuel. The measure refers to the combined mass of uranium and plutonium present in the fuel.

## 4.3 Comparison Between the 1999 LCCE and the 1996 LCCE

This section of the report compares the 1999 LCCE with the 1996 LCCE which was published by DOE in the *Technical Summary Report for Surplus-Weapons Usable Plutonium Disposition* (DOE/MD-0003, October 1996). The 1996 LCCE relied on preliminary laboratory-based concepts for plutonium disposition and assumed that much of the eventual processing operations would take place in existing facilities. In comparison to the 1999 LCCE, the 1996 LCCE contained different assumptions regarding technology maturity, building floor space requirements, and equipment costs. In addition, the 1996 LCCE did not include the costs of packaging and storage, the services of which were assumed to be provided from existing or planned on-site capabilities for packaging and storage, did not include any allowances for contingency or escalation over the life-cycle of the disposition mission, and did not include an irradiation services fee.

### 4.3.1 Comparison of Cost Data

The 1999 LCCE for the U.S. Plutonium Disposition Program of $4.159 billion represents a 73 percent increase over the 1996 life-cycle cost estimate of $2.405 billion. Table 4-5 provides a side-by-side comparison of the 1999 LCCE and the 1996 LCCE in a summary level work breakdown structure for the major components of the life-cycle costs.

**Table 4-5. Comparison Between 1999 LCCE and 1996 LCCE (millions of constant 2001dollars)**

| Project and Cost Category | 1999 LCCE | 1996 LCCE | Difference |
|---|---|---|---|
| **PDCF** | | | |
| *Design and Construction and Other* | | | |
| Facility | 341 | 398 [a] | (57) [a] |
| Contingency | 150 | 0 | 150 |
| *Operations* | | | |
| Facility | 761 | 1,070 [a] | (309) [a] |
| Contingency | 0 | 0 | 0 |
| **MOX** | | | |
| *Design and Construction and Other* | | | |
| Fuel Fabrication Facility | 608 | 398 | 210 |
| LTAs / Fuel Qualification / Reactor Licensing & Mods | 425 | 475 | (50) |
| Contingency | 129 | 0 | 129 |
| *Operations* | | | |
| Fuel Fabrication Facility | 756 | 750 | 6 |
| LTAs / Fuel Qualification / Reactor Licensing & Mods | 92 | 0 | 92 |
| MOX Fuel Credit | (578) | (1,027) | 449 |
| Contingency | 0 | 0 | 0 |
| **PIP** | | | |
| *Design and Construction and Other* | | | |
| Facility | 727 | 243 [a] | 484 [a] |
| Contingency | 152 | 0 | 152 |
| *Operations* | | | |
| Facility | 597 | 99 [a] | 498 [a] |
| Contingency | 0 | 0 | 0 |
| **PDSS** | | | |
| *Design and Construction and Other* | | | |
| Facilities | Not Included | | |
| Contingency | | | |
| **Total U.S. Plutonium Disposition Program** | **4,159** | **2,405** | **1,755** |

[a] In the 1996 LCCE, the processes in the current PDCF and PIP configuration were grouped differently. Conversion and 1st-stage immobilization of plutonium destined for immobilization (part of the PIP in the 1999 LCCE) were part of a "front-end" facility that also included conversion of plutonium destined for MOX. The cost of this "front-end" facility, which appears in Table 4-4 as the 1996 equivalent of the current PDCF, included these additional processes. Similarly, the cost of 2nd-stage immobilization, which appears in Table 4-4 as the 1996 equivalent of the PIP, excluded these processes.

## 4.3.2 Reasons for Difference in the Program Estimate

The following factors account for most of the $1.755 billion difference between the 1999 LCCE and the 1996 LCCE. Figure 4-2 and Table 4-6 summarize the major factors contributing to the differences between the 1999 LCCE and 1996 LCCE.

- **Fuel Credit.** The fuel credit decreased by $449 million from ($1,027 million) in the 1996 LCCE to ($578 million) in the 1999 LCCE. The larger 1996 value is based on a gross credit that assumes that the economic value of MOX fuel when used in a power reactor is equal to the LEU fuel it displaces. The 1999 value assumes that the economic value of MOX fuel is lower than that of the corresponding displaced LEU fuel by a factor that considers an irradiation fee charged by the reactor contractor. In addition, market prices for LEU fuel declined between 1996 and 1999.

- **Contingency.** The 1996 LCCE did not include any allowances for contingencies. The 1999 LCCE includes contingencies totaling $432 million.

- **Conversion and First-Stage Immobilization Processes.** In the 1996 LCCE, the disassembly and conversion of plutonium destined for MOX and the conversion and first-stage immobilization processes for plutonium destined for immobilization were to occur in a facility called the "front-end". After this processing, plutonium not suitable for reactor use was to be transferred to DOE's existing Defense Waste Processing Facility at Savannah River Site for second-stage immobilization. In the 1999 LCCE, the processes were separated so that processing of material destined for reactor use was included in the PDCF and processing of material destined for immobilization was relocated to the PIP. The processes were separated due to transportation, purity, processing, security, and international inspection requirements.

**Figure 4-2. Distribution of Cost Increases Between 1999 LCCE and 1996 LCCE ($1.755 billion increase)**

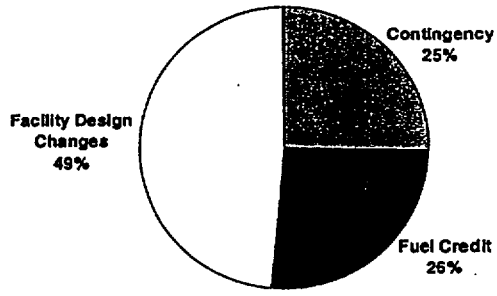



**Table 4-6. Major Factors Accounting for the Difference Between the 1999 LCCE and 1996 LCCE**

| Driver | Impact (millions of constant 2001 dollars) |
|---|---|
| Contingency | 432 |
| Fuel Credit | 449 |
| Facility Design Changes | 874 |
| **Total** | **1,755** |

- **Plutonium Oxide Purification Processes.** In the 1996 LCCE, a dry pyrochemical process in the "front-end" was originally planned to remove gallium and other plutonium impurities. In the 1999 LCCE, this was changed to a wet solvent extraction process in order to meet more stringent commercial reactor fuel purity requirements. In addition, wet process was incorporated into the MOX FFF. The wet process involves more equipment, floor space, and operations staffing levels than the dry process.

- **Floor Space.** The 1999 LCCE was based on a more complete understanding of the security, seismic, and safeguards design considerations than the 1996 LCCE. Efforts to meet these requirements resulted in an increase in facility floor space.

Table 4-7 compares the basic assumptions and design bases that were used to prepare the 1999 LCCE and the 1996 LCCE.

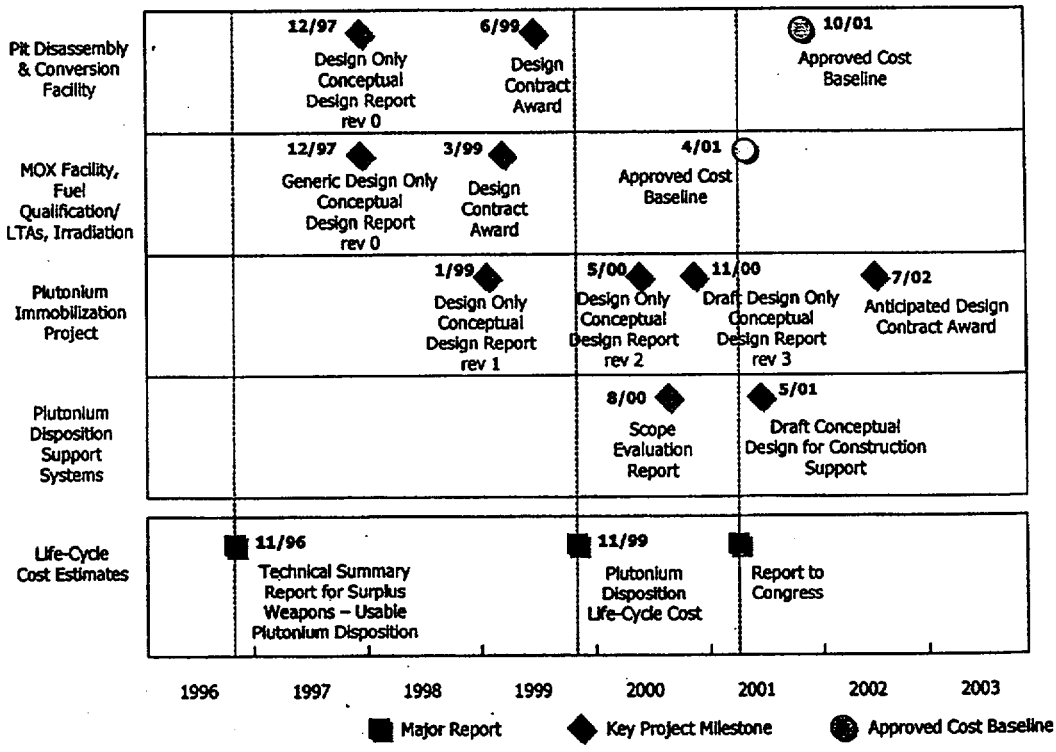
**Table 4-7. Facility-Level Summary of Differences Between the 1999 LCCE and the 1996 LCCE**

