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# REPORT ON PHASE III REMEDIAL ACTION PLAN
# FORMER MALDEN MGP SITE - UPLAND PORTION
# MALDEN, MASSACHUSETTS
# RTN 3-0362
# TIER IB PERMIT 7378

**VOLUME III OF III**



by

**Haley & Aldrich, Inc.**
**Boston, Massachusetts**

for

**Massachusetts Electric Company**
**Northborough, Massachusetts**

**File No. 06558-634**
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## APPENDIX D

## Cost Estimate Tables and Supporting Calculations

TABLE D-1
COST ESTIMATE
ALTERNATIVE 1-1
EXCAVATION OF DNAPL, LNAPL, TSM AND PETROLEUM IMPACTED SOIL, SHALLOW DNAPL MIGRATION CONTROL AND AUL
AREA 1

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 100,000 | $ 100,000 | Unit price is combined mobilization for excavation and barrier installation |
| EXCAVATION OF TSM | | | | | |
| Excavation of Clean Soil | CY | 3,725 | $ 15 | $ 55,875 | Based on engineer's experience; 1,900 cy, 12' deep excavation, top 6' of soil not impacted |
| Excavation of Impacted Soil | CY | 3,725 | $ 30 | $ 111,750 | Based on engineer's experience for limited production/handling; assume enclosure required and level B PPE |
| Clean Off-site Borrow, placed, compacted | CY | 3,725 | $ 20 | $ 74,500 | Based on engineer's experience |
| Re-use Clean soil, placed, compacted | CY | 3,725 | $ 10 | $ 37,250 | Based on engineer's experience |
| Temporary Dewatering | DAY | 35 | $ 500 | $ 17,500 | Based on engineer's experience |
| Water Treatment | GAL | 175,000 | $ 0.2 | $ 35,000 | assume 10,000 gallons/day; unit cost based on engineer's experience |
| Sprung Structure | LS | 1 | $ 130,000 | $ 130,000 | Based on engineer's experience |
| Sprung Structure-relocation | EA | 3 | $ 9,630 | $ 28,890 | Means crew B-69; assume 3 crew-days per move |
| Shoring | SF | 15,000 | $ 15.10 | $ 226,500 | Means 02250-400-1200; 15' deep excavation 20' long sheets |
| Soil T&D (Thermal Desorption), benzene Haz. | TON | 1,192 | $ 90 | $ 107,280 | Based on recent contractor (ESMI) quote; assume 20% of total volume |
| Soil T&D (Thermal Desorption), Non-Haz. | TON | 4,470 | $ 65 | $ 290,550 | Based on recent contractor (ESMI) quote; assume 75% of total volume |
| Soil T&D, benzene & Pb, Haz. | TON | 298 | $ 350 | $ 104,300 | Based on engineer's experience; assume 5% of total volume |
| Replace monitoring wells | EA | 4 | $ 1,000 | $ 4,000 | Based on engineer's experience |
| Repaving | SY | 1,900 | $ 23.61 | $ 44,859 | Means 18 02 0301; Asphalt pavement |
| | | | Subtotal | $ 1,268,254 | |
| EXCAVATION OF PETROLEUM IMPACTED SOIL | | | | | |
| Excavation of Impacted Soil | CY | 12,800 | $ 25 | $ 320,000 | Based on engineer's experience; 3,200 cy, 12' deep excavation |
| Clean Off-site Borrow, placed, compacted | CY | 12,800 | $ 20 | $ 256,000 | Based on engineer's experience |
| Temporary Dewatering | DAY | 35 | $ 500 | $ 17,500 | Based on engineer's experience |
| Water Treatment | GAL | 175,000 | $ 0.2 | $ 35,000 | assume 10,000 gallons/day; unit cost based on engineer's experience |
| Shoring | SF | 14,000 | $ 15.10 | $ 211,400 | Means 02250-400-1200; 15' deep excavation; 20' long sheets |
| Soil T&D (Thermal Desorption), Non-Haz. | TON | 19,456 | $ 65 | $ 1,264,640 | Based on recent contractor (ESMI) quote; assume 95% of total volume |
| Soil T&D, benzene & Pb, Haz. | TON | 1,024 | $ 350 | $ 358,400 | Based on engineer's experience; assume 5% of total volume |
| Maintenance garage demolition and disposal | LS | 1 | $ 40,000 | $ 40,000 | Based on engineer's experience |
| Repaving | SY | 3,200 | $ 23.61 | $ 75,552 | Means 18 02 0301; Asphalt pavement |
| | | | Subtotal | $ 2,578,492 | |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 800 | $ 65 | $ 52,000 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| | | | Subtotal | $ 52,000 | |
| | Capital Subtotal (not including engineering) | | | $ 3,998,746 | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 119,962 | $ 119,962 | Assume 3% of capital costs |
| Engineering Oversight | WEEK | 20 | $ 7,000 | $ 140,000 | Assume 20 weeks construction |
| | | | Subtotal Engineering | $ 259,962 | |
| | | | Subtotal | $ 4,258,708 | |
| | | | Contingency (15%) | $ 638,806 | |
| | | | Total Estimated Capital for 1-1: | $ 4,897,515 | |
| DNAPL MONITORING | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ 1,500 | Based on current H&A costs |
| | | | Subtotal Estimated Annual Monitoring | $ 1,500 | |
| | | | Contingency (15%) | $ 225 | |
| | | | Total Estimated Annual Monitoring | $ 1,725 | |
| | | | Net Present Value | $ 25,699 | Assume 30 years monitoring |
| | | | Net Present Value Project Cost | $ 4,923,214 | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Soil weight equals 1.6 tons per cubic yard.
3. Net Present Value based on 5% interest, 0% inflation.

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TABLE D-2
COST ESTIMATE
ALTERNATIVE 1-2
EXCAVATION OF DNAPL, IN-SITU CHEMICAL OXIDATION OF PETROLEUM IMPACTED SOIL, SHALLOW DNAPL MIGRATION CONTROL AND AUL
AREA 1

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 100,000 | $ 100,000 | Unit price is combined mobilization for excavation, chemical oxidation and barrier installation |
| EXCAVATION OF TSM | | | | | |
| Excavation of Clean Soil | CY | 3,725 | $ 15 | $ 55,875 | Based on engineer's experience; 1,900 cy, 12' deep excavation, top 6' of soil not impacted |
| Excavation of Impacted Soil | CY | 3,725 | $ 30 | $ 111,750 | Based on engineer's experience for limited production/handling; assume enclosure required and level B PPE |
| Clean Off-site Borrow, placed, compacted | CY | 3,725 | $ 20 | $ 74,500 | Based on engineer's experience |
| Re-use Clean soil, placed, compacted | CY | 3,725 | $ 10 | $ 37,250 | Based on engineer's experience |
| Temporary Dewatering | DAY | 35 | $ 500 | $ 17,500 | Based on engineer's experience |
| Water Treatment | GAL | 175,000 | $ 0.2 | $ 35,000 | assume 10,000 gallons/day; unit cost based on engineer's experience |
| Sprung Structure | LS | 1 | $ 130,000 | $ 130,000 | Based on engineer's experience |
| Sprung Structure-relocation | EA | 3 | $ 9,630 | $ 28,890 | Means crew B-69; assume 3 crew-days per move |
| Shoring | SF | 15,000 | $ 15.10 | $ 226,500 | Means 02250-400-1200; 15' deep excavation; 20' long sheets |
| Soil T&D (Thermal Desorption), benzene Haz. | TON | 1,192 | $ 90 | $ 107,280 | Based on recent contractor (ESMI) quote; assume 20% of total volume |
| Soil T&D (Thermal Desorption), Non-Haz. | TON | 4,470 | $ 65 | $ 290,550 | Based on recent contractor (ESMI) quote; assume 75% of total volume |
| Soil T&D, benzene & Pb, Haz. | TON | 298 | $ 350 | $ 104,300 | Based on engineer's experience; assume 5% of total volume |
| Replace monitoring wells | EA | 4 | $ 1,000 | $ 4,000 | Based on engineer's experience |
| Repaving | SY | 1,900 | $ 23.61 | $ 44,859 | Means 18 02 0301; Asphalt pavement |
| | | | **Subtotal** | **$ 1,288,254** | |
| CHEMICAL OXIDATION IN PETROLEUM IMPACTED SOIL | | | | | |
| Pilot Test | LS | 1 | $ 75,000 | $ 75,000 | Based on engineer's experience |
| Injection Well Installation | EA | 95 | $ 600 | $ 57,000 | Based on engineer's experience; wells spaced 20' on center |
| Hydrogen Peroxide Releasing Compound and Catalyst | GAL | 47500 | $ 3.15 | $ 149,625 | Based on engineer's experience; based on 3 injections/well; total volume 500 gal/well |
| Equipment and injection labor | LS | 1 | $ - | $ 112,219 | Based on engineer's experience; 75% of oxidant cost |
| Monitoring & Data Interpretation | LS | 1 | $ - | $ 60,000 | Based on engineer's experience |
| | | | **Subtotal** | **$ 318,844** | |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 800 | $ 65 | $ 52,000 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| | | | **Subtotal** | **$ 52,000** | |
| | **Capital Subtotal (not including engineering)** | | | **$ 1,739,098** | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 86,955 | $ 86,955 | Assume 3% of capital costs |
| Engineering Oversight | WEEK | 10 | $ 7,000 | $ 70,000 | Assume 10 weeks construction |
| | | | **Subtotal Engineering** | **$ 156,955** | |
| | | | Subtotal | $ 1,896,053 | |
| | | | Contingency (15%) | $ 284,408 | |
| | | | **Total Estimated Capital for 1-2:** | **$ 2,180,461** | |
| DNAPL MONITORING | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ 1,500 | Based on current H&A costs |
| | | | Subtotal Estimated Annual Monitoring | $ 1,500 | |
| | | | Contingency (15%) | $ 225 | |
| | | | **Total Estimated Annual Monitoring** | **$ 1,725** | |
| | | | **Net Present Value** | **$ 24,797** | Assume 30 years monitoring |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,500 | $ 2,500 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 2,500 | |
| | | | Contingency (15%) | $ 375 | |
| | | | **Total Estimated Annual Maintenance** | **$ 2,875** | |
| | | | **Net Present Value** | **$ 44,196** | Assume 30 years |
| | | | **Net Present Value Project Cost** | **$ 2,249,454** | |

Notes:
1 Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2 Soil weight equals 1.6 tons per cubic yard.
3 Net Present Value based on 5% interest, 0% inflation.

TABLE D-3
COST ESTIMATE
ALTERNATIVE 1-3
ENGINEERED BARRIER, SHALLOW DNAPL RECOVERY, SHALLOW DNAPL MIGRATION, AUL
AREA 1

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 100,000 | $ 100,000 | Unit price is combined mobilization for eng. barrier, DNAPL recovery and barrier installation |
| ENGINEERED BARRIER INSTALLATION (PETROLEUM AREA) | | | | | |
| Excavation of impacted soils | CY | 6,000 | $ 25 | $ 150,000 | Based on engineer's experience |
| BARRIER COMPONENTS | | | | | |
| Asphalt paving | SY | 23.61 | $ 3,200 | $ 75,552 | Means 18 02 0301; Asphalt pavement |
| 12" Sand | CY | 1,700 | $ 20 | $ 34,000 | Based on engineer's experience |
| Stenciled geotextile fabric | SY | 5,100 | $ 1.05 | $ 5,355 | Means 33 08 0531 |
| 12" Sand | CY | 1,700 | $ 20 | $ 34,000 | Based on engineer's experience |
| Geo-composite drainage layer | SF | 45,900 | $ 1.12 | $ 51,408 | Means 33 08 0532 |
| 60 mil HDPE | SF | 45,900 | $ 1.94 | $ 89,046 | Means 33 08 0572 |
| 12" Sand | CY | 1,700 | $ 20 | $ 34,000 | Based on engineer's experience |
| Soil T&D (Thermal Desorption), Non-haz. | TON | 9,600 | $ 65 | $ 624,000 | Based on recent contractor (ESMI) quote; assume 100% material treated by off-site thermal desorption |
| Maintenance garage demolition and disposal | LS | 1 | $ 40,000 | $ 40,000 | Based on engineer's experience; assume no hazardous materials |
| | | | Subtotal | $ 1,137,361 | |
| SHALLOW DNAPL RECOVERY (TSM) | | | | | |
| Recovery Well Installation | EA | 5 | $ 5,000 | $ 25,000 | Based on engineer's experience; stainless steel screen, 8" diameter 10-18 feet deep |
| Well Vault | EA | 5 | $ 2,000 | $ 10,000 | Based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 300 | $ 21.01 | $ 6,303 | Means 33 26 0821; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Based on engineer's experience for 200 gallon tank |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Based on engineer's experience |
| Pumps | EA | 5 | $ 5,000 | $ 25,000 | Based on engineer's experience |
| | | | Subtotal | $ 98,503 | |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 800 | $ 65 | $ 52,000 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| | | | Subtotal | $ 52,000 | |
| | Capital Subtotal (not including engineering) | | | $ 1,387,864 | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 138,786 | $ 138,786 | Assume 10% of capital costs |
| Engineering Oversight | WEEK | 12 | $ 7,000 | $ 84,000 | |
| | | | Subtotal Engineering | $ 222,786 | |
| | | | Subtotal | $ 1,610,650 | |
| | | | Contingency (15%) | $ 241,598 | |
| | | | Total Estimated Capital for 1-3: | $ 1,852,248 | |
| OPERATION AND MAINTENANCE (DNAPL Recovery) | | | | | |
| DNAPL Disposal (Assume 35 gal/mo) | GAL | 35 | $ 7 | $ 245 | Based on current H&A costs |
| Maintenance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | | Subtotal Estimated Monthly O&M | $ 2,245 | |
| | | | Contingency (15%) | $ 337 | |
| | | | Total Estimated O&M | $ 2,582 | |
| | | | Total Estimated Annual O&M | $ 30,981 | |
| | | | Net Present Value | $ 179,268 | Assume 7 years to remove DNAPL |
| DNAPL MONITORING | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ 1,500 | Based on current H&A costs |
| | | | Subtotal Estimated Annual Monitoring | $ 1,500 | |
| | | | Contingency (15%) | $ 225 | |
| | | | Total Estimated Annual Monitoring | $ 1,725 | |
| | | | Net Present Value | $ 26,517 | Assume 30 years monitoring |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,500 | $ 2,500 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 2,500 | |
| | | | Contingency (15%) | $ 375 | |
| | | | Total Estimated Annual Maintenance | $ 2,875 | |
| | | | Net Present Value | $ 44,196 | Assume 30 years |
| | | | Net Present Value Project Cost | $ 2,102,229 | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Soil weight equals 1.6 tons per cubic yard.
3. Net Present Value based on 5% interest, 0% inflation.

TABLE D-4
COST ESTIMATE
ALTERNATIVE 1-4
SHALLOW DNAPL RECOVERY, SHALLOW DNAPL MIGRATION, IN-SITU CHEMICAL OXIDATION OF TSM AND PETROLEUM IMPACTED SOILS, AUL
AREA 1

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 75,000 | $ 75,000 | Unit price is combined mobilization for DNAPL recovery system, chemical oxidation and sheeting installation |
| SHALLOW DNAPL RECOVERY (IN TSM) | | | | | |
| Recovery Well Installation | EA | 5 | $ 5,000 | $ 25,000 | Unit cost based on engineer's experience; stainless steel screen, 6" diameter 10-18 feet deep |
| Well Vault | EA | 5 | $ 2,000 | $ 10,000 | Unit cost based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 300 | $ 21.01 | $ 6,303 | Means 33 26 0621; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Unit cost based on engineer's experience for 200 gallon tank |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Unit cost based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Unit cost based on engineer's experience |
| Pumps | EA | 5 | $ 5,000 | $ 25,000 | Unit cost based on engineer's experience |
| | | | **Subtotal** | **$ 98,503** | |
| CHEMICAL OXIDATION (TSM & PETROLEUM AREA) | | | | | |
| Pilot Test | LS | 1 | $ 75,000 | $ 75,000 | Based on engineer's experience |
| Injection Well Installation | EA | 150 | $ 600 | $ 90,000 | Based on engineer's experience; wells spaced 20' on center |
| Hydrogen Peroxide Releasing Compound and Catalyst | GAL | 75000 | $ 3.15 | $ 236,250 | Based on engineer's experience; based on 3 injections/well; total volume 500 gal/well |
| Equipment and Injection labor | LS | 1 | $ - | $ 177,188 | Based on engineer's experience; 75% of oxidant cost |
| Monitoring & Data Interpretation | LS | 1 | $ - | $ 60,000 | Based on engineer's experience |
| | | | **Subtotal** | **$ 638,438** | |
| | | | **Net Present Value** | **$ 432,120** | Assume implemented in year 8 |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 800 | $ 65 | $ 52,000 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| | | | **Subtotal** | **$ 52,000** | |
| | | **Capital Subtotal (not including engineering)** | | **$ 657,623** | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 85,000 | $ 85,000 | Assume MCP Compliance $30k, Design $55k |
| Engineering Oversight | WEEK | 10 | $ 7,000 | $ 70,000 | |
| | | | Subtotal Engineering | $ 155,000 | |
| | | | Subtotal | $ 812,623 | |
| | | | Contingency (15%) | $ 121,893 | |
| | | **Total Estimated Capital for 1-4:** | | **$ 934,516** | |
| OPERATION AND MAINTENANCE (DNAPL Recovery) | | | | | |
| DNAPL Disposal (Assume 35 gal/mo) | GAL | 35 | $ 7 | $ 245 | Based on current H&A costs |
| Maintenance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | Subtotal Estimated Monthly O&M | | $ 2,245 | |
| | | | Contingency (15%) | $ 337 | |
| | | | Total Estimated O&M | $ 2,582 | |
| | | **Total Estimated Annual O&M** | | **$ 30,981** | |
| | | | **Net Present Value** | **$ 179,258** | Assume 7 years to remove DNAPL |
| DNAPL MONITORING | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ 1,500 | Based on current H&A costs |
| | | Subtotal Estimated Annual Monitoring | | $ 1,500 | |
| | | | Contingency (15%) | $ 225 | |
| | | **Total Estimated Annual Monitoring** | | **$ 1,725** | |
| | | | **Net Present Value** | **$ 26,517** | Assume 30 years monitoring |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,500 | $ 2,500 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | Subtotal Estimated Annual Maintenance | | $ 2,500 | |
| | | | Contingency (15%) | $ 375 | |
| | | **Total Estimated Annual Maintenance** | | **$ 2,875** | |
| | | | **Net Present Value** | **$ 44,196** | Assume 30 years |
| | | **Net Present Value Project Cost** | | **$ 1,140,301** | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation

6/27/2003

TABLE D-5
COST ESTIMATE
ALTERNATIVE 1-5
SHALLOW DNAPL RECOVERY, SHALLOW DNAPL MIGRATION, AULS
AREA 1

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 50,000 | $ 50,000 | Unit price is combined mobilization for DNAPL recovery system and sheeting installation |
| SHALLOW DNAPL RECOVERY (IN TSM) | | | | | |
| Recovery Well Installation | EA | 5 | $ 5,000 | $ 25,000 | Unit cost based on engineer's experience; stainless steel screen, 8" diameter 10-18 feet deep |
| Well Vault | EA | 5 | $ 2,000 | $ 10,000 | Unit cost based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 300 | $ 21.01 | $ 6,303 | Means 33 26 0621; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Unit cost based on engineer's experience for 200 gallon tank |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Unit cost based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Unit cost based on engineer's experience |
| Pumps | EA | 5 | $ 5,000 | $ 25,000 | Unit cost based on engineer's experience |
| | | | Subtotal | $ 98,503 | |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 800 | $ 65 | $ 52,000 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| | | | Subtotal | $ 52,000 | |
| | Capital Subtotal (not including engineering) | | | $ 200,503 | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 65,000 | $ 65,000 | Assume MCP compliance $30k, Design $35k |
| Engineering Oversight | WEEK | 4 | $ 7,000 | $ 28,000 | |
| | | | Subtotal Engineering | $ 93,000 | |
| | | | Subtotal | $ 293,503 | |
| | | | Contingency (15%) | $ 44,025 | |
| | | | Total Estimated Capital for 1-5: | $ 337,528 | |
| OPERATION AND MAINTENANCE (DNAPL Recovery) | | | | | |
| DNAPL Disposal (Assume 35 gal/mo) | GAL | 35 | $ 7 | $ 245 | Based on current H&A costs |
| Maintenance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | | Subtotal Estimated Monthly O&M | $ 2,245 | |
| | | | Contingency (15%) | $ 337 | |
| | | | Total Estimated O&M | $ 2,582 | |
| | | | Total Estimated Annual O&M | $ 30,981 | |
| | | | Net Present Value | $ 134,132 | Assume 5 years to remove DNAPL |
| DNAPL MONITORING | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ 1,500 | Based on current H&A costs |
| | | | Subtotal Estimated Annual Monitoring | $ 1,500 | |
| | | | Contingency (15%) | $ 225 | |
| | | | Total Estimated Annual Monitoring | $ 1,725 | |
| | | | Net Present Value | $ 26,517 | Assume 30 years monitoring |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,500 | $ 2,500 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 2,500 | |
| | | | Contingency (15%) | $ 375 | |
| | | | Total Estimated Annual Maintenance | $ 2,875 | |
| | | | Net Present Value | $ 44,196 | Assume 30 years |
| | | | Net Present Value Project Cost | $ 542,373 | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-6
COST ESTIMATE
ALTERNATIVE 1-6
LNAPL and Deep DNAPL Monitoring, AULs
AREA 1

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|---|
| ENGINEERING | | | | | | |
| MCP compliance | LS | 1 | $ 30,000 | $ | 30,000 | |
| | | | **Subtotal Engineering** | **$** | **30,000** | |
| | | | Subtotal | $ | 30,000 | |
| | | | Contingency (15%) | $ | 4,500 | |
| | | | **Total Estimated Capital for 1-6:** | **$** | **34,500** | |
| DNAPL MONITORING | | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ | 1,500 | Based on current H&A costs |
| | | | Subtotal Estimated Annual Monitoring | $ | 1,500 | |
| | | | Contingency (15%) | $ | 225 | |
| | | | **Total Estimated Annual Monitoring** | **$** | **1,725** | |
| | | | **Net Present Value** | **$** | **26,517** | Assume 30 years monitoring |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,500 | $ | 2,500 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance eve |
| | | | Subtotal Estimated Annual Maintenance | $ | 2,500 | |
| | | | Contingency (15%) | $ | 375 | |
| | | | **Total Estimated Annual Maintenance** | **$** | **2,875** | |
| | | | **Net Present Value** | **$** | **44,196** | Assume 30 years |
| | | | **Net Present Value Project Cost** | **$** | **105,213** | |

Notes:

1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-7
COST ESTIMATE
ALTERNATIVE 2-1
SHALLOW AND DEEP DNAPL RECOVERY, LNAPL EXTRACTION USING MPE, IN-SITU CHEMICAL OXIDATION OF TSM AND LNAPL SOILS,
DNAPL MIGRATION CONTROL, AUL
AREA 2

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 150,000 | $ 150,000 | Unit price is combined mobilization for DNAPL recovery system, MPE, chemical oxidation and sheeting installation |
| SHALLOW AND DEEP DNAPL RECOVERY | | | | | |
| Recovery Well Installation | EA | 13 | $ 5,000 | $ 65,000 | Based on engineer's experience; stainless steel screen, 8" diameter 10-18 feet deep |
| Well Vault | EA | 13 | $ 2,000 | $ 26,000 | Based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 750 | $ 21.01 | $ 15,758 | Means 33 26 0621; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Based on engineer's experience for 200 gallon tank |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Based on engineer's experience |
| Pumps | EA | 13 | $ 5,000 | $ 65,000 | Based on engineer's experience |
| | | | Subtotal | $ 203,958 | |
| MPE SYSTEM INSTALLATION (LNAPL AREA) | | | | | |
| Well Installation (12 MPE Wells) | EA | 12 | $ 1,500 | $ 18,000 | Based on engineer's experience; 20' radius of influence |
| Well Head (MPE) | EA | 12 | $ 500 | $ 6,000 | Unit cost based on engineer's experience |
| Well Vault (MPE) | EA | 12 | $ 2,000 | $ 24,000 | Based on engineer's experience |
| Distribution Pipe Installation (trench, pipe, bedding) | LF | 300 | $ 41.23 | $ 12,369 | Means 33 26 0624; 4", 6" double-wall piping with fittings |
| Multiphase skid 50 HP blower | EA | 1 | $ 60,000 | $ 60,000 | Unit cost based on engineer's experience |
| Electrical | LS | 1 | $ 15,000 | $ 15,000 | Unit cost based on engineer's experience |
| Oil/Water Separator | LS | 1 | $ 13,717 | $ 13,717 | Means 19 04 0412; 50 GPM |
| Catalytic Oxidizer for vapor treatment | EA | 1 | $ 30,000 | $ 30,000 | Unit cost based on engineer's experience |
| Treatment Enclosure | LS | 1 | $ 26,135 | $ 26,135 | Means 33 43 0108; 20' x 20', heated, insulated |
| RTU/Controls | LS | 1 | $ 5,000 | $ 5,000 | Unit cost based on engineer's experience |
| Filter Housings | EA | 2 | $ 1,500 | $ 3,000 | Unit cost based on engineer's experience |
| Liquid GAC vessels | EA | 2 | $ 5,000 | $ 10,000 | Unit cost based on engineer's experience; 2 x 500 lb vessels |
| MPE skid shipping/set-up | LS | 1 | $ 15,000 | $ 15,000 | Unit cost based on engineer's experience |
| System assembly | LS | 1 | $ 30,000 | $ 30,000 | Unit cost based on engineer's experience |
| | | | Subtotal | $ 268,221 | |
| CHEMICAL OXIDATION (TSM & LNAPL AREA) | | | | | |
| Pilot Test | LS | 1 | $ 75,000 | $ 75,000 | Based on engineer's experience |
| Injection Well Installation | EA | 245 | $ 600 | $ 147,000 | Based on engineer's experience; wells spaced 20' on center |
| Hydrogen Peroxide Releasing Compound and Catalyst | GAL | 122500 | $ 3.15 | $ 385,875 | Based on engineer's experience; based on 3 injections/well |
| Equipment and injection labor | LS | 1 | $ - | $ 289,406 | Based on engineer's experience; 75% of oxidant cost |
| Monitoring & Data Interpretation | LS | 1 | $ - | $ 60,000 | Based on engineer's experience |
| | | | Subtotal | $ 957,281 | |
| | | | Net Present Value | $ 559,703 | Assume implemented in year 11 |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 1050 | $ 65 | $ 68,250 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| Chemical Grouting beneath culvert | CF | 300 | $ 138 | $ 41,400 | Means 02250 050 0400 |
| | | | Subtotal | $ 109,650 | |
| | Capital Subtotal (not including engineering) | | | $ 1,291,531 | |

TABLE D-7
COST ESTIMATE
ALTERNATIVE 2-1
SHALLOW AND DEEP DNAPL RECOVERY, LNAPL EXTRACTION USING MPE, IN-SITU CHEMICAL OXIDATION OF TSM AND LNAPL SOILS,
DNAPL MIGRATION CONTROL, AUL
AREA 2

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| **ENGINEERING** | | | | | |
| Design/MCP Compliance | LS | 1 | $ 129,153 | $ 129,153 | Assume 10% of capital costs |
| Engineering Oversight | WEEK | 20 | $ 7,000 | $ 140,000 | |
| | | | **Subtotal Engineering** | **$ 269,153** | |
| | | | Subtotal | $ 1,560,684 | |
| | | | Contingency (15%) | $ 234,103 | |
| | | | **Total Estimated Capital for 2-1:** | **$ 1,794,787** | |
| **OPERATION AND MAINTENANCE (DNAPL Recovery)** | | | | | |
| DNAPL Disposal (Assume 90 gal/mo) | GAL | 90 | $ 7 | $ 630 | Based on current H&A costs |
| Maintenance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | | Subtotal Estimated Monthly O&M | $ 2,630 | |
| | | | Contingency (15%) | $ 395 | |
| | | | Total Estimated O&M | $ 3,025 | |
| | | | Total Estimated Annual O&M | $ 36,294 | |
| | | | **Net Present Value** | **$ 280,253** | Assume 10 years to remove DNAPL |
| **OPERATION AND MAINTENANCE (MPE)** | | | | | |
| Electrical | KWH | 25000 | $ 0.15 | $ 3,750 | Based on engineer's experience |
| Labor | HR | 20 | $ 80 | $ 1,600 | Based on current H&A costs |
| LNAPL Disposal (Assume 25 gal/mo) | GAL | 25 | $ 7 | $ 175 | Based on engineer's experience |
| Misc. Expenses (pump maint/waste disposal/etc) | LS | 1 | $ 500 | $ 500 | Based on engineer's experience |
| Natural gas consumption | LS | 1 | $ 200 | $ 200 | Based on engineer's experience |
| Liquid Treatment | | | | | |
| Carbon Change-out | MO | 1 | $ 4,000 | $ 4,000 | Based on engineer's experience |
| Bag filters | EA | 2 | $ 1 | $ 2 | Based on engineer's experience |
| | | | Subtotal Estimated Monthly O&M | $ 10,227 | |
| | | | Contingency (15%) | $ 1,534 | |
| | | | Total Estimated O&M | $ 11,761 | |
| | | | Total Estimated Annual O&M | $ 141,133 | |
| | | | **Net Present Value** | **$ 262,423** | Assume 2 years to remove LNAPL |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 3,000 | $ 3,000 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 3,000 | |
| | | | Contingency (15%) | $ 450 | |
| | | | Total Estimated Annual Maintenance | $ [illegible] | |
| | | | **Net Present Value** | **$ 53,035** | Assume 30 years |
| | | | **Net Present Value Project Cost** | **$ 2,390,498** | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-8
COST ESTIMATE
ALTERNATIVE 2-2
SHALLOW AND DNAPL RECOVERY, LNAPL EXTRACTION, SHALLOW DNAPL MIGRATION, AUL
AREA 2

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 70,000 | $ 70,000 | Unit price is combined mobilization for DNAPL/LNAPL recovery system and sheeting installation |
| SHALLOW DNAPL RECOVERY | | | | | |
| Recovery Well Installation | EA | 13 | $ 5,000 | $ 65,000 | Based on engineer's experience; stainless steel screen, 8" diameter 10-18 feet deep |
| Well Vault | EA | 13 | $ 2,000 | $ 26,000 | Based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 750 | $ 21.01 | $ 15,758 | Means 33 28 0821; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Based on engineer's experience for 200 gallon tank |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Based on engineer's experience |
| Pumps | EA | 13 | $ 5,000 | $ 65,000 | Based on engineer's experience |
| | | | Subtotal | $ 203,958 | |
| LNAPL RECOVERY | | | | | |
| Recovery Well Installation | EA | 6 | $ 2,500 | $ 15,000 | Based on engineer's experience; stainless steel screen, 8" diameter 10-18 feet deep |
| Well Vault | EA | 6 | $ 2,000 | $ 12,000 | Based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 300 | $ 21.01 | $ 6,303 | Means 33 28 0821; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Based on engineer's experience for 200 gallon tank |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Based on engineer's experience |
| Pumps | EA | 13 | $ 5,000 | $ 65,000 | Based on engineer's experience |
| | | | Subtotal | $ 130,503 | |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 1050 | $ 65 | $ 68,250 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| Chemical Grouting beneath culvert | CF | 300 | $ 138 | $ 41,400 | Means 02250 050 0400 |
| | | | Subtotal | $ 109,650 | |
| | Capital Subtotal (not including engineering) | | | $ 514,111 | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 100,000 | $ 100,000 | Assume MCP compliance $30k, Design $70k |
| Engineering Oversight | WEEK | 11 | $ 7,000 | $ 77,000 | |
| | | | Subtotal Engineering | $ 177,000 | |
| | | | Subtotal | $ 691,111 | |
| | | | Contingency (15%) | $ 103,667 | |
| | | | Total Estimated Capital for 2-2: | $ 794,777 | |
| OPERATION AND MAINTENANCE (DNAPL Recovery) | | | | | |
| DNAPL Disposal (Assume 90 gal/mo) | GAL | 90 | $ 7 | $ 630 | Based on current H&A costs |
| Maintenance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | | Subtotal Estimated Monthly O&M | $ 2,630 | |
| | | | Contingency (15%) | $ 395 | |
| | | | Total Estimated O&M | $ 3,025 | |
| | | | Total Estimated Annual O&M | $ 36,294 | |
| | | | Net Present Value | $ 280,253 | Assume 10 years to remove DNAPL |
| OPERATION AND MAINTENANCE (LNAPL Recovery) | | | | | |
| LNAPL Disposal (Assume 25 gal/mo) | GAL | 25 | $ 7 | $ 175 | Based on current H&A costs |
| Maintenance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | | Subtotal Estimated Monthly O&M | $ 2,175 | |
| | | | Contingency (15%) | $ 326 | |
| | | | Total Estimated O&M | $ 2,501 | |
| | | | Total Estimated Annual O&M | $ 30,015 | |
| | | | Net Present Value | $ 152,347 | Assume 6 years to remove LNAPL |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 3,000 | $ 3,000 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 3,000 | |
| | | | Contingency (15%) | $ 450 | |
| | | | Total Estimated Annual Maintenance | $ 3,450 | |
| | | | Net Present Value | $ 53,035 | Assume 30 years |
| | | | Net Present Value Project Cost | $ 1,280,412 | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-9
COST ESTIMATE
ALTERNATIVE 2-3
LNAPL and DNAPL Monitoring, AULs
AREA 2

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| ENGINEERING | | | | | |
| MCP compliance | LS | 1 | $ 30,000 | $ 30,000 | |
| | | | **Subtotal Engineering** | $ 30,000 | |
| | | | Subtotal | $ 30,000 | |
| | | | Contingency (15%) | $ 4,500 | |
| | | | **Total Estimated Capital for 1-5:** | $ 34,500 | |
| DNAPL MONITORING | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ 1,500 | Based on current H&A costs |
| | | | Subtotal Estimated Annual Monitoring | $ 1,500 | |
| | | | Contingency (15%) | $ 225 | |
| | | | **Total Estimated Annual Monitoring** | $ 1,725 | |
| | | | **Net Present Value** | $ 26,517 | Assume 30 years monitoring |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 3,000 | $ 3,000 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 3,000 | |
| | | | Contingency (15%) | $ 450 | |
| | | | **Total Estimated Annual Maintenance** | $ 3,450 | |
| | | | **Net Present Value** | $ 53,035 | Assume 30 years |
| | | | **Net Present Value Project Cost** | $ 114,052 | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-10
COST ESTIMATE
ALTERNATIVE 3-1
SHALLOW DNAPL RECOVERY, IN-SITU CHEMICAL OXIDATION OF TSM SOIL, SHALLOW DNAPL MIGRATION, AUL
AREA 3

