TRC

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April 2, 2014

New Jersey Department of Environmental Protection
Bureau of Case Management
Mail Code 401-05F
P.O. Box 420
Trenton, NJ 08625-0420

Attn: Donna Gaffigan, Case Manager

Re: *Remedial Investigation Report – Site-Wide Ground Water*
Hoffmann-La Roche Inc.
340 Kingsland Street
Nutley, New Jersey
SRP PI #s 009949, 614465, and 625447
TRC Project No. 105009/198233

Dear Ms. Gaffigan:

On behalf of Hoffmann-La Roche Inc. (Roche), TRC Environmental Corp. (TRC) has prepared the enclosed Remedial Investigation (RI) Report for Site-Wide Ground Water. The RI activities were performed in compliance with the NJDEP's Technical Requirements for Site Remediation (N.J.A.C. 7:26E) and applicable NJDEP Guidance, the approved Roche Remediation Road Map (September 2012), Deep Bedrock RI Workplan (October 2012), Shallow Ground Water RI Workplan (November 2012), Deep Bedrock and Shallow Ground Water RI Workplan Supplements No. 1 and 2, and associated correspondence (NJDEP comments, Roche Response letters). The required NJDEP forms have been included with this submission.

If you have any questions or need additional information, please contact me at 973-564-6006 ext. 234, or agoeller@trcsolutions.com.

Very truly yours,

Arthur F. Goeller, LSRP (No. 591661)
Project Director
TRC Environmental Corporation

Cc: Robert Dellon, Hoffmann-La Roche Inc.
Greg Cierpial, Hoffmann-La Roche Inc.
Chandra Patel, Hoffmann-La Roche Inc.
Teresa O'Meara, Hoffmann-La Roche Inc.

TRC

Nutley Site Remediation
Project No. S153.29215

NJDEP PI ID #s 009949, 614465, and 625447

Site-Wide Ground Water
Remedial Investigation Report

NJDEP Required Forms

Revision: 3

Prepared for:

Hoffmann-La Roche Inc.
340 Kingsland Street
Nutley, New Jersey 07110-1199

Prepared by:

TRC Environmental Corporation
57 East Willow Street
Millburn, NJ 07041

April 2, 2014

Site-Wide Ground Water

Remedial Investigation Report Form

New Jersey Department of Environmental Protection
Site Remediation Program

REMEDIAL INVESTIGATION REPORT FORM

Date Stamp
(For Department use only)

SECTION A. SITE NAME AND LOCATION

Site Name: Hoffmann-La Roche Inc.

List all AKAs: Roche

Street Address: 340 Kingsland Street

Municipality: Nutley (Township, Borough or City)

County: Essex Zip Code: 07110-1199

Program Interest (PI) Number(s): 009949, 625447 & 614465 Case Tracking Number(s): NJD002191211

Date Remediation Initiated Pursuant to N.J.A.C. 7:26C-2:

State Plane Coordinates for a central location at the site: Easting: 587196 Northing: 729465

Municipal Block(s) and Lot(s):

Block #	79.04 (Clifton)	Lot #	10 & 21	Block #	201 (Nutley)	Lot #	1
Block #	80.02 (Clifton)	Lot #	1 & 4	Block #	300 (Nutley)	Lot #	1
Block #	102 (Nutley)	Lot #	2 & 9	Block #	2101 (Nutley)	Lot #	1, 4, & 5
Block #	200 (Nutley)	Lot #	1, 2, 3, 4, 5, 6, & 24	Block #		Lot #	

SECTION B. SUBMITTAL STATUS

1. Indicate how the Electronic Data Deliverable (EDD) for this submittal is being provided to the NJDEP:
   - ☐ Via Email at srpedd@dep.state.nj.us (attach NJDEP confirmation email); or
   - ☒ CD (attach to this submittal)
2. Is a Classification Exception Area (CEA) Proposal included with this submission? .... ☒ Yes ☐ No
3. Complete the following Submittal and Permit Status Table:

	Not Applicable	Included in this Submission	Previously Submitted	Date Of Submission	Date of Revised Submission	Date of Document Withdrawal
Public Notification	☐	☐	☒	08/17/2009	06/05/2013	
Immediate Environmental Concern Report	☒	☐	☐			
IEC Engineered System Response Action Report	☒	☐	☐			
Vapor Concern Mitigation Report	☒*	☐	☐			
LNAPL Interim Remedial Measure Report	☒*	☐	☐			
Preliminary Assessment Report	☐	☐	☒	12/03/1998		
Receptor Evaluation	☐	☒	☐			
Site Investigation Report	☐	☐	☒	01/13/2001		
Remedial Investigation/Remedial Action Work Plan	☐	☒*	☐			
Remedial Action Report	☒	☐	☐			
Response Action Outcome	☒	☐	☐			
Alternative Soil Remediation Standard and/or Screening level Application Form	☒	☐	☐			
Case Inventory Document	☐	☐	☒	01/11/2013	08/30/2013	
Technical Impracticability Determination	☒	☐	☐			

* **Vapor Intrusion Investigation Report is being provided under separate cover, LNAPL detected (in 1 well) from off-site source (LNAPL Report not required), RAWP to be provided in future submission.**

Permit Application – list:	☒	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
	☐	☐	☐			
Radionuclide Remedial Investigation Workplan	☒	☐	☐			
Radionuclide Remedial Investigation Report	☒	☐	☐			
Radionuclide Remedial Action Workplan	☒	☐	☐			
Radionuclide Remedial Action Report	☒	☐	☐			

SECTION C. SITE USE

Current Site Use (check all that apply)

☒ Industrial ☐ Agricultural
☐ Residential ☐ Park or recreational use
☐ Commercial ☐ Vacant
☐ School or child care ☐ Government
☐ Other ____________

Intended Future Site Use (check all that apply)

☐ Industrial ☐ Park or recreational use
☐ Residential ☐ Vacant
☐ Commercial ☐ Government
☐ School or child care ☒ Future site use unknown

SECTION D. CASE TYPE: (check all that apply)

☐ Administrative Consent Order (ACO)
☐ Brownfield Development Area (BDA)
☐ Child Care Facility
☐ Chrome Site (Chromate chemical production waste)
☐ Coal Gas
☐ Due Diligence with RAO
☐ Hazardous Discharge Remediation Fund (HDSRF) Grant/Loan
☒ ISRA
☐ Landfill (SRP subject only)
☐ Regulated Underground Storage Tank (UST)
☐ Remediation Agreement (RA)
☐ School Development Authority (SDA)
☐ School facility
☐ Spill Act Defense – Government Entity
☐ Spill Act Discharge
☐ UST Grant/Loan

Federal Case (check all that apply)

☒ **RCRA GPRA 2020** ☐ **CERCLA/NPL** ☐ **USDOD** ☐ **USDOE** ☐ TSCA
☐ Other (explain): ____________

SECTION E. PUBLIC FUNDS

Did the remediation utilize public funds?.................... ☐ Yes ☒ No

If "Yes," check applicable: ☐ UST Grant ☐ UST Loan ☐ Brownfield Reimbursement Program
☐ HDSRF Grant ☐ HDSRF Loan ☐ Landfill Reimbursement Program
☐ Spill Fund ☐ Schools Development Authority

SECTION F. SCOPE OF THE REMEDIAL INVESTIGATION REPORT

1. Does the Remedial Investigation address:
   ☐ Area(s) of Concern (AOCs) Only
   ☒ Entire Site (based on a completed and submitted Preliminary Assessment/Site Investigation)
2. Total number of contaminated AOCs associated with the case: N/A **(AOCs addressed in individual IA RIRs)**
3. Total number of contaminated AOCs addressed in this submittal: N/A **(AOCs addressed in individual IA RIRs)**
4. Is the Remedial Investigation complete for the contaminated AOCs addressed in this submittal?............ ☒ Yes ☐ No
5. Is the Remedial Investigation complete for all AOCs associated with this case?.................... ☒ Yes ☐ No
   If "Yes," provide date: 04/02/2014

SECTION G. SITE CONDITIONS

1. Has dioxin been detected in any site media?.................**(Note: Not Analyzed in Ground Water)** ☒ Yes ☐ No
2. Check each media-type and highest concentration of contamination present above any applicable standards/criteria at the time of remedial investigation:

Soil in ppm	GW = Ground Water in ppb					SW = Surface Water in ppb					Sed = Sediment in ppm				
	Soil ppm	GW ppb	SW ppb	Sed ppm		Soil ppm	GW ppb	SW ppb	Sed ppm		Soil ppm	GW ppb	SW ppb	Sed ppm	
*VOCs	☐	☐	☐	☐	<100	☐	☐	☐	☐	100–1,000	☐	☒	☐	☐	>1,000
*SVOCs	☐	☒	☐	☐	<100	☐	☐	☐	☐	100–1,000	☐	☐	☐	☐	>1,000
*PAHs	☐	☒	☐	☐	<10	☐	☐	☐	☐	10–100	☐	☐	☐	☐	>100
*Metals	☐	☐	☐	☐	<100	☐	☐	☐	☐	100–1,000	☐	☒	☐	☐	>1,000
PCBs	☐	☐	☐	☐	<10	☐	☐	☐	☐	10–100	☐	☐	☐	☐	>100
*Pesticides	☐	☐	☐	☐	<1	☐	☒	☐	☐	1-10	☐	☐	☐	☐	>10
Chromium	☐	☐	☐	☐	<100	☐	☐	☐	☐	100–1,000	☐	☒	☐	☐	>1,000
Mercury	☐	☐	☐	☐	<100	☐	☐	☐	☐	100–1,000	☐	☐	☐	☐	>1,000
Arsenic	☐	☐	☐	☐	<10	☐	☐	☐	☐	10–100	☐	☒	☐	☐	>100
EPH	☐			☐	<1,700	☐			☐	1,700–5,100	☐			☐	>5,100

3. For any contaminant group (*) checked above, identify the contaminant with the highest concentration over its applicable remediation standard and/or screening level:

   Benzene (266,000 ppb) 2-Methylnaphthalene (40.4 ppb) Benzo(b)fluoranthene (0.65 ppb) Sodium (7,690,000 ppb) Dieldran (1.7 ppb)