| Project | Assumptions and Basis | | Difference in Life-Cycle Cost (millions of constant 2001 dollars) |
|---|---|---|---|
| | 1999 LCCE | 1996 LCCE | |
| PDCF | • Design based on 1997 DO-CDR Rev. 0<br>• Design costs are extracted from contract award documents<br>• Assumed new facility<br>• Design/construction contingency $150 million<br>• New secure shipping and receiving area included<br>• Processes included for pit disassembly and conversion<br>• Processes for gallium removal, non-pit conversion, and 1st stage immobilization transferred to other facilities | • Costs based on pre-conceptual analyses<br>• Assumed existing facility<br>• Contingencies not included in published cost<br>• Secure shipping and receiving area assumed to be provided by host site<br>• Processes included for pit disassembly, pit and non-pit conversion, thermal gallium removal, and first-stage immobilization | (216) |
| MOX | • Design adapted from 1997 DO-CDR, Rev. 0<br>• Net fuel credit included ($578 million)<br>• Design/construction contingency $129 million<br>• Assumed new facility<br>• Aqueous gallium removal process included<br>• Annual production 100 MTHM MOX fuel<br>• Design based on LEU fuel fabrication<br>• Limited secure shipping, receiving, and storage functions<br>• Life-cycle dispositioning of 33 MT plutonium | • Cost based on pre-conceptual analysis<br>• Gross fuel credit included ($1,027 million)<br>• Contingencies not included in published cost<br>• Assumed existing LEU fuel facility adapted to MOX production<br>• Receive powder from PDCF that was directly usable for fabricating MOX fuel<br>• Annual production ~70 MTHM MOX fuel<br>• Small, manually operated facility with a central in-line storage vault<br>• Life-cycle dispositioning of 33 MT plutonium over 14 years of operation | 836 |
| PIP | • Cost based on 1999 DO-CDR, Rev. 1<br>• Assumed new facility<br>• Design/construction contingency $152 million<br>• Processes included for non-pit conversion and 1st and 2nd stage immobilization<br>• Design/construction costs based on 50 MT Pu throughput over 10 years<br>• Increased development and testing requirements | • Cost based on pre-conceptual analysis<br>• Assumed the use of existing facilities<br>• Contingencies not included in published cost<br>• Processes included for 2nd stage immobilization<br>• Design/construction costs based on 17 MT throughput | 1,135 |
| PDSS | • Not included | • Not included | 0 |

# 5. Initiatives to Improve the U.S. Program Life-Cycle Cost Estimates

Since the inception of the Fissile Materials Disposition Program, a number of life-cycle cost estimates have been developed based on varying scope and schedule assumptions. As the program has matured, a better understanding and definition of the major elements of the program have resulted in more consistent life-cycle estimates. Figure 5-1 illustrates this maturation process. The first life-cycle cost estimate, which was developed in 1996, was based on very preliminary, pre-conceptual project information. In fact, no conceptual design work had been completed on any of the major facilities when this estimate was completed.

**Figure 5-1. Timeline of Life-Cycle Estimates and Degree of Project Definition**




By November 1999, when the program issued the second major life-cycle cost estimate, increased definition of the major elements of the program was possible. In particular, design only conceptual design reports (DO-CDR) had been completed for the MOX Fuel Fabrication Facility (MOX FFF), the Pit Disassembly and Conversion Facility (PDCF), and the Plutonium Immobilization Project (PIP). Design contracts were awarded in early 1999 for the PDCF and MOX FFF projects. However, the PIP remained at the conceptual stage at the time of the 1999 cost estimate, and the Plutonium Disposition Support Systems (PDSS) did not emerge as a new requirement until 2000.

Today, while the program definition has improved since the 1999 estimate, a large number of uncertainties remain. Title I (preliminary) design is complete for the MOX FFF and in progress for the PDCF. An initial scope document for the PDSS was issued in August 2000. A number of serious technical challenges face the program, including the deployment of first-of-a-kind technologies for both the PDCF and the PIP. Regulatory requirements and licensing issues also will add substantial uncertainty to the successful completion of the program.

The Office of Fissile Materials Disposition (OFMD) recognizes the significant challenges of developing a stable, credible life-cycle cost estimate for the program. To improve the life-cycle estimate, a number of initiatives are underway. This chapter describes three of these initiatives: independent cost estimates, external reviews, and a program change control system.

## 5.1 Independent Cost Estimates and External Reviews

Independent cost estimates (ICEs) are used to verify construction cost estimates prepared during the preliminary design phase of a project. These independently prepared estimates are used to increase the confidence of the project cost baseline prior to authorizing construction funding. This independent estimating process, in conjunction with an External Independent Review (EIR) to validate the project cost, schedule, and technical baselines, is part of the Critical Decision process specified in DOE Order 413.3, *Program and Project Management for the Acquisition of Capital Assets*. The purpose of this process is to provide the Program or Department Acquisition Executive with an assessment of the project's maturity and readiness to proceed to the next phase.

The Office of Engineering and Construction Management (OECM) is responsible for coordinating and facilitating these assessments, and ensuring that the project office has prepared all the materials, reports and procedures required for a specific Critical Decision for Major System Project (Total Project Cost greater than $400 million). These materials are presented to the Secretarial Acquisition Executive and the Energy Systems Acquisition Advisory Board for review and approval to proceed. Independent Cost Estimates are reconciled with the project cost baselines and are available to the Congress and any other oversight organizations. OFMD staff responsible for communicating and implementing program/project management policy have ensured compliance with these DOE management requirements and have closely coordinated their efforts with the OECM.

The EIR provides a structured review based on DOE requirements and best practice criteria and covers the project cost, schedule, technical baselines, and management systems. The review also identifies potential risks to successful execution and examines the project risk management processes. The EIR supports the Critical Decision process and culminates in a corrective action plan prepared by the project to address any negative findings presented in the review report. The implementation of corrective actions is tracked by the OECM.

Three ICEs are scheduled for the major elements of the U.S. Plutonium Disposition Program over the next 18 months. The MOX FFF ICE is currently being conducted and will be completed in March of this year. Table 5-1 outlines the schedule for the remaining projects.

**Table 5-1. Current Schedule for Performance Baseline Validation (Construction Phase)**

| Project | Conduct ICE and Establish Performance Baseline |
|---|---|
| PDCF | October 2001 |
| MOX | April 2001 |
| PIP | October 2004 |
| PDSS | Construction Support – June 2002<br>Permanent Systems – October 2003 |

The Plutonium Disposition Support Systems Project (PDSS) was planned to design and construct/modify site infrastructure to support the disposition projects and take advantage of economies of scale and increased facility integration. As a result, PDSS design and construction activities are phased to initially support construction of the other projects and later move onto construction of the permanent systems needed to support disposition operations.