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 100,000 | $ 100,000 | Unit price is combined mobilization for DNAPL recovery system, chemical oxidation and sheeting installation |
| SHALLOW DNAPL RECOVERY | | | | | |
| Recovery Well Installation | EA | 12 | $ 5,000 | $ 60,000 | Based on engineer's experience; stainless steel screen, 8" diameter 10-18 feet deep |
| Well Vault | EA | 12 | $ 2,000 | $ 24,000 | Based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 300 | $ 21.01 | $ 6,303 | Means 33 26 0621; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Based on engineer's experience for 200 gallon tank |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Based on engineer's experience |
| Pumps | EA | 12 | $ 5,000 | $ 60,000 | Based on engineer's experience |
| | | | **Subtotal** | **$ 182,503** | |
| CHEMICAL OXIDATION | | | | | |
| Pilot Test | LS | 1 | $ 75,000 | $ 75,000 | Based on engineer's experience |
| Injection Well Installation | EA | 180 | $ 600 | $ 108,000 | Based on engineer's experience; wells spaced 20' on center |
| Hydrogen Peroxide Releasing Compound and Catalyst | GAL | 90000 | $ 3.15 | $ 283,500 | Based on engineer's experience; based on 3 injections/well; total volume 500 gal/well |
| Equipment and injection labor | LS | 1 | $ - | $ 212,625 | Based on engineer's experience; 75% of oxidant cost |
| Monitoring & Data Interpretation | LS | 1 | $ - | $ 60,000 | Based on engineer's experience |
| | | | **Subtotal** | **$ 739,125** | |
| | | | **Net Present Value** | **$ 551,546** | Assume implemented in year 6 |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 2700 | $ 65 | $ 175,500 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| Chemical Grouting beneath culvert | CF | 300 | $ 138 | $ 41,400 | Means 02250 050 0400 |
| | | | **Subtotal** | **$ 216,900** | |
| | **Capital Subtotal (not including engineering)** | | | **$ 1,050,949** | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 105,095 | $ 105,095 | Assume 10% of capital costs |
| Engineering Oversight | WEEK | 12 | $ 7,000 | $ 84,000 | |
| | | | **Subtotal Engineering** | **$ 189,095** | |
| | | | Subtotal | $ 1,240,044 | |
| | | | Contingency (15%) | $ 186,007 | |
| | | | **Total Estimated Capital for 1-4:** | **$ 1,426,051** | |
| OPERATION AND MAINTENANCE (DNAPL Recovery) | | | | | |
| DNAPL Disposal (Assume 50 gal/mo) | GAL | 50 | $ 7 | $ 350 | Based on current H&A costs |
| Maintanance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | | Subtotal Estimated Monthly O&M | $ 2,350 | |
| | | | Contingency (15%) | $ 353 | |
| | | | Total Estimated O&M | $ 2,703 | |
| | | | Total Estimated Annual O&M | $ 32,430 | |
| | | | **Net Present Value** | **$ 140,405** | Assume 5 years to remove DNAPL |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,500 | $ 2,500 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 2,500 | |
| | | | Contingency (15%) | $ 375 | |
| | | | **Total Estimated Annual Maintenance** | **$ 2,875** | |
| | | | **Net Present Value** | **$ 44,196** | Assume 30 years |
| | | | **Net Present Value Project Cost** | **$ 1,610,652** | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-11
COST ESTIMATE
ALTERNATIVE 3-2
SHALLOW DNAPL RECOVERY, SHALLOW DNAPL MIGRATION, AUL
AREA 3

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 70,000 | $ 70,000 | Unit price is combined mobilization for DNAPL recovery system and sheeting installation |
| SHALLOW DNAPL RECOVERY | | | | | |
| Recovery Well Installation | EA | 12 | $ 5,000 | $ 60,000 | Unit cost based on engineer's experience; stainless steel screen, 8" diameter 10-18 feet deep |
| Well Vault | EA | 12 | $ 2,000 | $ 24,000 | Unit cost based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 300 | $ 21.01 | $ 6,303 | Means 33 26 0621; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Unit cost based on engineer's experience |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Unit cost based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Unit cost based on engineer's experience |
| Pumps | EA | 12 | $ 5,000 | $ 60,000 | Unit cost based on engineer's experience |
| | | | **Subtotal** | **$ 182,503** | |
| SHALLOW DNAPL MIGRATION CONTROL | SF | 2700 | $ 65 | $ 175,500 | Based on engineer's experience for small barrier (Waterloo or similar); 15' deep |
| Chemical Grouting beneath culvert | CF | 300 | $ 138 | $ 41,400 | Means 02250 050 0400 |
| | | | **Subtotal** | **$ 216,900** | |
| | | **Capital Subtotal (not including engineering)** | | **$ 469,403** | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 80,000 | $ 80,000 | Assume MCP compliance $30k, Design $50k |
| Engineering Oversight | WEEK | 6 | $ 7,000 | $ 42,000 | |
| | | | **Subtotal Engineering** | **$ 122,000** | |
| | | | Subtotal | $ 591,403 | |
| | | | Contingency (15%) | $ 88,710 | |
| | | | **Total Estimated Capital for 1-4:** | **$ 680,113** | |
| OPERATION AND MAINTENANCE (DNAPL Recovery) | | | | | |
| DNAPL Disposal (Assume 50 gal/mo) | GAL | 50 | $ 7 | $ 350 | Based on current H&A costs |
| Maintenance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | | Subtotal Estimated Monthly O&M | $ 2,350 | |
| | | | Contingency (15%) | $ 353 | |
| | | | Total Estimated O&M | $ 2,703 | |
| | | | Total Estimated Annual O&M | $ 32,430 | |
| | | | **Net Present Value** | **$ 140,405** | Assume 5 years to remove DNAPL |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,500 | $ 2,500 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 2,500 | |
| | | | Contingency (15%) | $ 375 | |
| | | | **Total Estimated Annual Maintenance** | **$ 2,875** | |
| | | | **Net Present Value** | **$ 44,196** | Assume 30 years |
| | | | **Net Present Value Project Cost** | **864,714** | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-12
COST ESTIMATE
ALTERNATIVE 3-3
DNAPL Monitoring, AULs
AREA 3

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| **ENGINEERING** | | | | | |
| MCP compliance | LS | 1 | $ 30,000 | $ 30,000 | |
| | | | **Subtotal Engineering** | **$ 30,000** | |
| | | | Subtotal | $ 30,000 | |
| | | | Contingency (15%) | $ 4,500 | |
| | | | **Total Estimated Capital for 1-5:** | **$ 34,500** | |
| **DNAPL MONITORING** | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ 1,500 | Based on current H&A costs |
| | | | Subtotal Estimated Annual Monitoring | $ 1,500 | |
| | | | Contingency (15%) | $ 225 | |
| | | | **Total Estimated Annual Monitoring** | **$ 1,725** | |
| | | | **Net Present Value** | **$ 26,517** | Assume 30 years monitoring |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,500 | $ 2,500 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 2,500 | |
| | | | Contingency (15%) | $ 375 | |
| | | | **Total Estimated Annual Maintenance** | **$ 2,875** | |
| | | | **Net Present Value** | **$ 44,196** | Assume 30 years |
| | | | **Net Present Value Project Cost** | **$ 105,213** | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-13
COST ESTIMATE
ALTERNATIVE 4-1
LNAPL EXTRACTION USING MPE, IN-SITU CHEMICAL OXIDATION OF TSM AND LNAPL SOILS, AUL
AREA 4

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 100,000 | $ 100,000 | Unit price is combined mobilization for MPE and chemical oxidation |
| MPE SYSTEM INSTALLATION | | | | | |
| Well Installation (12 MPE Wells) | EA | 20 | $ 1,500 | $ 30,000 | Based on engineer's experience; 20' radius of influence |
| Well Head (MPE) | EA | 20 | $ 500 | $ 10,000 | Unit cost based on engineer's experience |
| Well Vault (MPE) | EA | 20 | $ 2,000 | $ 40,000 | Based on engineer's experience |
| Distribution Pipe Installation (trench, pipe, bedding) | LF | 2000 | $ 41.23 | $ 82,460 | Means 33 26 0624; 4", 6" double-wall piping with fittings |
| Multiphase skid 50 HP blower | EA | 1 | $ 60,000 | $ 60,000 | Unit cost based on engineer's experience |
| Electrical | LS | 1 | $ 15,000 | $ 15,000 | Unit cost based on engineer's experience |
| Oil/Water Separator | LS | 1 | $ 13,717 | $ 13,717 | Means 19 04 0412; 50 GPM |
| Catalytic Oxidizer for vapor treatment | EA | 1 | $ 30,000 | $ 30,000 | Unit cost based on engineer's experience |
| Treatment Enclosure | LS | 1 | $ 28,135 | $ 28,135 | Means 33 43 0108; 20' x 20', heated, insulated |
| RTU/Controls | LS | 1 | $ 5,000 | $ 5,000 | Unit cost based on engineer's experience |
| Filter Housings | EA | 2 | $ 1,500 | $ 3,000 | Unit cost based on engineer's experience |
| Liquid GAC vessels | EA | 2 | $ 5,000 | $ 10,000 | Unit cost based on engineer's experience; 2 x 500 lb vessels |
| MPE skid shipping/set-up | LS | 1 | $ 15,000 | $ 15,000 | Unit cost based on engineer's experience |
| System assembly | LS | 1 | $ 30,000 | $ 30,000 | Unit cost based on engineer's experience |
| | | | Subtotal | $ 370,312 | |
| CHEMICAL OXIDATION | | | | | |
| Pilot Test | LS | 1 | $ 75,000 | $ 75,000 | Based on engineer's experience |
| Injection Well Installation | EA | 35 | $ 600 | $ 21,000 | Based on engineer's experience; wells spaced 20' on center |
| Hydrogen Peroxide Releasing Compound and Catalyst | GAL | 17500 | $ 3.15 | $ 55,125 | Based on engineer's experience; based on 3 injections/well |
| Equipment and injection labor | LS | 1 | $ - | $ 41,344 | Based on engineer's experience; 75% of oxidant cost |
| Monitoring & Data Interpretation | LS | 1 | $ - | $ 60,000 | Based on engineer's experience |
| | | | Subtotal | $ 252,469 | |
| | | | Net Present Value | $ 218,092 | Assume implemented in year 3 |
| | | Capital Subtotal (not including engineering) | | $ 688,404 | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 100,000 | $ 100,000 | Assume MCP compliance $30k, Design $70k |
| Engineering Oversight | WEEK | 15 | $ 7,000 | $ 105,000 | |
| | | | Subtotal Engineering | $ 205,000 | |
| | | | Subtotal | $ 893,404 | |
| | | | Contingency (15%) | $ 134,011 | |
| | | Total Estimated Capital for 1-4: | | $ 1,027,415 | |
| OPERATION AND MAINTENANCE (MPE) | | | | | |
| Electrical | KWH | 25000 | $ 0.15 | $ 3,750 | Based on engineer's experience |
| Labor | HR | 20 | $ 80 | $ 1,600 | Based on current H&A costs |
| LNAPL Disposal (Assume 100 gal/day) | GAL | 100 | $ 7 | $ 700 | Based on engineer's experience |
| Misc. Expenses (pump maint/waste disposal/etc) | LS | 1 | $ 500 | $ 500 | Based on engineer's experience |
| Natural gas consumption | LS | 1 | $ 200 | $ 200 | Based on engineer's experience |
| Liquid Treatment | | | | | |
| Carbon Change-out | [illegible] | 1 | $ 4,000 | $ 4,000 | Based on engineer's experience |
| Bag filters | EA | 2 | $ 1 | $ 2 | Based on engineer's experience |
| | | Subtotal Estimated Monthly O&M | | $ 10,752 | |
| | | | Contingency (15%) | $ 1,613 | |
| | | | Total Estimated O&M | $ 12,365 | |
| | | Total Estimated Annual O&M | | $ 148,378 | |
| | | | Net Present Value | 275,895 | Assume 2 years to remove LNAPL |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,000 | $ 2,000 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | Subtotal Estimated Annual Maintenance | | $ 2,000 | |
| | | | Contingency (15%) | $ 300 | |
| | | Total Estimated Annual Maintenance | | $ 2,300 | |
| | | | Net Present Value | $ 35,357 | Assume 30 years |
| | | Net Present Value Project Cost | | $ 1,338,868 | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation

TABLE D-14
COST ESTIMATE
ALTERNATIVE 4-2
LNAPL RECOVERY, AULS
AREA 4

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| MOBILIZATION | LS | 1 | $ 50,000 | $ 50,000 | Unit price is mobilization for LNAPL recovery system |
| LNAPL RECOVERY (Belt skimmers) | | | | | |
| Recovery Well Installation | EA | 13 | $ 2,500 | $ 32,500 | Based on engineer's experience; stainless steel screen, 8" diameter 10-18 feet deep |
| Well Vault | EA | 13 | $ 2,000 | $ 26,000 | Based on engineer's experience |
| Equipment/Storage building | SHED | 1 | $ 10,200 | $ 10,200 | Means 33 43 0104; 10' x 5.5' x 8.33' Hazardous material storage building |
| Collection Pipe Installation | LF | 300 | $ 21.01 | $ 6,303 | Means 33 26 0621; PVC double-wall piping with fittings |
| Product Recovery Tank | EA | 1 | $ 2,000 | $ 2,000 | Based on engineer's experience |
| Remote Telemetry Unit (RTU) | EA | 1 | $ 5,000 | $ 5,000 | Based on engineer's experience |
| Electrical & Equipment Installation | LS | 1 | $ 15,000 | $ 15,000 | Based on engineer's experience |
| Pumps | EA | 13 | $ 5,000 | $ 65,000 | Based on engineer's experience |
| | | | **Subtotal** | **$ 162,003** | |
| | **Capital Subtotal (not including engineering)** | | | **$ 212,003** | |
| ENGINEERING | | | | | |
| Design/MCP Compliance | LS | 1 | $ 50,000 | $ 50,000 | Assume MCP compliance $30k, Design $20k |
| Engineering Oversight | WEEK | 5 | $ 7,000 | $ 35,000 | |
| | | **Subtotal Engineering** | | **$ 85,000** | |
| | | | Subtotal | $ 297,003 | |
| | | | Contingency (15%) | $ 44,550 | |
| | | **Total Estimated Capital for 1-5:** | | **$ 341,553** | |
| OPERATION AND MAINTENANCE (LNAPL Recovery) | | | | | |
| LNAPL Disposal (Assume 40 gal/mo) | GAL | 40 | $ 7 | $ 280 | Based on current H&A costs |
| Maintenance (Assume 2 days/month) | DAY | 2 | $ 1,000 | $ 2,000 | Based on current H&A costs |
| | | Subtotal Estimated Monthly O&M | | $ 2,280 | |
| | | | Contingency (15%) | $ 342 | |
| | | | Total Estimated O&M | $ 2,622 | |
| | | Total Estimated Annual O&M | | $ 31,464 | |
| | | | **Net Present Value** | $ 136,223 | Assume 5 years to remove LNAPL |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,000 | $ 2,000 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | Subtotal Estimated Annual Maintenance | | $ 2,000 | |
| | | | Contingency (15%) | $ 300 | |
| | | **Total Estimated Annual Maintenance** | | **$ 2,300** | |
| | | | **Net Present Value** | **$ 35,357** | Assume 30 years |
| | | **Net Present Value Project Cost** | | **$ 513,133** | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

TABLE D-15
COST ESTIMATE
ALTERNATIVE 4-3
LNAPL Monitoring, AULs
AREA 4

| ITEM | UNITS | ESTIMATED QUANTITY | UNIT PRICE | ESTIMATED COST | NOTES |
|---|---|---|---|---|---|
| **ENGINEERING** | | | | | |
| MCP compliance | LS | 1 | $ 30,000 | $ 30,000 | |
| | | | **Subtotal Engineering** | **$ 30,000** | |
| | | | Subtotal | $ 30,000 | |
| | | | Contingency (15%) | $ 4,500 | |
| | | | **Total Estimated Capital for 1-5:** | **$ 34,500** | |
| **DNAPL MONITORING** | | | | | |
| Monitoring (Assume 3 days/year) | DAY | 3 | $ 500 | $ 1,500 | Based on current H&A costs |
| | | | Subtotal Estimated Annual Monitoring | $ 1,500 | |
| | | | Contingency (15%) | $ 225 | |
| | | | **Total Estimated Annual Monitoring** | **$ 1,725** | |
| | | | **Net Present Value** | **$ 26,517** | Assume 30 years monitoring |
| MAINTENANCE OF DIRECT CONTACT BARRIER (pavement) | LS | 1 | $ 2,000 | $ 2,000 | Based on engineer's estimate; annual cost derived from expected repaving/maintenance every 5 years |
| | | | Subtotal Estimated Annual Maintenance | $ 2,000 | |
| | | | Contingency (15%) | $ 300 | |
| | | | **Total Estimated Annual Maintenance** | **$ 2,300** | |
| | | | **Net Present Value** | **$ 35,357** | Assume 30 years |
| | | | **Net Present Value Project Cost** | **$ 96,374** | |

Notes:
1. Means: RS Means Environmental Remediation Cost Data - Assemblies and Unit Price 2003 or Means Heavy Construction Cost Data 2003.
2. Net Present Value based on 5% interest, 0% inflation.

| HALEY & ALDRICH | CALCULATIONS | File No. | 29847-000 |
|---|---|---|---|
| | | Sheet | 1 of 3 |
| Client | MEC | Date | 05-14-03 |
| Project | MALDEN MGP | Computed By | JCP |
| Subject | SOIL AREA/VOLUME : ALTERNATIVE 1-1 | Checked By | |

PETROLEUM IMPACTED AREA ($A_{PI}$)

$A_{PI} = \frac{1}{2}(210' + 180')(125') + \frac{1}{2}(70')(120') = 28,575 \text{ ft}^2$

$= 3,175 \text{ yd}^2$

SAY $3,200 \text{ yd}^2$

TSM AREA ($A_{TSM}$)

$A_{TSM} = A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8$

$A_1 = \frac{1}{2}(80')(37') = 1480 \text{ ft}^2$

$A_2 = \frac{1}{2}(100')(50') = 2500 \text{ ft}^2$

$A_3 = \frac{1}{2}(110')(42') = 2310 \text{ ft}^2$

$A_4 = \frac{1}{2}(110')(31') = 1705 \text{ ft}^2$

$A_5 = \frac{1}{2}(95' + 95')(55') = 5225 \text{ ft}^2$

$A_6 = \frac{1}{2}(85')(55') = 2338 \text{ ft}^2$

$A_7 = \frac{1}{2}(38')(50') = 950 \text{ ft}^2$

$A_8 = \frac{1}{2}(50')(10') = 250 \text{ ft}^2$

$A_{TSM} = 16,758 \text{ ft}^2 = 1862 \text{ yd}^2$

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| HALEY & ALDRICH | CALCULATIONS | File No. 29847-000 |
|---|---|---|
| | | Sheet 2 of 3 |
| Client | MEC | Date 5-14-03 |
| Project | MALDEN MGP | Computed By JCP |
| Subject | SOIL AREA/VOLUME · ALTERNATIVE 1-1 | Checked By |

DEPTH OF CONTAMINATION

PETROLEUM IMPACTED

| BORING | DEPTH [1] | TPH (mg/kg) [2] | FILL DEPTH [1] |
|---|---|---|---|
| B11A | 4-6' | 2,400,000 | 0-9' |
| B15A-53 | 7.5-9 | 810,000 | 0-9' |
| B6 | 7.7-9.2 | 6,600,000 | 0-9'2" |

NOTES: (1) BORING DATA OBTAINED FROM GEOLOGIC BORING LOGS DATED NOVEMBER 1987.
(2) ANALYTICAL DATA FROM TABLE VI SOIL BORING DATA IN H&A PHASE II DATED DEC 2001

∴ BASED ON ABOVE DATA, ASSUME

1) TOTAL DEPTH OF EXCAVATION IS 12'. THIS REMOVES IMPACTED ORGANIC MATERIAL BELOW FILL

$$\text{VOLUME TANK FARM} = V_{TF} = (4\ yd)(3{,}200\ yd^2)$$

$$= 12{,}800\ yd^3$$

2) IMPACTED ZONE: ~ 4' - 12' BGS (BASED ON BORING LOGS)

HOWEVER, BASED ON PRESENCE OF STORAGE TANKS ON TANK FARM AREA: ASSUME THAT ALL MATERIAL IS IMPACTED (0' - 12' BGS)

EXCAVATION TOTAL PETRO. AREA

$$12{,}800\ yd^3\ (1.6\ tons/yd^3) = 20{,}480\ tons$$

SAY 20,500 TONS

| HALEY & ALDRICH | CALCULATIONS | File No. | 29842-000 |
|---|---|---|---|
| | | Sheet | 3 of 3 |
| Client | MEC | Date | 5-14-03 |
| Project | MALDEN MGP | Computed By | JCP |
| Subject | SOIL AREA/VOLUME : ALTERNATIVE 1-1 | Checked By | |

DEPTH OF CONTAMINATION continued

TSM AREA

| BORING[1] | DEPTH - TSM IMPACTED |
|---|---|
| 97E-B623 | 4.5 - 10.5' |
| 99E-B822 | 8.5 - 13.5' |

NOTES: (1) OBTAINED FROM H&A BORING LOGS DATED JULY '97 AND JULY '99

∴ BASED ON ABOVE DATA, ASSUME:

1) TOTAL AVERAGE DEPTH OF EXCAVATION IS 12'

VOLUME TSM = $V_{TSM}$ = $(4\ yd)(1862\ yd^2)$

= $7{,}448\ yd^3$

SAY $7450\ yd^3$

2) IMPACTED ZONE ON AVERAGE : 6 - 12' (6' THICK)

∴ ASSUME 50% RE-USE OF EXCAVATED MATERIAL

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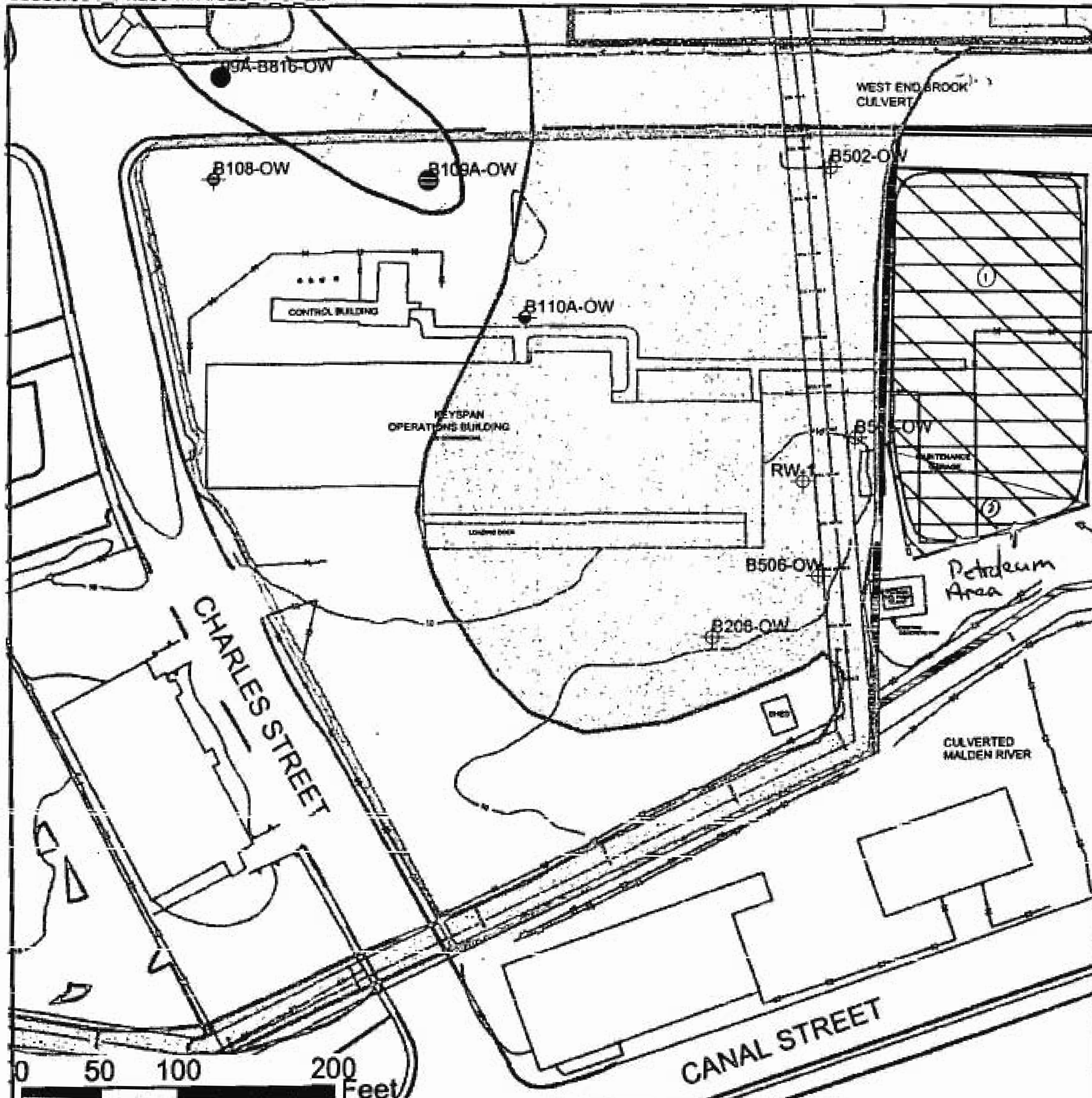
06558/634_Phase III/Areas_1_&_2.mxd




HALEY & ALDRICH
UNDERGROUND ENGINEERING & ENVIRONMENTAL SOLUTIONS

PHASE III - REMEDIAL ACTION PLAN
FORMER MALDEN MGP SITE
MALDEN, MASSACHUSETTS

CONCEPTUAL LAYOUT
ALTERNATIVE 1-1
EXCAVATION OF DNAPL, LNAPL, TSM AND PETROLEUM AREA

SCALE AS SHOWN
MAY 2003

| HALEY & ALDRICH | CALCULATIONS | File No. | 29847-000 |
|---|---|---|---|
| | | Sheet | 1 of 1 |
| Client | MEC | Date | 05-15-03 |
| Project | MAIDEN WGP | Computed By | JGP |
| Subject | ALTERNATIVE 1-2 | Checked By | |

EXCAVATION OF TSM

VOLUME OF EXCAVATION = 7,450 $yd^3$ (FROM ALT 1-1 CALC

ASSUME 50% RE-USE

CHEMICAL OXIDATION AREA (PETROLEUM IMPACTED)

NO. OF INJECTION WELLS — ASSUME 20' SPACING BASED ON ENGINEER'S EXPERIENCE

$A = \pi R^2 = \pi (10)^2 = 314 \ ft^2$

$= 34.9 \ yd^2$

TOTAL AREA TO BE TREATED = 3,200 $yd^2$ (FROM ALT. 1-1 CALC.)

∴ NO. OF WELLS = 3,200 / 34.9 $yd^2$ = 92 wells

SAY 95 WELLS

OXIDANT USE

ASSUME 500 GAL/INJECTION POINT NEEDED TO REMEDIATE (BASED ON ENGINEER'S EXPERIENCE)

ASSUME 3 INJECTIONS NEEDED TO DELIVER 500 GALLONS OXIDANT.

TOTAL OXIDANT

(95 WELLS)(500 GAL/WELL) = 47,500 GALLONS

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| HALEY & ALDRICH | CALCULATIONS | File No. | 29847.000 |
|---|---|---|---|
| | | Sheet | 1 of 2 |
| Client | MBC | Date | 05-29-07 |
| Project | MALDEN MGP | Computed By | JCT |
| Subject | ALTERNATIVE 1-2 | Checked By | |

ENGINEERED BARRIER AREA CALCULATIONS (SEE FIGURE 17)

ENGINEERED BARRIER IMPLEMENTED OVER TSM & TANK FARM AREA

$A_{PI}$ = 3,200 yd² (FROM ALT. 1-1 CALCULATION)

$A_{TSM}$ = 1,900 yd² (FROM AREA 1.1 CALC.)

$A_{TOTAL}$ = 5,100 yd²

EXCAVATION VOLUME (ENG BARRIER)

$V = (5,100\ yd^2)(3.5')(yd/3ft) = 5,950\ yd^3$

SAY 6000 yd³

TOP SOIL VOLUME

$V = (5,100\ yd^2)(6''\ \text{TOPSOIL})(ft/12'')(yd/3') = 850\ yd^3$ TOP SOIL

SAND 12" LIFT VOLUME

$V = (5,100\ yd^2)(12''\ \text{SAND})(ft/12'')(yd/3') = 1,700\ yd^3$ SAND

GEO-COMPOSITE & HDPE LAYER AREA

$A = (5,100\ yd^2)(3'/yd)(3'/yd) = 45,900\ ft^2$

Form No. HA-080-Metric

HALEY & ALDRICH

# CALCULATIONS

| | |
|---|---|
| File No. | 29847-000 |
| Sheet | 2 of 2 |
| Date | 05-29-03 |
| Computed By | JCP |
| Checked By | |

Client: MEC

Project: MALDEN MGP

Subject: ALTERNATIVE 1-3

DNAPL RECOVERY

- ASSUME 3,200 GAL DNAPL IN AREA 1 (SEE ATTACHED DNAPL VOLUME TABLE FOR ESTIMATE)

- BASED ON CURRENT PUMPING/RECOVERY RATE OF EXISTING DNAPL WELL ON-SITE

CURRENT RATE ≈ 0.74 gal/day

∴ ASSUME LONG TERM RATE = 0.35 gal/day

TOTAL DNAPL RECOVERY RATE

5 PROPOSED DNAPL WELLS (SEE FIG 17)

TOTAL DNAPL REMOVAL RATE = (5 WELLS)(0.35 gal/day)

= 1.75 gal/day

ESTIMATED RECOVERY TIME

$T = 3{,}200 \text{ gal} / 1.75 \text{ gal/day}$

= 1828 DAYS = 5 years

∴ SAY 5 to 7 YEARS TO REMOVE DNAPL

Form No. HA-080-Metric

Table 1
DANPL Volume Estimate Summary
Malden MGP
Malden, Massachusetts

| Column Number | 1 | 2 | 3 | 4 | | 5 | | 6 | | 7 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Formula | | | | | | | | =1x2x4x5x7.48gal/cf | | =1x3x4x5x7.48gal/cf x(sat-res) | | |
| Area Designation Formula | Area (sf) | Residual DNAPL Assumed thickness (ft) | Mobile DNAPL Assumed Thickness (ft) | Estimated Porosity | | DNAPL Saturation | | Immobile Tar Volume (Gallons) | | Mobile Tar Volume (Gallons) | | Average Mobile Tar Volume (Gallons) |
| | | | | HI | LOW | HI | LOW | HI | LOW | HI | LOW | |
| 1A | 7,200 | 3 | | 0.40 | 0.25 | 0.21 | 0.10 | 1,814 | 540 | - | - | |
| 1A | 7,200 | | 1 | 0.40 | 0.25 | 0.85 | 0.70 | 605 | 180 | 1,843 | 1,080 | 1462 } 3137 gal |
| 1B | 8,250 | 3 | | 0.40 | 0.25 | 0.21 | 0.10 | 2,079 | 619 | - | - | |
| 1B | 8,250 | | 1 | 0.40 | 0.25 | 0.85 | 0.70 | 693 | 206 | 2,112 | 1,238 | 1675 } |
| 2A | 28,125 | 2 | | 0.40 | 0.25 | 0.21 | 0.10 | 4,725 | 1,406 | - | - | |
| 2A | 28,125 | | 2 | 0.40 | 0.25 | 0.85 | 0.70 | 4,725 | 1,406 | 14,400 | 8,438 | 11419 |
| 2B | 10,400 | 2 | | 0.40 | 0.25 | 0.21 | 0.10 | 1,747 | 520 | - | - | |
| 2C | 9,500 | 1 | | 0.40 | 0.25 | 0.21 | 0.10 | 798 | 238 | - | - | |
| 3A | 18,000 | 3 | | 0.40 | 0.25 | 0.21 | 0.10 | 4,536 | 1,350 | - | - | |
| 3A | 18,000 | | 1 | 0.40 | 0.25 | 0.85 | 0.70 | 1,512 | 450 | 4,608 | 2,700 | 3654 |
| 3B | 9,900 | 1 | | 0.40 | 0.25 | 0.21 | 0.10 | 832 | 248 | - | - | |
| 4 | 6,400 | | 2 | 0.35 | 0.25 | 0.85 | 0.70 | 941 | 320 | 2,867 | 1,920 | 2394 |
| Totals | | | | | | | | 19,816 | 5,938 | 21,875 | 13,058 | 17,466 |

Notes and Assumptions:
1. Residual pore tar saturation from Cohen and Mercer, 1993
2. Porosity from Holtz and Kovacs, 1981 and Haley & Aldrich soil descriptions and sieve analysis.
3. For purposes of this estimate, it was assumed that only a NAPL residual and NAPL saturated zone exist in the subsurface.
4. Mobile DNAPL defined as that fractio of DNAPL that exists in pore spaces above the assumed residual saturation.

| HALEY & ALDRICH | CALCULATIONS | File No. 29847-000 |
|---|---|---|
| | | Sheet 1 of 2 |
| Client | MEC | Date 05-27-03 |
| Project | MALDEN MGP | Computed By UGP |
| Subject | ALTERNATIVE 1-4 | Checked By |

DNAPL RECOVERY

- ASSUME 3,200 GAL DNAPL IN AREA 1 (FROM ALT 1-3)

- BASED ON CURRENT PUMPING/RECOVERY RATE OF EXISTING DNAPL WELL ON-SITE

Current removal Rate = 0.74 Gal/DAY

Assume LONG TERM RATE = 0.35 gAL/DAY

⇒ 5 WELLS (SEE FIGURE 17)

TOTAL DNAPL REMOVAL = (5 wells)(0.35 gal/day)

= 1.75 gal/day

ESTIMATED TIME TO EXTRACT DNAPL

T = (3,200 GAL) / (1.75 gal/day) = 1828 DAYS

= 5 yrs

SAY 5 YEARS TO REMOVE DNAPL

Assume 5 to 7 years.

Form No. HA-080-Metric

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | 29847-000 |
| Project | MALDEN MGP | Sheet | 2 of 2 |
| Subject | ALTERNATIVE 1-4 | Date | 05-29-03 |
| | | Computed By | JCP |
| | | Checked By | |

CHEMICAL OXIDATION

INJECTION WELL INFLUENCE = 35 $yd^2$ (FROM ALT. 1-2 CALCULATION

AREA TO BE TREATED

$A_{TOTAL} = A_{TSM} + A_{TZ}$

$= 1{,}900\ yd^2 + 3{,}200\ yd^2$ (FROM ALT. 1-1 CALCULATI

$= 5{,}100\ yd^2$

NO. OF INJECTION WELLS

NO. OF WELLS = $5{,}110\ yd^2 / 35\ yd^2$ = 146 wells

∴ SAY 150 WELLS

AMOUNT OF OXIDANT REQUIRED

ASSUME 3 INJECTIONS/WELL TO DELIVER 500 GAL OXIDANT

TOTAL OXIDANT = (150 WELLS)(500 GAL/WELL)

= 75,000 GAL

Form No. HA-080-Metric

HALEY & ALDRICH

# CALCULATIONS

| | |
|---|---|
| Client | MEC |
| Project | MALDEN MGP |
| Subject | ALTERNATIVE 1-5 |
| File No. | 29847-000 |
| Sheet | 1 of 1 |
| Date | 05-15-03 |
| Computed By | JCP |
| Checked By | |

DNAPL RECOVERY

SEE ALT 1-3 FOR ASSUMPTIONS

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HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | 32497-000 |
| Project | WARDEN MGP | Sheet | 1 of 7 |
| Subject | ALTERNATIVE 2-1 | Date | 07 10 03 |
| | | Computed By | JCP |
| | | Checked By | |

DNAPL RECOVERY

- ASSUME [illegible] GAL DNAPL IN AREA 2 (NO [illegible] DNAPL [illegible])

- ESTIMATED DNAPL RECOVERY RATE = 0.35 GAL/DAY/WELL (FROM ALT. 1-2 CALC)

TOTAL DNAPL RECOVERY

13 PROPOSED WELLS (SEE FIG. [illegible])

TOTAL DNAPL RECOVERY RATE = (13 WELLS)(0.35 GAL/DAY)

= 4.6 GAL/DAY

SAY 4.5 GAL/DAY

ESTIMATED RECOVERY TIME

T = 11,500 GAL / 4.5 GAL/DAY

= 2,555 DAYS

= 7 YEARS

∴ SAY 7-10 YEARS TO REMOVE DNAPL

Form No. HA-080-Metric

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | 2[illegible]-0[illegible] |
| Project | MALDEN [illegible] | Sheet | 2 of [illegible] |
| Subject | ALTERNATIVE [illegible]-1 | Date | 0[illegible] |
| | | Computed By | [illegible] |
| | | Checked By | |

[illegible] EXTRACTION

AREA TO BE TREATED = [illegible] ([illegible]) ([illegible])

= 3[illegible] ft²

[illegible] AREA OF INFLUENCE

ASSUME [illegible] RADIUS OF INFLUENCE

$A = (10)^2 \pi = 314 \text{ ft}^2$

NO. OF WELLS

NO. OF WELLS = 3[illegible] ft² / 314 ft²

= 11.5 WELLS

SAY 12 M[illegible] WELLS

Form No. HA-080-Metric

| HALEY & ALDRICH | CALCULATIONS | File No. | 29342-0?? |
|---|---|---|---|
| | | Sheet | 3 of 7 |
| Client | MEC | Date | 6-13-03 |
| Project | MALDEN MGP | Computed By | JGP |
| Subject | ALTERNATIVE 3-1 | Checked By | |

SHALLOW DNAPL MIGRATION

GRAV VOLUME UNDER CULVERT:

- ASSUME 10' LONG × 25' WIDE × 3' DEEP

$V = (10')(25')(3') = 750\ ft^3$

- ASSUME 0.4 POROSITY

$V = (750\ ft^3)(0.4)$

$= 300\ ft^3$

Form No. HA-080-Metric

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | 29847-000 |
| Project | MALDEN MGP | Sheet | 1 of 1 |
| Subject | ALTERNATIVE 3-2 | Date | 05-30-03 |
| | | Computed By | JCP |
| | | Checked By | |

DNAPL RECOVERY

- 12 PROPOSED RECOVERY WELLS (SEE FIG. 19)
- ESTIMATE 3 TO 5 YEARS TO REMOVE 3,700 GAL DNAPL (BASED ON ALT. 3-1 CALCULATIONS)

Form No. HA-080-Metric

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | 29 947-000 |
| Project | MALDEN MGP | Sheet | 1 of 2 |
| Subject | ALTERNATIVE 4-1 | Date | 05-30-03 |
| | | Computed By | JCP |
| | | Checked By | |

MULTIPHASE EXTRACTION (LNAPL AREA)

SEE FIGURE 20 FOR LNAPL CONTAMINATION AREA

A = 5,070 ft² (DOES NOT INCLUDE AREA BENEATH BUILDING) (CALCULATED USING ARCVIEW)

NO. OF MPE WELLS

ASSUME MPE RADIUS OF INFLUENCE = 20'

∴ AREA INFLUENCED = 314 ft² (FROM ALT. 2 CALC.)