4. Were the laboratory reporting minimum detection limits below applicable remediation standards/ screening levels required for the site? .... ☒ Yes ☐ No

5. Are any of the following conditions currently present? (check all that apply)

Ground water:

☒ Contaminated ground water in the overburden aquifer
☐ Contaminated ground water in a confined aquifer
☒ Contaminated ground water in the bedrock aquifer
☒ Contaminated ground water in multiple aquifer units
☒ Multiple distinct ground water plumes
☒ Contaminated ground water migrating off-site
☒ Background ground water contamination
☐ Contaminated ground water discharging to surface water or Environmentally Sensitive Natural Resource (ESNR)
☒ Residual or free product **(Note: From Off-Site Source)**
☐ Radionuclides

Soil:

☐ On-site discharge(s) impacting soil off-site
☐ Chromate Chemical Production Waste/COPR
☐ Munitions and explosives of concern
☐ Contaminated soil in the saturated zone
☐ Historic pesticide impacts to soil
☐ Residual or free product
☐ Radionuclides
☐ Historic Fill
☐ Soil contamination due to naturally occurring background conditions
☐ Soil contamination in an ESNR

SECTION H. APPLICABLE REMEDIATION STANDARDS

1. Were Default Remediation Standards used for all contaminants? .... ☐ Yes ☐ No
   (If "Yes," check all that apply) **(Note: Not Applicable)**
   ☐ Direct Contact
   ☐ Impact to Ground Water Soil Screening Levels
   ☐ Ecological Screening Levels

2. Has compliance averaging been utilized to determine compliance with a pathway? .... ☐ Yes ☐ No
   If "Yes," check all that apply: **(Note: Not Applicable)**

Compliance Averaging Method Utilized

Pathway	Arithmetic Mean	95 Percent UCL	Spatially Weighted Average	75 Percent/ 10X Procedure
☐ Ingestion-Dermal Pathway	☐	☐	☐	☐
☐ Inhalation Pathway	☐	☐	☐	☐
☐ Impact to Ground Water Pathway	☐	☐	☐	☐

3. Has a compliance option been utilized to determine compliance with the Impact to Ground Water Pathway? (If "Yes," check all that apply) ☐ Yes ☐ No
(Note: Not Applicable)
   - ☐ Immobile Compounds
   - ☐ Data evaluation for metals and semi-volatiles
   - ☐ Data evaluation for volatile organics derived from discharges of petroleum mixtures

4. Were Alternate Remediation Standards used for the Ingestion/Dermal Pathway? ☐ Yes ☐ No
5. Were Alternate Remediation Standards used for the Inhalation Pathway? ☐ Yes ☐ No
6. Were Site Specific Standards used for the Impact to Ground Water Pathway? ☐ Yes ☐ No
(If "Yes," check all that apply)
   - ☐ Soil-Water Partitioning Equation ☐ SPLP ☐ Sesoil ☐ Sesoil/AT123D
   - ☐ DAF Modification ☐ Immobile Chemicals List
   - ☐ Soil and Ground Water Analytical Data Evaluation
7. Were Site Specific Ecological Remediation Goals used? ☐ Yes ☒ No
8. What is the ground water classification for this site as per N.J.A.C. 7:9C? (check all that apply)
   - ☐ Class I-A ☒ Class II-A
   - ☐ Class I-PL Pinelands Protection Area ☐ Class III-A
   - ☐ Class I-PL Pinelands Preservation Area ☐ Class III-B

SECTION I. BACKGROUND CONDITIONS

Did the RI demonstrate via a background investigation, outside the influence of on-site AOCs **and** operational areas, that:

1. All or any part of the ground water contamination is migrating onto this site per N.J.A.C. 7:26E-3.9? ☒ Yes ☐ No ☐ NA
2. Soil contamination is naturally occurring per N.J.A.C. 7:26E-3.8 ☐ Yes ☐ No ☒ NA

SECTION J. ALTERNATIVE STANDARD / VARIANCES

Alternative remediation standard
If proposing an alternative remediation standard pursuant to N.J.A.C. 7:26D-7.4, alternate vapor intrusion screening level, or ecological site specific goal check here ☐ and attach the Alternative Soil Remediation Standard and/or Screening Level Application Form as an addendum.

A site-specific screening level was developed for the evaluation of the VI pathway ☐ Yes ☒ No

Variance from regulations
If the Licensed Site Remediation Professional has varied from the Technical Rules, provide the citation(s) from which the remediation varied and the page(s) in the attached document where the rationale for the variance is provided.

N.J.A.C. 7:26E-__________ Page ______

N.J.A.C. 7:26E-__________ Page ______

N.J.A.C. 7:26E-__________ Page ______

SECTION K. HISTORIC FILL

Is historic fill present at the site? ☒ Yes ☐ No

If "Yes," answer the following questions:

1. Indicate how the presence of historic fill was determined (check all that apply):
☒ Boring logs ☒ Test Pits ☐ Trenches ☒ Aerial Photos ☐ NJDEP Mapped Areas
2. Was the historic fill characterized pursuant to N.J.A.C. 7:26E-4.7 and the NJDEP Historic Fill Material Technical Guidance Document? ☐ Yes ☐ No
(Note: Not Applicable)
3. Are any other AOCs (i.e., location of discharge and any contaminants that may have migrated from that area) located within the defined boundaries of the historic fill? ☐ Yes ☐ No
(Note: Not Applicable)
If "Yes," have the same contaminant type(s) (e.g., lead, arsenic, and/or benzo(a)pyrene, etc.) characterized as being present in the historic fill been **sampled for** as a contaminant of concern at these co-located AOCs? ☐ Yes ☐ No

SECTION L. GROUND WATER TRIGGER

1. Was a ground water investigation conducted at all AOCs where a ground water investigation was triggered pursuant to N.J.A.C. 7:26E-3.5 and 4.3? ☒ Yes ☐ No ☐ NA
2. Is contamination in soils fully delineated? ☐ Yes ☒ No

SECTION M. GROUND WATER REMEDIAL INVESTIGATION INFORMATION

1. Are contaminants present with a specific gravity less than that of water? ☒ Yes ☐ No
   a. If "Yes," were any monitor wells installed in unconfined aquifers in which the water table is higher than the top of the well screen? ☒ Yes ☐ No

   If "Yes" to 1a, identify the affected wells. Presented on Contour Map Reporting Forms
2. Are contaminants present with a specific gravity greater than that of water? ☒ Yes ☐ No
   a. If "Yes," were multiple depth discrete ground water samples collected in a vertical profile at each ground water sampling location where dense contaminants were suspected? ☒ Yes ☐ No
3. Is ground water in the bedrock aquifer contaminated? ☒ Yes ☐ No

   If "Yes," answer questions 3a and 3b.
   a. Were bedrock cores collected? ☒ Yes ☐ No
   b. Were geophysical logging methods conducted to characterize the bedrock aquifer in accordance with the NJDEP Ground Water Technical Guidance (3.4.2.2)? ☒ Yes ☐ No
4. Is contamination in ground water fully delineated? ☒ Yes ☐ No

SECTION N. ECOLOGICAL RECEPTORS

Note: Ecological Receptors are being evaluated in Site-Wide Ecological RI (to be submitted under separate cover)

1. Have soil, sediment, and/or surface water data been collected from Environmentally Sensitive Natural Resources (ESNR)? ☒ Yes ☐ No ☐ NA
   a. If "Yes," do contaminant concentrations at the ESNR exceed ecological screening criteria or the aquatic chronic NJSWQS [N.J.A.C.7:9B]? ☐ Yes ☐ No
   b. If "Yes," have soil and sediment data been collected from both surface and subsurface intervals in the ESNR? ☐ Yes ☐ No
   c. If "No" for 1b, provide explanation ______
2. Have contaminant migration pathways from the site/AOC to the ESNR been identified? ☐ Yes ☐ No
3. Do the results of the Ecological Evaluation require a remedial investigation of ecological receptors? ☐ Yes ☐ No

   If "No," provide explanation ______
4. Has an Ecological Risk Assessment been conducted [N.J.A.C.7:26E-4.8]? ☐ Yes ☐ No
5. Is remediation required in an ESNR? ☐ Yes ☐ No

SECTION O. LABORATORY DATA

1. Were all data submitted in the appropriate full and/or reduced formats according to the deliverables defined in N.J.A.C. 7:26E-2? ☒ Yes ☐ No
2. Do all data submitted meet the quality assurance/quality control (QA/QC) requirements incorporated by reference in N.J.A.C. 7:26E-2 for:

   sampling ☒ Yes ☐ No

   analysis ☒ Yes ☐ No
3. How was it determined that the data complied with the QA/QC requirements?

   ☒ Laboratory non-conformance summary/narrative

   ☐ Laboratory correspondence

   ☒ LSRP review

   ☐ Independent contractor review

   ☒ Other: Data Validation (provided with report)

4. Has any data been qualified and used? ☐ Yes ☒ No
5. Has any data been rejected and used? ☐ Yes ☒ No
6. Comments:

SECTION P. MISCELLANEOUS

1. Were any regulated USTs identified during the course of the RI that were not previously known? ☐ Yes ☒ No
   If "Yes," list tank size, contents and registration number(s). ____________________
   a. If "Yes," to item P.1. above and if these USTs were Federally Regulated, was the source/cause of release identified on a Confirmed Discharge Notification form? ☐ Yes ☐ No
      If "No," complete and submit a revised Confirmed Discharge Notification form.
2. Were additional Areas of Concern identified during the RI? ☐ Yes ☒ No
   If "Yes," identify AOC(s): ____________________
3. Identify Remedial Measures (RMs) conducted during the RI (check all that apply):
   - ☐ Soil excavation
   - ☐ Potable water supply treatment or replacement
   - ☐ Hydraulic containment of source area
   - ☐ Soil vapor extraction
   - ☐ Enhanced fluid recovery (EFR)
   - ☐ Other(s), specify: ____________________
   - ☐ UST closure
   - ☐ Free product recovery
   - ☐ Vapor intrusion mitigation
   - ☒ No RMs were conducted during the RI
4. Did the remedial investigation include sampling to characterize any on-site contaminated media for either on-site or off-site reuse? ☐ Yes ☒ No
5. Has clean fill has been brought onto the site? ☐ Yes ☒ No
   If yes, has it been analyzed? ☐ Yes ☐ No
6. Has new information (material facts, data or other information) been generated during the RI that corrects or contradicts information, or changes conclusions from, previously submitted reports or information? ☐ Yes ☒ No
   If "Yes," explain: ____________________
7. Have past deficiencies/notice of deficiencies been addressed in this submittal? ☒ Yes ☐ No

SECTION Q. PERSON RESPONSIBLE FOR CONDUCTING THE REMEDIATION INFORMATION AND CERTIFICATION

Full Legal Name of the Person Responsible for Conducting the Remediation: Hoffmann-La Roche Inc.