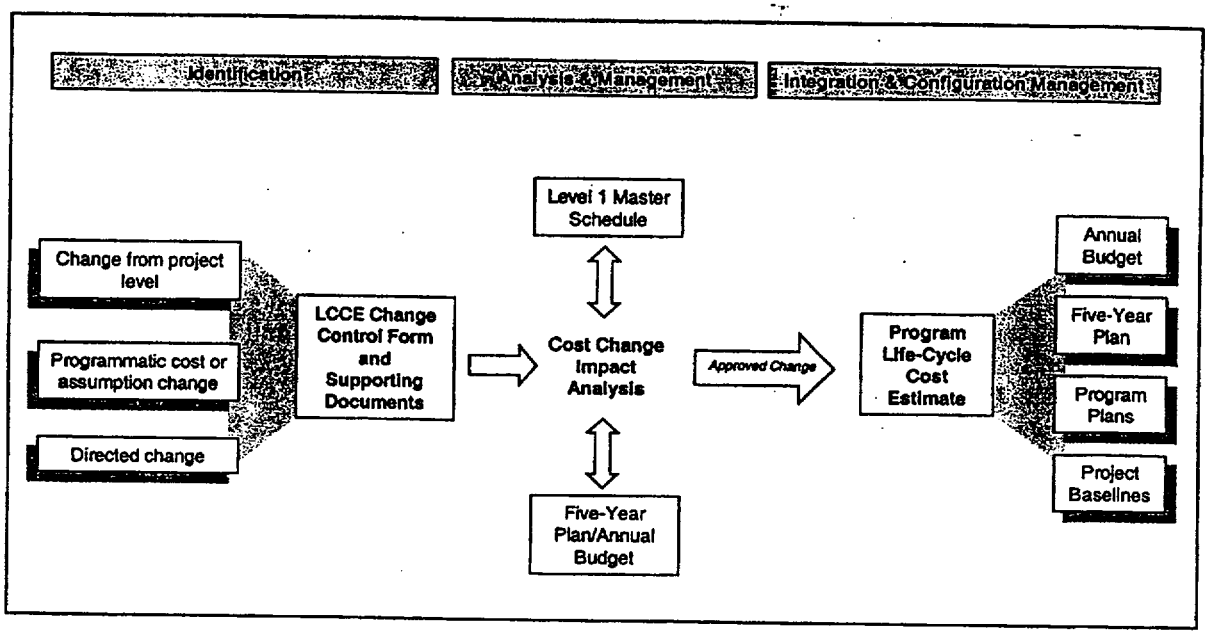
## 5.2 Program-Level Change Control Process for Life-Cycle Costs

The OFMD is developing a formal procedure and system for controlling and communicating changes to program life-cycle cost estimates. The program life-cycle cost estimate is comprised of the individual project life-cycle cost estimates (design, construction, and operations) and any other programmatic work supporting the disposition mission. This system will supplement the office's long-range planning and budget formulation efforts and provide source information for all data in the program life-cycle cost estimate. It will integrate with existing program change control processes for program planning and work scope definition.

This program change control system is based on comparable change control methods for large-scale projects but will focus on capturing, documenting and communicating program-level cost and assumption changes. Changes that occur at project levels will be integrated into the program-level system in a hierarchical fashion.

Figure 5-2 provides an overview of the planned program-level change control process for the life-cycle cost estimate. Headquarters program managers present changes to the program LCCE through the use of a standardized form which documents cost, schedule, and other impacts to the estimate. Justification for the change and potential impacts are detailed and analyzed prior to any modifications to the LCCE. Controlled distribution of the new estimate will ensure that program participants are planning against the most current, approved version. Changes to the LCCE may be directed from management when programmatic assumptions change or they may be presented as the result of a lower-level change. The OFMD Program Management Support Group will maintain the data and change control system for the program life-cycle cost estimate to ensure integration with other program plans and documents, and provide appropriate management visibility of proposed changes and their potential impacts.

**Figure 5-2. Overview of the Program-Level Change Control Process**




Project-level change control is defined in project execution plans, which are required by DOE Order 413.3. Project execution plans specify the acquisition strategies and management controls for each project and are reviewed and approved by OECM and the Acquisition Executive. As part of the management controls, procedures are developed to identify, analyze and manage proposed changes to cost, schedule, and technical baselines. These procedures use a variance threshold method to identify and control changes at the appropriate level of management, and to elevate them to higher levels when resolution is not achieved. Change control boards are chartered with appropriate technical and management staff to review and disposition proposed changes. The OFMD requires that a federal project staff member reside on the lowest level change control board (including contractors) to allow visibility and approval of any proposed design changes.

# 6. Russian Plutonium Disposition Program

The U.S. program is linked in intergovernmental agreements with a similar disposition undertaking by the Russian Federation. Both countries will dispose of the same amount of weapons-grade plutonium (34 metric tons (MT) each) and according to essentially similar timetables. Neither country is obligated to dispose of more weapons-grade plutonium, or to dispose of it faster, than the other country. Although the program design and development schedules are somewhat different in the two countries, neither country will construct or operate facilities for plutonium disposition before the other is ready to do so.

This section discusses the intergovernmental agreements, the current status of the undertaking, current and planned assessments of costs of Russian plutonium disposition, and the current international efforts to provide funding and technical support for the Russian program.

## 6.1 Agreement Framework

Two U.S.-Russian intergovernmental agreements are applicable to the disposition of Russian plutonium. A third intergovernmental agreement—involving Russia, France and Germany—is also relevant, and is discussed below.

### 6.1.1 U.S.-Russian Scientific and Technical Cooperation Agreement – July 1998

*The Agreement Between the Government of the United States of America and the Government of the Russian Federation on Scientific and Technical Cooperation in the Management of Plutonium That Has Been Withdrawn From Nuclear Military Programs* was signed on July 24, 1998. This five-year agreement, extendable in five-year increments, provides the scientific and technical basis for decisions on how plutonium withdrawn from the countries' nuclear military programs should be managed.[1] It also establishes a framework for continued and expanded scientific and technical cooperation for the accomplishment of this objective.

Although the disposition methods for weapons-grade plutonium in both countries are not new or technologically radical concepts, some of the specific technologies are commercially unfamiliar and scientifically in need of testing, demonstration, and first-instance licensing in both Russia and the United States. The aim of the 1998 agreement is to support the necessary research, design and development, demonstration and testing.

The agreement provides for research, concept development, feasibility studies, experiments and small-scale tests and demonstrations, and for the design, construction and operation of pilot-scale facilities to demonstrate and test technological approaches. Virtually all of the work under the agreement is concerned with the disposition of Russian plutonium; Congress has separately supported research, design and development work on U.S. plutonium disposition. The United States supports the work with Russia through funds appropriated by the Congress for these purposes. The agreement establishes a U.S.-Russian Joint Steering Committee on Plutonium Management to coordinate and agree upon the scientific and technical work to be pursued. The Department of Energy is the U.S. executive agent for carrying out the provisions of the agreement.

[1] "Managed" in this context means the tranformation of the plutonium into spent fuel or other forms of equally unusable for nuclear weapons or other nuclear explosive devices, and may include conversion of plutonium and its manufacture into mixed oxide (MOX) fuel, use of MOX in nuclear reactors, and immobilization of plutonium in various forms.

The 1998 agreement was intended to be a scientific and technical cooperation agreement only. It does not commit the parties to actually dispose of weapons-grade plutonium. Nor does it commit them to construct or operate facilities for the actual disposition of plutonium. The pilot-scale facilities that it provides for are for testing and demonstration purposes only. The 1998 agreement does not address the terms and conditions that would apply to a commitment to proceed with actual disposition—these are the subjects of the second U.S.-Russian agreement in this area, signed in September 2000.