NO. OF WELLS = 5,070 ft² / 314 ft²

= 16.1 WELLS

∴ SAY 20 MPE WELLS

CHEMICAL OXIDATION

AREA TO BE TREATED = TSM AREA* + LNAPL AREA (* TSM AREA CALCULATED USING ARCVIEW SOFTWARE)

= 4,630 ft² + 5070 ft²

= 9,530 ft²

= 1055.6 yd²

∴ SAY 1100 yd²

Form No. HA-080-Metric

**HALEY & ALDRICH**

# CALCULATIONS

| | |
|---|---|
| File No. | 29847-000 |
| Sheet | 2 of 2 |
| Date | 05-30-03 |
| Computed By | JCP |
| Checked By | |

Client: MEC

Project: MALDEN MGP

Subject: ALTERNATIVE 4-1

CHEMICAL OXIDATION cont.

INJECTION WELL INFLUENCE AREA = 35 yd² (FROM ALT. 1-2 CALC)

ROI = 20'

NO. OF WELLS = 1100 yd² / 35 yd²

= 31.4 wells

∴ SAY 35 INJECTION WELLS

TOTAL OXIDANT REQUIRED

ASSUME 500 GAL/WELL NEEDED TO REMEDIATE (BASED ON ENG EXPERIENCE)

VOL. = (35 WELLS)(500 gal/well)

= 17,500 GAL OXIDANT

Form No. HA-080-Metric

| | | | |
|---|---|---|---|
| HALEY & ALDRICH | **CALCULATIONS** | File No. | 29847-000 |
| | | Sheet | 1 of 2 |
| Client | MEC | Date | 05-30-03 |
| Project | MALDEN MGP | Computed By | JCP |
| Subject | ALTERNATIVE 4-2 | Checked By | |

LNAPL EXTRACTION (Belt-Skimmers)

LNAPL THICKNESS = 0.35' (BASED ON ALT. 2-2 CALC.)

LNAPL VOLUME

$V = (0.35')(5070\ ft^2) = 1,775\ ft^3$ LNAPL

- ASSUME 0.4 POROSITY

$\therefore V = (1,775\ ft^3)(0.4) = 710\ ft^3$ LNAPL

$= (710\ ft^3)(7.46\ gal/ft^3)$

$= 5296.6$ gal LNAPL

$\therefore$ SAY 5300 GAL LNAPL

LNAPL RECOVERY RATE

- 13 PROPOSED LNAPL EXTRACTION WELLS (SEE FIG. 20)

- ASSUME 0.25 GAL/DAY EXTRACTION (BASED ON ENG. EXPERIENCE)

$\therefore$ TOTAL LNAPL REMOVAL RATE = (13 WELLS)(0.25 GAL/DAY)

= 3.25 GAL/DAY

Form No. HA-080-Metric

| HALEY & ALDRICH | CALCULATIONS | File No. | 29847-000 |
|---|---|---|---|
| | | Sheet | 2 of 2 |
| Client | MEC | Date | 6-12-03 |
| Project | Malden MGP | Computed By | SMC |
| Subject | Alternative 5-2 | Checked By | |

SRCO, cont

Estimated impacted groundwater volume:

$(450{,}000\ ft^3)(0.3\ \text{porosity})(28.31\ \ell/ft^3) = 3{,}821{,}850$ liters

Estimated mass of contaminant in groundwater:

$(3{,}822{,}000\ \ell)(80\ mg/\ell) =$ **306 Kg BTEXSN**

Estimated groundwater flow velocity:

=> Refer to 4/14/03 summary sheet for estimated groundwater flow rates based on site observations. Flow rate ranges from 0.4 to 1.3 ft/days, average velocity. Assume 0.8 ft/day

=> Approx. Distance from injection wells to downgradient plume end is 270 ft (Refer to fig. 21).

∴ Groundwater travel time is estimated as approx $\frac{270\ ft}{0.8\ ft/day}$ = 337 Days, or approx. 1 year

Rate of degradation is not known. Assume 3 pore volume flushes required to reach remedial goals.

∴ Time to complete ≅ 3 years

Note: Contractor estimate is 12 to 18 months. Additional time includes potential additional remediation required for contaminated soil.

Installation Time: Assume 1 well per day, + trenching + clean-up => Indoor work duration = 1 to 2 weeks, Assume 2 weeks of 5-day weeks, 8-hr days.

CAL02AFH.FRP 20 November 1997

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | |
| Project | Malden Former MGP Phase III | Sheet | 1 of 1 |
| Subject | 129 Commercial St - Summary of gw flow estimates | Date | 4/14/03 |
| | | Computed By | SMC |
| | | Checked By | |

This sheet provides a summary of the 2/5/03 calculations of groundwater flow rates at the 129 Commercial St. Property. Refer to the attached figure for locations.

Darcy groundwater flow equation : $q = K \nabla h$

K = hydraulic conductivity (assume K = 111 ft/day, as estimated from slug tests in B918.)
$\nabla h$ = hydraulic gradient
q = Darcy velocity

Average velocity : $\bar{v} = \frac{q}{n}$ where n = porosity ; use 0.3

<u>For the distance between MW-1 and NC-3</u>:

Estimated $\bar{v}$ ranges from 0.43 ft/day to 0.86 ft/day

Estimated travel time ranges from 139 to 278 days.

<u>For the distance between NC-3 and 02B-B918-MW</u>:

Estimated $\bar{v}$ ranges from 1.1 to 1.3 ft/day.

Estimated travel time ranges from 110 to 126 days.

∴ Estimated travel time for groundwater flowing beneath the building, from the location of 02B-B918-MW to MW-1 near the property boundary is approximately

<u>249 to 404 days.</u> Note that spatial variability in K may be significant due to high-K seams, etc. Therefore considerable uncertainty in this estimate.

# CALCULATIONS

HALEY & ALDRICH

| | | | |
|---|---|---|---|
| Client | MEC | File No. | |
| Project | Malden MGP PL III | Sheet | 1 of 1 |
| Subject | 129 Commercial St - gw travel time estimates | Date | 2/5/03 |
| | | Computed By | SMC |
| | | Checked By | |

$$\frac{d}{\Delta t} = \frac{111 \times \Delta h/d}{0.3}$$

$$0.3d = \Delta t(111 \times \Delta h/d)$$

$$\boxed{\frac{0.3d}{111 \times \frac{\Delta h}{d}} = \Delta t}$$

$$q = k \nabla h$$

$$v = 111 \times \frac{\Delta h}{d}$$

$$\bar{v} = \frac{111 \times \frac{\Delta h}{d}}{0.3}$$

$$\frac{d}{\Delta t} = \frac{111 \times \Delta h/d}{.3}$$

120 ft (MW-1 to NC-3)

| | Δh (ft) | Δt (days) |
|---|---|---|
| July 00 | 0.23 | 169 |
| Dec 00 | 0.20 | 195 |
| Mar 02 | 0.17 | 205 |
| May 02 | 0.28 | 139 |
| July 02 | 0.14 | 278 (9 months) |

max $\bar{v}$ = 0.86 ft/day
min $\bar{v}$ = 0.43 ft/day

140 ft (NC-3 to 02B-B918-MW)

| | Δh (ft) | Δt (days) |
|---|---|---|
| Mar 02 | 0.42 | 126 |
| May 02 | 0.35 | 130 |
| July 02 | 0.48 | 110 |

max $\bar{v}$ = 1.3 ft/day
min $\bar{v}$ = 1.1 ft/day

| | MW-1 | ∇ | NC-3 | ∇ | 02B-B918-MW | ∇ |
|---|---|---|---|---|---|---|
| July 00 | 3 | 2.92 | 93 | 3.15 | — | |
| Dec 00 | 6 | 2.97 | 58 | 3.17 | — | |
| March 02 (3/12) | 0.04 | 2.27 | 11 | 2.46 | 121 | 2.88 |
| May 02 (5/7) | N/A | 2.66 | 31/24 | 2.94 | 105 | 3.27 |
| July 02 (8/1) | 0.001 | 2.43 | 13 | 2.57 | 78 | 3.05 |

dissolved BTEXSN conc

Approximate cross-section - Parcel B
02B-B918-GW K = 111 ft/day

CAL02AFH.FRP 20 November 1997

HALEY & ALDRICH

# CALCULATIONS

File No. ______
Sheet ______ of ______
Client ______
Date ______
Project ______
Computed By ______
Subject ______
Checked By ______

Impacted Area: 130 feet wide x 240 feet long

pore space = 130 x 240 x 12 x 0.3 = 112,320 ft

At flow rate of 200 ft³/min, 1 pore volume is purged in $\frac{112,320 \text{ ft}^3}{200 \text{ ft}^3/\text{min}}$ = 561 min, or 9.4 hours

500 pore volumes would be removed in 4700 hours or ~ 196 days.

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | 29847-000 |
| Project | MALDEN MGP | Sheet | 2 of 2 |
| Subject | ALTERNATIVE 5-1 | Date | 6-12-03 |
| | | Computed By | JCP |
| | | Checked By | |

OXIDANT INJECTION continued

AMOUNT OF OXIDANT REQUIRED

ASSUME 3 INJECTIONS/POINT TO DELIVER 500 GAL OXIDANT

TOTAL OXIDANT = (50 POINTS)(500 GAL/POINT)

= 25,000 GALLONS OXIDANT

Form No. HA-080-Metric

| HALEY & ALDRICH | CALCULATIONS | File No. | 29847-000 |
|---|---|---|---|
| | | Sheet | 1 of |
| Client | MEC | Date | 6-12-03 |
| Project | Malden MGP | Computed By | SMC |
| Subject | Alternative 5-2 | Checked By | |

SLOW-RELEASE CHEMICAL OXIDATION (SRCO)

=> Based on discussions with potential Remedial Service provider (EBSI), system will consist of the following:

- 5 four-inch diameter, double-screened injection wells
  - => Screen intervals approx. 3 to 8 ft and 23 to 30 feet bgs
  - => Radius of influence approx. 50 feet due to enhanced distribution (mounding @ well location)
- Vapor extraction system on wellheads to remove vapors + reaction by-products from well
- Chemical oxidant holding tank + piping to deliver oxidant to wellheads

=> Installation costs: Estimated at $100k to $150k plus cost of well installation. Assume $150k.

↳ Based on previous experience installing monitoring wells inside facility, ASSUME $10K PER 4-inch WELL (Includes Driller, materials, + support crew for inside work)

=> Time to reach Remedial goals:

Includes several factors:

- Estimated contaminant mass
  - Approx max. average observed BTEXSN concentration ≈ 80 mg/l. (in groundwater)
  - Approx. average impacted area => Assume 15 feet
  - Approx. impacted area = 250 ft x 120 ft = 30,000 $ft^2$

Approx. volume of impacted aquifer media =

$(30,000\ ft^2)(15\ ft\ thick) = 450\ ft^3$

CALD2AFH.FRP 20 November 1997

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | 29847-000 |
| Project | MALDEN MGP | Sheet | 2 of 2 |
| Subject | ALTERNATIVE 4-2 | Date | 05-30-03 |
| | | Computed By | JCP |
| | | Checked By | |

ESTIMATED LNAPL RECOVERY TIME

- ASSUME 50% TOTAL LNAPL VOLUME RECOVERED (ENG. EXP.)

∴ V = (5310 gal)(0.5) = 2650 gal LNAPL

T = 2650 gal / 3.25 gal/DAY = 815.4 DAYS

= 2.2 YRS

∴ SAY 3 TO 5 YEARS

Form No. HA-080-Metric

HALEY & ALDRICH

# CALCULATIONS

File No. [illegible]
Sheet: 1 of 2
Client: MEC
Date: [illegible]
Project: MALDEN MGP
Computed By: [illegible]
Subject: ALTERNATIVE 5-1
Checked By:

SVE SYSTEM:

ASSUME 8 WELLS (SEE FIG. 21)

ASSUME 235' HORIZONTAL SVE PIPING (SEE FIG. 21)

GEOPROBE OXIDANT INJECTION

OXIDANT INJECTION INFLUENCE = 35 yd² (FROM ALT. 1-2 CALCULATION)

- ALT. 1-2 USED INJECTION WELLS, HOWEVER, GEOPROBE INJECTION WILL LIKELY PRODUCE SAME RADIUS OF INFLUENCE

AREA TO BE TREATED

$A_{TOTAL}$ = 16,500 ft² (FROM ARCVIEW AREA CALCULATION)

= 1,833 yd² (EXCLUDES AREA BENEATH BRICKELY PROCESS ITEM)

NO. OF INJECTION POINTS

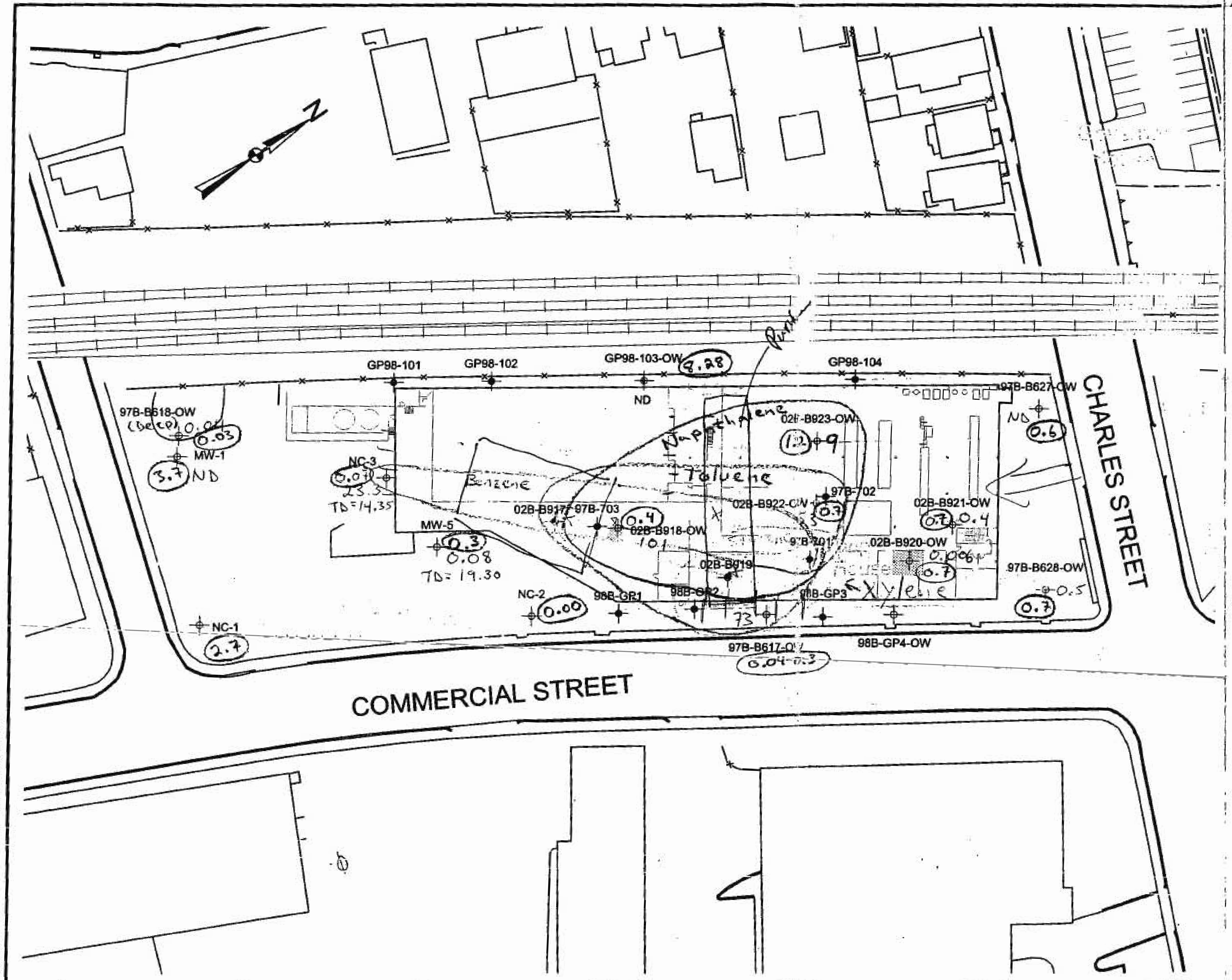
NO. OF POINTS = 1833 yd² / 35 yd²

= 52.4 POINTS

∴ SAY 50 INJECTION POINTS

Form No. HA-080-Metric

g:/06558/616/ARCVIEW/MALDEN MGP.APR




| | MW |
|---|---|
| B: | 78 |
| T: | 92 |
| X: | 106 |
| S: | 104 |
| E: | 106 |
| N: | 128 |

LEGEND:

- HISTORIC MGP STRUCTURES
- SHALLOW MONITORING WELL LOCATION
- SOIL BORING LOCATION
- BAKERY PRODUCTION FACILITIES
- 73 Total Detected VOC Concentration, May 2002
- (1.23) Dissolved oxygen concentration

NOTES:

1. BASE PLAN ADAPTED FROM "TOPOGRAPHIC WORKSHEET OF THE MANUFACTURED GAS PLANT, MALDEN, MA" FOR MASSACHUSETTS ELECTRIC COMPANY BY EASTERN TOPOGRAPHICS, JUNE 1995, AND CITY OF MALDEN ASSESSOR'S PLAN, SHEETS 1 AND 2, JUNE 1995, AND SHEET NO. 53 BY FAY, SPOFFORD & THORNDIKE, INC., UPDATED JUNE 1976 AND REVISED 30 JULY 1979.
2. ELEVATIONS ARE IN FEET AND RELATIVE TO NGVD.

60 0 60 Feet

HALEY & ALDRICH
UNDERGROUND ENGINEERING & ENVIRONMENTAL SOLUTIONS

FORMER MALDEN MGP SITE
120 COMMERCIAL STREET
MALDEN, MASSACHUSETTS

GROUNDWATER SAMPLE LOCATIONS
MARCH 2002

SCALE: AS SHOWN

MAY 2002

FIGURE 1

September 9, 2002

Malden, MA

Sean,

We can conduct a pilot demo within the building using the one inch diameter wells. We have available a programmable release process system that will slowly release a measured quantity of a dilute peroxide solution to the groundwater into a one inch well. The unit operates on a 110 volt, timed pumping system that pumps the dilute PRP solution into the well on a time and volume programmable interval.

What we need to know is the general geochemistry of the groundwater in the area we are to treat. I realize we have data on the dissolved oxygen; however, we also will need to know the concentrations of total and dissolved iron, the redox, pH, conductivity and alkalinity (total and bicarbonate alkalinity) of the groundwater to allow us to determine the optimal process to deploy. For example, if the dissolved iron is low, we may want to use the PRP system to initially diffuse a dilute iron solution into the well(s) to affect low level insitu Fenton Reagent reactions followed by a peroxide solution. If there is sufficient dissolved iron available, we would go directly to the diffusion of the peroxide solution.

What would be required is a restricted area, approximately 100 $ft^2$, at or near the wells to be treated to allow us to safely keep the PRP solution reservoir (55 gallon drum). This solution will be pumped into the impacted groundwater to: 1) modify the geochemistry of the groundwater to affect the desired insitu reactions, and to 2) modify the redox of the plume to promote aerobic degradation. Because we use dilute reagents, the reactions are mild although as the compounds are degraded, reaction products are formed. Intermediate vapors may therefore diffuse from the groundwater into the building. At PAH sites we have treated, we have noted the formation of intermediate product vapors (1 to 5 ppmv above background in treatment area well headspaces, 0 to 2 ppmv above background in the breathing zone). It would therefore be advisable to err on the side of safety and therefore keep the areas of the building being treated ventilated. This can be easily engineered using plastic curtains and a small blower to draw air from the treatment area to the exterior of the building.

In summary, I am confident we can use the existing wells to safely conduct a pilot demonstration at the Malden site. We need to learn more about the groundwater geochemistry as noted above and we would likely need to operate for a few months in order to determine effects of the PRP on the concentrations and distributions of the contaminants.

Call if you care to discuss in greater detail and if there is additional interest, we would be pleased to submit a proposal describing our specific technical approach and costs.

R. J. Scrudato. Ph.D

Mail

Nexic

Close

Previous Next

**From:** Ron Adams
**To:** Sean Carroll
**CC:** Mark Vigneri; Rjscrudato@aol.com
**Date:** 9/17/2002 1:18 PM
**Subject:** Malden MGP Site

Sean - providing the following after talking over with Ron S:

-we expect to see measureable changes (e.g. greater than the normal sampling data fluctuations you may observe when sampling gw at the site - on the order of 25% to 50% change) in contaminant concentrations in groundwater at the two target wells.
-we expect to see the site gw DO and ORP shift such that the targeted area is clearly aerobic after 3 months;
-we expect to see carbon dioxide levels increase in the targeted wells due to both oxidation and respiration;

Full-Scale

-Up to 3 to 4 more recirc wells would be needed to provide full coverage and sufficient overlap;
-they could operate off one feed system or dedicated feed systems;
operating time would likely be 12 to 18 months with monthly or quarterly visits needed to check system ops.
-assumed H&A would install PVC wells, conduct periodic (weekly or monthly) site gw measurements, and all analytical;
Install cost is estimated at $100k to $150k with monthly EBSI costs of $5000 to $10,000 including chems, labor, travel, and equip.

Hope this helps, let me know if you need anything else

Regards,

--
Ron Adams, P.E.
Sr. VP Client Services
EBSI, Inc.
830-13 A1A North, #371
Ponte Vedra, FL 32082
(904) 280-2596
Fax (904) 280-2597
(703) 282-4206 cell
www.on-contact.com

Mail

Nexic

Close

Previous Next

**From:** Ron Adams
**To:** Sean Carroll
**CC:** Rjscrudato@aol.com; Mark Vigneri
**Date:** 9/17/2002 2:07 PM
**Subject:** Malden MGP - one last thing

Spoke to developer of RECORS technology (the recirc well with chem injection) and got he following input:

- well should be 4" diam, 30 ft deep
-casing from 0 to 3, screen from 3 to 8 ft, casing from 8 to 23, screen from 23 to 30.

hope this helps, let me know if any questions

--
Ron Adams, P.E.
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Previous Next

**From:** Ron Adams
**To:** Sean Carroll
**CC:**
**Date:** 9/17/2002 4:34 PM
**Subject:** Re: Malden MGP - one last thing

based on a couple of things
-upper screen has to intersect water table;
-ROI is influenced by the length of the spacing between upper and lower screens - selected 15 to maximize ROI;
-lower screen length only needs to be 5 ft - I stretched it to make the numbers even at 30

Ron

Sean Carroll wrote:

Ron,

Thanks for the additional info. What is the depth of these wells based on? We haven't really nailed down the vertical extent of the contamination, but what we have seen has been generally about 4 to 6 feet of soil contamination along the water table - is it necessary to go down to 30 feet with the remediation well?

Sean

Ron Adams 09/17/02 02:07PM >>>

Spoke to developer of RECORS technology (the recirc well with chem injection) and got he following input:

- well should be 4" diam, 30 ft deep
-casing from 0 to 3, screen from 3 to 8 ft, casing from 8 to 23, screen from 23 to 30.

hope this helps, let me know if any questions

--
Ron Adams, P.E.
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**ENVIRONMENTAL BUSINESS SOLUTIONS INTERNATIONAL, INC.**
1127 Crossing Way
Wayne, NJ 07470
(973) 686-3701
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EBSI
Environmental Business Solutions International, Inc.
*The Rapid Remediation Company*℠

September 13, 2002

***ELECTRONIC QUOTATION***
(Pilot- scale SRCO Installation)

To: Sean M. Carroll
Haley & Aldrich, Inc.
465 Medford Street, Suite 2200
Boston, MA 02129-1400
617-886-7494
Fax 617-886-7794
smca@haleyaldrich.com

From: Ron Adams, P.E.
(904) 280-2596
Fax (904) 280-2597
radams@ebsi-inc.com

RE: Engineering Estimate
Former Malden MGP Site
EBSI Proposal No. 05-0323-DR

Dear Mr. Carroll:

Environmental Business Solutions International, Inc. ("EBSI") is pleased to provide Haley and Aldrich, Inc. (H&A) via email, this proposal for applying the On-Contact Remediation Process® ("Process") at the Malden MGP site in Massachusetts. This proposal provides EBSI's general technical approach and associated costs for treatment of the site using the PRP Process®.

## 1.0 INTRODUCTION

The On-Contact Process® uses stages of proprietary physical and chemical application methods that are applied through injection points directly into the area of concern. EBSI is uniquely qualified to perform this work because:

- **Pay-For-Performance Contracting.** EBSI will commit to achieving the Responsible Party's project goals, putting a large portion of our proposed costs at risk if our techniques are not successful. This proposal has been developed to conduct treatments on a 'best-effort' basis. We will be glad to prepare a pay-for-performance estimate following initial demonstration studies.

- **Massachusetts Experience.** EBSI and our staff have conducted several in-situ remediation projects in Massachusetts. We have experience in closing LNAPL sites in Danvers, Watertown, and are completing a project in Newton. We have also closed a site in Framingham impacted with CVOC.

- **Speed**. The Process treats contaminated soil and groundwater in-situ. Reductions in total VOC compounds are produced in a matter of weeks, as compared to many months or years required for conventional remediation technologies such as bioremediation or soil vapor extraction/air sparging;

- **Successful Chemical Applications** - Our use of various remediation chemicals with our unique delivery system is a far safer approach than conventional methods since the delivery system allows us to quickly disperse oxidizers and other materials over a broad area, eliminating the localized heating and vapor production effects observed when these materials are injected into modified monitoring wells. EBSI's efficient chemical formulations also eliminate the need for injecting large quantities of highly concentrated material, allowing EBSI sites to receive much lower injection volumes at lower concentrations.

- **Unique Delivery System**. The injection point approach utilized by EBSI is capable of achieving radii of influence of up to 60 feet. Substantially fewer injection points are required to remediate the site, as opposed to the conventional in-situ oxidation injection well approach with typical radii of influence of only 10 to 20 feet.

- **Specialized Field-Monitoring**. EBSI conducts in-situ monitoring for groundwater parameters during the project to gage the progress of remediation, eliminating the need for costly interim sample collection and analysis costs;

## 2.0 REMEDIAL ACTION SCOPE OF WORK

### 2.1 Site Background

H&A is currently evaluating remedial alternatives at the Malden MGP site to address petroleum impacted site groundwater. The site is currently developed and operated as a commercial bakery. The site has previously been investigated to delineate the lateral and vertical extent of contaminants in soil and groundwater. Subsurface soils are described as fine to silty sands with a hydraulic conductivity in the range of 0.01 cm/s. Groundwater is encountered at approximately 7 feet bgs and flows to the west. The most severe impacts are below the bakery operations production area.

### 2.2 Treatment Program

EBSI's general approach for this pilot demonstration is to install a single four inch re-circulation/injection well between wells MW-922 and MW-923 which will provide for a wide area coverage of continuously injected treatment chemicals. EBSI has assumed for this estimate that H&A would conduct the drilling and install the well to our specifications. The combination of patented techniques is available through licensing agreements EBSI maintains with the re-circulating well developers. The re-circulation well is expected to influence up to 50 ft radially – the two existing monitoring wells will each be approximately 25 feet from the recirculation/injection well. Following startup of the recirculation well, a chemical feed will be added to the system. The chemical feed will be from external 15 gallon tanks located outside of the building and connected to the well by tubing (piping) run along internal walls to minimize interference with the bakery operations. We believe this is the most efficient way to distribute treatment reagents over the broad area covered by the site building.

EBSI would provide well installation specifications to H&A who will install the approximately 20 ft deep, double screened well (e.g. screened from 3 to 10 ft bgs, riser from 10 ft to 13 ft, screen from 13 to 20 – exact specification will be provided after an initial site visit). An air lift pump powered by an air compressor external to the building would circulate water in the subsurface. The well would be sealed and a vacuum drawn on the well head to remove vapors to the exterior of the building. A 15 gallon storage tank will be located outside the building and small volumes of reagents will be fed to the recirculating groundwater to produce dilute in-well concentrations of the catalyst, tracers and hydrogen peroxide. The in-well concentration of the peroxide solution will be maintained at less than three percent during the three month demonstration period.. EBSI will operate the system for 3 months and H&A will be responsible for the collection and analysis of samples before, during and after the demonstration to evaluate the effectiveness of the system in: 1) altering the site geochemistry over a wide areal; 2) initiating low-level Fenton Reagent -like reactions to degrade contaminants; and 3) to enhance biological degradation within in the demonstration area.

The design of this demonstration of the PRP technology will enable full scale deployment with minimal additional requirements.

## 2.3 Technical Information

The Peroxide Release Process (*patent pending*) involves the slow and continuous release of an admixture of a dilute $H_20_2$ solution, an acid, natural, inert tracers and a catalyst into existing or specifically drilled monitoring and/or recharge wells. The process (PRP) consists of the slow and continuous release of a stoichiometrically balanced solution into contaminated groundwater to affect a three phased process including:

**Phase 1. Insitu oxidative processes.** In this phase, ***insitu*** Fenton Reagent reactions are generated to produce hydroxyl radicals to degrade dissolved and sorbed chlorinated and non-chlorinated organic contaminants.

Because Fenton Reagent reactions result in the production of iron hydroxides, dissolved trace metals are complexed with the hydroxides and bound to and/or trapped by the soils.

**Phase 2. Plume Redox Modification.** In this phase the introduced, dilute $H_20_2$ solution, modifies the anaerobic regions of the plume through the slow and continuous release of oxygen as the $H_20_2$ degrades creating a conducive environment for the propagation of aerobic bacteria.

The dilute $H_20_2$ solution will be effective in modifying and maintaining the redox of the plume at about 1/3 the cost of existing oxygen release products.

**Phase 3. Microbial Degradation**. Because dilute concentrations of the $H_20_2$ solution are used in the PRP process, soil microbes are not destroyed enabling aerobic bacteria to flourish once aerobic conditions are restored in the aquifer.

**Plume Tracer.** The inert tracer will enable ready tracking of the rate and direction of groundwater migration by sampling and analyzing groundwater collected from downgradient monitoring wells. Inexpensive ICP/MS analysis readily detects the tracers at the part per trillion concentrations.

Because the PRP is inserted into existing wells, the insitu process can operate continuously for periods of two months or more in heavily trafficked or remote locations. Once the inserts are installed, there is no evidence of ongoing remediation.

A pilot scale demonstration conducted at an upstate New York petroleum spill site demonstrated the effectiveness of the process to degrade BTEX and MTBE within six months at a site that had used conventional pump and treat processes for more than nine years.

## 3.0 Remedial Action Estimated Costs

The following is a summary of the costs associated with the aforementioned services delineated in the above SOW to be provided by EBSI.

<u>**Summary of Services**</u>

*Includes all labor, materials, and equipment costs recirculation devices, support equipment, vacuum extraction, and chemical treatment. Independent testing and derived waste disposal to be conducted by others.*

- Conduct site visit to inspect work area for potential locations and installation details. Provide information and assistance for permitting as needed;
- Conduct initial charge of reagents followed by slow feed system set up and operation. Refill feed tank(s) and monitoring of the system on periodic basis.

- Real-time monitoring of groundwater parameters during treatment while onsite;
- Provide data, technical assistance, and other information as needed for final reporting requirements;
- Interior work to be completed during non-production hours;
- Estimated time to complete –3 - 4 months (from permitting to reporting).

Lump Sum Cost: $87,500 to 96,450

## 4.0 Confidentiality

All information in this quotation is confidential and may not be disclosed to third parties without written authorization from EBSI. All rights are reserved. By EBSI's submittal of this proposal, the recipient understands that all technical information provided by EBSI (whether in written, oral, or electronic form) regarding the On-Contact Remediation Process® and/or the PRP process technologies in the proposal itself, as well as during any follow-up response, is the proprietary and confidential property of EBSI. This information shall be mutually handled confidentially and not disclosed to third parties outside of the management or client for this project. In the event that EBSI is not awarded the work, all originals and copies of the proposal and other related technical information provided during the period of proposal preparation and consideration shall be promptly returned.

## 5.0 Assumptions

- Adequate facilities shall be available at the site for the unloading and storage of Process materials in or near the proposed treatment area.

- Potential injection points (MW, AS, or SVE wells) are accessible through roadboxes, or will be made accessible by H&A. EBSI did not include costs for exploration digging to locate and access subsurface injection points.

- Documentation shall be provided to EBSI that delineates the location of underground utilities including but not limited to, electrical, natural gas, telephone, communications, water supply, wastewater conveyance sewers, production or other product conveyance lines, etc.

- Utilities shall be made available at the site including a potable water supply and electrical service (120 V, 60 Hz, 15 amp electrical outlet) within 100 feet of the work areas.

- EBSI assumes that there are no other sources of contamination in the immediate vicinity of the treatment area, besides the contamination identified in data submitted to EBSI prior to this quotation. The presence of additional undocumented sources of contamination could diminish the effectiveness of the Process.

- EBSI may perform sample collection, analysis, and data validation in addition to client and independent testing. Copies of the raw data, summary data tables, and the final laboratory report will be provided to EBSI. EBSI may elect to obtain and analyze split samples for data verification purposes.

- H&A will provide access to all work areas as needed to implement remedial actions. EBSI will be allowed to conduct additional treatment as needed to achieve contaminant concentration reduction goals.
- If this scope of work is contracted on a pay-for-performance basis, the H&A will collect post-treatment samples in a timely manner following treatment (within 2 to 6 weeks).

## 6.0 Limitations

In preparing this proposal for performing the remediation using the Process, EBSI has relied upon the site characterization data provided. This existing site information may have included, without limitation, data regarding site history and the identification, location, concentration, quantity, and character of known or suspected soil and groundwater contamination. EBSI has relied upon the validity of this existing site information in designing and configuring the parameters of the specific Process application proposed for the site, without independent verification of the data provided in such information. The customer acknowledges that the effectiveness of the Process application proposed for this site depends upon the accuracy of the existing site information. If site conditions are found to differ from our proposal assumptions based on the information provided, thereby requiring an increase in the scope of work, EBSI will issue a change order for review and approval to modify the scope of work and contract price accordingly.

## 7.0 Payment Terms

For Pay-for-performance projects, EBSI proposes the following payment terms:

- 40% at contracting;
- 40% after start-up;
- 20% upon submitting technical information to H&A.