Representative First Name: Thomas Representative Last Name: Lyon

Title: Vice President, Site Head

Phone Number: (973) 562-2210 Ext: Fax: (973) 562-3977

Mailing Address: 340 Kingsland Street

City/Town: Nutley State: New Jersey Zip Code: 07110-1199

Email Address: tom.lyon@roche.com

This certification shall be signed by the person responsible for conducting the remediation who is submitting this notification in accordance with Administrative Requirements for the Remediation of Contaminated Sites rule at N.J.A.C. 7:26C-1.5(a).

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein, including all attached documents, and that based on my inquiry of those individuals immediately responsible for obtaining the information, to the best of my knowledge, I believe that the submitted information is true, accurate and complete. I am aware that there are significant civil penalties for knowingly submitting false, inaccurate or incomplete information and that I am committing a crime of the fourth degree if I make a written false statement which I do not believe to be true. I am also aware that if I knowingly direct or authorize the violation of any statute, I am personally liable for the penalties.

Signature: [signature] Date: 4/2/14

Name/Title: Thomas Lyon/Vice President, Site Head

No changes to contact information since last submittal ☐

SECTION R. LICENSED SITE REMEDIATION PROFESSIONAL INFORMATION AND STATEMENT

LSRP ID Number: 591661

First Name: Arthur Last Name: Goeller

Phone Number: (973) 564-6006 Ext: 234 Fax: (973) 564-6442

Mailing Address: 57 East Willow Street

City/Town: Millburn State: New Jersey Zip Code: 07041

Email Address: agoeller@trcsolutions.com

This statement shall be signed by the LSRP who is submitting this notification in accordance with SRRA Section 16 d. and Section 30 b.2.

I certify that I am a Licensed Site Remediation Professional authorized pursuant to N.J.S.A. 58:10C to conduct business in New Jersey. As the Licensed Site Remediation Professional of record for this remediation, I:

[SELECT ONE OR BOTH OF THE FOLLOWING AS APPLICABLE]:

☐ *directly oversaw and supervised all of the referenced remediation, and\or*

☒ *personally reviewed and accepted all of the referenced remediation presented herein.*

I believe that the information contained herein, and including all attached documents, is true, accurate and complete.

It is my independent professional judgment and opinion that the remediation conducted at this site, as reflected in this submission to the Department, conforms to, and is consistent with, the remediation requirements in N.J.S.A. 58:10C-14.

My conduct and decisions in this matter were made upon the exercise of reasonable care and diligence, and by applying the knowledge and skill ordinarily exercised by licensed site remediation professionals practicing in good standing, in accordance with N.J.S.A. 58:10C-16, in the State of New Jersey at the time I performed these professional services.

I am aware pursuant to N.J.S.A. 58:10C-17 that for purposely, knowingly or recklessly submitting false statement, representation or certification in any document or information submitted to the board or Department, etc., that there are significant civil, administrative and criminal penalties, including license revocation or suspension, fines and being punished by imprisonment for conviction of a crime of the third degree.

LSRP Signature: [signature] Date: 4/2/14

LSRP Name/Title: Arthur F. Goeller/CPG, LSRP

Company Name: TRC Environmental Corporation

No changes to contact information since last submittal ☐

Completed forms should be sent to:

Bureau of Case Assignment & Initial Notice
Site Remediation Program
NJ Department of Environmental Protection
401-05H
PO Box 420
Trenton, NJ 08625-0420

Site-Wide Ground Water

Traditional Oversight Report Certification Form

New Jersey Department of Environmental Protection
Site Remediation Program

TRADITIONAL OVERSIGHT REPORT CERTIFICATION FORM

Date Stamp
(For Department use only)

SECTION A. SITE NAME AND LOCATION

Site Name: Hoffmann-La Roche Inc.

List All AKAs: Roche

Street Address: 340 Kingsland Street

Municipality: Nutley (Township Borough or City)

County: Essex Zip Code: 07110

Program Interest (PI) Number(s): 009949, 625447 & 614465 Case Tracking Number(s): NJD002191211

SECTION B. REPORT INFORMATION

Report Name: Site-Wide Ground Water Remedial Investigation Report

Report Date: 04/02/2014

Federal Traditional Case Type :

☒ **RCRA GPRA 2020** ☐ **CERCLA/NPL** ☐ **USDOD** ☐ **USDOE**

☐ Other (explain):

SECTION C. PERSON RESPONSIBLE FOR CONDUCTING THE REMEDIATION INFORMATION AND CERTIFICATION

Full Legal Name of the Person Responsible for Conducting the Remediation: Hoffmann-La Roche Inc.

Representative First Name: Thomas Representative Last Name Lyon

Title: Vice President, Site Head

Phone Number: (973) 562-2210 Ext: Fax: (973) 562-3977

Mailing Address: 340 Kingsland Street

City/Town: Nutley State: New Jersey Zip Code: 07110

Email Address: tom.lyon@roche.com

This certification shall be signed by the person responsible for conducting the remediation who is submitting this notification in accordance with Administrative Requirements for the Remediation of Contaminated Sites rule at N.J.A.C. 7:26C-1.5(a).

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein, including all attached documents, and that based on my inquiry of those individuals immediately responsible for obtaining the information, to the best of my knowledge, I believe that the submitted information is true, accurate and complete. I am aware that there are significant civil penalties for knowingly submitting false, inaccurate or incomplete information and that I am committing a crime of the fourth degree if I make a written false statement which I do not believe to be true. I am also aware that if I knowingly direct or authorize the violation of any statute, I am personally liable for the penalties.

Signature: [signature] Date: 4/2/14

Name/Title: Thomas Lyon / Vice President, Site Head

SECTION D. LICENSED SITE REMEDIATION PROFESSIONAL INFORMATION AND STATEMENT

LSRP ID Number: 591661

First Name: Arthur Last Name: Goeller

Phone Number: (973) 564-6006 Ext: 234 Fax: (973) 564-6442

Mailing Address: 57 East Willow Street

City/Town: Millburn State: New Jersey Zip Code: 07041

Email Address: agoeller@trcsolutions.com

This statement shall be signed by the LSRP who is submitting this notification in accordance with SRRA Section 16 d. and Section 30 b.2.

I certify that I am a Licensed Site Remediation Professional authorized pursuant to N.J.S.A. 58:10C to conduct business in New Jersey. As the Licensed Site Remediation Professional of record for this remediation, I:

[SELECT ONE OR BOTH OF THE FOLLOWING AS APPLICABLE]:

☐ *directly oversaw and supervised all of the referenced remediation, and\or*

☒ *personally reviewed and accepted all of the referenced remediation presented herein.*

I believe that the information contained herein, and including all attached documents, is true, accurate and complete.

It is my independent professional judgment and opinion that the remediation conducted at this site, as reflected in this submission to the Department, conforms to, and is consistent with, the remediation requirements in N.J.S.A. 58:10C-14.

My conduct and decisions in this matter were made upon the exercise of reasonable care and diligence, and by applying the knowledge and skill ordinarily exercised by licensed site remediation professionals practicing in good standing, in accordance with N.J.S.A. 58:10C-16, in the State of New Jersey at the time I performed these professional services.

I am aware pursuant to N.J.S.A. 58:10C-17 that for purposely, knowingly or recklessly submitting false statement, representation or certification in any document or information submitted to the board or Department, etc., that there are significant civil, administrative and criminal penalties, including license revocation or suspension, fines and being punished by imprisonment for conviction of a crime of the third degree.

LSRP Signature: [signature] Date: 4/2/14

LSRP Name/Title: Arthur F. Goeller / CPG, LSRP

Company Name: TRC Environmental Corporation

Completed forms should be sent to:

Assigned Case Manager
Bureau of Case Management
Site Remediation Program
NJ Department of Environmental Protection
401-05F
PO Box 420
Trenton, NJ 08625-0420

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

LIST OF APPENDICES

LIST OF APPENDICES (CONTINUED)

EXECUTIVE SUMMARY

On behalf of Hoffmann-La Roche Inc. (Roche), TRC Environmental Corporation (TRC) has prepared this Ground Water Remedial Investigation Report (GWRIR) to document the Site-wide ground water remedial investigation (RI) conducted at the 120-acre Roche facility (Site), located at 340 Kingsland Street, in the Township of Nutley, Essex County, New Jersey. The objectives of this RI program were to characterize the ground water conditions, identify contaminant sources and potential receptors, and delineate the extent of ground water contamination in accordance with the New Jersey Department of Environmental Protection's (NJDEP's) Technical Requirements for Site Remediation (TRSR) and applicable guidance documents.

In October 1992, Roche entered into a voluntary Memorandum of Agreement (MOA) with the NJDEP to investigate and remediate the Site. Since the execution of the MOA, Preliminary Assessment (PA) and Site Investigation (SI) activities have identified approximately 192 areas of concern (AOCs). On October 11, 2012, the NJDEP approved Roche's Remediation Road Map (Road Map) that outlined an accelerated approach for the completion of the Site-wide RI at the Roche facility. As defined in the Road Map, multiple Licensed Site Remediation Professionals (LSRPs) were retained to oversee and certify compliance with the TRSR and applicable guidance during the investigation of soil and ground water impacts identified in specific investigative areas (IAs). These activities have been documented in individual IA RI reports submitted to the NJDEP. The scope of the Site-wide ground water RI builds upon completed RI activities documented in these individual IA RI reports and past ground water RI programs, combining ground water information for the IAs on a Site-wide basis.