### 6.1.2 U.S.-Russian Plutonium Disposition Agreement – September 2000

The second U.S.-Russian agreement—*Agreement Between the Government of the Russian Federation and the Government of the United States of America Concerning the Management and Disposition of Plutonium Designated As No Longer Required For Defense Purposes And Related Cooperation*—was signed on September 1, 2000. It commits the two governments to each dispose of 34 MT of weapons-grade plutonium according to roughly parallel timetables. Implementation of the agreement will require the construction of new industrial-scale facilities to convert, fabricate into fuel, and irradiate this plutonium in both countries, and to immobilize a portion of the U.S. plutonium. Milestones and schedules for the design and construction of the industrial-scale facilities in both countries are set forth in an annex to the agreement, with the aim of positioning both countries to begin industrial-scale disposition of weapons-grade plutonium at the same time. Although the U.S. Department of State had the lead in negotiating the agreement, the Department of Energy is the U.S. executive agent for implementing the agreement's terms.

The agreement sets 2007 as the target date to begin operating these facilities on an industrial scale, with a minimum disposition goal of 2 MT per year thereafter. The United States and Russia also are committed to seek ways to at least double the annual disposition rate in a joint analysis of options (including possibilities of employing non-Russian reactors for plutonium disposition) in the 18 months after the agreement's signing. The agreement further provides that additional quantities of weapons-grade plutonium that may be withdrawn in the future from the two countries' nuclear military programs should be brought under the terms of the agreement or, at a minimum, be subject to comparable terms regarding transparency and disposition. A monitoring and inspection regime, applicable to both countries' plutonium disposition, is to be negotiated within 18 months of the agreement's signing.

Although the Russian Federation Government will contribute technical and financial resources to the disposition of Russian weapons-grade plutonium, Russian obligations in the September 2000 agreement are expressly conditioned on the provision of adequate additional international financing to support the Russian program. The agreement provides $200 million in U.S. funds in support of the Russian effort, and commits the Parties to conclude, within a year to 18 months after the agreement's signing, a multilateral agreement documenting near- and long-term international financial or other arrangements for support of the Russian program. If the multilateral financing arrangements are not agreed and in place within 18 months after the agreement's signing, the Parties are to consult about whether to adjust the agreed timetables for plutonium disposition or to terminate the agreement.

The United States and the other Group-of-Seven (G-7) countries, working with others, have agreed to develop an international financing plan for these purposes. In this connection, in July 2000, the Heads of State and Government of the Group-of-Eight (G-8) countries pledged to develop, by the time of the next G-8 summit in mid-2001, both an international financing plan and accompanying multilateral framework in support of Russian plutonium disposition, to expand the international effort to other interested countries in order to gain the widest possible international support, and to explore the potential for both public and private funding.

It should be noted that the September 2000 agreement does not replace the July 1998 U.S.-Russian agreement. Scientific and technical cooperation in support of Russian plutonium disposition will continue under the 1998 agreement, in accordance with the terms of that agreement, but with a clear focus on supporting the commitments set forth in the September 2000 agreement. Activities in Russia related to the design and development of industrial-scale facilities for plutonium disposition (vice the pilot-scale demonstration facilities provided for in the 1998 agreement) will be pursued under the September 2000 agreement.

### 6.1.3 Other International Support Arrangements for Russian Plutonium Disposition

U.S.-Russian cooperation is not the only scientific and technical activity in support of Russian plutonium disposition. Scientific and technical support and accompanying financial support have also involved other countries, such as the trilateral scientific and technical cooperation involving Russia, France and Germany. In June 1998, the three countries signed an intergovernmental agreement *Concerning Cooperation in the Utilization for Peaceful Purposes of Plutonium Derived From the Dismantlement of Surplus Nuclear Weapons*. Similar to the July 1998 U.S.-Russian agreement, the trilateral agreement's objectives are to carry out joint investigations for removing weapons-grade plutonium from Russia's defense programs and transforming it into mixed oxide fuel for use in nuclear reactors. France and Germany have supported these activities with funding and technical resources. The trilateral agreement was initially for a two-year period. In June 2000, it was renewed for another two years.

Japan, Canada, and the European Union, through the International Science and Technology Center, also have been engaged in cooperative scientific and technical endeavors in support of Russia's plutonium management and disposition. Other countries—e.g., Italy and Belgium—have played contributing roles.

These other-country efforts are largely complementary to U.S.-Russian scientific and technical cooperative activities, and are focused on specific technical aspects of interest to the sponsoring countries and international organizations.

## 6.2 Current Status in Russian Plutonium Disposition

The U.S.-Russian agreement in September 2000 establishes for the first time an agreed framework for the disposition of weapons-grade plutonium from Russia's nuclear military programs. Although the agreement is detailed, a number of essential elements of the Russian program remain to be analyzed, tested, costed, decided, negotiated, and agreed (these include, for example, where industrial-scale facilities in Russia will be located, the specific "load" capacities of various existing Russian nuclear reactors for the disposition of weapons-grade plutonium, and the nature and extent to which the Russian program will employ non-Russian technologies and equipment). Also, the terms and conditions of international financing support remain to be negotiated and established. These terms and conditions may also affect major program elements in the Russian disposition effort.

In the meantime, scientific and technical cooperation under the July 1998 U.S.-Russian and June 1998 Russian-Franco-German agreements is being accelerated in light of the September 2000 U.S.-Russian agreement. In the case of U.S.-Russian scientific and technical cooperation, the nature of the work is changing from basic research and development and small-scale tests and demonstrations to pilot-scale demonstrations of technologies.

Although U.S.-Russian-French-German technical coordination and information sharing have been in place since the two 1998 agreements were signed, concerted quadrilateral efforts are currently underway

to expand technical coordination and the cross-exchange of scientific and technical information through inter-ministerial arrangements and agreements.

## 6.3 Cost Estimates for Russian Plutonium Disposition

Because there was no actual and committed Russian disposition program until the signing of the U.S.-Russian agreement in September 2000, and because multinational financing arrangements are still being developed, systematic cost analyses of the expected Russian program have lagged behind cost analyses of the U.S. Plutonium Disposition Program. Absent some degree of basic clarity and commitment regarding the disposition of Russian plutonium (now obtained in the September 2000 U.S.-Russian agreement), the programmatic assumptions and bases for cost assessments are difficult to define. Estimates varied widely, in part because the assumptions about Russian program elements, components and time frames upon which the cost estimates were based also varied widely. As a result, estimates of Russian program costs ranged across a fairly broad spectrum, from less than $1 billion to more than $3 billion in unescalated U.S. dollars.

Recognizing these shortfalls, and the need to better inform international discussions about providing funding support for Russian plutonium disposition, the U.S.-Russian Joint Steering Committee on Plutonium Management established in October 1999 a Joint U.S.-Russian Working Group on Cost Analysis and Economics in Plutonium Disposition, and directed it to do a near-term macro-level study of the costs involved. Following the U.S.-Russian lead, a similar Russian-Franco-German cost analysis working group was established in December 1999 with a scope defined by the narrower terms of the Russian-Franco-German agreement of June 1998.

The preliminary U.S.-Russian working group report was issued in April 2000. The preliminary Russian-Franco-German report was issued in July 2000. Both reports focused on "additional costs" of Russian plutonium disposition--that is, costs directly related to the disposition of this plutonium that are above-and-beyond the routine and expected costs of generating nuclear energy in Russia through the use of nuclear fuel.[2] They include the costs of new and/or modified and upgraded facilities, associated infrastructure, and operations that will be needed for the disposition of Russia's weapons-grade plutonium, and the costs associated with the licensing and regulation of these activities. Specifically, they include costs associated with:

- Design, construction, and operation of a conversion facility in Russia to produce plutonium oxide suitable for manufacture of mixed oxide (MOX) fuel for Russian reactors.
- Design, construction, and operation of MOX fuel fabrication facilities in Russia.
- Modification, safety upgrades and portions of service life extensions of existing Russian nuclear reactors and site infrastructure necessary to support irradiation of this MOX fuel.
- Transportation, interim storage and waste management.

[2] Because the U.S.-Russian agreement on plutonium disposition was not concluded and signed until September 2000, the two reports relied on areas of general agreement in the U.S.-Russian negotiations at the time

- Attendant licensing and regulatory activities.

- Decontamination and decommissioning of the structures and facilities involved.