## 8.0 Schedule

EBSI can begin site work approximately one month following acceptance of this proposal. EBSI will schedule the site visit within two weeks of finalizing contracting procedures. Field work can begin within two weeks of the site visit and regulatory approval. EBSI has assumed that H&A will collect post-treatment samples between 2 to 3 weeks following treatment. Following receipt of analytical data, EBSI will prepare a letter report of our field activities and any recommendations or conclusions based on the available data. Total project timeframe is approximately 3 months, depending on regulatory approval timeframes and laboratory analytical turnaround times.

**9.0 Basic Ordering Agreement**

EBSI will provide our Basic ordering Agreement upon request for review by H&A.

This proposal remains in effect for 90 days. EBSI looks forward to working with you on this Project. Please call me at (904) 280-2596 or Dr. Ron Scrudato at 315 312-2883 (day), 315 342-2487 (evening), 845 259-2413 (cell) if you need any additional information or have questions or comments regarding this proposal.

Sincerely,

*Ron Adams*

Ronald F. Adams, P.E.
Sr. VP Client Services

LAKE HVAC

HVAC Contractors
41 Pleasant Street
Stoneham, Massachusetts 02180-3823
Telephone (781) 438-8814
Fax (781) 438-9504

# Fax

To: Haley & Aldrich    Attn: Sean Carrol

Fax: 617 886-2600    Pages: 1 of 12 INCLUDING COVER

From: Buddy Davis    Date: 1/8/03

Re: 129 Commercial St. Malden, MA 02148    CC:

☐ Urgent ☐ For Review ☐ Please Comment ☐ Please Reply ☐ Please Recycle

• Comments:

Please review attached.

PLEASE CALL IF YOU HAVE ANY PROBLEMS RECEIVING THIS FAX

LAKE HVAC

HVAC Contractors
41 Pleasant Street
Stoneham, Massachusetts 02180-3823
Telephone (781) 438-8814
Fax (781) 438-9504

January 8, 2003

Mr. Bruce Wilkinson
Haley & Aldrich
465 Medford Street
Suite 2200
Boston, MA 02129-1400

RE: 129 Commercial Street
Malden, MA 02148

Dear Mr. Wilkinson:

We propose to perform the following for the referenced project as per preliminary drawings dated 1/2/03 from R.J.C. Engineers. The following is the scope of work:

**Base Make Up Air System**

Furnish and install:

- (2) 10,000 cfm Gas Fired Electric Cooling Make-Up Air Unit with 100% outside air and return air dampers
- (2) Air distribution socks
- Seismic vibration curbs
- (1) Exhaust Fan for underslab exhaust
- (1) Exhaust Fan for general maintenance shop exhaust
- (1) Louver
- Electrical
- Roofing
- Gas piping
- Controls
- Steel roof deck angles
- Rigging/Scissors lifts
- Sheet metal material
- Starting, Testing & 1st Year warranty

**Enhanced Ventilation System**

Furnish and Install:

- (2) Canopy hood exhaust fans
- (2) General exhaust fans
- (9) Draft inducers fans
- (2) Turbine ventilators
- (4) Counterbalanced back draft dampers
- Exhaust fan starters
- Type B Gas vents
- (9) Barometric dampers
- Roofing
- Rigging/scissor lifts
- Insulation
- Air balancing
- Electrical
- Controls

We do not include:

- Gas Service Upgrade
- Bonding

Thank you for the opportunity to work with you on this project. We look forward to working with you on this and any other future projects.

Sincerely,
Lake HVAC

B. Davis

Buddy Davis
Vice President of Construction

**Project: 129 Commercial Street** HVAC Construction Budget
**Malden, MA**

| Item | Description Of Work | Cost |
|---|---|---|
| | | |
| | MAKE UP AIR SYSTEM | |
| | | |
| 1 | (2) 60 TON ELECTRIC COOLING/GAS HEATING UNITS | $112,547 |
| 2 | (2) SEISMIC VIBRATION CURBS | $8,200 |
| 3 | (2) EXHAUST FANS | $2,362 |
| 4 | (1) EXHAUST LOUVER | $420 |
| 5 | (2) DUCT SOCK AIR DISTRIBUTION SYSTEMS | $4,900 |
| 6 | SHEETMETAL MATERIAL | $15,680 |
| 7 | SHEETMETAL SHOP & FIELD LABOR | $32,400 |
| 8 | ELECTRICAL | $36,470 |
| 9 | GAS PIPING | $13,400 |
| 10 | RIGGING/SCISSOR LIFTS | $7,500 |
| 11 | INSULATION | $2,670 |
| 12 | ROOFING | $11,250 |
| 13 | CONTROLS | $8,670 |
| 14 | AIR BALANCING | $2,668 |
| 15 | STARTING. TESTING & 1ST YEAR SERVICE | $6,000 |
| | | |
| | **SUBTOTAL** | **$265,137** |
| | LAKE HVAC PROJECT MANAGEMENT | $12,000 |
| | FINAL DESIGN DOCUMENTS | $20,780 |
| | **TOTAL MAKE UP AIR SYSTEM TAX INCLUDED** | **$297,917** |
| | | |
| | | |
| | QUALIFICATION TO MAKE UP AIR SCOPE: | |
| | BASED ON MONTHLY UTILITY BILLS, THE EXISTING LOAD DURING THE SUMMER | |
| | MONTHS REACHES 80% OF THE RATING OF THE MAIN 12000 AMP CIRCUIT BREAKERS. | |
| | WITH THE NEW MUA UNITS, AN ADDITIONAL 286 AMPS WILL BE ADDED TO THIS | |
| | SERVICE. PER CODE, WE CANNOT LOAD AN OVER CURRENT DEVICE GREATER | |
| | THAN 80% OF ITS RATING. BASED ON THIS INFORMATION, WE HAVE INCLUDED THE | |
| | COST OF REPLACING THE MAIN SERVICE DISCONNECT WITH A 100% RATED, 1200 AMP | |
| | CIRCUIT BREAKER. THIS SHOULD SOLVE THE PROBLEM, BUT WITHOUT | |
| | FURTHER ENGINEERING CALCULATIONS, WE CANNOT RULE OUT THAT THE MAIN | |
| | SWITCHBOARD MAY HAVE TO BE REPLACED WHICH WOULD COST UP TO AN | |
| | ADDITIONAL $30,000.00 | |
| | | |

*Prepared By:* Lake HVAC, Inc. 1/8/03

**Project: 129 Commercial Street** HVAC Construction Budget
**Malden, MA**

| Item | Description Of Work | Cost |
|---|---|---|
| | | |
| | ENHANCED VENTILATION SYSTEM | |
| | | |
| 1 | EXHAUST FANS & STARTERS | $7,810 |
| 2 | DRAFT INDUCER FANS | $6,562 |
| 3 | TURBINE VENTILATORS | $2,100 |
| 4 | BACK DRAFT DAMPERS | $789 |
| 5 | TYPE B GAS VENTS | $3,281 |
| 6 | BAROMETRIC DAMPERS | $1,575 |
| 7 | SHEETMETAL MATERIAL | $12,949 |
| 8 | SHEETMETAL SHOP & FIELD LABOR | $23,660 |
| 9 | ELECTRICAL | $8,750 |
| 10 | INSULATION | $5,053 |
| 11 | ROOFING | $19,375 |
| 12 | CONTROLS | $6,250 |
| 13 | AIR BALANCING | $1,250 |
| 14 | RIGGING/SCISSOR LIFTS | $4,120 |
| 15 | STARTING, TESTING & 1ST YEAR SERVICE | $3,200 |
| | | |
| | SUBTOTAL | $106,724 |
| | LAKE HVAC PROJECT MANAGEMENT | $3,200 |
| | FINAL DESIGN DOCUMENTS | $8,500 |
| | TOTAL MAKE UP AIR SYSTEM TAX INCLUDED | $118,424 |

*Prepared By:* Lake HVAC, Inc. 1/8/03

RJC RICHARD J. COMEAU ENGINEERS, INC.
TEL (508) 255-7481
FAX (508) 255-5449
P.O. BOX 68, 34 WEST RD., ORLEANS, MASSACHUSETTS 02653 E-MAIL rjc.engineers@verizon.net

RJC J.O. No. 48-402
January 06, 2003

Lake Industries, Inc.
41 Pleasant Street
Stoneham, MA 02180

Attention: Mr Buddy Davis

Reference: 129 Commercial Street - Malden, MA
Bakery Ventilation System Renovations

Gentlemen:

This letter is written in reference to the submission of revised air balance calculations for the bakery area of the facility based upon completion of the preliminary design work for the subject project.

Specifically the purpose of this letter is to summarize the new air balance values for the facility based upon information received as part of the preliminary design work. The preliminary design work provided more detailed information relative to the bakery operation to insure that the proposed renovations would work. There are other bakery equipment considerations which impact the overall installation which should be addressed, but that alteration work is not considered part of the basic fix to the building to provide for pressurization during normal operations. The basic work has to address the potential of the bakery operation accomplishing the necessary renovations to their baking oven installation but should not include that actual work. We have also included a separate description, as an enhanced alteration approach, which also addresses the bakery equipment installation. In any event the following applies:

A. BASIC ALTERATIONS:

1. The proposed makeup air equipment as part of the initial analysis was to consist of two 8,000 CFM conditioned makeup air units which would provide heated air during winter periods and conditioned air during summer occupied periods. The original concept on how to deliver that makeup air to the bakery area was based upon single point delivery from each makeup air unit utilizing 'duct socks'. Based upon the preliminary design work this concept appears to be the correct approach and the location and orientation of that air delivery system has been more defined. The use of a 'duct sock' for supply air delivery to the space in this sort of application has FDA approval and the arrangement can be used for a low velocity delivery method. In other words it provides a lot of makeup air within a relatively small area at low velocity so that the air supply does not upset desired local space/equipment ventilation system air patterns. Please note from the preliminary drawings the intent is to surround the baking area, just outside it, with the new supply air rather than try to drop this amount of air directly within the baking area. It is intended that the makeup air equipment is to be provided with return air connections back to the space so that during nighttime periods the equipment could be used for basic space heating on an on call basis.

2. The provision of the 16,000 CFM, 50 ton, of makeup air amounts to approximately 0.4 CFM/GSF over the entire building area. This amount of air delivered directly into the bakery area amounts to about 1.42 CFM/GSF over that 11,258 GSF area or 3.55 air changes assuming a 24' roof deck height. The 24' roof deck height distorts the hourly air change rate and thus is inappropriate for comparative purposes. Using a 12' high space occupancy yields a 7.10 air change rate in the bottom half of the space yields more useful comparative information.

3. The provision of cooling to the rooftop equipment is a modification based upon the results of the early testing accomplished to determine if the space could be pressurized. During that brief testing period, on a very warm day, the bakery area temperature exceeded 95°F and the space was too hot to carry on baking operations. At that point it was determined, by all involved, that the makeup air equipment would require cooling capability.

4. The existing main freezer underfloor duct system would be connected to its own above floor duct system and directly exhausted out of the building thus eliminating this duct system from the overall building air pressurization issue.

5. There are a number of inoperative roof exhaust fans above the second floor mechanical room which would be removed with the roof openings/roofing sealed and patched. This inactive equipment impacts the ability to control overall space relative humidity during summer periods and allows uncontrolled air infiltration during winter periods.

6. The existing second floor air compressor outdoor ventilation system would remain as currently configured. This area is sufficiently isolated from the bakery area so that it should not have a significant impact on the bakery area humidity control.

7. The basic fix has to allow for the potential that the existing baking area equipment would be retrofitted at some point in the future , but is not included in this scope of work. There are, however, several basic repairs which have to accomplished otherwise the proposed equipment sizing would be too small. This work is summarized as follows:

   a. The existing first floor mechanical equipment room exhaust equipment has to be replaced as it draws 12,000 CFM from the facility. This fan would have to be eliminated and a smaller 2,000 CFM fan, manually controlled on a timer, installed if the scheme is to work at all.

   b. The existing small baking area makeup air units/related air distribution system would be taken out of service, abandoned in place, permanently disabled from operation and the rooftop air inlets sealed. This has to be done as the untreated outdoor air supply would destroy any ability to control space relative humidity. The enhanced solution would include removal of the equipment/system totally to insure roof system integrity as abandoned equipment usually becomes a source of roof leaks in a relatively short period.

   c. The existing skylight units would be closed and sealed shut. This equipment has exhibited the ability to also introduce outdoor air directly into the baking area thus would adversely impact summer space humidity control. The enhanced approach has this equipment being replaced with roof exhaust fans which could enhance the operation of the baking equipment temperature control as well as enhanced control of oven area baking pan oil mist.

The basic overall air flow balance would now look like the following scenario:

Makeup air supply:

2 rooftop units at 8,000 CFM each = .............................. 16,000 CFM

Building - Bakery area exhaust:

| | |
|---|---|
| Baking oven gas furnace exhaust needs, estimated max. = | 2,250 CFM |
| Baking oven direct exhaust needs, estimated max.= | 2,000 CFM |
| Baking oven canopy exhaust needs, currently nonfunctional = | 4,500 CFM |
| Proofing ovens furnace exhaust needs, variable - max. = | 500 CFM |
| Hot water boiler exhaust needs, variable - max. = | 500 CFM |
| Baking area oven aisle roof exhaust fans, controllable = | 0 CFM |
| First floor mechanical room exhaust fan, intermittent - max. = | 2,000 CFM |
| Total Basic building exhaust = | 11,250 CFM |
| Net building pressurization = | 4,750 CFM |

The net building pressurization is theoretically 4,750 CFM which would be considered more than enough for a 40,000 GSF facility in this situation. However, the exhaust flow rates are assuming the production area in full operation so there is real additional pressurization air capacity available at part loads. How much is subject to debate depending on what is going on in the building, but the above numbers are based upon projected worst case scenario. The rooftop equipment is provided with return air duct connections to the space thus there is the ability to adjust daytime actual outdoor air flows based upon utilizing a building pressurization controller, which previously has not been discussed, but may be a more effective energy control scenario than heat/energy recovery. Our office has looked at application of an energy saving exhaust scenario but the problem is that the most of the proposed exhausts would/should be picked up may contain grease which would quickly plug the desiccant wheels making them worthless. The best current approach appears to be controlling the operation of individual items.

B. ENHANCED RENOVATIONS:

The preliminary design layout also reflects additional work believed to be required to enhance the operation of the bakery area equipment with particular emphasis of the baking oven vent systems. The work described under the basic alterations is included and then enhanced by the inclusion of the additional work perceived to be required under this approach. It is believed that this enhancement work will significantly improve the apparent existing baking oil misting now occurring in the baking area. There is also a perception that the existing baking area oven systems do not work well based upon on-site observations and running of the theoretical air flow numbers.

1. The various exhaust air points in and around the bakery area have now been more accurately defined for the bakery area with the help of the bakery operating personnel. The following description of the various exhaust points and their impact is described in some detail so that this writer can check his own logic by repeating it but also so that the bakery operation personnel can also follow along and double check our basic thinking. The various exhaust points in and around the bakery area can be summarized as follows:

    a. The individual baking ovens actually consist of a gas fired hot air furnace which is equipped with an air-air heat exchanger which then heats the air in the oven section by means of its own circulation fan. This arrangement allows for some sophisticated baking techniques to be employed in the oven section which do not impact the actual furnace section. The net result is that you have to deal with two different processes which consist of the furnace section and then the oven section as they accomplish their individual functions. For the furnace section there is the need to provide for combustion air directly in the combustion chamber for burning and then there is the need to provide for control of the air pressure within the furnace section so that the combustion can occur in a controlled manner and then be able to discharge the products of combustion out of the furnace through the roof in a regulated manner regardless of outside ambient conditions. For an individual oven this means that room air is drawn into each furnace, about 112 CFM. This air is burned with natural gas and the products of combustion then enter the furnace chimney. The furnace chimney is fitted with a mechanical draft inducer which insures an exhaust flow rate out of the oven under all atmospheric conditions. The flue from the furnace outlet to the draft inducer inlet is fitted with a barometric damper which automatically allows room air to enter the flue to maintain the furnace under its design negative pressure during operation. This setup is fairly common with all types of heating equipment. The existing draft inducers are sized for roughly 250 CFM which includes the products of combustion from the furnace and room induced air in order to regulate the furnace interior air pressure.

b. Currently the existing ovens have pairs of furnaces hooked up to a single chimney section up through the roof. That means that two draft inducers are connected to the same flue which is unusual as normally draft inducers should be isolated to their own flue so that the fans do not fight each other. We would thus recommend that each furnace section be individually vented through the roof to provide for more accurate individual furnace pressure control as well cut down on the amount of air being exhausted from the building to only that amount required because that individual oven is in operation. The total exhaust air from the ovens could be 9 furnaces at 250 CFM each or 2,250 CFM.

c. The baking oven actual baking section is totally separate operation from the furnace and relates to the preparation/cooking of a particular product. There are two separate vents out of the oven section which vent heated air and vapor created as part of some of the baking process. These vents are more of a gravity release process versus the more vigorous combustion process, i.e. the expanded air from within the oven during the baking process as well as water vapor used during portions of the baking process. A mechanical exhaust of this portion of the oven would not work well in this situation. In this case it is proposed to collect the various oven vents in each bank and duct them through the roof with a gravity wind turbine vent for discharge to atmosphere. Each of the two exhaust systems would be fitted with duplexed barometric dampers to insure that excessive negative pressure was not created with the ovens during the baking process. The four barometric dampers could draw up to 250 CFM each and oven doors left open could double the air flow rate for a total of 2,000 CFM. Each rooftop turbine ventilator unit would also be equipped with a motorized damper to isolate this equipment during facility shutdown periods. This revision is believed to be one of the key factors in controlling pan oil misting with the bakery area, but not the total correction.

d. The baking ovens are equipped with 24" deep canopy exhaust hoods over each oven access door. The objective obviously is to catch excess heat from the oven when the access door is opened. As demonstrated by bakery operation personnel the oven canopy exhaust hoods actually had air coming out of them rather then into them thus totally negating their function. We have analyzed their function together with the direct oven venting system. It is believed that if the oven venting system described above in item 1B can be rebuilt the canopy system would be effective in the overall processing of the product, i.e.

if at the end of the baking process the oven could be shut off or time out and the oven door opened. Between the oven interior gravity vent and the powered canopy vent the baked product may be able to achieve its initial cooling if the baking rack was simply moved 2' out of the oven, outer rack edge under the outer canopy edge, so as to be under the influence of the canopy vent. The canopy vents are not kitchen hood appliances and are evidently intended to function as 'low level exhausts. The canopy hoods are equipped with 8" connections which indicates an intent to only exhaust about 500 CFM per canopy for a total of 4,500 CFM. Each set/row of banked ovens with a continuous canopy setup would provide more local product cooling effect as the ovens are cycled. These exhaust fans, 1 @ 2,000 CFM and 1 @ 2,500 CFM, would be fitted up as standard 'kitchen' exhaust fans to catch what grease was being picked up from the canopies.

e. There are hot water boilers and proofing ovens in the baking area which are gas fired and fitted with individual flues. There are 4 such flues which we are rating at approximately 250 CFM each as far as space direct air exhaust is concerned.

f. The baking area operates with rolling pallets of freshly baked goods emerging from the ovens on a regular basis which means that some amount of baking pan oil is still being emitted when the rolling pallets are being withdrawn from the ovens. This situation can be mitigated by the conversion of the existing skylight units to baking access aisle exhaust fans which are figured at about 2,500 CFM each. This approach would require increasing the size of the makeup air equipment from 8,000 CFM/50 tons to 10,000 CFM/60 tons each.

2. This approach would require increasing of the makeup air unit capacity from 8,000 CFM/50 ton capacity each, to 10,000 CFM/60ton capacity each, and then installing a pair of 2,500 CFM aisle area roof exhaust fans. It is believed that this equipment would be fairly effective in removing local space oil misting. There is a concern relative to the existing oil misting impact on the existing space environmental condition as our office is not qualified to evaluate same, however, there is a perceived problem that probably requires addressing.

3. Assuming that all of the foregoing is accomplished the creation of local space misting would be diminished but not totally eliminated, refer to the comment in 1f above. The objective of the current design is to mitigate the space negative pressure during bakery operations. It is not intended to provide total control of the space environment as that environment has been created by the setup of the bakery operation. The foregoing simply describes how to control mist creation in the baking area. The overall design is intended to deal with what to do with the residue, maybe a large amount of pan oil residue mist, that releases into the baking area. That problem is proposed to be addressed by roof exhaust fans located above the central oven access aisle area. As baking racks are extracted from the ovens slowly, i.e. the 2' mentioned above, and then pulled out into the central aisle for cooling the heat from these racks would create a small individual plume of heat and oil which then be picked up by the oven baking aisle central roof exhaust fans. Right now it is planned that these roof exhaust fans would be sized at approximately 2,500 CFM each for a total of 5,000 CFM. These fans would be fitted up as standard 'kitchen' exhaust fans to catch what grease was being picked up from the general area.

The overall air flow balance now looks like the following scenario:

Makeup air supply:

2 rooftop units at 10,000 CFM each = ........................ 20,000 CFM

Building - Bakery area exhaust:

| | |
|---|---|
| Baking oven gas furnace exhaust needs, estimated max. = ............ | 2,250 CFM |
| Baking oven direct exhaust needs, estimated max. = ................ | 2,000 CFM |
| Baking oven canopy exhaust needs, continuous = ................... | 4,500 CFM |
| Proofing ovens furnace exhaust needs, variable - max. = ............ | 500 CFM |
| Hot water boiler exhaust needs, variable - max. = .................. | 500 CFM |
| Baking area oven aisle roof exhaust fans, controllable = ............ | 5,000 CFM |
| First floor mechanical room exhaust fan, intermittent = ............ | 2,000 CFM |
| Total Basic building exhaust = ................................ | 16,750 CFM |
| Net building pressurization = ................................. | 3,250 CFM |

The net building pressurization is theoretically 3,250 CFM which would be considered the minimum allowable for a 40,000 GSF facility in this situation. However, the exhaust flow rates are assuming the maximum number of ovens in operation so there is real additional pressurization air capacity available at part oven load usage. How much is subject to debate depending on what is going on in the building, but the above numbers are based upon projected worst case scenario. The rooftop equipment is provided with return air duct connections to the space thus there is the ability to adjust daytime actual outdoor air flows based upon utilizing a building pressurization controller, which previously has not been discussed, but may be a more effective energy control scenario than heat/energy recovery. Our office has looked at application of an energy saving exhaust scenario but the problem is that the most of the proposed exhausts would/should be picked up may contain grease which would quickly plug the desiccant wheels making them worthless. The best current approach appears to be controlling the operation of individual items.

The proposed control system for the facility mechanical system has evolved into the following scenario:

The rooftop makeup air equipment would work as follows:

1. The rooftop equipment operation would be controlled by means of a programmable electronic time clock which is to be set to determine starting and stopping times as suits the bakery operation.

2. During occupied periods the rooftop makeup air units, AC-1 and AC-2, would start and provide treated outdoor air to the facility. During occupied periods each rooftop unit would run and its outdoor air damper open and the return air damper would be closed. Air would be discharged from the unit with an adjustable discharge temperature of 55°F, adjustable 55°F to 65°F. During summer periods, i.e. over 55°F, the mechanical cooling would be energized to maintain discharge setpoint and during periods below 55°F the heating section would be energized to maintain discharge setpoint.

3. During unoccupied periods the rooftop units, AC-1 and AC-2, shall shutdown, the outdoor air dampers close and the return air dampers shall open. A space heating/cooling thermostat would be provided to cycle the rooftop AC units on a call for space heating only. The space thermostats shall have a manual heating/cooling selector switch to enable unoccupied period

space cooling.

4. Smoke/heat detectors shall be provided for each rooftop to disable the equipment in the event of actuation.

The exhaust ventilation equipment shall operate as follows:

1. Oven operation would be controlled by means of the existing integral oven control equipment. The individual oven flue exhaust draft inducer would be interlocked with the respective oven combustion controls. This equipment would be able to operate independently of the makeup air system operation.

2. The baking oven gravity exhaust system isolation damper located at each roof level turbine vent inlet shall open for each oven bank. These two systems would be interlocked with the respective oven bank operation independent of the makeup air system operation...

3. The oven canopy hood exhaust fans for each bank of ovens, one exhaust fan for each oven bank, shall be manually controlled from the oven area. These exhaust fans would be interlocked with the makeup air system operation so as to only be enabled during occupied cycles.

4. The two oven area general exhaust fans shall be controlled by means of a local high limit thermostat which shall energize the exhaust fans in the event that the space thermostat exceeds setpoint, i.e. 80°F adjustable. These exhaust fans would be interlocked with the makeup air system operation so as to only be enabled during occupied cycles.

5. The exhaust fan serving the underground freezer frost control ventilation system would operate continuously.

6. The first floor mechanical room local exhaust would be manually controlled by means of a local wall switch equipped with a 1 hour timer switch.

In summary please review the foregoing and provide comments before we include the foregoing information on the preliminary drawings. If there are any questions please contact this writer. In submission of this letter together with the prior preliminary drawing our office assumes the preliminary design effort is complete.

Very truly yours,

Richard J. Comeau

enclosure: Preliminary Design Drawing dated 01-02-03

| HALEY & ALDRICH | CALCULATIONS | File No. 29847-000 |
|---|---|---|
| | | Sheet 1 of 2 |
| Client | MEC | Date 6-12-03 |
| Project | Malden MGP | Computed By SMC |
| Subject | Alternative 5-4 | Checked By |

- SVE - Same as Alternative 5-1.
- Oxygen injection

⇒ Refer to 2/5/03 calculations for estimated groundwater flux rates.

⇒ Approx. 1.8 lb $O_2$/day would be required to maintain concentrations of 40 mg/l in injection wells.

⇒ From Alt. 5-2, estimated contaminant mass in groundwater = 306 kg BTEXSN.

⇒ System would rely on natural groundwater flow to flush $O_2$ through contaminated soil + groundwater. From Alt. 5-2, estimated travel time from middle of building to downgradient end of plume is approximately 1 year.

However, $O_2$ will be depleted quickly at start-up due to high concentration of contaminants. System relies on biodegradation rates, which are unknown.

⇒ Based on common rule of thumb of a 3 to 1 oxidant to contaminant ratio, can deliver requisite oxygen in following time:

Note: Refer to "Oxygen Revisited", p. 45 and p. 48 for reference

Contaminant mass = 306 kg BTEXSN

Required $O_2$ mass = Approx 1,000 kg $O_2$ (2205 lb)

Delivery rate = 1.8 lb/day

Delivery Time = $\frac{2205 \text{ lb}}{1.8 \text{ lb/day}}$ = 1225 days, or 3.4 years.

⇒ Assume additional time for degradation of contaminant mass on soil grains + multiple flushes of pores ⇒ Assume 10 years to complete

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | 29847-000 |
| Project | Malden MGP | Sheet | 2 of 2 |
| Subject | Alternative 5-4 | Date | 6-12-03 |
| | | Computed By | SMC |
| | | Checked By | |

<u>Required Number of Wells</u>

Well spacing will be determined by interior building layout and other considerations. Goal is to set up a "curtain" of oxygen injection. According to attached references (Oxygen Revisited) radius of Influence ranges from 10 to 32 ft. Assume approx. 20 feet.

Refer to Figure 21 for proposed well layout.

<u>Assume 15 injection wells in 3 rows.</u> Spacing within rows is approx. 20-25 ft, Spacing between rows is approx. 40 ft.

Assume piping to wells is installed in sub-slab Conduits, similar to Alternative 5-2 for Slow-release chemical oxidation. Install along column grid - can combine SVE trenching + $O_2$ Injection in same trench.

Based on attached reference, 15 wells should be sufficient to deliver assumed rate of 1.8 lb/day.

<u>Installation costs</u>

Well installation: Will require indoor drill rig and Support crew. Based on previous experience, cost will be approx. <u>$2,000 per well</u>, plus Support costs (mobilization includes these).

<u>Installation Time</u>

Assume 2 wells installed per day, 8-hr work days. Including clean-up, system installation would require approximately 7 Days (Assume 2 weeks)

Assume trenching for distribution piping can be conducted simultaneously.

HALEY & ALDRICH

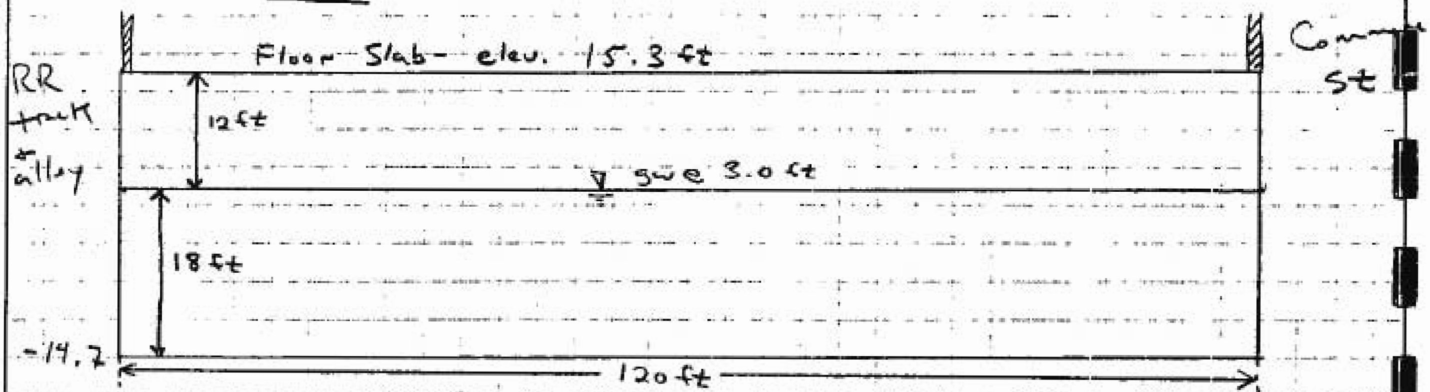
# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | |
| Project | Malden Ph. III / 129 Commercial St | Sheet | 1 of 2 |
| Subject | Oxygen Canister Calcs | Date | 2/5/03 |
| | | Computed By | SMK |
| | | Checked By | |

Isoc

Assuming 10 ft water, 1 ft/day flow rate, Isoc guide says can achieve ~ 50 mg/l $O_2$ in well. Assume 40 mg/l

Cross-section:




Area = 18 x 120 = 2160 $ft^2$

q = (111 ft/day)(.003) = 0.33 ft/day (darcy flux)

Q = 719.3 $ft^3$/day x 28.31 l/$ft^3$ = <u>20363 l/day</u>

=> ∴ To maintain concentration of 40 mg/l,

$$\left(40 \frac{mg}{l}\right)\left(20363 \frac{l}{day}\right) = 814 \text{ grams } O_2/\text{day}$$

$$\left(814 \frac{grams}{day}\right)\left(0.0022 \text{ lb/g}\right) = 1.8 \text{ lb/day}$$

CAL02AFH.FRP 20 November 1997

HALEY & ALDRICH

# CALCULATIONS

| | | | |
|---|---|---|---|
| Client | MEC | File No. | |
| Project | Malden Ph. III / 129 Comm. | Sheet | 2 of 2 |
| Subject | $O_2$ Canister Calcs | Date | 2/5/03 |
| | | Computed By | SMC |
| | | Checked By | |

Estimate mass of BTEXSN in groundwater beneath 129 Commercial St building:

Use max conc. BTEXSN Detected recently:

922: 87 mg/l
923: 10
918: 121
NC-3: 93

} Average = 78 mg/l

Approx. impacted area = 250 x 120 feet = 30,000 $ft^2$
Approx. depth = 15 feet (?)

Approx. volume impacted aquifer media = 450,000 $ft^3$

x 0.3 porosity = 135,000 $ft^3$ water
x 28.31 l/$ft^3$ = 3,821,850 l water

=> Est. total BTEXSN mass = (3,822,000 l)(78 mg/l) = **298 kg**

Assuming 300 kg contaminant mass in groundwater, approx. 900 kg of $O_2$ will be required, assuming 3:1 ratio.

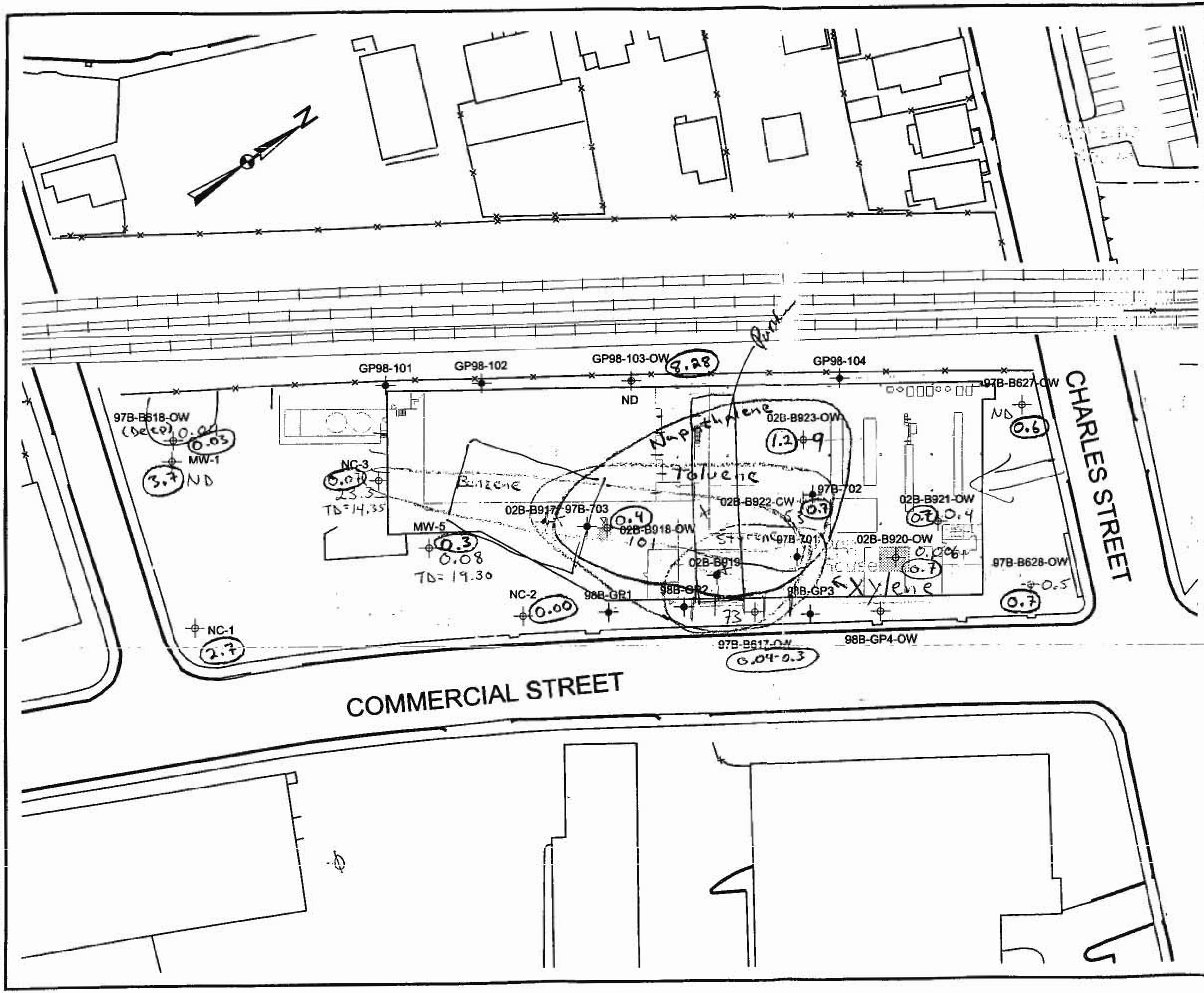
Assume 0.8 kg $O_2$ delivery per day => 900/0.8 = 1125 Days
= 3 years

=> However, significant uncertainty in mass of contaminant, rate of biodegradation. Also, sorbed concentration on soil will desorb once aqueous concentration decreases

∴ likely to require longer => use ~ 10 yrs

CAL02AFH.FRP 20 November 1997

g:/06558/616/ARCVIEW/MALDEN MGP.APR




| | MW |
|---|---|
| B: | 78 |
| T: | 92 |
| X: | 106 |
| S: | 104 |
| E: | 106 |
| N: | 128 |

LEGEND:

- HISTORIC MGP STRUCTURES
- SHALLOW MONITORING WELL LOCATION
- SOIL BORING LOCATION
- BAKERY PRODUCTION FACILITIES
- 73 Total Detected VOC Concentration, May 2002
- (1.23) Dissolved oxygen concentration

NOTES:

1. BASE PLAN ADAPTED FROM "TOPOGRAPHIC WORKSHEET OF THE MANUFACTURED GAS PLANT, MALDEN, MA" FOR MASSACHUSETTS ELECTRIC COMPANY BY EASTERN TOPOGRAPHICS, JUNE 1995, AND CITY OF MALDEN ASSESSOR'S PLAN, SHEETS 1 AND 2, JUNE 1995, AND SHEET NO. 53 BY FAY, SPOFFORD & THORNDIKE, INC., UPDATED JUNE 1976 AND REVISED 30 JULY 1979.
2. ELEVATIONS ARE IN FEET AND RELATIVE TO NGVD.