This report also presents the scope and findings of ground water RI activities conducted at the Site between 2007 and 2013. Within this time period, ground water RI workplans were submitted to and approved by the NJDEP to investigate the nature of the overburden and fractured bedrock aquifer system, and the presence of volatile organics (VOCs), semi-volatile organics (SVOCs), pesticides and metals in the shallow ground water (from ground surface to approximately 80 feet deep) and the deep bedrock ground water (at depths greater than 80 feet). Currently, there are more than 440 monitoring wells installed as part of the Site-wide ground water RI program. In some areas, there are well clusters (multiple wells at one location) constructed at varying depths to monitor discrete hydraulically transmissive intervals and to provide a vertical water quality profile.

Ground water primarily occurs in the bedrock fractures/partings beneath the Site; the water table is within 20 feet below ground surface (bgs). Based on geophysical logging observations across the Site, most of the bedrock fractures are oriented northeast to southwest and are cross-cut by a subordinate, north-northwest to south-southeast trending fracture system. Vertical fractures are numerous and extensive, and interconnect the low-angle bedding plane fractures**.** The greatest frequency of fractures is found in the central portion of the Site within the shallow, intermediate and deep bedrock. This highly fractured region is associated with a documented regional fault system. The local and regional system of fractures and faults constitute the structural framework affecting local and regional ground water flow.

In this report, ground water flow and quality conditions are discussed in relation to seven, elevation-based hydrostratigraphic zones (S1 through S3 and D1 through D4), which extend from the ground surface to greater than 700 feet bgs. The elevations of monitoring well screen intervals correlates with these hydrostratigraphic zones. Ground water in Zone S1 flows under water table conditions from the northern portion of the Site to the south and southeast. There is a significant downward vertical flow component from Zone S1 to the deeper intervals (S2, S3) in key areas of the Site, with the exception of largely lateral flow in the near surface intervals. Ground water in Zones S2 to D3 flows from the northwest to the southeast. Ground water in Zone S1, and to a lesser extent in Zone S2, is influenced by local surface water bodies (Valley Drain and the brooks) and exhibits flow toward those features. Hydraulic gauging studies have shown that there is currently no significant influence (e.g., gradient reversal) on the ground water flow regime from locally active supply wells. The results of three aquifer tests suggest that the bedrock aquifer is heterogeneous and anisotropic under pumping conditions. However, under natural conditions, the ground water flow field conforms to the topographic relief of the regional drainage basin.

Ground water sampling results confirm the presence of VOCs, SVOCs, pesticides and metals contamination in the shallow ground water under the Site. Through the installation of an extensive network of on- and off-Site monitoring wells, the vertical and horizontal extent of ground water contamination has been delineated at on- and off-Site locations. The most prevalent constituents are chlorinated VOCs (specifically, tetrachloroethene [PCE], trichloroethene [TCE], cis-1,2-dichloroethene [cis-1,2-DCE] and vinyl chloride [VC]), which have been detected throughout the shallow and deep ground water zones across and along the boundaries of the Site. The distribution of chlorinated VOCs in ground water correlates with the ground water flow paths defined within the bedrock aquifer system. Low concentrations of SVOCs, metals, and pesticides have also been detected in multiple locations across the Site and have been attributed to the presence of artificial fill and/or on- and off-Site sources.

Former operations on Roche property have resulted in localized ground water impacts which include chlorinated VOC, benzene and toluene releases associated with the pipeway in IA-9; chloroform, benzene, methylene chloride and toluene releases in the former tank field in IA-2; a chlorobenzene release in the vicinity of former Building 15 in IA-6; and a small chlorinated

VOC release in the vicinity of former Building 104 in IA-10. These plume areas have been delineated areally and vertically.

The sampling results from off-Site monitoring wells installed north of Route 3 indicate that PCE has been discharged off-Site from an upgradient source, transported within the Clifton-Allwood sewer to both off-Site and on-Site locations, and released into the environment from multiple compromised sections (one off-Site and several on-Site) of the municipal sanitary sewer which enters and traverses the Roche Site. These sewer discharges are proximal to a highly fractured bedrock area in the central portion of the Site. Sampling results for off-Site wells located near the municipal sewer show high concentrations of chlorinated VOCs (>1,000 µg/L) in Zone S2 (50 to 80 feet above mean sea level [msl]) through Zone D2 (to 250 feet below msl). High VOC concentrations (≥ 10,000 µg/L) are also found in on-Site wells near the municipal sewer line, adjacent to the Route 3 guard shack (in IA-12) and upgradient from any Roche operations. Data from wells displaying PCE concentrations at concentrations greater than 1,500 µg/L (1% of the aqueous solubility of PCE, which is 150,000 µg/L) suggest that they are located in close proximity to a dense non-aqueous phase liquid (DNAPL) source area. These historic sewer discharges (source areas) have produced a commingled chlorinated VOC plume that migrates southward through the facility (parallel to the orientation of the regional fracture system). The distribution of ground water contamination around these localized release areas, which display PCE degradation products (TCE, cis-1,2-DCE, VC) and deep vertical plume penetration, suggest that the discharges were historic and chronic.

PCE releases from the municipal sanitary sewer to the ground water are also evident at other on-Site locations in IA-3, IA-7, IA-11 and IA-15 (along the current Clifton-Allwood Sanitary Sewer alignment, and the former alignment of this sewer further east, under existing Building 123), although Roche process lines that parallel the municipal sewer system in some areas of the Site had the potential to contribute to the PCE contamination at these locations. The Zone S1 VOC impacts are not continuous along this utility corridor, indicating that the backfill around these utilities is not acting as a significant conduit facilitating continuous lateral migration from the releases documented north of Route 3 and in IA-12.

The ground water quality data for on-Site wells installed west of the municipal sewer area (along the northern boundary of the Roche property), suggest that there is another off-Site VOC source(s) located upgradient of the Roche Site that has produced a separate chlorinated VOC plume (total VOCs in excess of 100 µg/L) which enters the Roche Site between Zone S2 and Zone D2 approximately 1,350 feet west of the guard shack (south of Route 3). The ground water quality data for on-Site wells installed east of the municipal sewer area (along the northern boundary of the Roche property), also suggest that there is another off-Site VOC source located upgradient of the Roche Site that has produced a separate chlorinated VOC plume (total VOCs in excess of 100 µg/L) that enters the Roche property between Zone S3 and D2, approximately 500 to 900 feet east of the guard shack (south of Route 3).

On the western portion of the Site, in IA-10, the direction of ground water flow and distribution of 1,1,1-trichloroethane (1,1,1-TCA) and its breakdown products in deep ground water (Zones D1, D2 and D3) indicates that this contamination is derived from an off-Site source. 1,1,1-TCA (as well as PCE) was historically detected in shallow and deep ground water on the former Deluxe Check facility, and was found in their source area. Given the absence of this suite of chlorinated VOCs in the shallow ground water under the Roche Site, the 1,1,1-TCA and associated breakdown products in deep ground water appear to have originated on off-Site property or properties west and possibly northwest of the Site.

Ground water flow and water quality conditions in the seven hydrostratigraphic zones have been sufficiently characterized to complete delineation for the RI. Based on the information presented in this GWRIR, it is concluded that the Site-wide ground water RI has achieved the program objectives within the statutory deadline (May 7, 2014) and is considered complete.

The work proposed in the approved October 2013 Bedrock Ground Water RI Workplan Supplement 2 is ongoing and will be completed before the 2^{nd} quarter of 2014. The results of this program will further characterize the ground water quality and flow conditions along the northern and northwestern boundaries within multiple hydrostratigraphic zones. The findings of this program will refine and further characterize the contamination originating from off-Site sources.

A quarterly ground water sampling program has been initiated to monitor and document ground water quality and ground water flow conditions across the Site over time. Data collected from these sampling events may be used to assist future remedial action decisions and may provide evidence and documentation to support a monitored natural attenuation (MNA) proposal for portions of the chlorinated VOC plume. In addition, Pre-Design Investigation (PDI) Workplans (including environmental sample collection, bench-scale and pilot-scale test activities) have been developed and are being implemented to collect supplemental data and information required to design appropriate remedies. The aforementioned activities as they relate specifically to ground water remediation (and in support of the RI Report) will be documented in a future annual progress report and in Remedial Action Workplans.

1.0 INTRODUCTION

On behalf of Hoffmann-La Roche Inc. (Roche), TRC Environmental Corporation (TRC) has prepared this Ground Water Remedial Investigation Report (GWRIR) to document the Site-wide ground water remedial investigation (RI) conducted at the 120-acre Roche facility (Site), located at 340 Kingsland Street, in the Township of Nutley, Essex County, New Jersey. The location of the Roche facility is provided as Figure 1.

The RI was conducted in accordance with the New Jersey Department of Environmental Protection's (NJDEP's) Technical Requirements for Site Remediation (TRSR) (N.J.A.C. 7:26E) and in compliance with applicable guidance and RI Workplans previously approved by the NJDEP. The objectives of the Site-wide ground water RI were to characterize the ground water conditions, identify contaminant sources and potential receptors, and delineate the extent of ground water contamination.

1.1 Statutory Timeframe

The New Jersey Site Remediation Reform Act (SRRA) imposed a statutory deadline of May 7, 2014 to complete the RI for certain contaminated sites, including the Roche Site. The NJDEP has issued a Policy Statement (June 2013) that is an interpretation of the SRRA Requirement to complete the RI before the required deadline. This policy is discussed in more detail in Section 3.2 of this RIR.

To certify that the RI activities documented in this RIR have complied with the TRSR and applicable guidance, this report includes the required NJDEP certification forms associated with the Site-wide ground water RI (RIR form and Traditional Oversight Report Certification Form) that have been executed by Roche and the LSRP retained for the Roche Site.