Both cost assessment working groups had to explicitly exclude from their preliminary estimates a number of cost categories, because either: (1) not enough, or not precise enough, information was available regarding these categories to permit the assessment of macro-level cost implications at the time; or (2) no intergovernmental discussions, understandings or agreements had yet taken place, or were in place, concerning whether and/or how to take these categories into account. Also, in order to provide a single and consistent framework for analyzing and estimating threshold costs across the breadth of the Russian program, and over time, both reports developed for purposes of these initial cost estimates "disposition scenarios" for Russian plutonium disposition. The two expert working group reports explicitly cautioned that the disposition scenarios were developed and employed solely for initial, systematic cost assessment, and did not imply policy, programmatic, or technical decisions concerning the elements covered in the scenario.

Within these limitations, the U.S.-Russian working group report suggested an overall "starting" cost of approximately $1.7 billion (in constant 2000 U.S. dollars) over approximately a 26-year timeframe (Table 6-1). It roughly charted the distribution of these costs over the period 2001-2026 (Table 6-2). This projection is based on a plausible, technically feasible, and comparatively economical disposition scenario that is distinct from the corresponding U.S. approach. The scenario was approved by the Russian Ministry of Atomic Energy to serve as the basis for Russian cost estimates of plutonium disposition. This scenario includes 34 MT of plutonium composed of 25 MT clean metal, 8 MT oxide, and 1 MT impure oxide, to be dispositioned as follows according to a schedule roughly comparable to the one projected for the U.S. Disposition Program:

- 21.4 MT fabricated into MOX fuel to be used at four Russian VVER-1000 power reactors, which are roughly comparable in design to the commercial pressurized light water reactors to be used in the U.S. MOX FFF project.

- 14.8 MT fabricated into MOX fuel to be used as driver fuel in the Russian BN-600 fast reactor.

- 1 MT immobilized.

- 0.45 MT fabricated into MOX fuel to be used as driver fuel in the Russian BOR-60 fast reactor.

(The amounts of plutonium shown here include an additional ~3 MT of plutonium to be added to mask the original isotopic composition of Russia's military plutonium.)

**Table 6-1. Summary of Projected "Starting" Costs for Russian Plutonium Disposition (thousands of 2000 constant dollars)**

| Cost Element | Research, Development, and Pre-Capital Costs | Design and Construction of Facilities and Equipment Costs | Operating Costs | Total |
|---|---|---|---|---|
| Plutonium Conversion | 12,600 | 97,390 | 175,300 | 285,290 |
| MOX Fuel Fabrication | 101,725 | 207,700 | 378,800 | 688,225 |
| Reactor Modifications and Operations | 22,600 | 193,900 | 104,400 | 320,900 |
| Transportation | 3,900 | 28,100 | 84,450 | 116,450 |
| Spent Fuel Storage for BN-600[a] | 1,900 | 18,300 | 87,500 | 107,700 |
| Immobilization[b] | 29,000 | 64,900 | 106,100 | 200,000 |
| **SUBTOTAL** | **171,725** | **610,290** | **936,550** | **1,718,565** |
| Value-Added Tax | | | 170,540 | 170,540 |
| **TOTAL** | **171,725** | **610,290** | **1,107,540[c]** | **1,889,105[c]** |

[a] For 40 years of operation.
[b] Includes facilities at Mayak and Krasnoyarsk.
[c] Assumes Value-Added Tax, which may or may not be included in the future.
Source: *Preliminary Cost Assessment for the Disposition of Weapon-Grade Plutonium Withdrawn From Russia's Nuclear Military Programs: Report of the Joint U.S.-Russian Working Group on Cost Analysis and Economics in Plutonium Disposition,* April 5, 2000.

**Table 6-2. Costs in Time Profile[a] (thousands of 2000 constant dollars)**

| Year | Annual | Cumulative | Year | Annual | Cumulative |
|---|---|---|---|---|---|
| *2001* | 48 | 48 | *2014* | 99 | 1,318 |
| *2002* | 78 | 126 | *2015* | 99 | 1,417 |
| *2003* | 107 | 232 | *2016* | 98 | 1,515 |
| *2004* | 118 | 351 | *2017* | 78 | 1,594 |
| *2005* | 118 | 469 | *2018* | 78 | 1,672 |
| *2006* | 114 | 584 | *2019* | 78 | 1,750 |
| *2007* | 81 | 665 | *2020* | 28 | 1,778 |
| *2008* | 88 | 753 | *2021* | 28 | 1,806 |
| *2009* | 72 | 825 | *2022* | 28 | 1,834 |
| *2010* | 99 | 924 | *2023* | 25 | 1,860 |
| *2011* | 99 | 1,022 | *2024* | 20 | 1,880 |
| *2012* | 99 | 1,121 | *2025* | 6 | 1,886 |
| *2013* | 99 | 1,220 | *2026* | 3 | 1,889 |

[a] Assumes Value-Added Tax, which may or may not be included in the future.
Source: *Preliminary Cost Assessment for the Disposition of Weapon-Grade Plutonium Withdrawn From Russia's Nuclear Military Programs: Report of the Joint U.S.-Russian Working Group on Cost Analysis and Economics in Plutonium Disposition,* April 5, 2000.

The separately conducted Russian-Franco-German cost assessment, employing slightly different Russian plutonium disposition scenarios, estimated similar "starting" costs of between $1.17 billion and $1.73 billion in its July 2000 report.[3]

In viewing these preliminary estimates, a number of things need to be kept in mind:

- Both reports preceded the signing of the September 2000 U.S.-Russian agreement, and are unofficial estimates by technical international working groups. Although the analytical rigor of both working groups, and the forthright expression of analytical limitations in their reports, have garnered a considerable degree of international credibility for the estimates as presented, the reports are still only preliminary, limited, and unofficial estimates.

**Escalation of the Russian Program Cost Estimate ($1.72 billion)**

Escalating the Russian Program cost estimate is difficult because the costs of the various portions of the program that may be performed by Russia, the United States, and other countries would need to be known and would increase according to the different inflation rates within each of the respective countries. Escalating the cost by a single year (from constant 2000 to constant 2001 dollars) will change the cost by a few percent, not a significant amount given the relatively uncertain nature of the cost estimate. Assuming a 2 .5 percent inflation factor would increase the estimate to $1.76 billion.

- Because of conceptual, methodological and analytical uncertainties in projecting the compounding and interactive effects of inflation and exchange rate fluctuations in an internationally funded and supported Russian Disposition Program over a 26-year period, neither report attempted to take into account cost escalation.

- Both reports were intended only to establish an analytically-based threshold, minimum, and order-of-magnitude "starting" cost for the Russian program for purposes of informing discussions about international financing leading up to the G-8 Summit in Okinawa in July 2000.

- Each of the reports is scenario-dependent. The disposition scenarios employed for cost estimation in the reports reflect plausible, technically feasible, and comparatively economical approaches to Russian plutonium disposition, but they are neither predictions nor conclusions about the details of the Russian program, and do not imply governmental decisions or agreements on the program elements in the scenarios.

- Both reports considered only the costs of a Russian program in which all 34 MT of Russian weapons-grade plutonium would be dispositioned in existing Russian nuclear reactors at an annual rate of approximately 2 MT. They did not consider the additional costs that would be involved in doubling this annual disposition rate, or in employing non-Russian commercial nuclear reactors in support of a larger annual disposition rate.

- Both reports address only additional costs of weapons-grade plutonium disposition in Russia. They do not address the additional costs of Russian and international management of an

[3] Although the independently arrived at order-of-magnitude "starting costs" were much the same in this report and the earlier U.S.-Russian experts' report, the assessment of the costs of specific components of the Russian program were different in some cases, chiefly because of different assumptions about specific Russian program elements. In September 2000, the U.S., Russian, French, and German co-chairs of the two working groups issued a joint quadrilateral letter clarifying the similarities and differences in the estimates of the two reports.

international funding program; these additional costs will need to be developed in the course of arranging for international financing.

- Potential offsetting revenue streams and other net-cost-reduction possibilities were explicitly outside the scope of the initial studies.