60 0 60 Feet

HALEY & ALDRICH
UNDERGROUND ENGINEERING & ENVIRONMENTAL SOLUTIONS

FORMER MALDEN MGP SITE
129 COMMERCIAL STREET
MALDEN, MASSACHUSETTS

GROUNDWATER SAMPLE LOCATIONS
MARCH 2002

SCALE: AS SHOWN

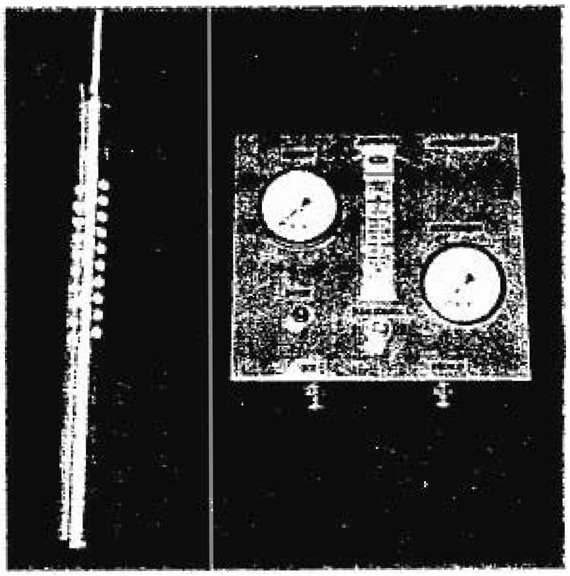
MAY 2002

FIGURE 1

inVentures
Technologies
incorporated
www.gasinfusion.com

# *iSOC*™

## Your *ultimate* managed attenuation tool ...



*iSOC*™ with Single Control Panel

### *iSOC*™ Bioremediation Enhancement

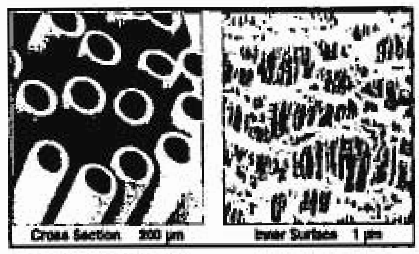
- **Supersaturates** monitoring well with low decay dissolved oxygen (DO), typically 40-200 PPM depending on depth in groundwater
- Natural convection current fills well with **uniform DO** curtain
- **Supersaturated DO curtain** of water **disperses** around the well into the adjacent groundwater
- Enhanced bioremediation **removes organics** through natural attenuation
- **Placement** of injection wells depends on site-specific conditions
- **Installed** in a **few hours** and easily moved from well to well to optimize performance

### What is *iSOC*™?

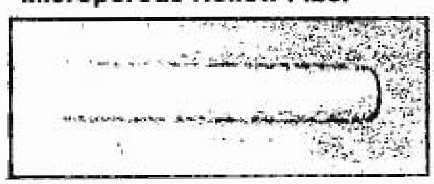
*iSOC*™ is an **ingenious** oxygen delivery technology, based on inVentures' **patented *Gas inFusion*™ technology**—a unique method of infusing supersaturated levels of dissolved gas into liquids. At the heart of *iSOC*™ is the **proprietary** structured polymer **mass transfer** device.

Microporous hollow fiber provides an enormous surface area for mass transfer— in excess of 7000 $m^2$ per $m^3$—and is hydrophobic (will not pass water). Maintaining a gas pressure, less than the liquid pressure ensures that ultra efficient mass transfer takes place without the formation of bubbles.

When suspended in existing monitoring wells, *iSOC*™ infuses *high levels of oxygen into groundwater*, **without bubbles**, and with a **very low decay rate** at atmospheric pressure.




Microporous Hollow Fiber

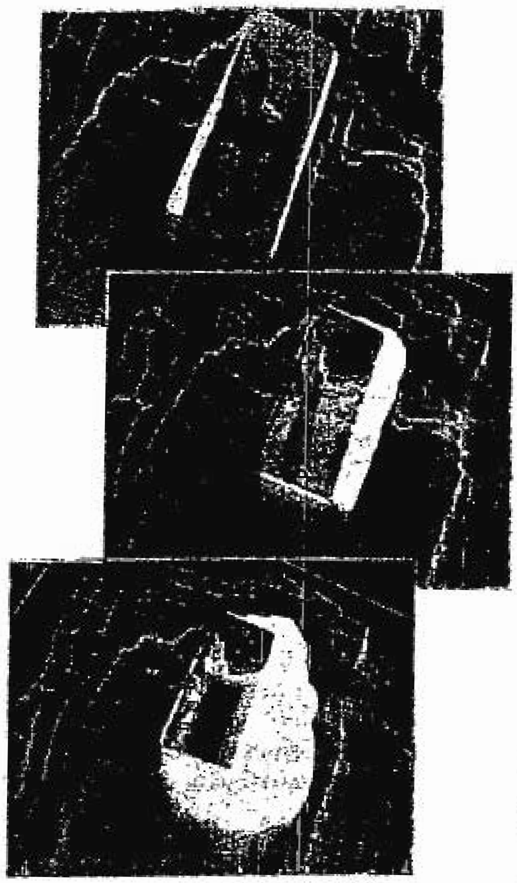


*iSOC*™ Mass Transfer Device

### What do consultants say about *iSOC*™?

Several leading environmental firms have achieved **significant reductions** in MTBE, BTEX, and TBA, and have commented:

- "In **less than 3 months** since *iSOC*™ installation, MTBE & TBA have decreased by an order of magnitude, DO has increased in monitoring wells 30' away, and ferrous iron and BOD have dropped."
- "Since installation of *iSOC*™, MTBE has been reduced from **3500 to under 200 PPM** in fractured bedrock in about **4 weeks.**"
- "We established an effective barrier of DO in ~**3 months with reductions of 84% MTBE, 31% TBA, 73% benzene** down gradient of $O_2$ barrier."



## Hydrocarbons and *iSOC™*

The use of dissolved oxygen in hydrocarbon-contaminated groundwater to **enhance natural attenuation of MTBE and BTEX** has been growing as a remediation technology since the mid-1990s.

Most conventional technologies, however, waste most of their oxygen because the bubbles rise to the top of the groundwater table and escape before they have a chance to dissolve or to be utilized by naturally occurring hydrocarbon degrading microorganisms.

The result is an inadequate biodegradation response in aquifers with high ferrous iron, moderate BOD, and/or high concentrations of hydrocarbon constituents.

***iSOC™* overcomes the conventional problems**

## *iSOC™* Remediation Approach

Create oxygen **barrier at leading edge** of contaminant plume to avoid boundary litigation, and to protect off-site receptors.

**Source treatment** reduces contamination levels with supersaturated oxygen at heart of the plume.

Achieve rapid, localized remediation of low-level contamination and **hot spots** in existing monitoring wells.

**Accelerate site closure** through natural attenuation as a primary remediation strategy or as a polisher.

Maintain **cost effective, passive** enhancement of natural bioremediation for less than normal monitoring costs.

## Where has *iSOC™* been used?

*iSOC™* has been used or approved for remediation use **in 21 US states** including Florida, Georgia, New Jersey, Delaware, Connecticut, Pennsylvania, New Hampshire, Vermont, Massachusetts, West Virginia, Maryland, Colorado, Wyoming, Montana, Washington, California, Arizona, Utah, New York, Indiana, and Michigan; several countries in **Europe, Canada,** and **Brazil**.

## *iSOC™* Oxygen Distribution

Mass transport laws govern **oxygen dispersion and distribution.**

The iSOC™ supplies oxygen according to demand.

Case studies show the typical **radius of influence to be 10 to 20 feet** from the *iSOC™* well, although each site must be judged by its specific characteristics.

*iSOC™* case studies show that a 2-well system can use as much as 32 pounds of oxygen over a 3 month period, and that a 3-well system can use as much as 64 pounds of oxygen over a 5 month period.

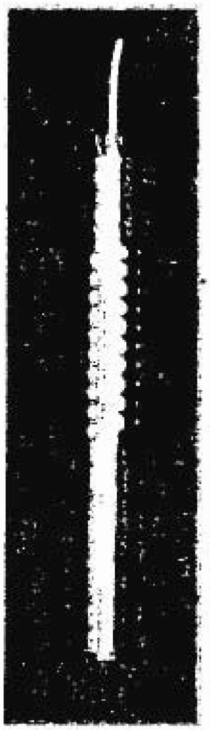
| Gas Type | Water Column Depth in Feet | | | | |
|---|---|---|---|---|---|
| | 5' | 10' | 15' | 20' | 50' |
| Oxygen | 42 | 55 | 62 | 69 | 111 |
| Methane | 22 | 30 | 33 | 37 | 59 |
| Propane | 66 | 88 | 99 | 110 | 175 |
| Hydrogen | 2 | 2 | 3 | 3 | 5 |
| Ethane | 57 | 75 | 85 | 95 | 150 |

***iSOC™* Dissolved Gas Concentrations in a Water Column**

## Can we use other gases with *iSOC™*?

**Yes** .... Consultants see the need to use other gases in their remediation approach, such as hydrogen, methane, and propane for remediation of chlorinated solvents.

*iSOC™* will transfer these gases into the groundwater as effectively as it transfers oxygen, as illustrated in the table to the left.



*ISOC™* **Unit**

## *iSOC™* Quality Construction

*iSOC™* is constructed of high quality **SS316 stainless** steel using the latest manufacturing equipment and a **proprietary** structured polymer **mass transfer** device.

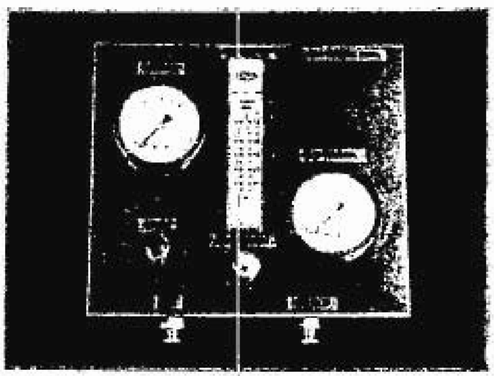
*iSOC™* is **1 5/8" diameter** and 15" long with a quick-connect swedge oxygen fitting for 0.25" polyflow tubing.

*iSOC™* has a lifting ring for connecting to a suspension line for insertion in **2"** or larger monitoring **wells.**

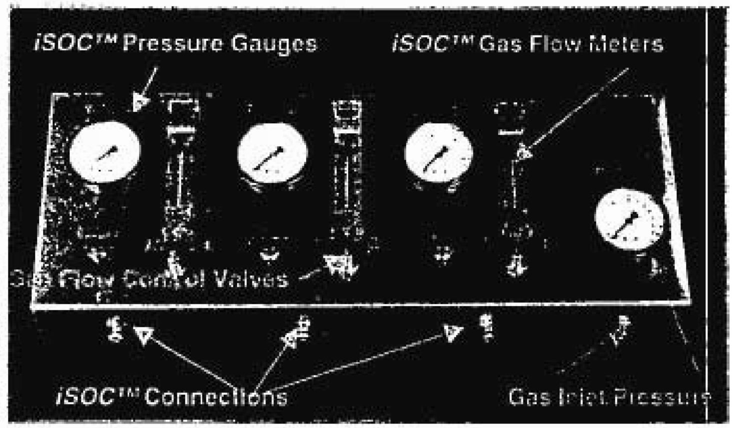
*iSOC's™* stainless steel case and polymer mass transfer device have a **very high tolerance to** most pure gas & **contaminant environments**

## *iSOC™* Advantages

- *iSOC™* infuses **4 to 10 times more DO** than any competitive technology
- *iSOC™* delivers **40 to 200 PPM DO** depending *iSOC™* depth
- *iSOC™* uses **existing 2-inch monitoring** wells used for installation
- *iSOC™* is **not bothered by iron or other oxygen sinks**
- *iSOC™* **connects to standard oxygen cylinder** using the *iSOC™* Control Panel
- *iSOC™* requires **no power requirements, off-gases, pumps, hazardous by-products, or permits**
- *iSOC™* is **small, simple, efficient**, predictable, easy to use, & very low in maintenance



*iSOC™* **1-Unit Control Panel**




*iSOC™* **3-Unit Control Panel**

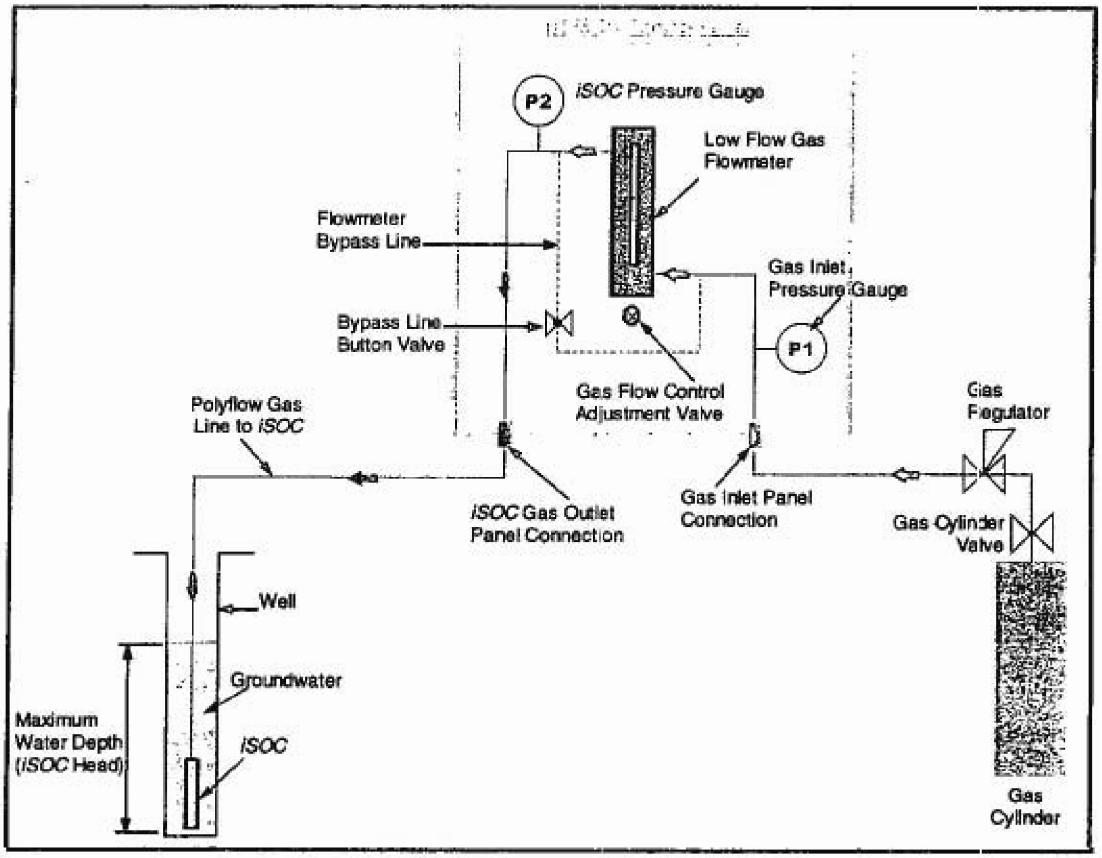
## The iSOC™ Control Panel

- *iSOC™* control panel comes in 1-unit and 3-unit models to control a single or three *iSOCs™*
- Panel is constructed of high quality **SS304 stainless steel** for use in most conditions or contaminant environments
- High quality **gas compatible** pressure gauges indicate the gas pressures in both PSI and BAR
- **Oxygen cleaned** components are used throughout and completely pressured tested prior to leaving manufacturing facilities
- A **unique flow control mechanism** is utilized to accurately control flows and allow the *iSOCs™* to be placed at different depths in the groundwater
- Quick-connect fittings allow the *iSOC™* and the *iSOC™* Control Panel to be **connected** by polyflow tubing **in seconds**
- 1-unit Control Panel is 3"X9"X8" and weighs 3 lbs.
- 3-unit Control Panel is 3"X21"X8" and weighs 8 lbs.
- Each Control Panel is shipped in a specially designed box for protection, and to arrive ready for quick connection.

## Why use the *iSOC™* Control Panel?

- Design based on actual installation and operation experience of remediation contractors
- Specially designed components eliminate typical system installation, start up and operation problems, provided *iSOC™* User Guide instructions followed
- **High quality** construction
- **Pressure tested** from the manufacturer
- Uses only **oxygen cleaned** components
- All **gas compatible** components
- Allows the *iSOC™* to be hung at **different depths** in the groundwater while maintaining proper control of all units
- **Costs less** time and money than it takes to source, assemble and pressure test oxygen cleaned and gas compatible components
- Allows for **rapid installation** and **easy operation** of the *iSOCs™*
- inVentures Technologies **warrants** the performance of the *iSOC™* when iSOC™ and the *iSOC™* Control Panel are used together

## What does an *iSOC™* System Look Like?




***iSOC™* Equipment Setup Schematic**

## How much does *iSOC™* and the Control Panel Cost?

The *iSOC™* groundwater remediation technology is the **leading** and **most cost effective solution** in the marketplace today. Some **state trust funds** will not reimburse a capital purchase but **will reimburse** a rental charge plus consultant's installation and operation costs – *iSOCs™* are available to rent for these situations.

Please contact your area representative for prices – they are listed in–

**www.gasinfusion.com**

Treatment Technology/

# Oxygen Revisited

by Evan K. Nyer, J. Scott Davis, and Isabel King

In 1987, one of the most advanced in situ technologies for remediation of sites was oxygen. I remember representatives of FMC Corp. wandering around one of the early conferences on remediation and hawking hydrogen peroxide. They had high hopes that environmental applications were going to be the next big use of $H_2O_2$. At that time, it was believed that in situ bacteria required $O_2$ to degrade petroleum hydrocarbons.

Of course, we all now know that it is the other, naturally occurring, electron acceptors that are responsible for the majority of the biochemical destruction of petroleum hydrocarbons. Every consultant worth his or her salt recommends a monitored natural attenuation (MNA) remediation strategy. MNA relies on the natural presence of alternate final electron acceptors to accomplish the remediation.

A funny thing has happened during the last couple of years. The importance of $O_2$ is making a comeback. It looks like a couple of compounds degrade only with bacteria that require $O_2$. Bacteria that require $O_2$ for their final electron acceptor are referred to as "obligate aerobic bacteria." For some reason, these bacteria are not able to use nitrate, sulfate, iron, manganese, or $CO_2$ as part of their enzyme systems. On the other hand, these bacteria are able to degrade some important contaminants.

The strongest evidence for obligate aerobic degradation seems to exist for methyl tert butyl ether (MTBE) and long-chain alkanes (the type of hydrocarbons found in diesel, fuel, oil, and other low-end distillates). Several projects have found that when they add $O_2$ to sites that contain these compounds, they have had success in destroying them. Laboratory work has confirmed the ability of several obligate aerobes for these types of biodegradation.

All of this means that $O_2$ is back. It has been a long time for many of us since we designed an oxygen delivery system. I thought that it would be a good idea to review the different methods for in situ delivery of $O_2$. While we are at it, we might as well discuss some economics. There have also been some new technologies introduced during the last 15 years, and we will include some of those. I have asked two engineers from our Tampa office to assist me with this article, Scott Davis and Isabel King.

## Case Study

To provide a baseline for our discussion in applying the various $O_2$ delivery techniques and comparing the economics, we must first develop a case study of a typical application site. Of course, we will pick a site within three hours of our office in sunny Daytona Beach, Florida. As shown in Figure 1, our study site is an existing retail gasoline service station where a release of diesel fuel occurred many years ago beneath a former fuel dispenser island. The release was not detected throughout the operation of these fuel dispensers until more than 10 years had passed, which has resulted in both adsorbed-phase and dissolved-phase impacts. Free-phase petroleum product has not been detected at the site.

The aquifer at the site comprises primarily medium- to fine-grained quartz sand with shell fragments increasing with depth. The depth to water at the site historically ranged from 5 to 6 feet below land surface (bls). However, a

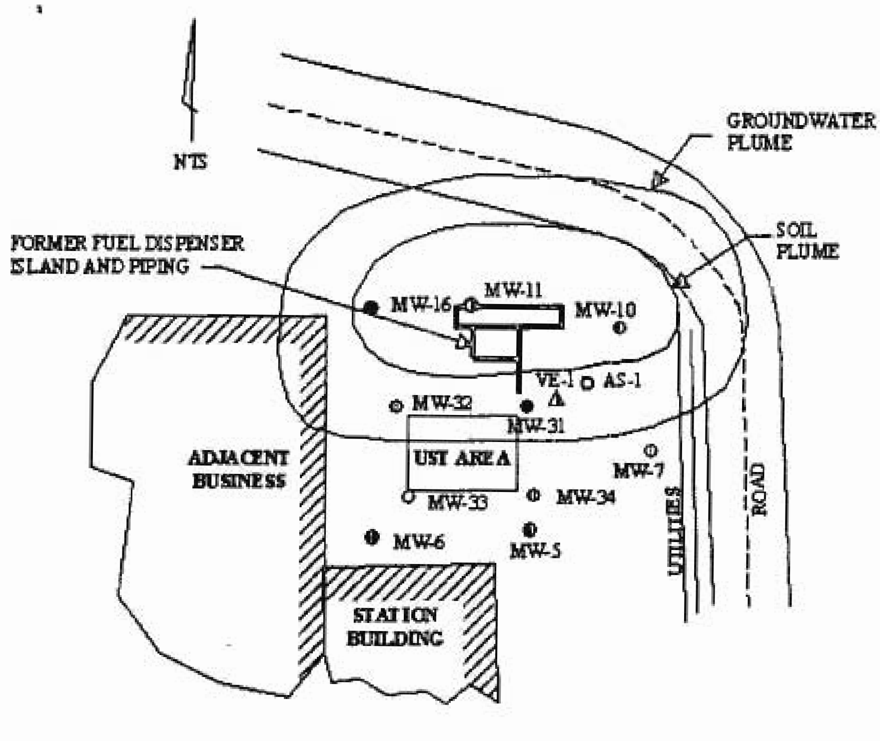



Figure 1. Case study site layout.

steady drought over the last two years has resulted in a depressed water table currently at a depth of 7 to 9 feet bls creating a 4-foot smear zone. Owing to the close proximity of the Atlantic Ocean and fresh water supply from tidal surges, the dissolved oxygen (D.O.) present in the ground water at the study site is naturally higher than inland Florida ground water with an average concentration of 3 mg/L. However, a biogeochemical evaluation conducted at the site showed that the D.O. was reduced to less than 1 mg/L within the dissolved hydrocarbon plume.

Because the origin of the release was the diesel fuel dispenser, the primary constituents of concern in the soil and ground water are the semivolatile polynuclear aromatic hydrocarbons (PAHs) and long-chain alkanes. These impacts are limited to the immediate vicinity of the former fuel dispenser island and extend vertically from 5 to 9 feet bls. For our study site, approximately 95% of the mass is adsorbed to the soils within the ground water fluctuation zone. Only 5% of the mass is in the dissolved phase because of the limited solubility of the PAHs and long-chain alkanes. This results in 143 pounds of petroleum hydrocarbons adsorbed to the soil, and only 7 pounds are dissolved in the ground water.

## Rationale for Oxygen Enhancements

As described previously, a dissolved hydrocarbon plume has been present at the site for more than 10 years. Although there are elevated concentrations of D.O. in the site ground water, the levels have been reduced to below 1 mg/L within the plume. At these reduced D.O. levels, the degradation pathways in an aqueous environment are susceptible to switching from aerobic to anaerobic. We all know that this results in much slower degradation rates, especially for the long-chain alkanes and high molecular weight PAH constituents, and that is the reason these constituents are still persistent in the ground water at the study site after abating the source of contamination many years ago.

One cost-effective alternative to remediate this site is to enhance the natural degradation processes by adding oxygen to switch the metabolic pathway from anaerobic conditions back to aerobic conditions. To design an effective, enhanced aerobic environment, we have already conducted a biogeochemical evaluation necessary to observe the ground water conditions both within and outside of the dissolved hydrocarbon plume. From this information, we can determine the mass of $O_2$ present in the ground water for comparison to the amount of $O_2$ required for degradation of the petroleum mass present. As discussed in many references and including my latest textbook, the second edition of *In Situ Treatment Technology*, the ratio of $O_2$ required to completely degrade petroleum hydrocarbons is approximately 3:1 on a mass basis. Based on the mass of the adsorbed and dissolved-phase hydrocarbons detected at the study site, we will need to deliver a total of 450 pounds of $O_2$ to aerobically degrade the diesel fuel constituents. This $O_2$ requirement is far greater than the amount of oxygen present naturally in the ground water, and therefore oxygen enhancements are warranted.

## Oxygen Delivery Methods

When thinking of oxygen delivery techniques, I like to classify the $O_2$ delivery methods into three categories: Classics, Neo Classics, and New Stuff. The Classics include technologies such as air sparging, vacuum extraction system (VES), and vacuum enhanced recovery (VER), where mechanical equipment is used to deliver atmospheric oxygen to the subsurface. Although we might view the primary removal mechanism as volatilization, these technologies also provide a viable $O_2$ source for aerobic degradation of less volatile compounds. The Neo Classics include technologies whereby chemicals such as hydrogen peroxide ($H_2O_2$) and oxygen-releasing materials (ORMs) are introduced into the subsurface to generate $O_2$ upon contact with the ground water and soil moisture. Finally, I like to think of the New Stuff as the latest and greatest techniques in pure $O_2$ delivery. These techniques can include but are not limited to pure $O_2$ sparging, gas diffusion technologies, and electrolytic $O_2$ generation processes. We will discuss the details of applying these technologies to the study site and later compare the per-pound cost of delivering $O_2$.

## Classics

### Air sparging

This technology involves the injection of atmospheric oxygen into the subsurface using an injection well and an air compressor. Because the petroleum constituents of concern are semivolatiles and long-chain alkanes, the petroleum mass will be removed primarily through aerobic degradation processes and not volatilization. Therefore, this remedial strategy is commonly referred to as biosparging. The limited volatility of the contaminants at the site also precludes the need for a vacuum extraction system for recovery of sparged vapors, thus reducing costs. We must remember that air contains only approximately 21% oxygen, compared to the pure $O_2$ delivery methods. Another limitation of air-phase delivery of $O_2$ into aqueous environments is that the oxygen-transfer efficiency is at most 2% (Kuo 1999). The remainder of the unused $O_2$ migrates to the unsaturated zone where it is available for use in aerobic degradation of the adsorbed-phase contaminants. In addition, $O_2$ has a low solubility in water and the oxygen saturation is limited to roughly 8 mg/L when ground water is completely saturated with air (Nyer 2001). Some aquifer conditions exist in which the oxygen demand of the aquifer is far greater than the mass of atmospheric oxygen that can be delivered. Under these conditions, the D.O. can rapidly decrease downgradient of the injection point.

Implementation of biosparging would entail installation of six sparge wells to a depth of 20 feet bls, approximately 2 feet below the vertical extent of the dissolved-phase impacts. Biosparging typically entails injection rates of 3 to 5 cfm per injection well or a total of 30 scfm for the study site. Based on the depth of the sparge wells and injection airflow rates, a 15-foot radius of influence is anticipated. Considering the saturated $O_2$ transfer efficiency of 2%, approximately 2.4 lbs/day of $O_2$ will be delivered to the dissolved-phase and adsorbed phase hydrocarbons located beneath the water table. The remaining 98% of the $O_2$ mass used in the vadose zone will provide oxygen to the adsorbed-phase contaminants in the unsaturated zone.

### Vacuum Extraction Systems

VES can be used to introduce atmospheric oxygen to the subsurface by applying a vacuum to a well screened within the unsaturated soils. The induced vacuum will move air into the impacted zone, thus providing a source of $O_2$ for aerobic degradation. Similar to air sparging, atmospheric oxygen is delivered to the subsurface but under a vacuum using VES, and the amount of $O_2$ in air is also limited to 21%. The limitation of using only this technology for addressing both the soil and ground water is the $O_2$ can be applied to the entire unsaturated zone, but only a blanket of oxygenated air can be applied to the top or surface of the impacted ground water. For the study site and similar conditions, VES would generally have to be used in conjunction with one of the ground water $O_2$ delivery methods listed later to be cost effective. However, removal of a majority of the mass from the unsaturated zone would prevent the continued leaching of contaminants, thus improving the overall condition of the ground water. Although each site will be different, we will assume a 2% transfer efficiency as we did for air sparging, because the natural bacteria reside in the soil moisture and the $O_2$ must transfer into the liquid phase for utilization.

To implement VES at the study site, a pilot test showed that applying a vacuum to the subsurface resulted in a 20-foot radius of influence and a subsurface airflow rate of 30 cubic feet per minute (cfm) per well. Three vertical vacuum extraction wells will be required to provide coverage of the area of the diesel fuel-impacted soil at a total flow rate of 90 cfm. Because the site is paved with very few pervious areas, installation of passive vents to the surface is recommended to ensure that a fresh supply of atmospheric $O_2$ is available. Based on this observed airflow rate, 21% $O_2$ in air and taking into consideration the oxygen-transfer efficiency, approximately 43.3 lbs/day of $O_2$ will be swept through the vadose zone and transferred to the soil moisture for use in the biodegradation process.

### Vacuum Enhanced Recovery

VER operates on the same principle as VES; however, the applied vacuum will be used to address both the unsaturated and saturated zones. For this strategy, recovery wells will be installed to a depth of 18 feet bls, which is the maximum depth of the dissolved-phase, diesel-fuel impacts. The recovery wells will be set up so that a drop tube is deployed to a depth of approximately 12 feet bls such that the saturated zone can be dewatered below 9 feet bls, where a majority of the adsorbed-phase hydrocarbons remain. This will allow delivery of atmospheric oxygen to the adsorbed-phase impacts for aerobic degradation.

Implementation of VER at the site would require installation of four recovery wells and a portable VER system comprising a vacuum pump, air-water separator, liquid-phase carbon for ground water treatment, and vapor-phase carbon treatment for the first 30 days of system operation for air-emissions treatment (Florida requirement). Because of the permeable sandy soils at the site, a positive displacement blower or rotary vane vacuum pump can be used instead of a liquid ring pump owing to the lower vacuum requirements. Based on the fine- to medium-grained sand aquifer, an airflow rate of up to 80 cfm is anticipated for this system with ground water being removed at a flow rate of up to 12 gpm for dewatering. While some petroleum mass will be recovered in the extracted ground water, more than 95% of the mass will be removed by the $O_2$ delivery and aerobic degradation process. Therefore, the dissolved-phase mass will be negligible compared to the adsorbed-phase mass. Based on the anticipated airflow rate, 21% $O_2$ in air and oxygen-transfer efficiency, approximately 38.5 lbs/day of $O_2$ will be delivered to the area of adsorbed-phase impacts.

## Neo Classics

### Oxygen Release Materials

ORM compounds such as ORC® (Regenesis Bioremediation Products, magnesium peroxide) and PermeOx® (FMC Corp., calcium peroxide) are mild oxidants that hydrolyze into molecular oxygen when saturated with water. These compounds are manufactured in a solid form (powder and granular); they are mixed with water and injected into the subsurface in a slurry form for in situ treatment applications. These compounds are typically injected into boreholes and wells by gravity or injected under pressure using a direct-push probing rig and high-pressure pump. The advantage of using these compounds is that they hydrolyze slowly and reportedly release $O_2$ over a period ranging from 100 to 200 days, according to the manufacturers. ORMs can increase the D.O. levels in ground water up to five times greater than using atmospheric air. Although not specified by the manufacturer, ORMs do not have a 100% transfer efficiency. Because the ORMs release oxygen slowly and form minimal bubbles, an $O_2$ transfer efficiency ranging from 25% to 50% is anticipated depending on the site conditions. Therefore, we will assume a 35% transfer efficiency for our case study. The delivery of the $O_2$ downgradient of the injection point is dependent upon the natural ground water velocity. Therefore, $O_2$ delivery using these products may be limited to the immediate vicinity of the injection point at sites with minimal ground water gradients. The use of these compounds for treatment of unsaturated soil is limited to ex situ mixing or application to the backfill of an open excavation. Sites with both soil and ground water contamination where site conditions prohibit excavation may need to use another treatment option for addressing the vadose zone contamination.

Application of these compounds at the study site to the diesel-fuel impacts beneath the water table will require approximately 4500 pounds of material to release 450 pounds of $O_2$ into the ground water. With an assumed transfer efficiency of 35%, a total of 12,850 lbs of ORM will be required to transfer 450 lbs of $O_2$ into the ground water. The solid material will be mixed with water such that a 30% solution is produced allowing direct injection into the aquifer using a direct-push probing rig and high-pressure pump. The material will extend from the top of the smear zone impacts at 5 feet bls to a maximum vertical depth of the dissolved-phase contamination at 18 feet bls. Based on the ground water velocity observed at the site, 30 injection points installed in a grid pattern will be required to deliver the $O_2$ to the entire impacted aquifer. The manufacturer's data indicates that ORMs release oxygen slowly over a three to seven month period depending on the site conditions. Based on the calculated mass of $O_2$ required, a total of three injections will be needed in one year to deliver the required quantity of $O_2$ to aerobically degrade the entire petroleum mass.

### Hydrogen Peroxide ($H_2O_2$)

Most of the recent applications of $H_2O_2$ involve the use of concentrated solutions (up to 20%) to aggressively oxidize organic contaminants. Because of the high reactivity and safety concerns associated with this application, these techniques cannot be used at operating sites. However, diluted $H_2O_2$ is a good source for deliverying oxygen for enhanced aerobic degradation. For such applications, a peroxide concentration ranging from 500 to 1000 mg/L can be safely used as an $O_2$ source while minimizing the dangerous subsurface reactions. The $H_2O_2$ can be delivered directly into the ground water using injection wells, or it can be allowed to infiltrate through the vadose and smear zones into the ground water using horizontal trenches. The transfer efficiency for diluted $H_2O_2$ is generally greater than atmospheric air but will be limited to a range of 20% to 50% because of the formation of bubbles and the fast release of the oxygen. In addition, the mass-transfer efficiency of $H_2O_2$ increases as the concentration of the solution decreases because of less bubble formation. For a 0.1% $H_2O_2$ solution, we will assume an oxygen-transfer efficiency of 35% for this case study.

Because of the presence of adsorbed-phase impacts within the ground water fluctuation zone, three horizontal trenches will be installed at 4 feet bls for application of the $H_2O_2$ through the smear zone and into the water table. A 50% peroxide solution will be diluted with sufficient water to create a 1000 mg/L or 0.1% peroxide solution. The total amount of liquid per injection event will be limited to 2% of the impacted ground water volume or approximately 3435 gallons of water. This volume can be injected while minimizing concerns for migration of the dissolved hydrocarbon plume but still providing sufficient volume to flood the adsorbed-phase impacts above the water table. Based on the solution volume and 35% transfer efficiency, only 5 pounds of $O_2$ will be injected during each event. This will result in a need for injections on a weekly basis for approximately two years; therefore, an automated injection system is warranted to reduce the cost of weekly labor requirements.