1.2 Document Organization

This document is organized into the following six sections (excluding the Introduction):

- Section 2.0 provides a review of background information on historic regulatory compliance, the physical setting (topography, surface water, geology, and hydrogeology), site location and history, and updated receptor evaluation information;

- Section 3.0 provides a technical overview (scope/methods) of the RI program;

- Section 4.0 provides the findings of the Site-Wide Ground Water RI;

- Section 5.0 provides support documentation to establish a Classification Exception Area (CEA);

- Section 6.0 provides conclusions and recommendations; and

- Section 7.0 provides the references that were relied upon to prepare this document.

2.0 BACKGROUND INFORMATION

This section provides background information to support the following report sections. The information contained in Section 2.0 represents a compilation of approximately 20 years of ground water investigation and research.

2.1 <u>Site Description and History</u>

The Site occupies approximately 120 acres straddling the municipal/county boundary of the Township of Nutley, Essex County and the City of Clifton, Passaic County in northeastern New Jersey (Figure 1). It is bounded to the north by New Jersey State Highway Route 3 (Route 3); to the south by Kingsland Street, Nichols Park, residential properties, and St. Paul's Brook; to the east by residential properties; and to the west by residential, commercial, and industrial properties. The Site is entirely developed and contains multiple office, laboratory/research, production, and maintenance buildings, parking and internal roadways, landscaped areas, a railroad easement (Norfolk-Southern/Conrail), and other improvements. For reference, Figure 2 provides a NJDEP GIS Land Use/Land Cover Map, and Figure 3 provides the NJDEP GIS Landscape Project Map.

During its history, the Roche Nutley operations have included vitamin and pharmaceutical manufacturing and laboratory research in nutrition and disease diagnostics. Roche installed multiple production wells from the 1930s through to the 1960s to provide water for their facility operations.

A pump and treat ground water remediation system was installed in IA-6 in 2004 as an IRM (to address the chlorobenzene contamination in the area) and continues to operate to this date. Remediation wells RW-51 (71 feet deep) and RW-96 (19 feet deep) pump ground water from the plume, providing a level of hydraulic control and preventing VOC-contaminated ground water from migrating off-Site.[1] RW-51 and RW-96 are the only active pumping wells operating at the Site.

There are multiple sump pumps[2] that remain in operation at the Site. A list of on-Site Buildings with active sump pumps (and their respective locations) is provided below.

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[1] As per the 2013 O&M logs, the average pumping rate for RW-51 and RW-96 were estimated as 4.7 and 5.0 gpm, respectively. These wells remained operational during the synoptic ground water gauging event conducted in September 2013.

[2] Sump pumps are self-activating electrical pumps that are installed in a sump (low point) below basement or crawlspace floors to remove rising groundwater and surface runoff before it can seep into a building. Accumulated water can cause interior damage and encourage the growth of mold, mildew, and fungus. Pumps are usually maintained and equipped with all necessary components in order to ensure their reliability.

- Building 52 - Sump pump located in a vault;
- Building 8 (Utility Tunnel) – Numerous sump pumps (> 50) located throughout the length of the Utility Tunnel;
- Building 39 – Sump pumps located in the basement;
- Building 76 - Sump pump located in a vault;
- Building 1 - Sump pump located in a vault;
- Building 115 - Multiple sump pumps;
- Building 118 - Sump pump located in a vault; and
- Building 116 - Multiple sump pumps.

2.2 Physical Setting

2.2.1 *Topography*

Figure 4 provides a map depicting the topography surrounding the Site. The regional surface drainage slopes to the south toward the Passaic River, but is locally disrupted by small topographic ridges that trend northeast/southwest. The Site is located between topographic highs to the east and west that reach elevations over 200 feet above mean sea level (msl). The Site is located at an elevation ranging from approximately 68 to 158 feet above msl. The highest elevation point is located in the northeastern corner of the Site. The lowest elevation point is located at the southeastern corner of the Site, near Nichols Park and St. Paul's Brook.

The surface of the majority of the Site is gently sloping to generally flat within the former central process areas. In general, the surface of the central and western portions of the Roche facility slopes from north to south toward St. Paul's Brook.

2.2.2 *Surface Water Hydrology*

The Site lies within the Lower Passaic River Basin. Figure 5 provides a site plan with the local surface water bodies. Figure 6 provides Wetlands Location Maps developed by the National Wetlands Inventory and the NJDEP. As shown on Figure 6, there are no wetlands on the Site.

There are three streams that transect, are adjacent to, and are down-stream of the Site. These streams are: Springer Brook, St. Paul's Brook, and the Valley Drain (a culverted former stream). These streams coalesce into St. Paul's Brook and join the Third River about 1,500 feet southeast of the facility. The Third River meanders from its headwaters at the Great Notch Reservoir (Woodland Park, New Jersey) northwest of the Site, flowing southerly, and then turns north to join the Passaic River approximately 1.2 miles southeast of Roche (Figure 4).

Springer Brook is presently a buried pipe (culvert) that flows southeast along the county line, south of Building 103 in IA-10 (on Roche property), and empties into St. Paul's Brook. The confluence of Springer Brook and St. Paul's Brook is located in an on-Site manhole MHD-111S-1, southeast of Building 103. A network of subsurface drains beneath the northwest corner of the Site collects shallow ground water that historically discharged as springs in this area (in the vicinity of Building 103), and discharges to St. Paul's Brook.

St. Paul's Brook enters the Site at the northernmost corner of the property from drainage ditches that route surface water from areas north of and under Route 3. The brook enters a 48-inch reinforced concrete pipe (RCP) where it is conveyed east, then southeast alongside and parallel to the Norfolk-Southern Conrail railway. It emerges briefly as an open channel from a headwall south of Building 1, and is conveyed in another pipe as it exits Roche property (beneath Kingsland Street) and emerges at a headwall at Bloomfield Avenue. St. Paul's Brook is dammed in Nichols Park, creating a pond behind the dam. There is a drop of 16.9 feet from the water level in the pond to the stream level below the dam. St. Paul's Brook parallels the railroad easement between IA-10 and the rest of the Roche facility, and after exiting the Site flows southeast and then east toward a confluence with the Third River, approximately 1,500 feet to the southeast of the Site.

The Valley Drain receives surface water runoff from a commercial area north of Route 3 and storm water drainage from Route 3 itself, and is routed through surface ditches and City of Clifton storm sewers. It is possible that the Valley Drain or its trench and bedding material receive some discharge[3] of shallow ground water north of Route 3, as has been documented on Roche property. Once on the property, the Valley Drain is mostly buried, flowing northeast to southwest through a 48-inch diameter pipe that runs parallel to First Avenue on the Roche property and discharges to St. Paul's Brook at the Nichols Park dam.

The NJDEP's surface water classification for St. Paul's Brook and the downstream Third River is Freshwater 2-Non-Trout\Saline Estuary 2 (FW2-NT\SE2). The limit of SE2 designation has not been identified by the NJDEP for the Third River tributaries in the vicinity of the Site.

Surface water runoff for the Site west of the railroad tracks is conveyed via a storm sewer system that discharges to St. Paul's Brook. The surface water runoff for the Site east of the railroad tracks is discharged to the Passaic Valley Sewerage Commission (PVSC); the Site has the ability (during significant rain events) to discharge surface water runoff to St. Paul's Brook. Based on available information, springs have existed historically at the Site (within IA-10 and IA-14). Due to past site development, the springs were buried and flow from the springs was enclosed in

[3] Or infiltration of water (documented to contain 5-10 µg/L PCE of VOCs). This will be further discussed in the Surface Water RIR.

sub-grade piping associated with the on-Site storm sewer drainage system. The spring water discharge is ultimately conveyed through an open culvert and storm sewer piping off Roche property via St. Paul's Brook.

2.2.3 *Regional Geology*

The Site is located within the Newark Basin in Essex and Passaic Counties, New Jersey. The basin is an extensional rift feature (half graben) filled with over 20,000 feet of interbedded non-marine sedimentary and igneous rocks of Triassic and Early Jurassic age. The Newark Basin forms the largest physiographic province (Piedmont province) in the northern half of New Jersey. The beds within this portion of the Newark Basin typically display a northeastern strike, tilted to the northwest at angles of 5°-15°, and may be locally faulted and folded (Olsen 1980; Schlische 1992; Herman 2001). The sedimentary formations consist of repeated sequences of sandstone, siltstone and mudstone beds, in varying proportions, which reflect climate-driven oscillation, from fluvial deposition during the Stockton Formation to the lacustrine cycles in Lockatong, Passaic and Feltville Formations.

2.2.4 *Local Geology*

The Site is underlain by overburden consisting of artificial fill and glacial deposits. The artificial fill is the shallowest unit within the overburden and is composed of a heterogeneous mixture of sand, silt, clay, gravel and man-made materials (e.g., bricks, glass, concrete, coal/ash, wood, and metal debris). The artificial fill is underlain by glacial deposits of the Rahway Till. The Rahway Till is composed of non-stratified, reddish-brown, poorly sorted sandy silt to sandy clayey silt, with occasional lenses of pebbles, cobbles and boulders. In a small area located in the northwestern corner of the Site (in IA-10), the artificial fill is underlain by Swamp Deposits, consisting of black-grey to brown organic silt and clay with peat.

The glacial deposits are underlain by the Passaic Formation. The Passaic Formation is an interbedded sequence of reddish-brown sandstone and pebbly sandstone, pebble conglomerate, siltstone, silty shale and shale. The sandstone and pebbly sandstone are thin to thickly bedded, planar to cross-bedded with local lenses of pebble conglomerate. A weathered bedrock zone overlies the competent bedrock interface; the weathered bedrock zone varies in thickness across the Site (10 feet to 20 feet).

A lithologic contact occurs between the Passaic Formation and the Orange Mountain Basalt approximately 1.8 miles west of the Site. The Orange Mountain Basalt is a fine grained, greenish-grey to black volcanic rock and occurs as a prominent, northeast-trending ridge.

Figure 7 depicts the regional surficial geology. As shown on Figure 7, the bedrock surface elevation contours (from 100 to 150 above msl) form a linear ridge along the eastern portion of the Site. Figure 8 is a map depicting the regional bedrock geology. As shown on Figure 8, two northeast-trending faults have been mapped by the New Jersey Geological Survey (NJGS) approximately 1 mile north of the Site.