The two international working groups have second-stage analyses underway to further develop the analysis of the costs of the Russian Disposition Program, and also examine a number of cost categories that were excluded from the preliminary estimates in 2000. The second-stage analyses are expected to be issued in early 2001, and to be considerably more systematic and detailed than was feasible in the preliminary reports in 2000. Also, the U.S.-Russian working group intends to conduct a separate analysis in early-mid 2001 of cost escalation scenarios, in order to better illuminate the range of likely overall costs.

The two working groups are supporting the G-8 structure in better understanding the costs of Russian plutonium disposition for purposes of international financing support in the lead-up to the next G-8 summit. Because the costs to the United States and the international community of supporting Russian plutonium disposition (and also cost-sensitive judgments about some of the Russian program's elements) are matters of intergovernmental review, negotiation, and agreement as well as matters of analysis and technical evaluation, DOE believes this to be the appropriate and most informative approach to estimating these costs at this time. Reports of the U.S.-Russian working group will be made available to the Congress when issued.

## 6.4 Russian, U.S., and International Funding Support

The "additional" costs that these unofficial analyses are attempting to estimate will need to be borne in international understandings involving Russia, the United States, and other countries. The September 2000 U.S.-Russian agreement calls on the two governments to "develop near-term and long-term international financial or other arrangements for the support of activities [in plutonium disposition] to be undertaken by the Russian Federation [under the agreement], in combination with contributions by [Russia] and assistance provided by ... the United States... in order to achieve and sustain" a Russian disposition rate of at least 2 MT/year and possibly also a doubling of this disposition rate. This international funding is to be incorporated in a multilateral agreement to be developed within 18 months after the signing of the September 2000 agreement.

**Gas Turbine-Modular Helium Reactor Program**

The Gas Turbine-Modular Helium Reactor (GT-MHR) program is dedicated toward developing the GT-MHR as a potential approach for increasing the rate at which Russian surplus plutonium can be dispositioned. The projected costs include $320 million to complete the reactor design in Russia, $273 million to construct a prototype reactor module, and $1.8 billion to develop an eight-module facility capable of dispositioning 2 MT of Russian surplus weapons plutonium per year (costs in constant 1998 dollars). These projected costs are based on calculations that supported development of the GT-MHR Conceptual Design and reflect a correspondingly high level of uncertainty. If these projected costs are fully funded by the United States, Russia, and other countries, the prototype could begin operation in 2009, with the additional startup of one module per year beginning in 2012.

The projected costs could be offset by revenue from the 285 megawatts of electric power generated by each module. Additional funding to support the program beyond the current and projected U.S. funding levels would need to be provided by other G-8 countries. To date, Russia has matched dollar-for-dollar U.S. expenditures of $12 million, the European Commission has provided $0.3 million, Framatome of France has provided $0.8 million, and the Japanese Government has pledged to provide $1 million annually for the next seven years. DOE has recognized that the significant international funding commitments to continue this project have not yet been forthcoming and is continuing to encourage future commitments of long-term support by government and private organizations in Russia, Japan, and the European Union.

Issues still being developed at this time include how Russian, American, and international funding support for the Russian plutonium disposition effort will be developed; what the funding will support and how; how multinational contributions will be consolidated to support an integrated program of Russian plutonium disposition; and how the funding and technical responsibilities will be allocated among countries. At the G-8 summit in Okinawa, Japan, on July 23, 2000, the heads of state and government agreed on the following statement of intention: "Our goal for the next summit is to develop an international financing plan for [Russian] plutonium management and disposition based on a detailed project plan, and a multilateral framework to coordinate this cooperation. We will expand our cooperation to other interested countries in order to gain the widest possible international support, and will explore the potential for both public and private funding." An international Plutonium Disposition Planning Group, co-chaired by the United States and Russia, has been established under G-8 auspices to develop the financing plan and the accompanying framework.

Thus far, several countries have pledged funding in support of the Russian program. The United States is providing $200 million. Initial funds under this authority were provided in fiscal year 2001, subsequent to the signature of the September 2000 U.S.-Russian agreement, and will continue through fiscal year 2004. (The U.S. Government has previously announced an intention to seek $200 million in additional appropriations through fiscal year 2004.) The United Kingdom has announced it will contribute £70 million, a current equivalent of over $100 million, over the next ten years. France has announced that it is considering providing approximately 450 million Francs, about $60 million over the next 6 years. Japan has pledged almost $34 million, specifically for MOX fuel technology development in Russia. Multinational discussions about additional funding support are on-going, in preparation for the next G-8 summit in mid-2001, as well as discussions and analyses of possible avenues for private (or quasi-public) financing, and discussions of international financing and program management for the Russian effort.

Although the full extent of Russian Federation resource contributions is still currently under discussion, it seems reasonably clear that Russia will contribute industrial nuclear site areas and infrastructure, technologies, specialists, and important portions of costs associated with the transportation of materials.

A better sense of these various contributions--and of how they stack up against the estimated costs of the Russian disposition effort--should be in hand by the time of the G-8 Summit in mid-2001. In the meantime, more confident and comprehensive understandings of the full expected costs of the Russian program are underway or planned for the immediate time ahead.

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# 7. Parity and Equivalence in the U.S. and Russian Plutonium Disposition Undertakings

Because weapons-grade plutonium is involved--much of it from dismantled U.S. and Russian nuclear weapons--it is essential in U.S-Russian agreements and arrangements for the mutual disposition of this plutonium that parity and equivalence exist between both countries' disposition undertakings. U.S. weapons-grade plutonium subject to the September 2000 agreement with Russia[1] will not be dispositioned in whole or part unless and until accompanied by a similar disposition of the Russian weapons-grade plutonium that is subject to the agreement.

Although the design and development of the two countries' disposition programs are necessarily asymmetrical, the United States will not begin to construct industrial-scale facilities for weapons-grade plutonium disposition before and until the Russian Federation is ready to begin comparable construction, and will not operate these facilities until comparable Russian facilities also are operational. If at any time in the approximately 25-year period of disposition the Russian Federation falls significantly behind agreed schedules and disposition volumes and milestones, the United States will, at a minimum, adjust its own disposition efforts accordingly. These parity and equivalence considerations are discussed in this section.

## 7.1 Achieving Parity

The September 2000 agreement calls for periodic checkpoints in US-Russian bilateral efforts:

- The agreement calls for the development of a detailed bilateral monitoring and inspection effort to enable each country to verify that the quantities and forms of plutonium are dispositioned in accord with the terms of the agreement, including disposition plutonium, blend stock, spent mixed oxide fuel, immobilized forms, and disposition facilities. The agreement also includes provisions for review after 18 months to determine whether sufficient multilateral arrangements are in place or whether schedules need to be revised or whether the agreement should be terminated.

- For any assistance provided to Russia by the U.S., the agreement specifies that the U.S. has the right to examine the use of the equipment, supplies, materials, training, or other services.

- The agreement allows the United States to suspend proportionately its implementation activities should Russia not meet its commitments under the agreement.

To avoid the disruptions and increased costs that would result from any delays in design and licensing activities for the U.S. facilities, two hold points are established by the Office of Fissile Materials Disposition: Start of construction and start of operations. At each hold point, a review of comparable Russian progress will be conducted and a decision will be made, with appropriate governmental and Congressional involvement, whether to proceed to the next phase.