## New Stuff

### Pure $O_2$ Sparging

Pure $O_2$ sparging is similar in design to sparging with atmospheric oxygen except for some slight differences. A compressor is used in combination with a pressure swing adsorption (PSA) $O_2$ generator as the oxygen source (Zamsojski 1999). The pure $O_2$ is injected into the subsurface at much lower injection rates in the range of 3 to 10 cubic feet per hour (cfh), compared to the higher injection rates of 3 to 5 cfm for biosparging. The $O_2$ injections are pulsed to allow the generator sufficient time to produce oxygen. The injection cycling and lower injection rates are practical due to the higher (90% to 95%) $O_2$ concentrations than the 21% $O_2$ in atmospheric air. Because lower injection flow rates are used, the production of bubbles is minimized. Between the higher $O_2$ and the smaller bubbles, an oxygen-transfer efficiency of 20% will be assumed. A limitation in using the lower flow rate $O_2$ sparging is that the radius of influence is usually less because of decreased flow and injection pressures. The ground water flow velocity plays a greater role in the delivery and success of this method.

Because of the lower injection flow rates and diffusion-controlled delivery of $O_2$ sparging, a greater number of closely spaced injection wells will be required. For this site, 12 sparge wells installed with a 20-foot spacing should provide adequate delivery and coverage of the plume area. The design $O_2$ injection flow rate per sparge well of 5 cfh and a cycle time of 10 minutes on and 50 minutes off is the anticipated operating frequency for each well. Considering the higher saturated $O_2$ transfer efficiency of the 95% $O_2$ air stream and low injection rates, only 0.3 lb/day of $O_2$ will be delivered to the dissolved-phase and adsorbed-phase hydrocarbons beneath the water table because of the lower injection flow rates and required system cycling.

### $O_2$ Diffusion

A new technique for delivering pure $O_2$ into the ground water is gas diffusion. One such technique is the Gas inFusion® technology referred to as in situ submerged oxygen curtain (iSOC®)

developed by inVentures Technology Inc. This technology supersaturates the ground water with low decay D.O. at concentrations ranging from 40 to 200 ppm depending on the aquifer conditions and depth of injection. This pure $O_2$ delivery method eliminates the requirement for mechanical equipment such as air compressors and $O_2$ generators, thus reducing capital and operating expenses. An in-well diffuser comprising a large surface area of microporous, hollow fibers allows increased mass transfer of $O_2$ to the ground water without the creation of air bubbles and minimizing the loss of $O_2$ to the vadose zone. Therefore, oxygen-transfer efficiency will approach 100% and complete transfer will be assumed for this evaluation.

The oxygen source is an $O_2$ canister connected to the in-well diffuser using small diameter poly-tubing. The advantage of the smaller diameter tubing is that it can be easily installed without the need for large subsurface trenches. The $O_2$ flow rate can be controlled by a rotometer at each wellhead. Typical injection rates are in the cubic centimeter per minute range (cc/min) and the manufacturer reports that up to 64 pounds of oxygen can be delivered over a five-month period using a three-well system. Delivery of the $O_2$ downgradient of the diffusion well is dependent on ground water velocity and the oxygen demand of the aquifer. The radius of influence is reported as ranging from 10 to 32 feet from the injection point.

Similar to $O_2$ sparging, the horizontal velocity of the ground water will be the basis for selecting the number and spacing of the $O_2$ diffusion wells. Twelve wells installed at a spacing of 20 feet will be required to provide adequate coverage of the impacted area. This should allow adequate delivery of the $O_2$ and creation of a radius of influence between the injection points. For a 12-well system and considering a 100% transfer efficiency, approximately 1.7 lbs/day of $O_2$ will be transferred to the aqueous phase. The volume of the $O_2$ cylinder will be sized such that a replacement can be installed conveniently during normal site visits.

### $O_2$ Electrolytic Generation

Another new technique in generating $O_2$ is using electrolysis to dissociate water into hydrogen and oxygen within a well. One such technology is Iso-Gen® developed by Environmental H2O LLC. This technology generates $O_2$-enriched ground water using a down-well unit comprising a circulation pump, electrolytic cell, diffuser tube, and AC voltage regulator/transformer. The circulation pump is placed at the base of the well to uptake water. The water is pumped past the electrolytic cell where the oxygen and hydrogen are dissociated from the water. The $O_2$-enriched water is discharged back into the aquifer through well screens at the upper portion of the well. The hydrogen gas is released to the atmosphere through the well casing. The electrolytic cell operates approximately 10 minutes on and 40 minutes off, and the circulation pump run cycle is approximately 15 minutes on and 35 minutes off to allow for adequate $O_2$ generation. The manufacturer's data reports generation of D.O. concentrations up to 20 mg/L in ground water and a radius of influence of up to 30 feet from the well. The influence area will be affected by the varying aquifer conditions (oxygen demand, velocity, etc.).

Again, the diffusion controlled delivery and ground water velocity will also be the basis for selecting the number and spacing of the $O_2$ generation wells. However, the in-well circulation capabilities will increase the area of distribution of the oxygen. Based on these considerations, only nine circulation wells would be required to provide adequate coverage of the contaminant source area. However, the manufacturer's data indicates that the delivery capabilities are limited to approximately 0.4 lb/month per well. Because of the low oxygen generation and delivery rates for this technology, additional injection wells will be installed to increase the oxygen supply and to accommodate the 450 pounds of $O_2$ required and to complete the degradation process. A total of 15 injection wells will be installed resulting in a total delivery of 72 lbs/year of $O_2$.

## Economic Analysis of Oxygen Delivery

Table 1 is a cost evaluation of the $O_2$ delivery methods discussed above. The cost evaluation provides the total cost per pound of $O_2$ delivered, which includes the periodic performance monitoring and equipment maintenance (if required) over a one-year period. We have ranked each site beginning with the least costly delivery method. If you are a vendor of a specific technology, please don't get mad at us if you are not pleased with this ranking. This cost estimate was developed based on our case study site and our stated assumptions.

Based on our case study site, which had a significant adsorbed mass remaining within the ground water fluctuation zone, we have found that mechanical systems can deliver significantly more $O_2$ than injection or passive delivery techniques over a one-year period. This should not be a surprise to anyone because we all know that we can more efficiently move more pore volumes of air than liquid. Therefore, once we overcome the initial capital expenses of VES, VER, and air sparging, the $O_2$ delivery costs continue to decrease the longer we operate these systems. The $O_2$ diffusion technology was the next most cost-effective method because of the ability to release oxygen slowly at the maximum oxygen-transfer efficiency and relatively low capital and operating expenses. Diluted peroxide was not as cost effective because of its inability to release the $O_2$ slowly and its limited transfer efficiency. The cost of the ORMs and number of required injections resulted in higher costs for this method. The low generation rates and limited area of influence rendered pure $O_2$ sparging and electrolytic $O_2$ generation the highest cost alternatives.

Now let's revisit our cost evaluation and re-rank our technologies based on the cost of 450 pounds of $O_2$ required for the degradation of the existing petroleum mass. We have also included the approximate time for each technology to achieve the oxygen requirement assuming that the oxygen uptake rate (OUR) will be equivalent to the $O_2$ delivery rate. For VES and VER, where it will take less than two weeks to deliver the entire amount of oxygen required, it would not be practical to assume an operation time of less than three months for these systems. These costs are presented in Table 2.

Table 2 shows that VES, air sparging, and VER still retain their top rankings for the case study site; however, the margin in cost between most of these technologies has decreased to within the same order of magnitude. The primary reason is that mechanical systems have higher initial capital and operating expenses than the other technologies, and a majority of the $O_2$ generated is wasted because the delivery rate far exceeds the OUR of the microbes. The $O_2$ diffusion cost was 50% more than the mechanical air-phase delivery methods. This is a result of the high-transfer efficiency and relatively low capital and operating costs. The other $O_2$ generation and delivery methods are more costly because the oxygen is being produced at slower rates than mechanical means and delivered beyond the injection point by slower advective and diffusion transport processes.

This case study was skewed toward large quantities of oxygen delivery. Would I ever want to use any of the passive, pure $O_2$ delivery methods? These passive techniques would be ideal for sites where polishing off a dilute dissolved-phase hydrocarbon plume is needed or any other time the total mass of the project is low and located mainly in the aquifer.

## Table 1

**Cost Evaluation of Oxygen Delivered in One Year**

| Technology | Pounds $O_2$ Delivered for 1 Year | Total Cost for 1 Year | Cost per Pound of $O_2$ Delivered |
|---|---|---|---|
| Vacuum extraction | 15,812 | $98,300 | $6 |
| Vacuum enhanced recovery | 14,056 | $145,590 | $10 |
| Air sparging | 878 | $93,200 | $106 |
| $O_2$ diffusion | 619 | $119,900 | $194 |
| Dilute $H_2O_2$ solutions | 246 | $104,843 | $426 |
| Oxygen-releasing materials | 421 | $205,255 | $487 |
| Pure $O_2$ injection | 114 | $150,550 | $1326 |
| Electrolytic $O_2$ generation | 72 | $113,740 | $1580 |

## Table 2

**Cost Evaluation of 450 Pounds of Oxygen Used**

| Technology | Pounds $O_2$ Used for Degradation | Total Cost for Delivering 450 Pounds $O_2$ | Time to Deliver 450 Pounds $O_2$ | Cost per Pound of $O_2$ Used |
|---|---|---|---|---|
| Vacuum extraction | 450 | $63,500 | 10 days | $141 |
| Air sparging | 450 | $73,500 | 187 days | $163 |
| Vacuum enhanced recovery | 450 | $93,460 | 12 days | $208 |
| $O_2$ diffusion | 450 | $119,050 | 265 days | $265 |
| Electrolytic $O_2$ generation | 450 | $159,550 | 6.25 years | $355 |
| Dilute $H_2O_2$ solutions | 450 | $160,468 | 1.8 years | $357 |
| Oxygen-releasing materials | 450 | $210,010 | 1 year | $467 |
| Pure $O_2$ injection | 450 | $242,050 | 4 years | $538 |

## The Last Problems

We have two final problems. First, it is relatively easy to determine the amount of mass in the dissolved-phase contamination from the large well network and the data that is normally collected at a site. However, it is very difficult to accurately estimate the adsorbed-phase mass using the soil sampling and analytical methods. Typically, we do not collect enough soil data. Petroleum mass is difficult to estimate using field screening meters with correlation to only a few confirmatory laboratory samples. We verify this when we estimate only 200 gallons of fuel was released but our vapor-phase emissions on our vacuum systems show that we have recovered hundreds of pounds per day of petroleum mass.

Our analysis shows that there is a good dichotomy between low oxygen demand situations and high oxygen demand situations. The problem is to determine which situation exists at your site. Don't worry; it is only hundreds of thousands of dollars of your client's money and your career on the line.

The second problem occurs only if you are lazy (stupid) enough to directly use the values that we have presented in Tables 1 and 2. Every situation is unique. Do your own d— cost estimates.

## References


Kuo, J. 1999. *Practical Design Calculations for Groundwater and Soil Remediation.* Boca Raton, Florida: CRC Press LLC.

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Zamojski, L.D., J.R. Stachowski, and S.R. Carter. 1999. A case history of enhanced bioremediation utilizing pure oxygen injection. In *In Situ Bioremediation of Petroleum Hydrocarbon and Other Organic Compounds*, vol. 5, no. 3. Columbus, Ohio: Battelle Press.


## Biographical Sketches


**J. Scott Davis**, *P.E., is a senior engineer with the ARCADIS Tampa, Florida, office, where he is the project manager and lead engineer for the assessment and remediation of chemically impacted sites in Florida. He has 10 years of experience in the design and implementation of soil and ground water strategies using both traditional and innovative technologies. He has a B.S. in civil engineering and an M.S. in environmental engineering from the University of South Florida.*

**Isabel King** *is an engineer with the ARCADIS Tampa, Florida, office, where she is involved in the design and implementation of soil and ground water remediation strategies, including air sparging, vacuum extraction, vacuum-enhanced recovery, and enhanced biodegradation. She has a B.S. in chemical engineering from the University of South Florida.*

**Evan K. Nyer** *is a senior vice president with ARCADIS, where he is responsible for maintaining and expanding the company's technical expertise in geology/hydrogeology, engineering, modeling, risk assessment, and bioremediation.*

## APPENDIX E

**Brown and Caldwell Focused Area 5 Feasibility Study**

# Remedial Action Plan Addendum
# Former Malden MGP Site
# Parcel B
# Malden, Massachusetts

June 2003

# REMEDIAL ACTION PLAN ADDENDUM
# FORMER MALDEN MGP SITE
# PARCEL B
# MALDEN, MASSACHUSETTS

Prepared for:

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A Subsidiary of National Grid USA
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Prepared by

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June 2003

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# 1.0 INTRODUCTION

This Phase III Remedial Action Plan (RAP) Focused Evaluation Addendum has been prepared by Brown and Caldwell for the Former Malden Manufactured Gas Plant (MGP) Site (the Site) in Malden, Massachusetts. The former MGP site includes approximately 16.4 acres located in an urban area, consisting of five different parcels with eight different property owners. The former holdings occupy land currently referred to as Parcels A, B, C, D, and E. (A site map including the parcel designations is included as Figure 1-1.)

This RAP addresses Parcel B (129 Commercial Street), and specifically focuses on the evaluation remedial alternatives to address the issues related to exposures to indoor air and soil vapors inside the building. (Additional discussion of the Risk Characterization results is included in Section 2.) This Focused Evaluation is intended to be submitted as an addendum to the RAP for the entire site.

This Focused Evaluation RAP was prepared in accordance with the requirements of the MCP (310 CMR 40.0853), the performance standards for a Phase III evaluation. The MCP states that "a Phase III evaluation shall result in the identification of remedial action alternatives which are reasonable likely to achieve a level of No Significant Risk considering the oil and hazardous material present, media contaminated, and site characteristics, and, the recommendation of a remedial action alternative that is a Permanent or Temporary Solution, where a Permanent Solution includes measures that reduce, to the extent feasible, the concentration of oil and hazardous material in the environment to levels that achieve or approach background."

Site History and Background

The site was the location of a manufactured gas plant from 1855 to the 1970s. The types of manufacturing processes conducted at the former Malden MGP site included coal gasification (sometimes referred to as coal carbonization) (1855 to 1907), carbureted water gasification (1907 to 1954) and oil gasification (1954 to the 1970's). The process operations that were conducted on Parcel B included gas purification.

From results of the site investigation, benzene, toluene, ethylbenzene, xylenes, styrene, naphthalene (BTEXSN) and cyanide were the primary constituents of concern (COCs) found in the soil and groundwater at Parcel B. Specifically, in the soil, BTEXSN were found at levels approximately half of the UCL concentration at a depth that is coincident with groundwater (approximately 8 to 10 feet below grade surface). In the groundwater, BTEXSN concentrations were also detected (with toluene and benzene above UCL concentrations) at three locations beneath the building.

The impacted media on Parcel B include soil, groundwater and air, with the most significant impacts to groundwater and air. The presence of COC's in the soil most likely is a result of historical manufacturing operations at the Parcel B. The contamination of the groundwater is likely the result of the dissolution of COC's from the impacted soil beneath the building. Indoor impacts appear to result from volatilization of contaminants from impacted groundwater. Sampling of the indoor air at the facility located at the property detected elevated concentrations of benzene, toluene, naphthalene and styrene. The concentrations did not exceed the applicable occupational standards set by the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH).

The Phase II Report does not confirm an area of concentrated contamination of the COCs in groundwater and air. Additional site investigation activities were conducted in July 2002 in an attempt to locate an area of concentrated contamination. Geophysical procedures were considered, but deemed ineffective due to the building being located directly over the suspected location(s) of elevated concentrations. Soil samples were collected at locations corresponding to the drip tanks based on historical maps. The results of the soil sample analyses did not confirm the location of a source area, however, stained soils and elevated contaminant concentrations were detected at or near the observed groundwater table elevation. The apparent pattern of dissolved phase BTEX is consistent with an area of elevated contamination located beneath the footprint of the existing building.

The Phase III Report includes a risk characterization that was prepared in accordance with the requirements of the Massachusetts Contingency Plan (MCP) Method 3 Risk Characterization (310 CMR 40.0901 through 40.0999) and the MADEP's *Guidance for Disposal Site Risk Characterization – In Support of the Massachusetts Contingency Plan* (MADEP, 1995). The original human health risk characterization concluded that a Condition of No Significant Risk for the indoor air inhalation pathway at Parcel B was not demonstrated. The Risk Characterization was revised to incorporate additional data obtained after the completion of the original Risk Characterization. The revised Risk Characterization, based on indoor air data collected between September 1999 and October 2002, demonstrated a condition of No Significant Risk to the current commercial worker via the indoor air pathway. This change is likely due to the slightly lower VOC concentrations that have been observed during recent indoor air sampling events inside the facility undertaken as part of an ongoing RAM.

Release Abatement Measures were instituted to address indoor air quality. An attempt was made to seal the floors in the packaging room area of the facility to reduce BTEX migration into the building. However, this procedure was not successful and in 1999, an active sub-slab venting system was installed to create a negative pressure gradient beneath the slab. The venting system was not intended to remediate the area of concentrated contamination of BTEX, but to reduce migration of BTEX into the building. The system is currently operating, but does not consistently control vapor migration into the building. These operational inconsistencies may be caused by the facility operations, which include ovens that require significant volumes of combustion air.

Therefore, because marginal changes in indoor air concentration could change the outcome of the Risk Characterization for the indoor air pathway and since the data used in the Risk Characterization was collected inside the facility with the RAM system in operation, an evaluation of remedial alternatives for reducing concentrations of VOCs was performed. (Phase III, RAP, Haley & Aldrich.)

Phase III RAP Addendum Contents

This RAP Addendum includes the identification, evaluation and selection of remedial action alternatives for Parcel B to address contamination in accordance with the Phase III requirements of the MCP (310 CMR 40.0850 – 40.0862). This report consists of the following sections:

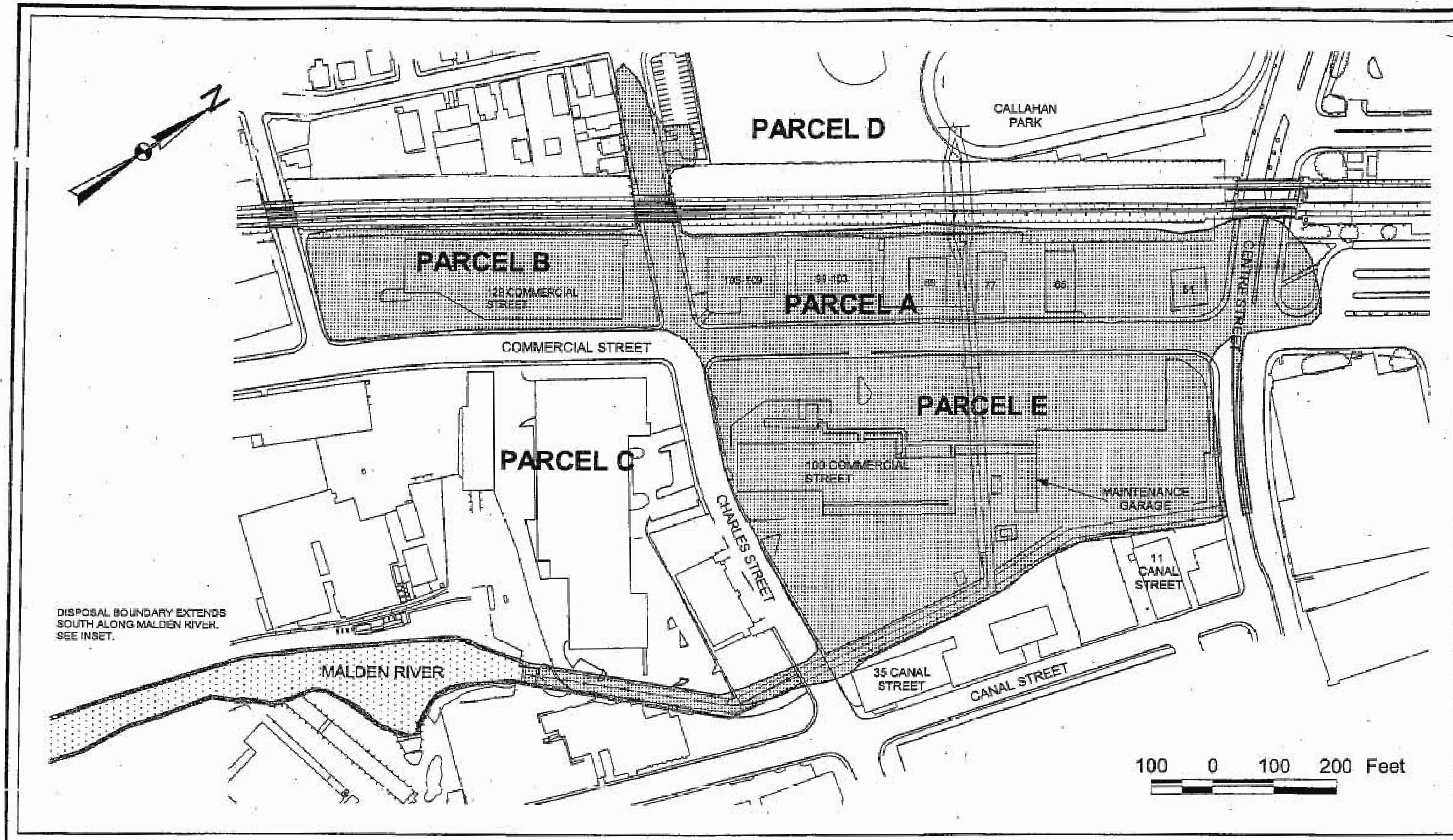
- Section 2: Remedial Action Objectives - Presents the remedial action objectives and the areas, media and constituents of concern to which remedial action alternatives will be applied.

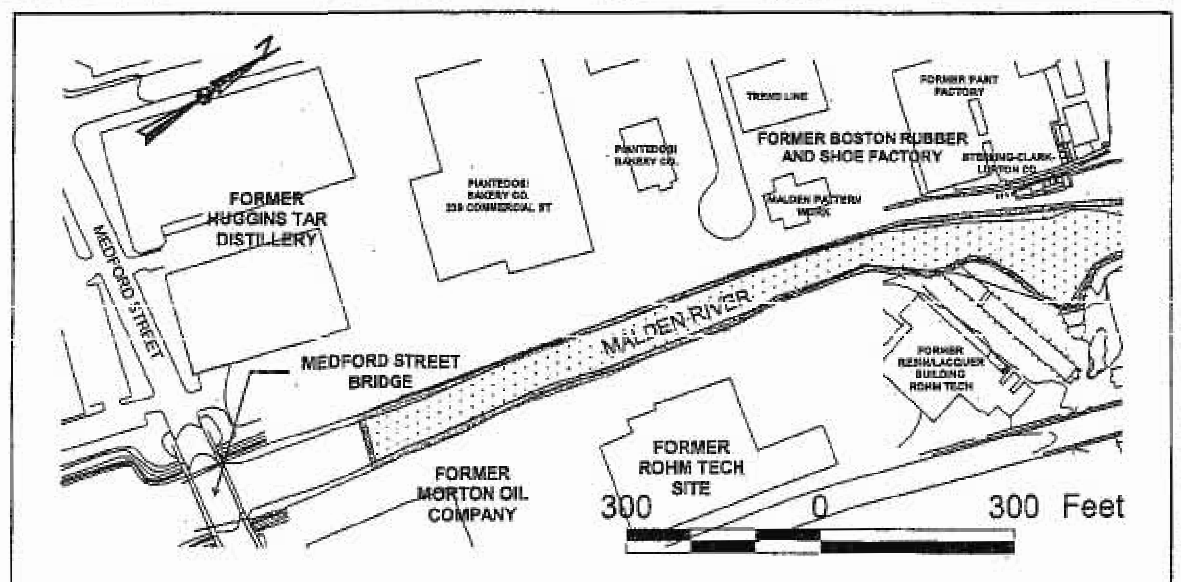
- Section 3: Identification and Initial Screening of Technologies, and Development of Remedial Action Alternatives - Identifies remedial technologies and presents the results of technology screening. Assembles remedial technologies into remedial action alternatives. Develops and screens the remedial action alternatives.

- Section 4: Detailed Evaluation of Remedial Action Alternatives - Presents the Detailed Evaluation of the remedial action alternatives using the criteria specified in the MCP.

- Section 5: Selection of Remedial Action Alternative - Compares and selects the remedial action alternatives based on the results of the Detailed Evaluation and describes the response action outcome that the selected alternative is expected to achieve. Also presents evaluations of the feasibility of achieving a Permanent versus a Temporary Solution, the feasibility of reducing concentrations in oil to levels below the Upper Concentration Limits, and the feasibility of approaching or achieving background concentrations at the Site.

Descriptions of the Site background, Site history and Site investigations are described in the Phase III Remedial Action Plan, prepared by Haley & Aldrich.




SOURCE: PHASE III REMEDIAL ACTION PLAN, PREPARED BY HALEY AND ALDRICH.

LEGEND:

- FORMER MALDEN MGP DISPOSAL SITE BOUNDARY
- TERRESTRIAL PORTION OF THE FORMER MALDEN MGP DISPOSAL SITE
- PILE - SUPPORTED CONCRETE CULVERTS INSTALLED BY MDC

NOTES:

1. BASE PLAN ADAPTED FROM "TOPOGRAPHIC WORKSHEET OF THE MANUFACTURED GAS PLANT, MALDEN, MA" FOR MASSACHUSETTS ELECTRIC COMPANY BY EASTERN TOPOGRAPHICS, JUNE 1995, AND CITY OF MALDEN ASSESSOR'S PLAN, SHEETS 1 AND 2, JUNE 1995, AND SHEET NO. 53 BY FAY, SPOFFORD & THORNDIKE, INC., UPDATED JUNE 1976 AND REVISED 30 JULY 1979.

FIGURE 1-1

DISPOSAL SITE BOUNDARY

MASSACHUSETTS ELECTRIC CO.
FORMER MALDEN MGP SITE
MALDEN, MASSACHUSETTS

BROWN AND CALDWELL Allendale, New Jersey

# 2.0 REMEDIAL ACTION OBJECTIVES

This section describes the remedial action objectives for Parcel B. This section also provides a summary of the areas, media and constituents of concern that have been identified for remedial actions. The purpose of the remedial action objectives is to define the medium specific goals for Parcel B that will result in the protection of health, safety, public welfare and the environment. The remedial action objectives are used in the evaluation of the remedial alternatives.

## 2.1 AREAS, MEDIA, AND CONSTITUENTS OF CONCERN

Investigations have been conducted at the Site since 1987. The facility at Parcel B appears to have been built on a layer of fill material ranging from approximately 3 to 10 feet thick. The fill overlies native sands and silty, fine sands. These materials become generally finer-grained (and thus less permeable) with depth. The organic layer that is present on other portions of the Site is not present beneath Parcel B. During the April 1999 groundwater level measurement event, only two monitoring points were available on Parcel B. The direction of groundwater flow was interpreted to be to the southwest, parallel to Commercial Street via extrapolation from the numerous data points to the north. This flow direction was confirmed by measurements from five additional wells (7 in total) on Parcel B that were available during two subsequent water level rounds conducted in July/August and December, 2000. These data clearly indicate that groundwater flow is to the southeast, with Charles Street and Parcel A being upgradient of Parcel B.

For the soil samples, there were no samples reported to have concentrations above the MCP Upper Concentration Limits (UCLs). However, UCLs were exceeded in groundwater samples taken on the property. Benzene and toluene exceeded UCLs at three locations.

## 2.2 RISK CHARACTERIZATION SUMMARY

A Risk Characterization was prepared by AMEC Earth and Environmental and was presented in the Phase II – Comprehensive Site Assessment. Subsequent sampling data became available and the Risk Characterization was revised and included in the Phase III – Remedial Action Plan. The results of the Risk Characterization were as follows:

- There is a Condition of No Significant Risk for the indoor air inhalation pathway. However, the level of potential risk presented by the elevated levels of VOCs is approximately equivalent to the MADEP criteria at which a condition of No Significant Risk cannot be satisfied. Also, the indoor air samples were collected with the RAM system in operation. Therefore, an evaluation of remedial alternatives to address indoor air will be conducted.

- A Condition of No Significant Risk to Public Welfare was demonstrated for the site, as stated in the Risk Characterization in the Phase II Report. In accordance with the MCP (310 CMR 40.0996(2)), the comparisons of groundwater concentrations to UCL's can be made using the arithmetic average concentration of hazardous material at a site. Therefore, even though there were some exceedances of contaminant concentrations above UCL's, the average concentrations of contaminants at Parcel B did not exceed UCL's.

- A Condition of No Significant Risk to the environment was demonstrated for the terrestrial portion of the site.

- For soil, two "hotspots" were identified at the Site. However, the risk characterization demonstrated a condition of No Significant Risk for both soil hot spots, including scenarios for current and future utility workers (which would, potentially, have the greatest calculated risk due to exposures to subsurface soils).

The calculations for the Risk Characterization, included in the Phase II- Comprehensive Site Assessment, Appendix N, Volume XIII, show that benzene contributes the highest calculated value for the Hazard Index, with naphthalene contributing the second highest value. For the Excess Lifetime Cancer Risk, benzene was the only compound that contributed to the risk.

## 2.3 REMEDIAL ACTION OBJECTIVES

The Remedial Action Objectives for Parcel B were developed based on the results of the Risk Characterization. As mentioned above, a risk to human health due to exposures of the concentrations of COC's in indoor air (resulting from migration of contaminants from the groundwater) was slightly below the MADEP target levels. Since an incremental increase in the concentrations of BTEXSN in indoor air would result in an exceedance and the indoor air samples were taken while the RAM system was in operation, a remedial alternative evaluation was conducted for mitigation of this risk. The risk characterization calculations show that the compound that contributes the most significant risk is benzene, with naphthalene contributing the next highest risk.

Therefore, the Remedial Objective for Parcel B is to reduce the concentrations of BTEXSN in the indoor air in the building. This could be accomplished by either reducing the concentrations of COCs in groundwater, controlling vapor migration with a soil vapor extraction (SVE) system and/or, controlling vapor migration by modifying the HVAC system in the building.

Of note, MEC is conducting an evaluation of the HVAC system inside the building to assess the feasibility of making modifications to the existing system. The evaluation is being conducted to assess if implementation of modifications to the existing system or a new system is a feasible measure to control the infiltration of vapors from the subgrade. Therefore, this report does not include evaluation of the remedial alternatives for the HVAC system. Instead, this report will include remedial alternatives for reducing concentrations of COC's in the groundwater and implementation of an SVE system.

It may be possible to achieve the Remedial Objectives with just the implementation of an SVE system. However, an SVE system would not address the saturated zone or the contaminants in the groundwater. A remedial action alternative that consists only of SVE would not have the potential to achieve a Permanent Solution.

# 3.0 INDENTIFICATION, INITIAL SCREENING OF REMEDIAL ACTION TREATMENT TECHNOLOGIES, AND DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

This section includes the identification of groundwater treatment technologies that are potentially applicable to the site and the initial screening of the technologies. The remedial alternatives were then developed from technologies that passed the initial screening. The remedial alternatives are evaluated in a detailed analysis that is included in Section 4.0.

## 3.1 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

The identification and initial screening of the technologies was conducted in accordance with the requirements of the MCP. The MCP (310 CMR 40.0856) states that "An initial screening of remedial technologies shall be conducted to identify remedial action alternatives for further evaluation which are reasonably likely to be feasible, based on the oil and hazardous material present, media contaminated, and site characteristics." "…remedial action alternatives are reasonably likely to be feasible if: (a) the technologies are employed by the alternative area reasonably likely to achieve a Permanent or Temporary Solution; and (b) individuals with the expertise needed to effectively implement available location would be available, regardless of arrangement for securing their services."

In addition to identifying technologies that are applicable based on the remedial objectives identified in Section 2.0, site-specific considerations were also taken into account. These considerations include constraints that may affect the implementability of technologies and/or alternatives due to physical and/or operational limitations. These site-specific constraints are as follows:

- The building is currently occupied and cannot be removed for implementation of remedial alternatives.

- Interruptions to operations in the building during the remedy implementation must be minimized.

- The remedial alternative must not be obtrusive.

- Floor penetrations, if necessary, should be minimized so that additional pathways for vapor migration are not created.

- It is possible that an area of concentrated contamination (i.e., such a purifier box) could be present above the groundwater table. However, even if it could be located through additional investigation, a large excavation through the floor slab would be necessary. This is not, most likely, a feasible option due to access and space constraints.

- Space limitations on site preclude the installation of ex-situ on-site treatment of extracted groundwater. The building itself occupies a large portion of the site and the paved lot, located at the southern end of the property, is used for truck loading and employee parking.

## 3.2 REMEDIAL TECHNOLOGIES

The following sections include descriptions of the technologies that are potentially applicable for remediation of BTEXSN in groundwater at Parcel B. Considering the remedial objectives (in Section 2.0) and the above specific site conditions, groundwater remedial technologies that may be appropriate for Parcel B are listed below. As mentioned previously, ex-situ treatment of the groundwater is not feasible due to space limitations at Parcel B. Therefore, the technologies that were considered for the site included in-situ groundwater technologies. The candidate technologies focused on the BTEXSN present in the shallow groundwater.

The key parameters that determine the effectiveness of an in-situ groundwater treatment technology are the hydraulic conductivity of the aquifer, the biodegradability of the COCs, the aquifer geochemistry, the accessibility of the COCs in the subsurface, and the ability to place wells, trenches or injection points in locations where they would most efficiently address the COCs. For Parcel B, the parameters for the application of an in-situ treatment technology appear favorable. The fill material is fairly permeable (although the permeability decreases with depth) and there is no organic layer in this area that could retard groundwater flow or be detrimental to chemical, nutrient and oxygen delivery.

There are a variety of in-situ technologies that may be applicable to Parcel B. The technologies include:

- Air Sparging
- Enhanced Bioremediation
  - Hydrogen Peroxide Injection
  - Biosparging
- Chemical Oxidation
  - Fenton's Reagent
  - Permanganate
  - Ozone
- In-well Air Stripping

The applicability of a specific technology for Parcel B is a function of the COCs (BTEXSN), the degree of impact (BTEXSN, but other constituents, including reduced iron, manganese and natural organic material will consume oxygen or other chemical agents), the hydrogeology/lithology, and parcel related issues (i.e., access, logistics, etc.).

Descriptions of each of these technologies are presented below. The descriptions include the basic principles of each technology and a brief description of implementation characteristics. In addition, a discussion of the implementation of horizontal wells is included. Since the areas targeted for remediation are beneath the building, and installation of vertical wells may be prohibitive due to restrictions from production equipment and the potential migration of vapors through floor penetrations, horizontal wells are the most appropriate type of injection system for this site.

Air Sparging

Air sparging is the direct injection of air into the groundwater. Air rises through the aquifer to the water table surface. VOCs are volatilized in the process and transferred to the unsaturated zone. Additionally, some biodegradation will occur in the saturated zone due to the increase in dissolved oxygen. In the unsaturated zone, the VOCs may adsorb to and desorb from the soil matrix. While adsorbed to the soil matrix, the VOCs will undergo biodegradation. The portion of the VOCs not biodegraded will eventually reach the ground surface or migrate into buildings or utility trenches. To prevent impact from the vapors at or near the surface, air sparging is frequently implemented in conjunction with a soil vapor extraction (SVE) system to collect vapors generated through sparging. SVE uses slotted piping located within the unsaturated zone. Systems may use vertical or horizontal piping. A vacuum is applied to the SVE piping to draw in air and VOC vapors. The recovered gases are normally treated at the surface by granular activated carbon or thermal destruction units.

Since vapor migration is already a concern at Parcel B, the generation of additional vapors that are released at the water table would not be desirable. Therefore, an SVE system would have to be implemented if air sparging were implemented. (This is further discussed in Section 3.4.)

Enhanced Bioremediation

In-situ bioremediation can be accomplished by enhancing aerobic or anaerobic biodegradation processes naturally occurring in the environment. In-situ aerobic bioremediation is a process whereby the natural biodegradation process is accelerated by providing an electron acceptor (usually oxygen), occasionally nutrients (phosphorus and nitrogen compounds) and rarely, other microorganisms for the conversion of the BTEXSN to innocuous products (bioremediation end products are carbon dioxide and water). The electron acceptor source is supplied by either sparging air or oxygen below the water table or by introducing a dilute hydrogen peroxide solution (500-2000 mg/L) to the treatment areas.