Stratigraphic cross-sections depicting the local surficial and bedrock geology are presented on Figures 7 and 8.

2.2.5 *Regional Hydrogeology*

There are four hydrogeologic units within the Newark Basin that have been defined as principal bedrock aquifers; these are the Stockton, Lockatong, Diabase and Brunswick Aquifers (Herman 2010). The Brunswick Aquifer is subdivided into eight aquifer zones, which reflect compositional and textural variations in different parts of the basin. The region surrounding the Site is underlain by the Brunswick Aquifer zone termed “Sandstone Red Beds” (Herman 2010). Within the northeastern region of New Jersey, the Brunswick Aquifer is productive and used for public, industrial and domestic water supplies.

2.2.6 *Local Hydrogeology*

Ground water at the Site is found in the overburden and the bedrock. Within the overburden, the depth to ground water generally occurs between 5 to 15 feet below ground surface (bgs). Ground water primarily occurs in the bedrock fractures/partings beneath the Site (within 20 feet bgs). Historical measurements of water levels collected from wells screening the overburden and bedrock indicate that shallow ground water flow is generally south and southeast, following the surface topography toward the Passaic River. Additionally, shallow ground water discharges locally to culverted and open reaches of St. Paul's Brook and the utility corridor associated with the Valley Drain.

2.3 <u>Historic Regulatory Compliance</u>

In October 1992, Roche entered into a voluntary Memorandum of Agreement (MOA) with the New Jersey Department of Environmental Protection (NJDEP) to investigate and remediate soil and ground water contamination found on Roche property. Since the execution of the MOA, Preliminary Assessment (PA) and Site Investigation (SI) activities have identified 192 areas of concern (AOCs). In addition to NJDEP oversight, Roche operations have been subject to the U.S. Environmental Protection Agency’s (USEPA’s) RCRA Corrective Action program. From the inception of the MOA, Roche has actively coordinated with the NJDEP and, more recently with the USEPA, to address and mitigate the transport of and exposure to the identified Site contaminants.

To facilitate the Site investigation of soil and ground water conditions, Roche, with NJDEP's approval, divided the Site into specific Investigative Areas (IAs) within distinct geographic confines. Over time, the boundaries of these original IAs were modified to include additional AOCs identified within an IA's proximity. Additional IAs were also created, as necessary and appropriate, to facilitate the investigation (Figure 5). In total, Roche currently has 15 Investigative Areas covering the entire Site and incorporating all of the known existing AOCs. On September 17, 2012, Roche submitted a Remediation Road Map to the NJDEP case team outlining an accelerated approach for the completion of a Site-wide RI at the Roche facility. The NJDEP approved this Remediation Road Map on October 11, 2012.

As discussed in the Remediation Road Map (2012), the boundaries of original IAs were reconfigured to establish 15 IAs within the Site boundaries; these were labeled IA-1 through IA-15[4]. To assist the NJDEP case team, multiple Licensed Site Remediation Professionals (LSRPs) were retained to oversee and certify compliance with the TRSR and applicable guidance during the investigation of soil and ground water impacts identified in specific investigative areas (IAs). These activities have been documented in individual IA RI reports submitted to the NJDEP. The scope of the Site-wide ground water RI builds upon completed RI activities documented in these individual IA RI reports and past ground water RI programs, combining ground water information for the IAs on a Site-wide basis.

2.4 Historic Ground Water RI Submissions to NJDEP

As part of the MOA (October 1992), Roche provided the NJDEP with a Baseline Ground Water Monitoring Report (September 2002) that presented a summary of quarterly ground water sampling conducted from the initiation of ground water monitoring at the facility in 1987 through to calendar year 2000. Thereafter, quarterly ground water monitoring results were submitted on an annual basis beginning with 2001 and continuing through 2011.

The baseline program focused on sample collection of the shallow ground water system (wells screening Zone S1, and to a lesser extent Zones S2 and S3). Each annual report included a

[4] Roche's Remediation Road Map described how Roche would address the investigation within the reconfigured boundaries of the original IAs as well as the newly identified IAs (IA-1 through IA-15) to be investigated (Figure 5). In the redefining of the IAs at the Roche site, one considerable change transpired that affected IA-8. IA-8 was initially identified as an investigation of all on-Site process, sanitary and storm water sewers and waste lines; this is no longer considered a separate IA, and investigation of the process, sanitary, and storm water and waste lines has been completed within each IA where the particular piping runs are located (see Figure 5).

summary of the quarterly sampling program, an evaluation of ground water data quality and usability, an assessment of the ground water quality indicators, potentiometric maps, ground water constituent isopleths**,** and a discussion of the ground water quality fluctuations over time.

All of these yearly ground water assessment reports were submitted to and approved by the NJDEP during the course of the ground water monitoring program. In 2012, with the initiation of the Site-wide RI at the Site, the NJDEP was petitioned and agreed to the discontinuation of the yearly ground water reporting in support of implementing the Site-wide ground water RI.

Several historic ground water investigation activities were key toward providing information essential to completing the Site-wide ground water RI (as documented in this GWRIR). The most significant of these activities were documented in reports previously submitted to the NJDEP. These reports included:

- Installation of coreholes CH-1 through CH-10 (2002-2003);
- Completion of the MW-51 (subsequently re-designated as RW-51) pumping test (2002);
- Completion of the CH-1 pumping test and submission of the Core Hole 1 Aquifer Test Report (TRC, 2005); and
- Additional findings and data from pre-2007 investigative work completed by TRC and others (i.e., ERM-Northeast [ERM] and Roux Associates [Roux]).

These reports documented the initial characterization of the geologic structure and ground water flow conditions within the bedrock aquifer system and facilitated the development of a conceptual site model.

From these activities, additional RI workplans were developed and submitted to the NJDEP for approval. The NJDEP approval and comment correspondence associated with Site-Wide Ground Water RI activities has been based on proposals and data summarized in the following work plans:

- December 2007 - Phase One Remedial Investigation Work Plan;

- October 2012 - Deep Bedrock Ground Water RI Work Plan;

- November 2012 – Shallow Ground Water RI Work Plan;

- April 2013 – Shallow Ground Water RI Work Plan – Supplement 1;

- May 2013 - Deep Bedrock Ground Water RI Work Plan – Supplement 1;

- June 2013 - Shallow Ground Water RI Work Plan – Supplement 2; and
- October 2013 - Deep Bedrock Ground Water RI Work Plan – Supplement 2.

3.0 TECHNICAL OVERVIEW

This section provides a technical overview of the ground water RI activities conducted at the Site between 2007 and 2013. Table 1 provides a sample collection summary (including the QA samples) for this investigation period. The findings of these RI activities are presented in Section 4.0.

This technical overview section includes a description of the methods and procedures employed to characterize ground water conditions on- and off-Site and other related compliance activities. The ground water RI activities discussed in this section were performed in compliance with the TRSR, NJDEP guidance documents and NJDEP-approved RI Workplans.

3.1 Remedial Investigation Objectives

The overall objectives of the ground water RI are to characterize the ground water conditions, determine the presence of ground water contamination, identify potential receptors, delineate the vertical and areal extent of ground water contaminants, and provide the data necessary for the development and implementation of appropriate remedial action strategies.

3.2 Remediation Standards and Criteria

As part of this RI, ground water samples were collected from monitoring wells and analyzed for a suite of chemical compounds (constituents). Any chemical compound detected in ground water with a concentration that exceeds the New Jersey Ground Water Quality Standards [GWQS] (N.J.A.C. 7:9C) is defined as a ground water constituent of concern (COC, or contaminant). Conversely, any constituents detected in ground water with a concentration below the GWQS are of no concern and are not site contaminants.

The identification and delineation of ground water contaminants for this RI was based on a comparison of the ground water analytical results with the GWQS. In accordance with the NJDEP Compliance Attainment Guidance (2012), single-point compliance was employed to determine compliance with the applicable GWQS. Horizontal and vertical delineation for ground water contaminants is considered complete when ground water contaminant concentrations in the perimeter monitoring wells are less than or equal to the applicable GWQS for each contaminant identified. In some instances, where single point compliance was not achievable due to specific site constraints (e.g., site access), the LSRP employed data extrapolation from established concentration gradients (derived from the analytical results of perimeter points) to define the specific compliance point or "clean zone" (as per NJDEP Policy Statement Interpretation of SRRA Requirement to Complete the Remedial Investigation by May 2014, NJDEP June 2013).

3.3 Receptor Evaluation

As part of the ground water RI and to comply with the TRSR (specifically N.J.A.C. 7:26E-1.13 to 1.16), a receptor evaluation was conducted for the Site. The receptor evaluation (RE) included four components: land use, ground water, vapor intrusion and ecological. In February 2011, Roche submitted an updated receptor evaluation (including the RE form) for the Roche Nutley facility.

Updates to the RE are required with certain remedial phase reports (e.g., with the RIR). Updated RE information applicable to the Site-Wide Ground Water RI is provided in Section 4.5 (Findings).

3.4 Recent Ground Water RI Program

Between 2007 and 2013, multiple boreholes and monitoring wells were installed at on- and off-Site locations to characterize the ground water flow and water quality conditions. Figure 9 provides a monitoring well location map. RI activities were completed in compliance with the following work plans:

- Phase One Remediation Work Plan (RIWP) (TRC, 2007);
- Site-Wide Deep Bedrock RIWP (including RIWP Supplements 1 and 2) (TRC, 2012a; TRC, 2013a; and TRC 2013b);
- Site-Wide Shallow Ground water RIWP (including RIWP Supplements 1 and 2) (TRC 2012b, TRC 2013c, and TRC 2013d);
- NJDEP comments on the Site-Wide Deep Bedrock RIWP and the Shallow Ground Water RIWP, and Responses to NJDEP comments (Appendix A); and
- Quality Assurance Project Plan (QAPP) (TRC, 2013).

The objectives and primary work components for each RIWP are listed below. A detailed description of these work activities is presented in the following subsections.