[1] DOE (U.S. Department of Energy), 2000, *Agreement Between the Government of the United States and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as no Longer Required for Defense Purposes and Related Cooperation*, Office of Fissile Materials Disposition, Washington, DC, September 1. http://www.doe-md.com/

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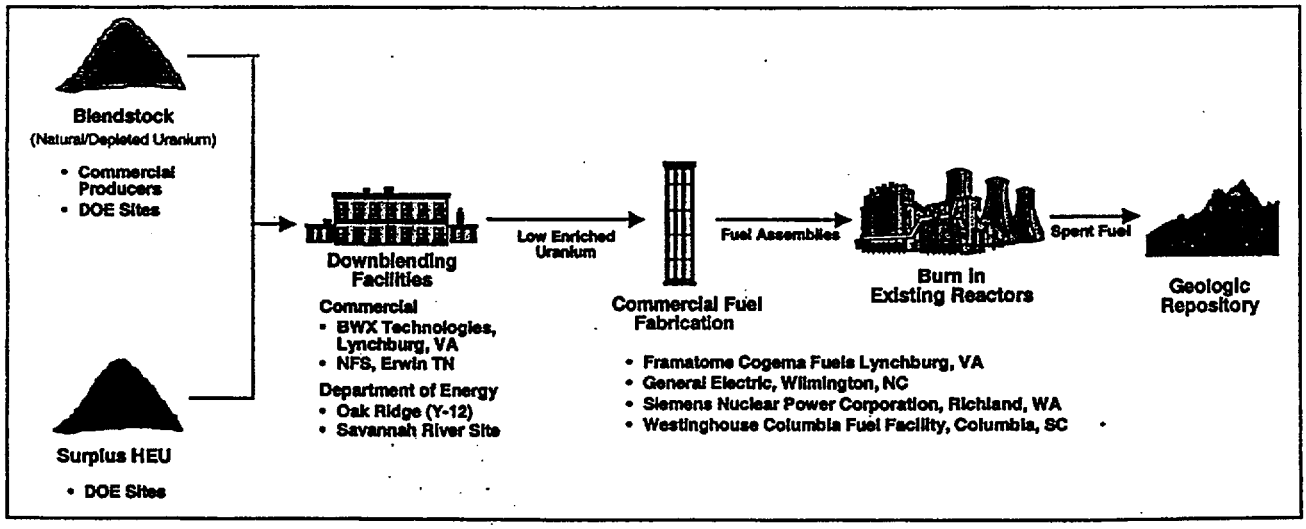
# 8. U.S. Surplus Highly Enriched Uranium Disposition Program

## 8.1 Program Objective and Scope

The objective of the U.S. Surplus Highly Enriched Uranium (HEU) Disposition Program is to make surplus HEU non-weapons usable, mostly by blending it down to low-enriched uranium (LEU). DOE will gradually sell the resulting LEU over time for commercial use as fuel feed for nuclear power plants to generate electricity. A small fraction of the surplus HEU will be disposed of as spent nuclear fuel or other radioactive waste. The current program scope covers 142 metric tons (MT) of HEU remaining for disposition as LEU reactor fuel. The quantity of HEU designated as surplus by the U.S. (174 MT) includes the remaining 142 MT, 14 MT that has already been downblended, and approximately 18 MT present in spent nuclear fuel.

The Surplus HEU Disposition Program differs from the Plutonium Disposition Program in several fundamental ways. In particular, the program is less technically complex and relies on the well-established commercial marketplace for LEU. It is also being conducted without any direct linkage to the Russian HEU disposition program. Under the program, HEU will be transferred from DOE inventories to one of four DOE or commercial facilities for downblending to LEU. Through a variety of mechanisms, the resulting LEU will be fabricated into reactor fuel and eventually used in nuclear reactors (Figure 8-1). Spent fuel from the reactors will be disposed in a geologic repository.

**Figure 8-1. Disposition Pathway of U.S. Surplus HEU**



## 8.2 Program Projected Life-Cycle Cost

The current projected life-cycle cost of the U.S. Surplus HEU program is $928 million (in constant 2001 dollars). This cost was developed using the same methodology as was used to estimate the Plutonium Disposition Program cost. This process began with the most recent cost estimate issued by DOE in the *Surplus Highly Enriched Uranium Disposition Program Viability Assessment* (HDPO/00-2, March 2000). The cost information in that report was updated based on more recent information about the scope, implementation, and other aspects of the program. The cost projection in the Viability Assessment was $891 million in 2000 constant dollars, or $910 million in 2001 constant dollars.

These projected costs do not include the revenue to the U.S. government that would be collected from the commercial LEU sales. The current projection for this revenue is $760 million (constant 2000 dollars, Table 8-1). This amount includes $231 million in revenues that will be derived from HEU that is a byproduct of the Pit Disassembly and Conversion Facility (discussed in Chapter 2, section 1). These revenues will be used to partially offset the operating cost of the MOX Fuel Fabrication Facility (MOX FFF). However, the amount collected would be dependent on future market prices for uranium, conversion, and enrichment services over the duration of the program as well as the amount of LEU ultimately sold.

**Table 8-1. Projected Revenues from Sale of LEU Derived from Surplus HEU**

| Type of Surplus HEU | Revenues (millions of constant 2000 dollars) |
|---|---|
| Under IAEA Safeguards at Y-12 | 186 |
| Derived from Pits in PDCF | 231 |
| Other Classified Metal | 110 |
| Other Surplus HEU | 233 |
| **Total Projected Revenues** | **760** |

The projected amounts of LEU produced from this program have resulted in concerns within the commercial U.S. uranium production and enrichment industries about the potential effect these LEU sales will have on market prices. In particular, there is concern that soft market prices for uranium and enrichment services will adversely impact the viability of the program to purchase LEU derived from 500 MT of Russian surplus HEU. Whether the LEU sales associated with the program have an adverse material impact on domestic industries is one factor that could potentially affect the ultimate cost and schedule of the program. The current schedule for future U.S. HEU disposition actions already reflects a significant slowing compared to earlier plans, in light of current soft market conditions. The cost projections and schedule cited here assume that no adverse material impacts will be determined.

The projected program cost of $928 million is composed of two major components—$839 million for HEU disposition and $88.5 million for HEU storage. The HEU storage component was not included in the projection issued in the March 2000 Viability Assessment and represents an increase in the program scope. The HEU storage cost has, until this year, been funded by other DOE programs that manage the HEU prior to transferring it to the Office of Fissile Materials Disposition (OFMD). However, beginning in FY 2001, the budget authority for this activity at the primary HEU storage site, the Y-12 Nuclear Security Complex in Oak Ridge, Tennessee, has been transferred to the OFMD. Another significant difference between the two projected life-cycle costs is that there has been a substantial shift from capital cost to operating expense due to a decision to downblend a greater portion of the surplus HEU at commercial facilities rather than DOE facilities.

Although the disposition strategy of the program did not change significantly in the last year, the program scope is considerably smaller than that considered in 1996. At that time, different alternatives for the program scope and cost were analyzed in *Cost Comparison for Highly Enriched Uranium Disposition Alternatives* (Y/ES-122, April 1996). The 1996 projected cost of $1.65 billion covered disposition of 200 MT of HEU, 58 MT more than the current program scope. The 1996 projection assumed that 170 MT of HEU would be dispositioned through downblending and LEU market sales and an additional 30 MT of HEU that has no commercial value would be downblended to LEU and disposed of as low-level radioactive waste.

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# Appendix A. U.S. Plutonium Disposition Project Contingencies by Cost Category

**Table A-1. PDCF Projected Annual Costs (millions of constant 2001 dollars)**

| Cost Category | Total Costs | Sunk Costs | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design and Construction | 477 | 17 | 20 | 41 | 106 | 166 | 127 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Contingency | 157 | - | - | 14 | 36 | 64 | 43 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Operations | 797 | - | - | - | - | - | - | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 7.9 | 7.9 | 7.9 |
| Contingency | 80 | - | - | - | - | - | - | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 0.9 | 0.9 | 0.9 |
| Other | 343 | 90 | 27 | 37 | 30 | 50 | 58 | 49 | 1.5 | - | - | - | - | - | - | - | - | - | - | - | - |
| Contingency | 63 | - | - | - | 10 | 14 | 21 | 19 | 0.5 | - | - | - | - | - | - | - | - | - | - | - | - |
| PDCF Support | 219 | 0.8 | 0.5 | - | 0.8 | 0.8 | 0.8 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | - | - | - |
| Contingency | 22 | - | - | - | - | - | - | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | - | - | - |
| Total PDCF Costs | 2,157 | 108 | 47 | 91 | 182 | 294 | 250 | 167 | 101 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 8.8 | 8.8 | 8.8 |