Anaerobic bioremediation (using nitrates or sulfates as electron donors) was not considered a strong candidate for this application since it has been demonstrated that benzene is slower to biodegrade under anaerobic conditions. Also, these alternative electron donors are seldom used. They offer the advantage that they are not likely to be consumed by reduced species in the soils and groundwater since many hydrocarbon-impacted aquifers are already partially reduced. On the other hand, regulatory agencies limit the concentrations of nitrate that can be introduced and sulfate causes some concern about the formation of sulfide. For the purpose of this evaluation, oxygen as the electron acceptor was considered (i.e., aerobic bioremediation).

Aerobic bioremediation of BTEXSN compounds has been successful. Published data indicate reductions of BTEXSN and other hydrocarbons at hundreds of sites. In similar aquifers, bioremediation has achieved cleanup levels over reasonably short time periods. Two technologies applicable for the introduction of oxygen to the aquifer are discussed below.

Hydrogen Peroxide Injection

The traditional form of in-situ bioremediation involves the injection of water containing an oxygen source, namely, dilute hydrogen peroxide (500 to 2,000 mg/L). Hydrogen peroxide will degrade to produce oxygen for biodegradation. The injected water will move with the groundwater flow, thereby delivering the oxygen across the treatment area. The process is typically implemented by recovering groundwater from the downgradient portion of the plume and removing VOCs at the surface, or by using water from a local water supply, amending with hydrogen peroxide (and sometimes nutrients), and reinjecting in the middle of and/or upgradient portion of the plume. With the proper design, this process can be relatively inconspicuous once installed.

Biosparging, Oxygen Injection

The most commonly used and generally most cost-effective approach for bioremediation of BTEXSN is referred to as biosparging. It uses essentially the same design as air sparging, except that the injection rates are much lower and typically carried out using an intermittent injection schedule. The result is that oxygen is supplied for biodegradation with minimal volatilization. Oxygen (from an oxygen tank at the surface) or air is piped to the desired depth and introduced within the aquifer where biodegradation is promoted. The process may also increase available oxygen within the unsaturated zone and result in degradation in that zone as well. Degradation within the vapor phase should reduce the migration of VOCs that may enter buildings and utility trenches, etc. Remediation should be substantially more rapid if oxygen is injected rather than air. Oxygen can be supplied from cylinders, or as an alternative, a membrane system that separates oxygen from air could be used.

Biosparging is most often used at sites with contaminants with lower vapor pressures since lighter constituents volatilize readily and are removed more rapidly using air sparging. For this site, as stated previously, BTEXSN the contaminants of concern. (Benzene is a volatile constituent with a relatively high vapor pressure (76 mm Hg at 20°C), while naphthalene is a polycyclic aromatic hydrocarbon (PAH) with a lower vapor pressure (0.5 mm Hg at 20°C).)

The most important characteristic of the soil for determining the effectiveness of biosparging is the permeability. The bacteria use oxygen to metabolize organic material into carbon dioxide and water. Therefore, oxygen is required for the metabolizing process and for the sustainment of a substantial bacterial population. For sites with intrinsic permeabilities of less than $10^{-9}$ ($cm^2$), biosparging effectiveness is marginal.

**Chemical Oxidation**

Chemical oxidation is the chemical conversion of hazardous constituents to less toxic compounds that are more stable, less mobile or inert. For hydrocarbons, the end products are carbon dioxide and water. Ozone, hydrogen peroxide, potassium permanganate, sodium permanganate, potassium persulfate, and Fenton's Reagent (reduced iron and hydrogen peroxide at low pH) have been used to address the types of constituents present in groundwater at Parcel B. Degradation reactions are quite rapid. The rate-controlling step is the ability of the implementation system to deliver the chemical oxidant throughout the impacted soils and groundwater. It is essential that the correct oxidant and in-situ delivery systems be utilized for achieving the desired reduction goals under site-specific conditions. For instance, Fenton's Reagent requires numerous closely spaced injection points that might not be feasible in the vicinity of the facility.

Factors that can affect performance of chemical oxidation are pH, temperature, the concentration of the oxidant, and the concentration of other oxidant consuming substances (such as organic matter). Delivery systems for the oxidant can use either vertical or horizontal injection wells with sparge points (or tubing with spaced discharged points inside the horizontal well). This technology can be applied to area of concentrated contamination areas or a plume of dissolved phase constituents. The equipment utilized for this technology is readily available and not complex.

Additional specific information regarding possible chemical oxidants that could be used at Parcel B is presented below.

Fenton's Reagent

Various vendors implement the chemical oxidation remedial technology using Fenton' Reagent using somewhat different methods. Some vendors, but not all, add a ferrous sulfate solution or equivalent while others rely on native iron in the formation. Most vendors add various amounts of dilute acid to lower the pH, and add hydrogen peroxide solutions through injection points/wells. Hydrogen peroxide concentrations used vary from about 6 percent to as high as 50 percent. At many sites, the introduction of Fenton's Reagent using high concentrations of hydrogen peroxide has resulted in the formation of steam that has come to the surface and buckled the asphalt paving. Explosions are possible and have occurred at sites where higher concentrations of hydrogen peroxide were used. Also, VOC vapors may be created in the unsaturated zone. The implementation of this remedial technology requires a high level of field personnel training, a high level of activity at the site, and the careful handling of high strength hydrogen peroxide. In addition, if free phase product is present, then larger quantities of the oxidizing agent are required and the operation of the technology may become cost prohibitive.

Permanganate

Permanganate (including potassium or sodium) has largely been used for chlorinated ethenes, and is not generally selected for hydrocarbons. However, it will react with BTEXSN. Potassium permanganate requires highly trained personnel for handling, and requires a hopper and mixing equipment in order to create the proper solution prior to injection into the subsurface. The solutions can be explosive if not handled correctly. Sometimes, persulfate is added with permanganate to enhance performance.

Implementation of a sodium permanganate system is accomplished with an aqueous injection system into the subsurface. Sodium permanganate is shipped as a liquid in drums, usually as a 20 percent solution. It is usually diluted in a tank at grade surface and, delivered and metered into water injection wells. It is slightly more expensive than potassium permanganate, but is more soluble and easier to apply. One other issue with permanganate is that it will leave high levels of manganese dioxide in the ground. This is not necessarily a problem, as much as a perception issue, since manganese is a regulated substance. Another concern that frequently arises with the implementation of this technology is that a build up of manganese dioxide may clog the aquifer; however, this would not likely to be a problem because of the permeability of the soil matrix (namely, the fill material) at Parcel B.

Typically, the addition of sodium permanganate would be made in batches at a frequency of one batch per week, and subsequently decreasing to one per month. After the first few additions, additional water would be added following injection of the permanganate to push the reagent further out into the aquifer. Activities could take place in a small shed on-site to reduce visibility to the public.

Ozone

Ozone is another type of oxidant that could be used. Ozone is typically generated on site. The generator could be placed in a trailer or small shed. Ozone can be sparged or dissolved in water and injected into the subsurface. If the ozone is sparged, there could be concerns about vapors migrating into the facility unless a soil vapor extraction system was used in conjunction with ozone sparging. If the ozone is dissolved in water, the injection system/process would be similar to that used for chemical oxidation with sodium permanganate or in-situ bioremediation.

In order to enhance treatment times or ozone utilization efficiencies, a groundwater recirculation system could be used. As described previously, the groundwater downgradient of the treatment area is pumped to the surface, contaminants are removed, ozone may be added in the dissolved phase, and reinjected upgradient or in the middle of the treatment area. While this may be appropriate in some locations, the pumping, treating and reinjecting of the groundwater is problematic at Parcel B, since there is limited available space on site.

**In-Well Air Stripping**

In-well air stripping is similar in theory to air sparging, where air is injected into the groundwater; however, with in-well air stripping, the air is injected into the formation at such a rate as to volatilize the VOCs within the well. The volatilized VOCs are subsequently captured and treated at the surface. There are several variations on the basic concept. In one method, the air is injected into wells that have been screened at two locations. The lower screen is set in the groundwater, and the upper screen is located either in the vadose zone or the saturated zone. The groundwater is aerated within the well, and the VOCs volatilize within the well, travel up through the aquifer, and the vapors are drawn off by an in-well vapor extraction system. The vapors may then require treatment above the surface.

## Horizontal vs. Vertical Well Installation

The radius of influence of vertical injection wells for in-situ bioremediation and chemical oxidation, while highly dependent on the subsurface conditions, typically range from 10 to 20 feet. (Some sites have achieved a radius of influence up to as high as 100 feet, although this is not typical.) This means that in order to address areas under the building, numerous vertical wells would have to be installed through the floor slab inside the building. A preliminary calculation shows that, most likely, approximately 25 wells would be required. Also, a vertical well injection system would require the installation of a header system inside the building either in the floor slab or overhead. Therefore, the use of horizontal wells for this site is recommended.

Horizontal drilling can be performed adjacent to and outside of the building. The boring head is directed into the subsurface under the building and can be directed, to some degree, around obstacles. The drill bit is outfitted with a radio transmitter and the exact location can be tracked from the surface. Typically, a driller would monitor the drill bit location directly above it at the surface. However, if access to the building is not available, the drill bit location can be tracked remotely from outside the building. A horizontal well can completely span the distance under the building, or it can extend to the desired location and partially span the distance under the building. Once the boring is completed, a well casing is installed. Then, the appropriate delivery system can be installed at the desired locations. If, in the future, the location of the delivery system needs to be modified, the locations can be adjusted relatively easily.

The drill rig that is used is smaller than a conventional drill rig. Generally, a lay down area of approximately 20 feet by 30 feet is required for the rig operations. An additional area of approximately 10 feet by 30 feet is required for the support trucks. Also, the drilling operations schedule could be adjusted to fit the project needs. Drilling contractors can operate at night or on weekends in order to limit disruption to facility operations.

While the drilling assembly can be steered to predetermined points in both the vertical and horizontal plane, it should be noted that a thorough utility location effort is required and also, information regarding the foundation system is necessary. If this information is not available, a field investigation to obtain as much site information as possible would be beneficial. Historical maps show that it is possible that structures relating to the former MGP operations may be present in the subsurface at the site. If these structures are encountered during drilling operations, the well installation layout may have to be revised to accommodate these structures. It may be possible to drill through the former MGP structure depending on the condition and the types of material used for construction. Also, the presence of the structures may provide preferential pathways for air or oxidants, and may reduce treatment efficiencies.

The wells would run the length of the building since access is limited behind (by the railroad) and in front of the building (along Commercial Street). A conceptual layout of the injection wells and the SVE extraction wells is shown on Figure 3-1. In order to minimize costs, it may be possible to install vertical wells along the front of the building where the treatment area extends beyond the footprint of the building. So, the most appropriate well configuration may be a combination of horizontal and vertical wells. The injection wells will be placed in the upper portion of the Silty Fine Sand deposit as shown on Figure 3-2. This position is approximately 8 to 10 feet below the groundwater table. The SVE wells will be placed in the Fill material, approximately 5 feet below the building slab. The exact depth of the SVE wells may be modified based on information obtained regarding the building footings, etc. Pre-design field testing will be conducted to obtain site specific information that would be used to develop design parameters. The results of the testing would be used to calculate parameters, such as, well spacing, well placement, well piping design, flow pressures and flow rates.

The final design of the horizontal well system will be dependent on site specific conditions, including the location and type of the building foundation system, underground utilities, former MGP manufacturing structures, etc. If, after a site field investigation is conducted, a determination may be made that horizontal well installation may not be feasible due to the presence of subsurface structures, utilities or other obstructions. A re-evaluation of the project may be required at that time.

## 3.3 INITIAL SCREENING OF GROUNDWATER TREATMENT TECHNOLOGIES

As stated above, the initial screening of groundwater treatment technologies was conducted in accordance with requirements of the MCP and in consideration of the site-specific conditions identified in Section 3-1. Some technologies that are generally applicable to the contaminants and hydrogeologic conditions are not implementable at Parcel B and, therefore were eliminated in the technology screening. The screening is presented on Table 3-1.

The groundwater technologies that were retained for further evaluation are listed below. They include:

- Air Sparging
- Biosparging
- Chemical Oxidation Using Ozone

## 3.4 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

From the results of the initial screening, the technologies that were retained provided a basis for the development of remedial action alternatives. The alternatives were intended to provide a range of treatment options for evaluation against the criteria in the MCP (310 CMR 40.0858).

Each of the technologies listed above will become a potential remedial alternative for the treatment of groundwater at Parcel B. In addition, there are several other aspects of a remedial alternative that must be considered in order for the alternative to address site specific characteristics. At this portion of the Site, there are several issues that must be taken into account. They are the occupied building that is located on Parcel B, and the management of the migration of vapors into the building to address concerns regarding potential exposures to facility employees.

The presence of the building poses inherent restrictions on the location of the installation of vertical wells. Since the building is currently in use for bakery operations, there is process equipment located throughout the building that would preclude the installation of vertical wells in many areas. Also, there are concerns that penetrations of the existing floor slab would increase the potential of migration of vapors into the building. As discussed in Section 3.2, the remedial alternatives will be developed utilizing the installation of horizontal wells for each of the technologies. In addition, where appropriate, consideration was given to the installation of vertical wells or injection points outside the footprint of the building where these wells/injection points would enhance the performance, effectiveness, timeliness, etc., of the selected treatment technology.

Another consideration for the development of the alternatives is the potential for the creation and migration of vapors into the building. Since recent Release Abatement Measures have been conducted with limited success, the inclusion of a vapor management system would be prudent. Therefore, it was conservatively assumed that an SVE system would be installed with whichever remedial action alternative is selected. Even though bioremediation is the mechanism for reduction in one technology (biosparging), benzene is a volatile compound and will most likely undergo some volatilization with the introduction of air or oxygen to the subsurface. This being the case, in the detailed evaluation (in Section 4.0), the remedial alternatives (with the exception of Alt-1, No Further Action) were evaluated with SVE as a component of each alternative.

Based on the results of the initial technology screening and given the considerations listed above, several remedial action alternatives were developed. In addition, a No Action Alternative was included to provide a baseline for comparison to other alternatives. They are:

- Alternative 1 – No Further Action
- Alternative 2 – Air Sparging with SVE
- Alternative 3 – Biosparging with SVE
- Alternative 4 – Chemical Oxidation using Ozone with SVE

### 3.4.1 No Further Action (Alt-1)

This alternative would include no further remedial measures to address groundwater and soil vapor impacts at Parcel B. This alternative would include annual monitoring of the groundwater. This alternative is included in the Detailed Evaluation of remedial action alternatives to provide a baseline for comparison to other alternatives.

### 3.4.2 Air Sparging with Soil Vapor Extraction (Alt-2)

This alternative consists of air sparging of the groundwater beneath the building. As previously discussed, vapor management is an issue at Parcel B. Since this technology utilizes a phase transfer mechanism and the contaminants will go from a dissolved phase to a vapor phase, an SVE system will be a component of this alternative. When air sparging is combined with SVE, the SVE system creates a negative pressure in the unsaturated zone through a series of extraction wells that are intended to control the vapor plume migration. The vapors are then treated in an on-site facility and discharged to the atmosphere. A description of the air sparging system is included herein. A description of the SVE system is included in Section 3.4.5.

An air sparging system will include a series of horizontal wells installed below the water table for the purpose of delivering the air to the subsurface. The horizontal wells will be connected to manifold piping that runs to a compressed air system housed in a shed or a trailer in a convenient location on site. The air delivery system will also include monitoring and controls in order to fine tune the system for optimum performance.

In preparing a conceptual design of an air sparging system, the two major factors that determine the effectiveness of air sparging are the vapor/dissolved phase partitioning of the constituents and the permeability of the soil. The combined effect of these two factors determines the rate at which the constituents will be removed. These factors also influence the placement and number of air sparge points required to sufficiently reduce the concentrations.

Other parameters are involved in the design of an air sparging system. These includes the well spacing, the air sparging flow rate and sparging air pressure, and methods to evenly distribute air along the length of the horizontal pipe.

The design for the spacing of the air sparging wells is determined based on a calculated radius of influence (ROI). The ROI is the distance from the air sparging well at which sufficient air flow and pressure are present to facilitate the transfer of constituents from the dissolved phase to the vapor phase. The ROI is used to determine the number, spacing and location of wells. The ROI depends primarily on the hydraulic conductivity of the aquifer and physical properties of the soil, including permeabilities, and the layering of soils of varying permeabilities. Often, the ROI is determined from field testing. For this report, the ROI was calculated from available data in the Phase II – Comprehensive Site Assessment. For the final design, the ROI will be calculated on site data obtained during a pre-design field testing program. (A description of the field testing program is included in Section 5.5.)

Empirical data from prior air sparging projects indicate that the radius of influence of vertical wells can range from 5 to 100 feet (USEPA, 1992) but is typically less than 25 feet. The use of horizontal application wells is likely to increase the efficiency of air distribution by a factor of five over vertical wells (Looney, et. al., 1991). One case study reported by USEPA (1992) at the Savannah River site reported an average "distance of influence" of 10 to 15 feet for horizontal wells. Despite this rather large range of well spacing reported in the literature, it is clear that the actual distance of influence is highly dependent on the intrinsic permeability of the soil (USEPA, 1995). The intrinsic permeability can be estimated from the hydraulic conductivity of the soil by the relationship;

$$K = K(u/pg)$$

Where: k = intrinsic permeability ($cm^2$)

K = hydraulic conductivity (cm/sec)

u = water viscosity (g/cm-sec)

p = water density ($g/cm^3$)

g = acceleration due to gravity ($cm/sec^2$)

Hydraulic conductivity data were reported in the Phase II report for three monitoring wells at the Site (B3-OW, B503-OW, B303L-OW). Two of the wells were screened in the Fill material and one in the underlying silty sand. Since the application of air sparging will be primarily within the upper portion of the Silty Fine Sand layer (refer to Figure 3-2), the reported hydraulic conductivity from this layer of $7 \times 10^{-4}$ cm/sec was used to estimate the intrinsic permeability. Using default values for the properties of water (i.e., at 20 degrees C), this calculation resulted in an intrinsic permeability of $7 \times 10^{-9}$ $cm^2$, which is within the lower portion of the range considered "generally effective" by USEPA (1995).

Based on a review of the soil descriptions for this area, the permeability of the overlying soils (Upper Sands) and Fill, is likely to be at least an order of magnitude greater than the Silty Fine Sands, and thus even more conducive to this application. For this conceptual design, the selection of a 30 foot spacing assumes a radius of influence of approximately 20 feet with a five foot overlap. This assumption appears reasonable considering the nature of the soil beneath the building, and the use of the more effective horizontal wells. Final well spacing will be determined from the results of the pilot tests that should be conducted prior to final design.

The air sparging flow rate is the rate required to provide sufficient air flow to enhance the mass transfer in the saturated zone. This is usually determined based on pilot-testing results. Intermittent operation of the air flow system sometimes provides better distribution and mixing of the air in the vadose zone and contact with the dissolved phase COC's, and therefore enhanced performance of the system. For this report, the conceptual design was based on a typical average air flow rate of 1.0 scfm per foot of slotted pipe (750 scfm total). The slotted pipe was assumed to be installed in the area defined by the groundwater plume, as shown in the Phase II Report, and as shown on Figure 3-1. In order to prepare a final design, field testing would be required and the design of an air sparging system would be based on actual site data, if this alternative were selected.

The sparging air pressure is the pressure at which air is injected into the subsurface. In order to overcome static head pressures and the head due to capillary forces of the water in the soil pores, the air sparging pressure must be greater than the sum of these pressures. Typically, systems operate at 10 to 15 psig. For this report, it was assumed that a system would operate in this range. For a final design, this air pressure would be confirmed based on pilot testing.

### 3.4.3 Biosparging with Soil Vapor Extraction (Alt-3)

Biosparging is a technology that is very similar to air sparging, with regard to mechanical delivery systems. This technology pumps air (and if needed, nutrients) into the subsurface in a well and manifold piping system similar to the configuration described above for air sparging. The major difference is that biosparging relies on biological activity to reduce contaminant concentrations in the groundwater, in the soil below the water table and in the capillary fringe. Biosparging utilizes lower air flow rates that are more suitable for promoting biological growth. When volatile compounds are present, there will also be some degree of volatilization that will occur. Generally, air injection rates used in biosparging are low enough so that vapor migration is not a major issue. However, to be conservative, as with the other alternatives, SVE was included in this alternative for vapor management.

The components of a biosparging system include a series of horizontal wells that will be installed below the water table for the purpose of delivering the air to the subsurface. The horizontal wells will be connected to manifold piping that runs to a compressed air system housed in a shed or trailer in a convenient location on site. The air delivery system will also include monitoring and controls in order to fine tune the system for optimum performance. If nutrients are required, a nutrient delivery system will be included. This would be determined in a pilot study. For this report, it was assumed that a nutrient delivery system would not be required.

The mechanical components of a biosparging system are very similar to an air sparging system, and the layout and well spacings are similar. For this report, it was assumed that a well spacing of 30 feet, the same as for air sparging would be adequate. The layout is shown on Figure 3-1.

Other site-specific parameters that are factors in the design of a biosparging system are the soil structure and stratification, the temperature and pH of the groundwater, the microbial population density, nutrient concentrations, and the concentration of iron dissolved in the groundwater. For the conceptual design included in this report, available data from the Phase II – Comprehensive Site Assessment was used. If this alternative were selected, then additional effort would be required to confirm these site parameters prior to preparing the final design.

The air flow rates for biosparging systems are typically around 0.5 scfm per foot of slotted pipe and the total flow rate is estimated to be 375 scfm. As with air sparging systems, intermittent operation of the air flow may provide better distribution and mixing of the air in the saturated zone. The air pressure in the system should be maintained at a similar pressure as air sparging. The air pressure should be greater than the static water pressure and the head due to capillary forces of the water in the soil pores. Typical systems operate at 10 to 15 psig. This pressure range was assumed for this project.

Typically, the SVE system is started up first, before starting the biosparging system. This will remove the VOCs already in the vapor phase and increase the oxygen the vadose zone. Thus the VOCs reaching the vadose zone will be degraded to their full potential. Also, starting the SVE system prior to the biosparging system will avoid creating positive air pressure under the building, which could increase the potential for vapor migration.

### 3.4.4 Chemical Oxidation Using Ozone with SVE (Alt-4)

The chemical oxidation system would include the application of an oxidizing agent to chemically degrade the contaminants. For this application, ozone would be the oxidant of choice because it could be delivered in gaseous form via horizontal wells and would have a greater radius of influence than the liquid oxidants. Ozonation has documented effectiveness for degradation of BTEXSN compounds.

Ozone would be applied to groundwater in a horizontal well system similar to an air sparging system or biosparging system. With ozone sparging, the VOCs could volatilize and potentially migrate inside the buildings. Therefore, as mentioned earlier, an SVE system would be installed to control migration of vapors. The well spacing was assumed to be consistent with the other alternatives for this report. A field study would have to be conducted in order to determine the optimum spacing.

Ozone gas can oxidize contaminants in two ways, either directly or through the formation of free radical intermediates. The oxidation reaction can occur rapidly. Due to ozone's high reactivity and instability, ozone must be generated on site. This eliminates the storage and handling problems associated with other oxidants. Typical application rates of ozone range from 1-10 lbs per pound of contaminant. It has been documented that moderate ozone gas saturation in the subsurface achieves treatment effectiveness for similar sites.

The equipment necessary for ozone groundwater treatment include ozone generation equipment, a horizontal well system for injection, and vapor extraction and treatment. The ozone could be generated on site and the application system would operate mechanically, which would reduce the manual labor requirements typically associated with chemical oxidation application. Ozone has a very short life span and since there may be a contaminant area of concentrated contamination area under the building, ozone may need to be applied over a long time frame. Groundwater monitoring would be conducted to determine the effectiveness and duration of operation of chemical oxidation.

### 3.4.5 Soil Vapor Extraction (SVE)

As mentioned previously, Alt-2, Alt-3, and Alt-4 would include the installation of an SVE system. The purpose of this system would be to capture the vapors that are generated from the groundwater treatment system.

For this system, a vacuum is applied by a pump or blower, through the horizontal wells in the unsaturated zone. The vacuum induces gas flow through the soil toward the wells. The removed vapors are treated in a vapor treatment system located on-site, before the air is discharged to the atmosphere. Typical components of an SVE system include manifold piping, extraction wells, control valves to adjust flow, vacuum blowers and controls, pressure gauges and flow meters, an air water separator, and a vapor treatment unit. A conceptual layout of a soil vapor extraction system piping is shown on Figure 3-1.

The design of a vapor extraction system is based on the radius of influence. The radius of influence is the extent of measurable vacuum in the subsurface during vapor extraction. Vapor extraction systems should be designed based on providing adequate air flow to achieve remediation goals over the target area and should also account and provide for deviations in performance due to site specific conditions. The final design should be based on data obtained from field studies.

The SVE system should have a greater flow capacity and area of influence than the biosparging system. SVE extraction systems generally have extraction rates 1.25 to 5 times greater than the biosparging rate. Of note, a review of the facility HVAC should be conducted prior to the design of the SVE system in order to avoid possible interference of the operation of these two systems.

TABLE 3-1

SCREENING OF REMEDIAL TECHNOLOGIES
FOR GROUNDWATER REMEDIATION
FORMER MALDEN MGP SITE
MALDEN, MASSACHUSETTS

| Technology | Applicability to Treat or Contain COCs | Comments | Retain? (Yes/No) |
|---|---|---|---|
| **In-Situ Technologies**<br>Air Sparging | + | Can be effectively implemented to reduce BTEXSN concentrations | Yes |
| **Enhanced Bioremediation**<br>Hydrogen Peroxide Injection | +/- | Other bioremediation techniques would be more effective at this site. | No |
| Biosparging | + | Successfully implemented at other sites to reduce BTEXSN. | Yes |
| **Chemical Oxidation**<br>Fenton's Reagent | + | This technology requires high level of operator training and site maintenance activities due to the materials management procedures necessary for handling these chemicals. Also, this technology is difficult to implement in a horizontal well system and a vertical well injection system is not feasible at Parcel B. | No |
| Permanganate | +/- | This technology requires high level of operator training and site maintenance activities due to the materials management procedures necessary for handling these chemicals. Also, this technology is difficult to implement in a horizontal well injection system and a vertical well injection system is not feasible at Parcel B. | No |
| Ozone | + | Can be effectively implemented to reduce COCs via a horizontal well system. | Yes |
| In-Well Air Stripping | + | This technology requires the installation of closely spaced vertical wells, which is not feasible at site due to physical constraints (i.e., building). | No |

Notes:
(+) Better, (+/-) Average, (-) Worse

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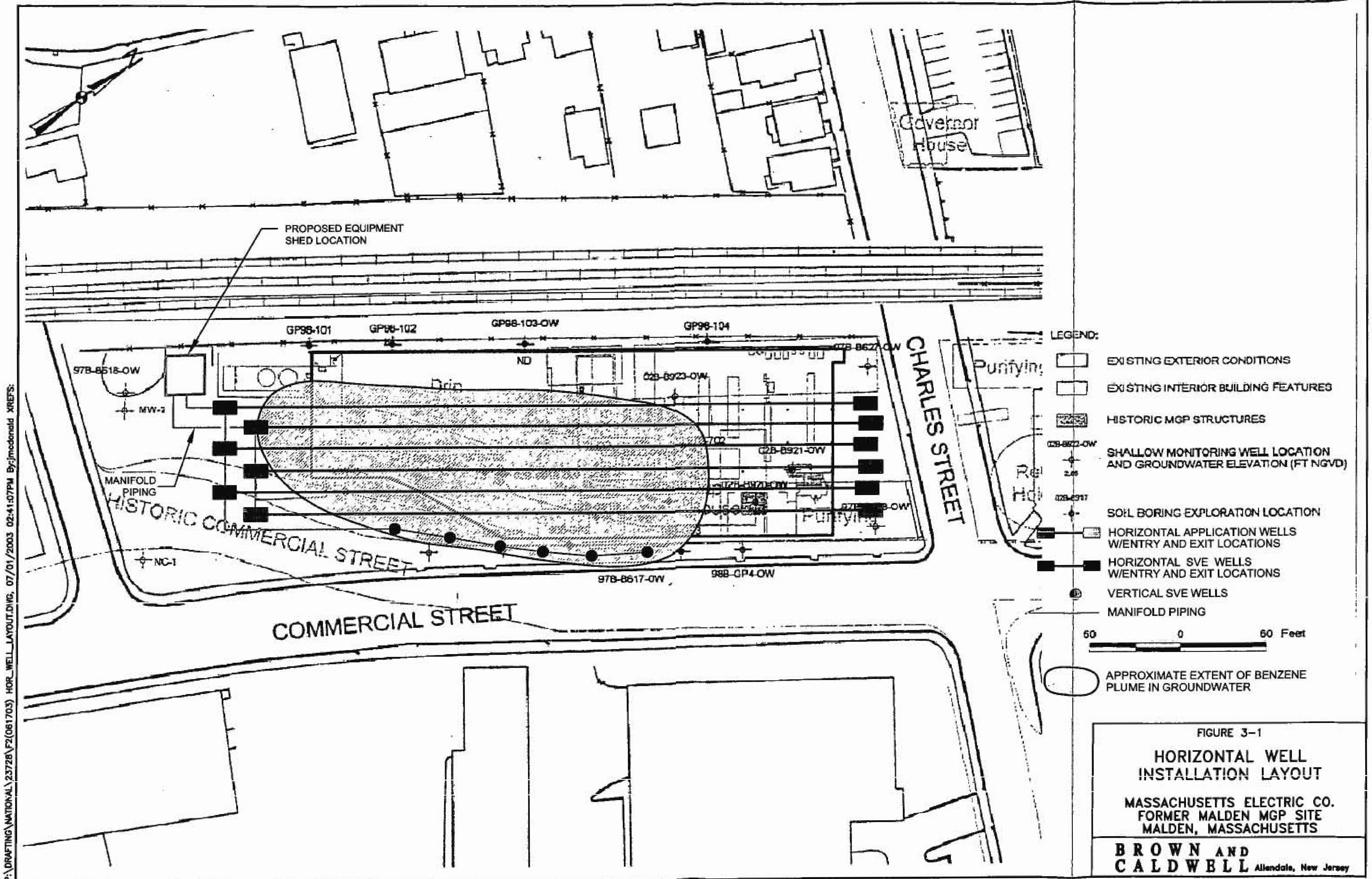


FIGURE 3-1

HORIZONTAL WELL INSTALLATION LAYOUT

MASSACHUSETTS ELECTRIC CO.
FORMER MALDEN MGP SITE
MALDEN, MASSACHUSETTS

BROWN AND CALDWELL Allendale, New Jersey

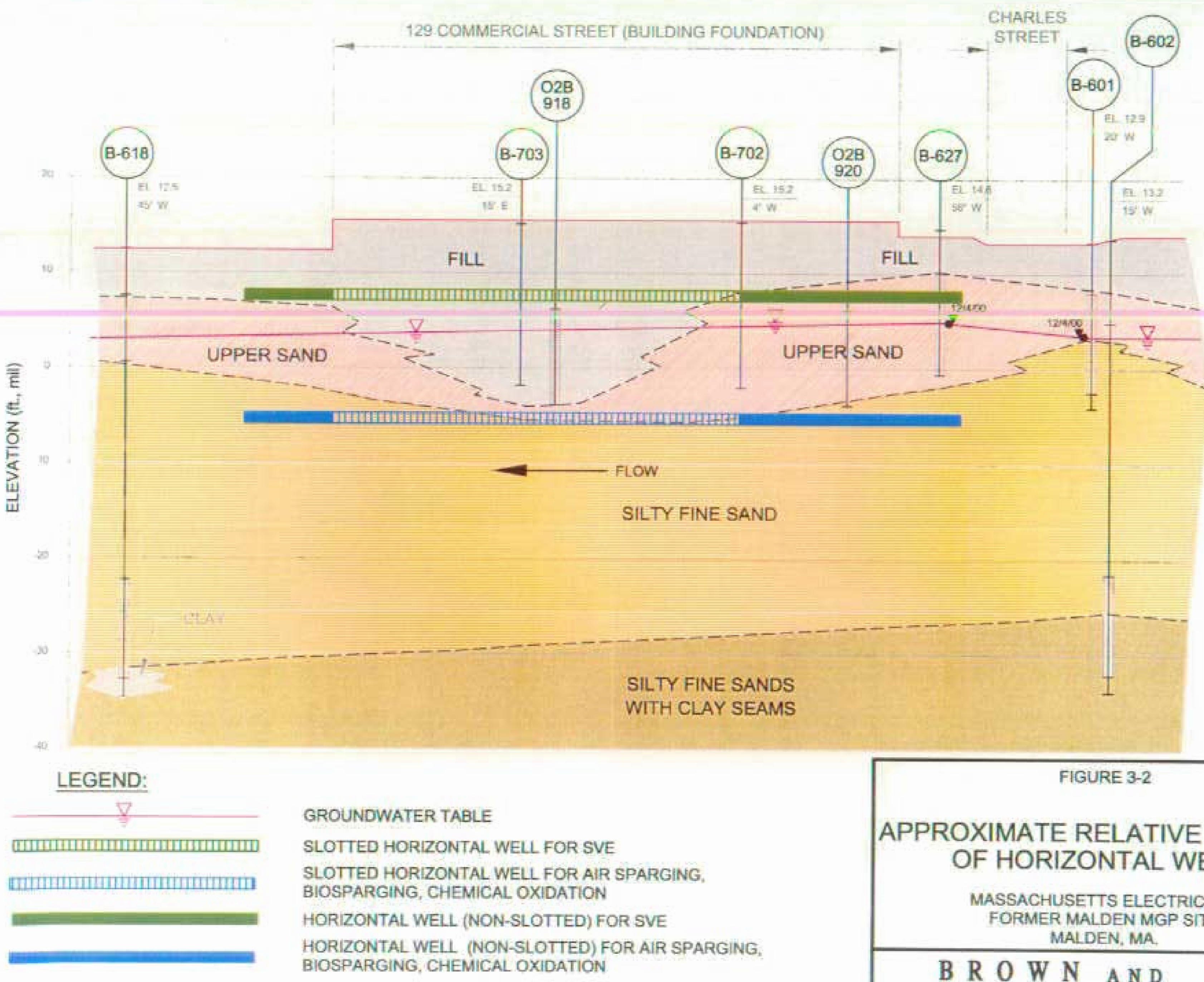


FIGURE 3-2

APPROXIMATE RELATIVE POSITION OF HORIZONTAL WELLS

MASSACHUSETTS ELECTRIC CO.
FORMER MALDEN MGP SITE
MALDEN, MA.

BROWN AND CALDWELL Allendale, New Jersey

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# 4.0 DETAILED EVALUATION OF REMEDIAL ACTION ALTERNATIVES

This section presents the detailed evaluation of the remedial action alternatives for Parcel B that were developed from the technologies retained after initial screening. The detailed evaluation provides a basis for the selection of a recommended remedial action alternative. The criteria used in the detailed evaluation are included in the MCP (310 CMR 40.0858) and are as follows:

- Effectiveness - The effectiveness of the remedial action alternatives is evaluated in terms of:

  - achieving a permanent solution;
  - reusing, recycling, destroying, detoxifying, or treating oil and hazardous material; and
  - achieving or approaching background concentrations.

- Reliability - The short-term and long-term reliability of the remedial action alternatives is evaluated in terms of:

  - degree of certainty that the alternative will be successful; and
  - effectiveness of measures required to manage residues or discharges to the environment.

- Difficulty in Implementation - The difficulty in implementation of the remedial action alternatives is evaluated in terms of:

  - technical complexity;
  - integration with existing site operations and conditions;
  - monitoring, maintenance, or operation requirements;
  - availability of services, materials, equipment, or specialists;

- availability of off-site treatment, storage and disposal facilities; and
- compliance with regulatory requirements, approvals, permits or licenses.

- Cost - The factors to be considered in the evaluation of this criterion include the capital and long-term operation and maintenance costs for each alternative.