3.4.1 *2007 Phase One RIWP:*

Objectives:

- Investigate bedrock geology in the eastern part of the facility;
- Obtain detailed geologic data on lithology, stratigraphy and fractures (orientation, frequency, identification of hydraulically transmissive zones, etc.);
- Gather ground water quality data to determine the vertical extent of ground water contamination;

- Determine aquifer parameters in the bedrock in the eastern part of the Site;
- Assess the hydraulic connection between the shallow and deep ground water under the east side of the facility; and
- Assess the influence of a central, presumed downgradient pumping well to induce capture across the eastern side of the facility.

Work Components:

- Subsurface utility clearance;
- Installation of deep bedrock boreholes CH-11 through CH-20 and associated monitoring wells MW-113 through MW-122;
- Borehole geophysical logging at selected locations;
- Packer testing (fracture-specific ground water sampling to assess ground water quality) at selected deep bedrock borehole locations;
- Monitoring well survey (geographic position and elevation);
- Aquifer pumping test at borehole CH-16;
- Borehole testing using a FLUTe™ hydraulic conductivity profiler ; and
- Development of an initial site conceptual model for ground water movement and contaminant distribution.

3.4.2 *2012 Deep Ground Water RIWP (including its two supplements):*

Objectives:

- Characterize the local geology, including structural features influencing ground water flow in the bedrock (bedding plane fractures, joint sets, foliation and lineaments, etc.);
- Identify transmissive fractures that control ground water flow at the site, define ground water flow, recharge and discharge zones for these fractures (viewed as aquifer units), and characterize their hydraulic properties;
- Characterize ground water flow and delineate volatile organics (VOCs) constituents in deep bedrock ground water (including addressing data gaps [Supplement 1] and background water quality conditions [Supplement 2]; and
- Review the previously developed conceptual model and synthesize the data into a revised conceptual site hydrogeologic model.

Work Components:

- Off-Site access negotiations (where required);
- Subsurface utility clearance;
- Installation of additional deep bedrock boreholes at locations planned for borehole testing and permanent monitoring well construction;
- Borehole geophysical logging surveys;
- Borehole packer testing and sampling to assess ground water yield and quality;

- Construction of deep bedrock monitoring well clusters, including conversion of selected existing boreholes into permanent monitoring wells, and the drilling and installation of additional monitoring wells to create a Site-wide deep bedrock monitoring well network;
- Monitoring well survey (geographic position and elevation);
- Abandonment of boreholes CH-15 and CH-18;
- Ground water gauging study to assess the potential presence of regional pumping influences on the deep bedrock aquifer system;
- Surface geophysics survey to evaluate the Site for potential structural features (large vertical fractures or faults);
- Monitoring well gauging to develop potentiometric maps and vertical flow nets; and
- Collection of ground water samples from newly-constructed deep bedrock monitoring wells (September 2013 comprehensive sampling event).

3.4.3 *2012 Shallow Ground Water RIWP (including its two supplements):*

Objectives:

- Identify potential source area (based on ground water constituent distribution and concentration gradients, and/or passive soil gas surveys);
- Delineate shallow ground water constituents in accordance with the TRSR and associated guidance documents; and
- Address data gaps [Supplements 1 and 2].

Work Components:

- Off-Site access negotiations (where required);
- Subsurface utility clearance;
- Passive soil gas surveys (IA-10);
- Installation of temporary well boreholes (80 feet bgs);
- Sampling of selected discrete 10-foot intervals of temporary well boreholes (generally by packer testing) to screen ground water quality;
- Construction of monitoring wells in selected temporary well boreholes (and formal abandonment of remaining boreholes);
- Installation of additional monitoring wells at specific locations to complete monitoring well clusters;
- Ground water gauging study to assess the influence of precipitation events on the water table in proximity to surface water bodies; and
- Ground water gauging and sampling of newly-constructed shallow ground water monitoring wells (including the September 2013 comprehensive ground water sampling event).

3.5 Conceptual Hydrostratigraphic Model

Following the implementation of the December 2007 Phase One RIWP, an initial conceptual hydrostratigraphic model was established using the generic conceptual model defined in the NJDEP guidance. As described below, with the implementation of two subsequent RIWPs (2012), new data was generated that warranted the modification of this conceptual model.

NJDEP guidance describes a generic conceptual model of the Brunswick Aquifer as an anisotropic, heterogeneous, multi-layered aquifer system, where discrete thin (few feet thick) fracture zones, parallel to the bedding, have relatively high permeability. These thin fracture zones (discrete aquifers) are separated by thick zones (10 to 100 feet or more in thickness) of relatively low permeability, massive mudstone (aquitards) (Michalski, 1990). In this model (Leaky Multi-Aquifer System [LMAS]), ground water within the thin permeable fracture zones (discrete aquifers) moves preferentially along the bedding strike and dip. When employing this model for investigations, monitoring wells are typically installed to screen these thin, discrete aquifers, as these zones are anticipated to be primary contaminant transport pathways.

This initial model (discrete flow or LMAS model) served as the technical basis for the work plan activities that were proposed in the 2012 Shallow and Deep Ground Water RIWPs. Under this initial model, shallow ground water was defined in specific depth zones and specific transmissive units were identified in the deeper bedrock. Within the shallow aquifer, ground water was evaluated in three depth zones (0 to 30 feet bgs, 30 to 50 feet bgs, and 50 to 80 feet bgs). Within the deep bedrock, three distinct transmissive zones (denoted A, B, and C) were interpreted to occur from the hydrogeologic data (borehole logs and observations of water yield from specific depth intervals). These zones were viewed as discrete regions of higher conductivity within the formation (relative to more massive strata of relatively low conductivity), and were oriented roughly parallel to the plane of bedrock bedding. Using this model as a guide, monitoring wells were installed to screen these thin, discrete aquifers (A, B, C).

Data collected during the implementation of the 2012 Shallow and Deep Ground Water RIWPs suggested that vertical fracturing and fault systems (across the Site) played a greater role in the rock structure and ground water flow dynamics than had been previously anticipated. This finding has been reported by other researchers in the past. Researchers have identified localities within the Newark Basin that depart from the generic conceptual site model (e.g., LMAS). Specifically, Knapp (1904), Veccholi (1965) and Spayd (1985) have documented that steeply dipping (near vertical) fractures serve as major conduits for ground water recharge, storage and flow (Herman 2010).

Borehole data collected at the Site (2012-2013) suggested that there was high frequency of vertical fractures in portions of the Site, facilitating hydraulic communication from shallow to deeper bedrock zones. As such, the initial conceptual model for the Site was modified to reflect these RI findings (e.g., interconnection/hydraulic communication of vertical fractures and bedding plane partings, approximating a continuum flow model). Under this modified model, discrete aquifers (single fracture zones) are less important in contaminant transport than the totality of the fractured aquifer system. Monitoring wells do not need to be installed in discrete units (A, B, and C) to trace contaminant transport but instead can be constructed in any depth interval where transmissive fractures are present and would be expected to encounter some level of contamination (within the plume), due to the high degree of fracture interconnectivity of the bedrock system (i.e., lack of aquitards).

Under this modified model, the thickness and boundaries of the hydrostratigraphic zones were subdivided into elevation-based intervals that correlated with the screened intervals of the constructed monitoring well network. Table 2 presents a summary of the established hydrostratigraphic zones and their respective elevation range. Monitoring wells whose screens were completed at elevations above msl (i.e., > 0 feet msl) are referred to as "shallow" or "S-series" wells and sub-divided into three hydrogeologic zones as follows:

- Zone S1 includes 251 wells (226 Roche monitoring wells, 5 monitoring wells at 413 Kingsland Street, and 20 former Deluxe Check monitoring wells) screened higher than 80 feet above msl;
- Zone S2 includes 102 wells (85 Roche monitoring wells, 4 former Deluxe Check monitoring wells, and 13 Nova monitoring wells) screened at 80 to 50 feet above msl; and
- Zone S3 includes 71 (62 Roche monitoring wells, 2 former Deluxe Check monitoring wells, and 7 Nova monitoring wells) screened at 50 to 0 feet above msl.

The deep bedrock has been separated into zones defined by elevation (instead of specific bedding planes) and wells installed below msl (i.e., < 0 feet msl) are referred to as "deep" or "D-series" wells and sub-divided into four hydrogeologic zones as follows:

- Zone D1 includes 28 wells (26 Roche monitoring wells and 2 former Deluxe Check monitoring wells) screened at elevation 0 to 100 feet below msl;
- Zone D2 includes 23 wells (19 Roche monitoring wells and 4 former Deluxe Check monitoring wells) screened at elevation 100 to 250 feet below msl;
- Zone D3 includes 20 wells (all of which are Roche monitoring wells) screened at elevation 250 to 400 feet below msl; and

- Zone D4 includes 3 wells (all of which are Roche monitoring wells) screened deeper than 400 feet below msl.

The ground water quality and characteristics of these hydrostratigraphic zones are discussed in Section 4 of this GWRIR. The monitoring wells installed at the Site have screens or open intervals that are less than 25 feet in length (Table 3).

3.6 Off-Site Access Negotiations and Approvals

As part of the ground water RI program, it was necessary to negotiate with private parties and/or government agencies and obtain permission to access off-Site property to install monitoring wells and to complete associated investigation activities at several locations. These parties included the Township of Nutley, the City of Clifton, the New Jersey Department of Transportation (NJDOT), the owners of private properties located at 789 and 800 Bloomfield Avenue (Nutley), the owners of the Route 3 Plaza (Route 3 Westbound, Clifton, New Jersey), and the responsible parties for two adjoining properties subject to the NJDEP's Site Remediation Program (SRP). The off-Site locations that were accessed as part of these investigation activities are as follows:

Properties Accessed for Well Installation and Related Activities:

- Township of Nutley rights-of-way for Alexander Avenue, Edison Avenue, Spruce Street, Funston Place, Cottage Place, Colonial Terrace, Hillside Avenue, and Terrace Avenue;
- Township of Nutley parklands (Nichols Park);
- City of Clifton right-of-way for Lois Avenue;
- NJDOT right-of-way for Route 3 Eastbound and Westbound, Clifton, NJ;
- Private property located at 789 Bloomfield Avenue (Nutley);
- Private properties located at Route 3 Westbound, Clifton, NJ and 800 Bloomfield Avenue, Nutley (for materials staging in support of well installations on adjoining parcels only).