**Table A-2. MOX Projected Annual Costs (millions of constant 2001 dollars)**

| Cost Category | Total Costs | Sunk Costs | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design and Construction | 929 | 40 | 26 | 62 | 272 | 296 | 167 | 66 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Contingency | 223 | - | - | 3.2 | 56 | 73 | 65 | 27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Operations | 1,257 | - | - | - | - | - | - | 22 | 93 | 89 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 84 | 25 | 20 | 20 |
| Contingency | 170 | - | - | - | - | - | - | 13 | 13 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | - | - | - |
| MOX Fuel Credit | (552) | - | - | - | - | - | - | - | - | (46) | (46) | (46) | (46) | (46) | (46) | (46) | (46) | (46) | (46) | (46) | - | - | - |
| HEU Credit | (231) | - | - | - | - | - | - | - | - | - | - | (29) | (29) | (29) | (29) | (29) | (29) | (29) | (29) | - | - | - | - |
| Other | 537 | 123 | 48 | 59 | 65 | 50 | 88 | 100 | 3.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Contingency | 130 | - | - | 16 | 34 | 30 | 25 | 25 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Total MOX Costs | 2,463 | 164 | 74 | 141 | 426 | 447 | 345 | 254 | 109 | 55 | 57 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 57 | 50 | 25 | 20 | 20 |

**Table A-3. PIP Projected Costs (millions of constant 2001 dollars)**

| Cost Category | Total Costs | Sunk Costs | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design and Construction | 400 | - | 3.0 | 1.9 | 7.3 | 21 | 40 | 62 | 122 | 128 | 15 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Contingency | 115 | - | - | 0.6 | 2.1 | 6.1 | 11 | 18 | 35 | 37 | 4.4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Operations | 566 | - | - | - | - | - | - | - | - | - | - | 28 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 31 | 5.0 | 4.0 |
| Contingency | 57 | - | - | - | - | - | - | - | - | - | - | 2.8 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 3.1 | 0.5 | 0.4 |
| Other | 356 | 101 | 21 | 22 | 24 | 22 | 17 | 10 | 16 | 24 | 64 | 35 | - | - | - | - | - | - | - | - | - | - | - | - |
| Contingency | 41 | - | - | 0.1 | 2.7 | 2.6 | 2.1 | 1.4 | 2.2 | 1.7 | 19 | 9 | - | - | - | - | - | - | - | - | - | - | - | - |
| Total PIP Costs | 1,535 | 101 | 24 | 24 | 36 | 52 | 70 | 91 | 176 | 191 | 103 | 74 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 34 | 5.5 | 4.4 |

**Table A-4. PDSS Projected Annual Costs (millions of constant 2001 dollars)**

| Cost Category | Total Costs | Sunk Costs | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| **Design and Construction** | **69** | - | 4.9 | 11 | 14 | 32 | 7.3 |
| Contingency | **19** | - | - | 3.0 | 3.9 | 9.4 | 2.2 |
| **Operations** | - | | | | | | |
| Contingency | - | | | | | | |
| **Other** | **9.0** | | - | 2.2 | 2.2 | 3.6 | 1.0 |
| Contingency | **0.9** | - | - | 0.2 | 0.2 | 0.4 | 0.1 |
| **Total PDSS Costs** | **97** | - | 5 | 16 | 20 | 45 | 11 |

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# Appendix C. Acronyms

| | |
|---|---|
| DCS | Duke Engineering & Services, COGEMA, Stone & Webster |
| DNFSB | Defense Nuclear Facilities Safety Board |
| DO-CDR | Design Only Conceptual Design Report |
| DOE | Department of Energy |
| DWPF | Defense Waste Processing Facility (at Savannah River Site) |
| EIR | External Independent Review |
| FFTF | Fast-Flux Test Facility |
| G-7 | Group-of-Seven |
| G-8 | Group-of-Eight |
| GT-MHR | Gas Turbine-Modular Helium Reactor |
| HEU | Highly Enriched Uranium |
| ICE | Independent Cost Estimate |
| LCCE | Life-Cycle Cost Estimate |
| LEU | Low-Enriched Uranium |
| LTA | Lead Test Assembly |
| MOX | Mixed Oxide (fuel) |
| MOX FFF | Mixed Oxide Fuel Fabrication Facility |
| MT | Metric Ton |
| NRC | Nuclear Regulatory Commission |
| OECM | Office of Engineering and Construction Management |
| OFMD | Office of Fissile Materials Disposition |
| PDCF | Pit Disassembly and Conversion Facility |
| PDSS | Plutonium Disposition Support Systems |
| PIP | Plutonium Immobilization Project |
| SRS | Savannah River Site |

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# Appendix D. Glossary

**Can-in-Canister:** An approach to plutonium immobilization wherein cans of either ceramic or glass forms containing plutonium are encapsulated within canisters of high-level waste glass.

**Ceramic:** Surplus plutonium and other materials mixed to form a porcelain end product.

**Cesium:** A silver-white alkali metal. A radioactive isotope of cesium, cesium-137, is a common fission product.

**Cladding:** An external layer of material applied directly to nuclear fuel or other material to provide protection from a chemically reactive environment, containment of radioactive products produced during irradiation of the composite, or structural support.

**Commercial Power Reactor:** Privately-owned nuclear reactors used to produce electricity.

**Conversion:** An operation for changing material from one form, use, or purpose to another.

**Decommissioning:** Actions taken at the end of life of a facility to make it suitable for reuse, including surveillance, maintenance, decontamination, and/or dismantlement.

**Decontamination:** The removal of radioactive or chemical contamination from facilities, equipment, or soils by washing, heating, chemical or electrochemical action, mechanical cleaning, or other techniques.

**Design-Only Conceptual Design Report (DO-CDR):** An abbreviated conceptual design report prepared explicitly to support the authorization of design funds for a line item project.

**Disposition:** A process of use or disposal of materials that results in the remaining material being converted to a form that is substantially and inherently more proliferation-resistant than the original form.

**Fissile Material:** Plutonium-239, plutonium-241, uranium-233, uranium-235, or any material containing any of the foregoing.

**Geologic Repository:** A repository meeting the specifications of the Nuclear Waste Policy Act, as amended, for the disposal of high-level nuclear waste and spent nuclear fuel. The waste is isolated by placement in a continuous, stable geologic formation at depths greater than 300 meters (984 feet).

**Glovebox:** An airtight box used to work with hazardous material. It is vented to a closed filtering system, and has gloves attached inside to protect the worker.

**Highly Enriched Uranium (HEU):** Uranium enriched in the isotope uranium-235 to 20 percent or above, which thus becomes suitable for weapons use.

**Immobilization:** A process by which plutonium is converted to a chemically stable form for disposal.

**Irradiate:** To expose to ionizing radiation, usually in a nuclear reactor.

**Lead Assembly (LA):** A nuclear fuel assembly that is inserted in a reactor core to confirm its performance.

**Lead Test Assembly (LTA):** A lead assembly intended for performance tests which require destructive evaluation after irradiation.

**Low-Enriched Uranium (LEU):** Uranium enriched in the isotopic content of uranium-235 (greater than 0.7 percent but less than 20 percent of the total mass) for use as light water reactor fuel. Naturally occurring uranium contains only about 0.7 percent uranium-235, and almost all the rest is uranium-238.

**Mixed Oxide (MOX):** A physical blend of uranium oxide and plutonium oxide.

**Pit:** The core element of a nuclear weapon's "primary" or fission component. Pits are made of plutonium-239 surrounded by some type of casing.

**Plutonium:** A heavy, radioactive, metallic element with the atomic number 94. It is produced artificially in a reactor by the bombardment of uranium with neutrons and is used in the production of nuclear weapons. Plutonium has 15 isotopes with mass numbers ranging from 232 to 246. Weapons-usable plutonium consists mainly of Plutonium 239, which has a radiological half-life of 24,110 years.

**Spent Nuclear Fuel:** Irradiated reactor fuel that is no longer useful as fuel.

**Surplus Material:** Nuclear material that has no government use.

**Unsuitable for Reactor Use:** Plutonium that will not be used by this program as feed for the MOX FFF because it is not weapons-grade material due to its isotopic composition or would require excessive processing due to its chemical composition.

**Vitrification:** A process by which glass (for example, borosilicate glass) is used to encapsulate or immobilize radioactive wastes.

**Weapons-Grade:** Plutonium with a plutonium-240 concentration less than 7%.