- Risks - The risks of the remedial action alternatives are evaluated in terms of:

  - long- and short-term risks to health, safety, public welfare, and the environment associated with the implementation and operation of the alternative; and
  - potential risks to health, safety, public welfare, and the environment associated with the residual remaining on site after the alternative is implemented.

- Benefits - the benefits of the remedial action alternatives are evaluated in terms of:

  - restoration of natural resources;
  - providing for the productive reuse of the site;
  - avoided cost of relocating businesses, people or providing alternative water supplies; and
  - avoided loss value of the site.

- Timeliness - The timeliness of the remedial action alternative is evaluated in terms of eliminating uncontrolled area of concentrated contaminations and achieving a level of no significant risk.

- Non-Pecuniary Interests - The remedial alternatives are evaluated in terms of the relative effect of the non-pecuniary interests such as aesthetic values.

The results of the detailed evaluation for the alternatives are presented on Table 4-1.

## 4.1 EFFECTIVENESS

Alt-1 (No Further Action) would not achieve a Permanent Solution, does not treat or destroy the contaminants, and would not achieve or approach background levels. This alternative would rely on natural biodegradation of the contaminants. Alt-2 (Air Sparging), Alt-3 (Biosparging), and Alt-4 (Chemical Oxidation) would effectively treat the contaminants and achieve a Permanent Solution. However, the timeframe to achieve a Permanent Solution is uncertain because the potential area of concentrated contamination is not well defined and cannot be directly accessed. Published data has shown these technologies to successfully treat the types of contaminants present at Parcel B.

## 4.2 RELIABILITY

Alt-1 would not successfully achieve the remedial action objectives since no treatment would be conducted. Also, this alternative includes no measures to manage residues or discharges to the environment. For the remaining alternatives, the reliability of the treatment mechanisms has been shown to be effective for many sites with the types of contaminants present on Parcel B. For this application, the reliability of the alternatives is more dependent on the ability of the horizontal well injection system to deliver the air, nutrients or ozone to the treatment area. The building is located over the majority of the groundwater plume and access through the building is not feasible. Therefore, as previously mentioned, a horizontal well system is the most appropriate delivery system for this application. It has been reported in some cases, horizontal wells provided more surface area for sparging than a vertical well and provided uniform pressure throughout the length of the well.

With regard to the effectiveness of the measures required to manage residues or discharges to the environment, the three treatment alternatives include an SVE system that would extract the vapors and provide on-site treatment. So, the only discharge to the environment would be treated air from the SVE system. Therefore, for this category, these remedial alternatives are rated as good.

## 4.3 DIFFICULTY IN IMPLEMENTATION

Alt-1 is No Further Action, therefore, there is no technical complexity.

Alt-2 would require the design and installation of an on-site blower station, horizontal well injection system, and a vapor extraction and treatment system. The horizontal well system would have to be designed to not interfere with subgrade utilities, the foundation structure of the building and possibly historical MGP manufacturing structures. Field testing prior to the design would be necessary in order to determine well spacing. Monitoring would also be required to assess the effectiveness of the alternative. O&M requirements would include maintenance for proper functioning of the horizontal injection well and extraction well systems, and the blower station. There is sufficient availability of services, materials, equipment and specialists for implementation of this and the other two alternatives.

Alt-3 and Alt-4 would require similar design activities as mentioned above. For Alt-3, field testing would be required to determine if the addition of nutrients would be required to enhance the performance of the bioremediation of the contaminants. In addition, the determination of the well spacing would need to be calculated based on field studies. The system could be integrated with existing site operations and conditions. O&M requirements would include maintenance for proper functioning of the horizontal injection and extraction well system, the blower station and the nutrient injection system, if necessary. For Alt-4, installation of an ozone generating station would require more highly trained field personnel. O&M requirements would also include maintenance for the injection and extraction well system, and an on-site ozone generation station. O&M activities would be more intense with this alternative. As with the other systems, this treatment alternative could be integrated with existing site operations and conditions. For this category, Alt-2 and Alt-3 were rated as good and Alt-4 was rated as fair.

## 4.4 COSTS

The cost estimates for the remedial action alternatives are presented in Table 4-2 through 4-5. The following is a summary of the capital and present worth cost estimates for each of the alternatives.

| Remedial Alternative | Estimated Capital Cost | Estimated Total Present Worth of O & M Costs | Total |
|---|---|---|---|
| Alt-1 – No Further Action | $0 | $440,000 | $440,000 |
| Alt-2 – Air Sparging with SVE | $900,000 | $100,000 | $1,000,000 |
| Alt-3 – Biosparging with SVE | $840,000 | $130,000 | $970,000 |
| Alt-4 – Chemical Oxidation using Ozone with SVE | $1,100,000 | $100,000 | $1,200,000 |

## 4.5 RISKS

Alt-1 does not have short-term risks associated with implementation, since there would be no implementation. The long-term risks to human health would be the exposures from the potential migration of VOCs into the building. Risks to the environment would be the potential migration of the contaminant plume. Since this alternative does not include treatment, the contamination would remain for a considerable timeframe and could pose a long term risk.

The short-term risks for Alt-2, Alt-3, and Alt-4 would be the limited potential exposures to soils from cuttings during the installation of the horizontal well system. Since the groundwater would not be extracted, the potential for exposures to the groundwater is minimal. For Alt-4, there is the potential for exposures to ozone gas, if leakage occurs. However, ozone has a low odor threshold, lower than concentrations at hazardous levels.

For Alternatives Alt-2, Alt-3 and Alt-4, monitoring would be conducted to assess the extent of treatment, the extent the alternatives are expected to reduce groundwater contamination levels, and the risks associated with any residuals remaining on Parcel B would be minimal.

A Health and Safety Plan (HASP) would be prepared to identify hazards associated with the implementation and operation of the selected treatment system. The HASP would include health and safety procedures designed to reduce the risk posed to site workers and others through treatment completion.

## 4.6 BENEFITS

Alt-1 does not accomplish the restoration of the sites within a reasonable time frame. Alt-2, Alt-3, and Alt-4 would lower the concentrations of contaminants in the groundwater and, therefore would enhance the restoration of the property. Parcel B is currently being used as a commercial bakery facility and, implementation of the alternatives would not affect these operations since on-site blower operations and a treatment equipment building could be located in a non-obtrusive location. Also, the implementation of the alternatives would not require relocation of the Parcel B commercial facilities. In addition, Parcel B is serviced by a public water supply system so the installation of the remedial alternatives would not require alternative water supplies. The remedial alternatives would not reduce the current value of the property.

## 4.7 TIMELINESS

Alt-1 would require the longest time frame to achieve the remedial objectives, since it would rely on natural degradation of the contaminants. Alt-2, Alt-3, and Alt-4 include treatment of the area exhibiting the highest concentrations of constituents. Most likely, Alt-4, treatment by chemical oxidation with ozone, and Alt-2, air sparging would probably require the shortest timeframe. It was estimated that these treatment durations would be 3 years. Alt-3, biosparging, would most likely take the longest timeframe. It was estimated that the treatment timeframe would be 5 years. Since this alternative relies on biological mechanisms, the remedial timeframe cannot be estimated with certainty.

## 4.8 NON-PECUMIARY INTERESTS

Alt-1 would not have any effect on non-pecuniary interests. The remaining treatment alternatives would all require the installation of the horizontal well system and a treatment equipment building needed to house equipment. The treatment alternatives would also require personnel to operate and monitor the treatment equipment and the effectiveness of the remedial alternative. This means that there would be equipment located on site and field personnel on-site on a periodic basis to conduct O&M activities.

TABLE 4-1

# REMEDIAL ACTION ALTERNATIVE EVALUATION
# FORMER MALDEN SITE
# PARCEL B
# MALDEN, MASSACHUSETTS

| EVALUATION CRITERIA | Alt-1: No Further Action | Alt-2: Air Sparging with SVE | Alt-3: Biosparging with SVE | Alt-4: Chemical Oxidation with SVE |
|---|---|---|---|---|
| **1) EFFECTIVENESS** | | | | |
| • Achieving a Permanent or Temporary Solution. | This alternative would require a lengthy time frame to achieve a permanent solution. | Could achieve a permanent solution in a relatively short timeframe provided there is no area of elevated concentrations in the soil. If there is an area of elevated concentrations, treatment times may be extended. | Could achieve a permanent solution in a relatively short timeframe provided there is no area of elevated concentrations in the soil. If there is an area of elevated concentrations, treatment times may be extended. | Could achieve a permanent solution in a relatively short timeframe provided there is no area of elevated concentrations in the soil. If there is an area of elevated concentrations, treatment times may be extended. |
| • Reusing, recycling, destroying, detoxifying, or treating oil and hazardous material | Natural degradation of contaminants would be only mechanism to reduce concentrations. | Air sparging would reduce contaminant levels through volatilization. | Biosparging reduces concentration through aerobic bioremediation. | Chemical oxidation chemically destroys contaminants using ozone. |
| • Achieving or approaching background concentrations | This alternative would require a lengthy timeframe to approach background conditions. | Could be operated until concentrations achieve or approach background provided that there is no area of elevated concentrations. | Could be operated until concentrations achieve or approach background provided there is no area of elevated concentrations. | Could be operated until concentrations achieve or approach background provided there is no area of elevated concentrations. |
| **Effectiveness Rating** | **Poor** | **Good** | **Good** | **Good** |
| **2) RELIABILITY** | | | | |
| • Degree of certainty that the alternative will be successful | This alternative would not be very reliable in reducing concentrations. | Air sparging has documented success at remediating BTEX and naphthalene. High degree of certainty that it would be successful provided that there is no area of elevated concentrations. | Bioremediation has documented success at remediating BTEX and naphthalene. High degree of certainty that it would be successful provided that there is no area of elevated concentrations. | Chemical oxidation has had documented success at remediating BTEX and naphthalene. High degree of certainty that it would be successful provided that there is no area of elevated concentrations. |
| • Effectiveness of measures required to manage residues or discharges to the environment | Natural degradation would address residuals. There would be no discharges to the environment. | No residuals generated. Discharges to the environment would be only air pumped to subsurface. | No residuals generated. Discharges to the environment would be only air pumped to subsurface. | No residuals generated. Discharges to the environment would be ozone pumped to subsurface. |
| **Reliability Rating** | **Poor** | **Good** | **Good** | **Good** |

TABLE 4-1

# REMEDIAL ACTION ALTERNATIVE EVALUATION
# FORMER MALDEN SITE
# PARCEL B
# MALDEN, MASSACHUSETTS

| EVALUATION CRITERIA | Alt-1: No Further Action | Alt-2: Air Sparging with SVE | Alt-3: Biosparging with SVE | Alt-4: Chemical Oxidation with SVE |
|---|---|---|---|---|
| **3) DIFFICULTY IN IMPLEMENTATION** | | | | |
| • Technical complexity | No technical complexity. | Minimal technical complexity associated with design of the well and application system. | Minimal technical complexity associated with design of well and application system. | Moderate technical complexity associated with design of well and ozone generation system. |
| • Integration with existing site operations and conditions | No integration required. | Horizontal wells would not require access inside building. | Horizontal wells would not require access inside building. | Horizontal wells would not require access inside building. |
| • Operation, maintenance, and monitoring (OMM) requirements | This alternative would include groundwater monitoring for 30 years. | Low OMM requirements with air blower systems. | Low OMM requirements with air blower systems. | Intense OMM associated with ozone system. |
| • Availability of services, materials, equipment, or specialists | Not required. | Readily available. | Readily available. | Readily available. |
| • Availability of off-site treatment, storage and disposal facilities | Not required. | No off-site treatment, storage, or disposal of groundwater. Off-site disposal of spent carbon from SVE system would be required. | No off-site treatment, storage, or disposal of groundwater. Off-site disposal of spent carbon from SVE system would be required. | No off-site treatment, storage, or disposal of groundwater. Off-site disposal of spent carbon from SVE system would be required. |
| • Compliance with regulatory requirements, approvals, permits or licenses | Does not address regulatory requirement to reduce contaminants. | Would comply. May need an air discharge permit for SVE treatment system. | Would comply. May need an air discharge permit for SVE treatment system. | Would comply. May need an air discharge permit for SVE treatment system. |
| **Implementation Rating** | **Poor** | **Good** | **Good** | **Fair** |
| **4) COST** | | | | |
| • Capital | $0 | $900,000 | $840,000 | $1,100,000 |
| • Present Worth (O&M) | $440,000 | $100,000 | $130,000 | $100,000 |
| **Cost Rating** | **Good** | **Fair** | **Fair** | **Fair** |

TABLE 4-1

# REMEDIAL ACTION ALTERNATIVE EVALUATION
# FORMER MALDEN SITE
# PARCEL B
# MALDEN, MASSACHUSETTS

| EVALUATION CRITERIA | Alt-1: No Further Action | Alt-2: Air Sparging with SVE | Alt-3: Biosparging with SVE | Alt-4: Chemical Oxidation with SVE |
|---|---|---|---|---|
| **5) RISKS** | | | | |
| • Long- and short-term risks to health, safety, public welfare, and the environment associated with the implementation and operation of the alternative | No risks associated with implementation. No operational risks. | Risks of exposures to drill cutting during well installations. | Risks of exposures to drill cuttings during well installations. | Risks of exposures to drill cutting during well installations. Risks of exposures to ozone during operation. |
| • Potential risks to health, safety, public welfare, and the environment associated with the residuals remaining on site after the alternative is implemented | Potential exposures to vapors migrating to inside building would remain. | Would reduce the concentrations and risks are anticipated to be minimal following treatment. SVE will control vapor migration until concentrations are reduced to levels such that SVE is no longer needed. | Would reduce the concentrations and risks are anticipated to be minimal following treatment. SVE will control vapor migration until concentrations are reduced to levels such that SVE is no longer needed. | Would reduce the concentrations and risks are anticipated to be minimal following treatment. SVE will control vapor migration until concentrations are reduced to levels such that SVE is no longer needed. |
| **Risks Rating** | **Poor** | **Good** | **Good** | **Good** |
| **6) BENEFITS** | | | | |
| • Restoration of natural resources | Would require a long timeframe to restore groundwater. | Could reduce timeframe to reduce concentrations. | Could reduce timeframe to reduce concentrations. | Could reduce timeframe to reduce concentrations. |
| • Providing for the productive reuse of the site | Not applicable. | Not applicable. | Not applicable. | Not applicable. |
| • Avoided cost of relocating businesses, people, or providing alternative water supplies | Not applicable. | Not applicable. | Not applicable. | Not applicable. |
| • Avoided loss value of the site | No lost value. | No lost value. | No lost value. | No lost value. |
| **Benefits Rating** | **Poor** | **Good** | **Good** | **Good** |

TABLE 4-1

# REMEDIAL ACTION ALTERNATIVE EVALUATION
# FORMER MALDEN SITE
# PARCEL B
# MALDEN, MASSACHUSETTS

| EVALUATION CRITERIA | Alt-1: No Further Action | Alt-2: Air Sparging with SVE | Alt-3: Biosparging with SVE | Alt-4: Chemical Oxidation with SVE |
|---|---|---|---|---|
| **7) TIMELINESS** | | | | |
| • Time to eliminate any uncontrolled sources and achieve a level of No Significant Risk | Would not reduce concentrations in a timely manner and would require a long timeframe to achieve a level of no significant risk. | Could address the contaminants in a shorter timeframe. SVE will achieve a Condition of No Significant Risk upon startup by controlling vapor migration. GW treatment may reduce concentrations such that operation of SVE system is no longer needed and a Permanent Solution is attained. | Could address the contaminants in a shorter timeframe. SVE will achieve a Condition of No Significant Risk upon startup by controlling vapor migration. GW treatment may reduce concentrations such that operation of SVE system is no longer needed and a Permanent Solution is attained. | Could address the contaminants in a shorter timeframe. SVE will achieve a Condition of No Significant Risk upon startup by controlling vapor migration. GW treatment may reduce concentrations such that operation of SVE system is no longer needed and a Permanent Solution is attained. |
| **Timeliness Rating** | **Poor** | **Good** | **Good** | **Good** |
| **8) NON-PECUNIARY INTERESTS** | | | | |
| • Aesthetics | No effects on aesthetics. | Moderate site disturbance with installation of wells and equipment shed. | Moderate site disturbance with installation of wells and equipment shed. | Moderate site disturbance with installation of wells and equipment shed. |
| **Non-Pecuniary Rating** | **Good** | **Fair** | **Fair** | **Fair** |

**TABLE 4-3**
**ALTERNATIVE 2: Air Sparging with SVE**
**COST ESTIMATE**
**FORMER MALDEN MGP SITE**
**PARCEL B**
**Malden, Massachusetts**

**Capital**

| ITEM[a] | NOTES[b] | UNIT[c] | QUANTITY[a] | UNIT COST[d] | INSTALLED COST[e] |
|---|---|---|---|---|---|
| Mobilization and Demoblization | 4 | LS | 1 | $5,000 | $5,000 |
| Site Preparation | 5 | LS | 1 | $5,000 | $5,000 |
| Horizontal Well Installation | 6 | LF | 2,520 | $140 | $352,800 |
| Treatment equipment enclosure | 7 | LS | 1 | $5,000 | $5,000 |
| Instrumentation, Electrical, and Controls | 8 | LS | 1 | $20,000 | $20,000 |
| Air Sparging System | | | | | |
| Blower | 9 | EA | 1 | $6,000 | $6,000 |
| Manifold Piping | 10 | LF | 150 | $8 | $1,100 |
| Solid Horizontal Well Pipe | 11 | LF | 510 | $3 | $1,300 |
| Slotted Horizontal Well Pipe | 12 | LF | 750 | $20 | $15,000 |
| Utility Vaults | 13 | EA | 4 | $2,000 | $8,000 |
| Soil Vapor Extraction System | | | | | |
| Vacuum Pump | 14 | EA | 1 | $73,000 | $73,000 |
| Vapor Control and Treatment System (Activated Carbon) | 15 | EA | 1 | $6,000 | $6,000 |
| Manifold Piping | 10 | LF | 460 | $13 | $6,000 |
| Solid Horizontal Well Pipe | 11 | LF | 510 | $3 | $1,300 |
| Slotted Horizontal Well Pipe | 16 | LF | 750 | $6 | $4,100 |
| Utility Vaults | 13 | EA | 6 | $2,000 | $12,000 |
| Vertical Extraction Wells | 17 | EA | 5 | $1,500 | $7,500 |
| System Start-up and Optimization | 18 | LS | 1 | $5,000 | $5,000 |
| Miscellaneous | | % | 25 | | $133,500 |
| | | | | SUBTOTAL | $668,000 |
| Engineering Design & Reporting | 19 | % | 15 | | $100,200 |
| Project/Construction Management | | % | 10 | | $66,800 |
| Contingency | | % | 10 | | $66,800 |
| | | | | TOTAL CAPITAL COST | $900,000 |

# TABLE 4-3
# ALTERNATIVE 2: Air Sparging with SVE
# COST ESTIMATE
# FORMER MALDEN MGP SITE
# PARCEL B
# Malden, Massachusetts

**Operation and Maintenance**

| ITEM[a] | NOTES[b] | O&M PERIOD[f] | FREQUENCY | ANNUAL COST[e] | PRESENT WORTH[g] |
|---|---|---|---|---|---|
| Quarterly Monitoring | 20 | 3 | Quarterly | $3,500 | $40,000 |
| Carbon Changeouts | 21 | 3 | Quarterly | $500 | $5,700 |
| Plant Operations and Equipment Replacement | 28 | 3 | Annually | $20,000 | $56,600 |
| | | | | TOTAL PRESENT WORTH | $100,000 |

Notes:

a: Items and quantities included in this estimate are based on preliminary system designs for the purpose of the Phase III Detailed Evaluation and may change based on system design.

b: Notes are presented in the pages following the cost tables.

c: LS: Lump Sum, LF: Linear Foot, SY: Square Yard, CY: Cubic Yard

d: Unit costs represent Year 2003 dollars and are estimated based on cost estimating guidances and Brown and Caldwell experience.

f:. Installed costs are rounded to the nearest hundred, subtotals are rounded to the nearest thousand, and totals are rounded to the nearest ten thousand.

e:. Installed costs are rounded to the nearest hundred, subtotals are rounded to the nearest thousand, and totals are rounded to the nearest ten thousand.

f: O&M Period refers to the estimated monitoring time for the remedial option. These timeframes are estimates and actual operating times could be shorter or longer.

g: Present worth estimates are based on extending the annual cost over the O&M period at a discount rate of 3%.

**TABLE 4-4**
**ALTERNATIVE 3: Biosparging with SVE**
**COST ESTIMATE**
**FORMER MALDEN MGP SITE**
**PARCEL B**
**Malden, Massachusetts**

**Capital**

| ITEM[a] | NOTES[b] | UNIT[c] | QUANTITY[a] | UNIT COST[d] | INSTALLED COST[e] |
|---|---|---|---|---|---|
| Mobilization and Demoblization | 4 | LS | 1 | $5,000 | $5,000 |
| Site Preparation | 5 | LS | 1 | $5,000 | $5,000 |
| Horizontal Well Installation | 6 | LF | 2,520 | $140 | $352,800 |
| Treatment equipment enclosure | 7 | LS | 1 | $5,000 | $5,000 |
| Instrumentation, Electrical, and Controls | 8 | LS | 1 | $20,000 | $20,000 |
| Air Sparging System | | | | | |
| Blower | 22 | EA | 1 | $3,000 | $3,000 |
| Manifold Piping | 10 | LF | 150 | $8 | $1,100 |
| Solid Horizontal Well Pipe | 11 | LF | 510 | $3 | $1,300 |
| Slotted Horizontal Well Pipe | 12 | LF | 750 | $20 | $15,000 |
| Utility Vaults | 13 | EA | 4 | $2,000 | $8,000 |
| Soil Vapor Extraction System | | | | | |
| Vacuum Pump & Controls | 23 | EA | 1 | $37,000 | $37,000 |
| Vapor Control and Treatment System (Activated Carbon) | 15 | EA | 1 | $6,000 | $6,000 |
| Manifold Piping | 10 | LF | 460 | $13 | $6,000 |
| Solid Horizontal Well Pipe | 11 | LF | 510 | $3 | $1,300 |
| Slotted Horizontal Well Pipe | 16 | LF | 750 | $6 | $4,100 |
| Utility Vaults | 13 | EA | 6 | $2,000 | $12,000 |
| Vertical Extraction Wells | 17 | EA | 5 | $1,500 | $7,500 |
| System Start-up and Optimization | 18 | LS | 1 | $5,000 | $5,000 |
| Miscellaneous | | % | 25 | | $123,800 |
| | | | | SUBTOTAL | $619,000 |
| Engineering Design & Reporting | 19 | % | 15 | | $92,900 |
| Project/Construction Management | | % | 10 | | $61,900 |
| Contingency | | % | 10 | | $61,900 |
| | | | | TOTAL CAPITAL COST | $840,000 |

# TABLE 4-4
# ALTERNATIVE 3: Biosparging with SVE
# COST ESTIMATE
# FORMER MALDEN MGP SITE
# PARCEL B
# Malden, Massachusetts

**Operation and Maintenance**

| ITEM[a] | NOTES[b] | O&M PERIOD[f] | FREQUENCY | ANNUAL COST[d] | PRESENT WORTH[g] |
|---|---|---|---|---|---|
| Quarterly Monitoring | 20 | 5 | Quarterly | $3,500 | $64,800 |
| Carbon Changeouts | 21 | 5 | Quarterly | $500 | $9,300 |
| Plant Operations and Equipment Replacement | 28 | 3 | Annually | $20,000 | $56,600 |
| | | | TOTAL PRESENT WORTH | | $130,000 |

Notes:

a: Items and quantities included in this estimate are based on preliminary system designs for the purpose of the Phase III Detailed Evaluation and may change based on system design.

b: Notes are presented in the pages following the cost tables.

c: LS: Lump Sum, LF: Linear Foot, SY: Square Yard, CY: Cubic Yard

d: Unit costs represent Year 2003 dollars and are estimated based on cost estimating guidances and Brown and Caldwell experience.

f:. Installed costs are rounded to the nearest hundred, subtotals are rounded to the nearest thousand, and totals are rounded to the nearest ten thousand.

e:. Installed costs are rounded to the nearest hundred, subtotals are rounded to the nearest thousand, and totals are rounded to the nearest ten thousand.

f: O&M Period refers to the estimated monitoring time for the remedial option. These timeframes are estimates and actual operating times could be shorter or longer.

g: Present worth estimates are based on extending the annual cost over the O&M period at a discount rate of 3%.

# TABLE 4-5
# ALTERNATIVE 4: Chemical Oxidation with SVE
# COST ESTIMATE
# FORMER MALDEN MGP SITE
# PARCEL B
# Malden, Massachusetts

**Operation and Maintenance**

| ITEM[a] | NOTES[b] | O&M PERIOD[f] | FREQUENCY | ANNUAL COST[d] | PRESENT WORTH[g] |
|---|---|---|---|---|---|
| Quarterly Monitoring | 20 | 3 | 4 times/year | $3,500 | $40,000 |
| Carbon Changeouts | 21 | 3 | 4 times/year | $500 | $5,700 |
| Plant Operations and Equipment Replacement | 28 | 3 | Annually | $20,000 | $56,600 |
| | | | | TOTAL PRESENT WORTH | $100,000 |

Notes:

a: Items and quantities included in this estimate are based on preliminary system designs for the purpose of the Phase III Detailed Evaluation and may change based on system design.

b: Notes are presented in the pages following the cost tables.

c: LS: Lump Sum, LF: Linear Foot, SY: Square Yard, CY: Cubic Yard

d: Unit costs represent Year 2003 dollars and are estimated based on cost estimating guidances and Brown and Caldwell experience.

f:. Installed costs are rounded to the nearest hundred, subtotals are rounded to the nearest thousand, and totals are rounded to the nearest ten thousand.

e:. Installed costs are rounded to the nearest hundred, subtotals are rounded to the nearest thousand, and totals are rounded to the nearest ten thousand.

f: O&M Period refers to the estimated monitoring time for the remedial option. These timeframes are estimates and actual operating times could be shorter or longer.

g: Present worth estimates are based on extending the annual cost over the O&M period at a discount rate of 3%.

# 5.0 SELECTION OF A REMEDIAL ACTION ALTERNATIVE

This section presents a comparison of the alternatives evaluated in the detailed evaluation, a feasibility evaluation, and the recommended alternative to address groundwater and soil vapor impacts at Parcel B. The comparison of alternatives and selection of a remedial action alternative are based on the results of the detailed evaluation.

In accordance with the MCP (310 CMR 40.0860), this section includes a discussion of the evaluation of the feasibility of:

- Implementing a Permanent Solution;
- Reducing the concentration of oil and hazardous material in the environment to levels that achieve or approach background; and
- Reducing the concentrations of oil and hazardous material in soil at a disposal site to levels at or below applicable soil Upper Concentration Limits.

## 5.1 COMPARISON OF ALTERNATIVES

As shown in the detailed evaluation, Alt-1, No Further Action, rated the least favorable for most categories. While it is the least costly option, it does not reduce the contaminants in the subsurface or the associated risks. It does not provide any benefits, nor does it assist in the restoration of the aquifer within a reasonable time frame. Based on these factors, Alt-1 was not considered a viable alternative for Parcel B.

The remaining alternatives were rated comparatively favorable for this application. These technologies have been documented to reduce the COCs that are present and the evaluation of the site geology was favorable for an in-situ treatment application. The costs for the alternatives are comparable. Implementation of any of these three alternatives would probably result in a successful reduction of COCs.

There were slight disadvantages of one technology over the others relating to implementability. Alt-4 (Chem Ox) requires more intense training and higher level field personnel to meet operational requirements. The equipment is slightly more difficult and complex to install, operate and maintain. In addition, there is a limited potential for exposures to ozone by the field personnel. For Alt-2 (Air Sparging), while the volatilization of benzene may be easily accomplished, the volatilization of naphthalene may not be accomplished as easily. Since air sparing requires air flow rates twice as high as biosparging, air sparging equipment and operational costs will be greater. Also, this treatment has a higher potential to generate benzene in the vapor phase, since that is the treatment mechanism. Considering there is a concern for the potential migration of vapors into the building, this alternative is slightly less favorable than biosparging. Therefore, for this application, the one alternative that was slightly favored above the others was Alt-3, Biosparging with SVE.

## 5.2 FEASIBILITY OF IMPLEMENTING A PERMANENT SOLUTION

The MCP (310 CMR 40.0860) requires a feasibility evaluation of implementing a Permanent Solution only in cases where the remedial action alternative is a Temporary Solution. The recommended remedial action alternative is intended to address constituents in the indoor air such that concentrations present after implementation of the remedial action alternative do not pose a significant risk of harm to health, safety, public welfare or the environment during any foreseeable period of time. However, since an area of concentrated contamination in the soil that is most likely contributing to the groundwater and indoor air contamination has not been identified, there is uncertainty as to the timeframe that would be required to reduce the concentrations to a level where a No Significant Risk could be demonstrated. The remedy would be implemented under a Remedy Operation Status, but if it became apparent that it is not feasible to reduce the concentrations in a reasonable time frame, the remedy would be considered a Temporary Solution.

## 5.3 FEASIBILITY OF ACHIEVING OR APPROACHING BACKGROUND

The MCP requires an evaluation of the feasibility of reducing the levels of concentrations of oil and hazardous materials in the environment to levels that achieve or approach background when a remedial alternative is selected that constitutes a Class A-2, A-3, or A-4 RAO. To achieve or approach background levels, current COC concentrations in groundwater would have to be reduced and any areas of concentrated contaminations impacting site groundwater would have to be mitigated. As previously mentioned, an area of concentrated contamination of the groundwater contamination has not been definitively located. It is presumed to be beneath the building. Groundwater sampling upgradient of the building, north of Parcel B, indicated that the groundwater contamination is not from an upgradient source. If an area of concentrated contamination was identified beneath the building, excavation and removal of material is not feasible.

The objective of the remedial action alternatives is to control risks associated with the migration of VOCs to indoor air. This objective can be achieved by reducing the concentrations in groundwater or by collecting vapors with the SVE system. The SVE system will have some effect on the soil contaminant concentrations since this technology can result in the volatilization of contaminants in the vadose zone, but not the saturated zone. However, without knowing the location of the area of concentrated contamination, effectively reducing the concentrations in soil cannot be expected. The resulting impacts to groundwater from the soil may persist for some time. Therefore, treating groundwater to levels that achieve or approach background is not probable.

## 5.4 FEASIBILITY OF REDUCING CONCENTRATIONS IN SOIL TO BELOW UCLs

The Phase II investigation for the site reported that soil COCs above UCL's were not detected on Parcel B. However, as stated above, the area of concentrated contamination of the groundwater contamination has not been definitively located and it has been presumed that it is beneath the building. Soil sampling in borings drilled through the floor slab in suspected locations has not located an area of concentrated contamination. At this point, further investigation in an effort to locate an area of concentrated contamination is not considered to be feasible. Of note, some reduction of the COCs in the soil may occur in-situ as a side benefit of the installation and operation of a SVE system, although it is not the primary goal of that system. Therefore, reduction of concentrations of COCs may occur, but without knowing the location of the area of concentrated contamination, the feasibility of reducing the concentrations of a potential area of concentrated contamination is not predictable.

### 5.5 SELECTION OF ALTERNATIVES

As mentioned in Section 5.1, the remedial action alternative selected for the site is Alt-3, Biosparging with SVE. The selection of the recommended remedial alternative was based on the results of the detailed evaluation. The recommended remedial alternative is expected to achieve the remedial action objectives set forth in Section 2, and is technologically feasible, as defined by the MCP. However, the timeframe in which treatment would be required is uncertain. Therefore, potentially this remedial alternative could achieve a Permanent Solution, however, that would be determined based actual field operations.

A conceptual design of the system prepared for this report assumed that three horizontal delivery wells for biosparging would be installed and run the length of the building. The biosparging wells would be connected to manifold piping and a blower station located in the southwest corner of the property. The wells would be screened in the areas where the plume has been identified. If it is necessary that nutrients be added to the subsurface, the required equipment would be included in the system design.

The SVE system would include the installation of four horizontal wells in between the biosparging wells. The SVE would also be screened in the area where the plume has been identified. In an effort to be more cost effective, the area in front of the building vertical extraction wells could be installed. These wells would be located outside and adjacent to the foundation of the building. The SVE extraction wells would be connected to manifold piping and a vapor treatment system located in a shed or trailer on-site. The treated air would be released to the atmosphere. In order to adequately capture the vapors under the building, the SVE system should operate at an air flow rate approximately four times greater than the air flow rate of the biosparging system.

In addition to treatment, it was assumed that groundwater monitoring would be conducted at the site. This would include sampling of five wells quarterly during the operation of the treatment system (5 years was assumed).

Prior to the final design, field testing will be conducted to obtain site specific information that will be used to calculate design parameters. A site specific field testing program will be developed during the initial design activities. One option for determining the horizontal well spacing is conducting a two part field test for use in designing the SVE system and the air sparging system. The test would be fairly simple and would include the installation of several probes near an existing well, if possible, in an area that would not affect operations. The first part of the test would be to establish soil vapor extraction rates through the subgrade at selected locations. A vacuum would be applied to the well at different pressures and flow rates, and the vacuum in the GeoProbes® would be measured. This information would be used to design the SVE system. Then, for the second part of the test, air (and possibly a tracer, such as helium) would be injected in the well at different flow rates and pressures, and the GeoProbes® would be monitored for the tracer. This information would be used to design the biosparging system.

As previously mentioned in Section 2.3, MEC is conducting an evaluation of the HVAC system for the facility on Parcel B, and therefore, the implementation of a new or modified HVAC system was not included in this report. If, however, site conditions or other parameters interfere with the successful installation of a horizontal well system that would meet the design requirements of the remedial alternative selected for the site, then further effort will be directed towards the consideration of the implementation of an HVAC system for the facility at Parcel B that would minimize the infiltration of vapors from the subgrade.

## 6.0 PRELIMINARY SCHEDULE FOR IMPLEMENTATION OF PHASE IV ACTIVITIES

The MCP requires that the selected remedial alternative by developed and implemented in accordance with the Phase IV requirements of the MCP (310 CMR 40.0870). The MCP requires that a detailed design be presented in the format of a Remedy Implementation Plan (RIP). The RIP must include a list of relevant contacts, documentation of the engineering concepts and criteria used in the design and implementation of the remedy, construction plans and specifications, an operation, maintenance, and monitoring plan, a health and safety plan, and a list of any necessary federal, state or local permits. A description of long-term monitoring and maintenance activities will also be included in a plan.

As mentioned previously, the implementation of biosparging has been estimated to take five years to complete. A breakdown of the timeframes to complete the project is included below:

| | |
|---|---|
| Field/Lab Studies | 3 months |
| Preparation of Phase IV RIP | 5 months |
| Contractor Procurement | 2 months |
| Installation of Biosparge and SVE System | 2 months |
| Startup and Optimization | 1 month |
| Preparation of Final Inspection Report | 2 months |
| Remedy Operation | 5 years |
| Total Estimated Time | 6-7 years |

This is an estimated time frame. If a Permanent Solution is attained in 5 years or less, then a Class A RAO would be filed. Otherwise, a Class C RAO could be filed and the system would continue to operate as a Temporary Solution until it becomes feasible to implement a Permanent Solution.

# REFERENCES


1. USEPA, "A Technology Assessment of Soil Vapor Extraction and Air Sparging", Office of Research and Development, EPA 600/R-192/173, September 1992.

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3. USEPA, "Engineering Forum Issue Paper: Soil Vapor Extraction Implementation Experiences", Office of Solid Waste and Emergency Response, EPA/F-95/030, April, 1996.

4. USEPA, "Engineering Bulletin, Chemical Oxidation Treatment", Office of Emergency and Remedial Response, EPA/540/2-91/025, October, 1991.

5. Interstate Technology and Regulatory Cooperation Work Group, "Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater", June, 2001.

6. Haley & Aldrich, "Phase II-Comprehensive Site Assessment, Former Malden MGP Site, Malden, Massachusetts, RTN 3-0362, Tier IB Permit 7378, June, 2003."

7. Haley & Aldrich, "Phase III-Remedial Action Plan, Former Malden MGP Site, Malden, Massachusetts, RTN 3-0362, Tier IB Permit 7378, June, 2003."