Adjoining Parcels Subject to the NJDEP's SRP Whose Property and Wells Were Accessed:

- Former Deluxe Check facility, located at 1155 Bloomfield Avenue, Clifton, New Jersey (NJDEP PI No. 021924); and
- Former Nova Electric facility located at 263 Hillside Avenue, Nutley, New Jersey (NJDEP PI No. G000003468).

In each instance, property access was negotiated and secured by Roche for all required activities prior to the initiation of work activities.

3.7 Public Notifications and Meetings

Generally, wherever drilling and sampling activities were planned on public residential streets, Roche provided notification letters to residents in the vicinity of the planned work activities, describing the anticipated work activities and their duration, and providing interested residents with Roche contact information that they could utilize to address specific concerns or answer additional questions. Additionally, when requested by local government officials, Roche and TRC representatives attended and participated in public meetings where residents were given the opportunity to express questions or concerns regarding Roche's ground water investigation activities. These activities were completed with the intention of addressing community concerns regarding the investigation, and to minimize the impact of investigation activities on the community.

3.8 Subsurface Utility Clearance

Prior to any drilling activities, all drilling locations were identified in the field by the Osiris Group, Inc. of Stillwater, New Jersey (Roche's resident surveying contractor) and a geophysical survey was completed by either NAEVA Geophysics Inc. (Congers, NY) or Nova Geophysical Services Inc. (Douglaston, New York), to verify the absence of subsurface utilities in the planned drilling locations. In addition, as required by law, drilling contractors notified the NJ-One Call system prior to any drilling activities. At off-Site drilling locations, soft-dig procedures (or manual digging) were also typically utilized to depths of up to 5 feet bgs to verify the absence of subsurface utilities prior to advancing boreholes utilizing drilling equipment.

3.9 Passive Soil Gas Survey – IA-10

Historic ground water analytical data from the monitoring wells located at the former gasoline service station (413 Kingsland Avenue) revealed the presence of chlorinated VOCs at concentrations in excess of the NJDEP GWQS. To assess the upgradient source of the chlorinated VOC contamination, a passive soil gas survey (using a wide-spread sampling grid) was conducted in an upgradient area in IA-10. Approximately 200 soil gas modules (W.L. Gore & Associates, Inc. [W.L. Gore]) were installed into 1-inch diameter boreholes up to 3 feet bgs and remained in place for 2 weeks, after which TRC retrieved the modules for delivery to W.L. Gore for laboratory analysis. Following a review of the W.L. Gore report, monitoring wells were installed in specific locations (e.g., soil gas anomalies) to assess shallow ground water quality.

3.10 Deep Bedrock Borehole Advancement

As of 2007, ten deep bedrock boreholes had been installed (CH-1 through CH-10) and stabilized with blank FLUTe™. To expand upon this initial network, twenty-three bedrock boreholes (CH-

11 through CH-20, DW-1D, DW-3C, DW-4D, DW-5C, DW-7D, DW-8D, DW-9D, DW-10C, DW-11D, DW-17C, DW-18D, DW-22D, and DW-23D) were advanced to depths of up to 730 feet bgs to complete the delineation of the VOC plume. Appendix B contains the boring logs for these deep bedrock boreholes. The locations of these boreholes are shown on Figure 9. To complete these deep bedrock boreholes, initial boreholes were typically advanced to depths of 80 feet bgs and outer steel casings were grouted into bedrock. After the grout cured, bedrock boreholes were drilled deeper (inside the grouted steel casings) to the targeted bedrock depth.

During borehole advancement activities, drill cuttings were logged by a TRC geologist to document major lithologic changes, water-bearing fractures, and drilling properties of the rock. Prior to geophysical logging and monitoring well construction, open bedrock boreholes were developed to remove drill cuttings.

Boreholes CH-1 through CH-20 were utilized as part of the Site-wide ground water RI. Boreholes CH-1 through CH-20 were stabilized and temporarily sealed by the installation of blind FLUTe™ liners between drilling and subsequent investigation activities. The liners were removed from 12 of the boreholes in 2013 and those holes were completed as deep ground water monitoring wells or abandoned. The liners currently remain in boreholes CH-01, CH-5, CH-6, CH-13, CH-14, CH-16, and CH-20. Borehole CH-17 was converted into a monitoring location with the installation of a 12-port multi-port FLUTe™ liner, and boreholes CH-15 and CH-18 were abandoned.

3.11 <u>Surface Geophysics Survey</u>

The NJGS have mapped two northeast-trending faults approximately 1 mile north of the Site (Figure 8). Projection of these mapped fault lines to the southwest suggests that one or both of these faults could intersect the Site. Faults typically influence topography and the permeability of the rock. Due to the intense fracturing associated with the fault system, the permeability may be higher in the rock within these fault zones (relative to the surrounding areas). It was anticipated that one or more fault zones could exist at the Site, along or proximal to the existing surface water bodies (Valley Drain, St. Paul’s Brook).

Therefore, to assess the presence and orientation of these potentially transmissive features at the Site, Quantum Geophysics of Phoenixville, PA (Quantum) performed a series of 15 surface geophysical survey transects in September and October 2013 (identified as A-A’, B-B’, C-C’, D-D’, E-E’, F-F’, G-G’, H-H’, I-I’, J-J’, K-K’, L-L’, M-M’, N-N’ and O-O’) . Quantum utilized geophysical survey equipment to conduct multiple methods, including 2-dimensional electrical resistivity imaging (ERI), microgravity, and multi-channel analysis of surface waves (MASW). Appendix C contains the Quantum report of the surface geophysical surveys.

3.12 Borehole Geophysical Logging

Since 2007, bedrock boreholes CH-7, CH-11 through CH-20 and boreholes DW-1, DW-4, DW-5, DW-7, DW-9, DW-10, DW-11, DW-16, DW-17, and DW-18 have been logged using downhole geophysical equipment. Geophysical logging of these boreholes was completed by either Northeast Geophysical Services (NGS) of Bangor, ME or ARM Geophysics (ARM) of Hershey, PA, and generally consisted of 3-arm caliper, fluid temperature, fluid resistivity, short and long normal resistivity, fluid conductivity, single point resistance, spontaneous potential (SP), normal resistivity, natural gamma, and heat-pulse flow meter techniques, in addition to optical televiewer (OTV) and acoustical televiewer (ATV) logging. These geophysical data were reviewed and used to identify specific fracture intervals for conducting packer testing. Downhole geophysical data were also compiled and analyzed using graphical and statistical methods that are presented and summarized in a letter report (by ARM), included as Appendix D.

3.13 Deep Bedrock Packer Testing

Since 2007, packer testing was performed at numerous deep bedrock borehole locations throughout the Site, typically using a 10-foot length straddle packer assembly. Packer test intervals were selected based on drilling observations and the interpretation of borehole geophysics logs. Packer testing typically consisted of ground water quality sample collection for VOC analysis. At some locations, ground water samples were collected for additional analytical parameters. The analytical results of packer samples were used to guide the placement and construction of permanent monitoring wells.

At some locations, data from the pumping test portions of the packer testing effort were used in conjunction with downhole geophysical testing results to identify significant ground water flow intervals/features. The hydraulic conductivity of specific depth intervals within the deep bedrock aquifer was estimated using pumping yield data collected from the packer testing activities. These data are also presented in Appendix E.

3.14 CH-16 Aquifer Pumping Tests

As proposed in the December 2007 Phase One RIWP, a series of aquifer pumping tests were completed in borehole CH-16 in May 2010. The aquifer tests consisted of four components: (1) baseline water-level monitoring; (2) a series of short, variable rate "step tests" (May 19, 2010); (3) a 72-hour constant rate pumping test at a pumping rate of approximately 157 gallons per minute (gpm) (May 24, 2010); and, (4) recovery water-level monitoring. These data were used to estimate aquifer yield and transmissivity, and qualitatively assess aquifer heterogeneity and anisotropy.

Transducers were deployed in a total of 86 wells during the CH-16 pumping test. All of the coreholes (CH-1 through CH-20) and former production well PW-37 were utilized as monitoring points for the test. To support the test, ten monitoring wells screening the 60 to 80-foot depth interval (MW-113 through MW-122) were installed, and were used as monitoring points for the tests. In addition, 57 shallower bedrock monitoring wells were used as observation points. Additional information concerning the CH-16 aquifer pumping test is presented in Appendix F.

For historical context, the results of previously completed pumping tests (specifically MW-51 and CH-1 completed in 2002 and 2003, respectively) will be discussed in Section 4.2.2.5.

3.15 Shallow Ground Water Temporary Boreholes

Prior to the installation of permanent monitoring wells, temporary bedrock boreholes were utilized to obtain ground water samples for VOC analysis for field screening data. The screening-level data were used to guide the selection of locations and depths for permanent monitoring wells. During the initial phase of the 2012 program, the temporary boreholes were drilled as 4-inch or 6-inch diameter bedrock boreholes, and temporarily constructed of 2-inch PVC screens and risers, with temporary sand packs and bentonite seals installed to maintain hole integrity and isolate the well screen. This procedure was modified shortly after program initiation to utilize a packer assembly, so that multiple borehole intervals (10-foot length) could be isolated for testing. A total of 57 temporary boreholes were installed under this program and 267 bedrock intervals were sampled for VOCs. Additional information concerning the locations of these temporary well boreholes and their screening-level VOC analytical results is presented in Appendix G.

Following packer testing, each temporary well borehole was either constructed as a permanent shallow ground water monitoring well or properly abandoned by a New Jersey-licensed well driller. Well construction documentation is provided in Appendix H.

3.16 Monitoring Well Construction and Development

Currently there are more than 440 monitoring wells installed as part of the Site-wide ground water RI program. Of these wells, at least 277 were installed between 2007 and 2013 in support of the three RIWPs, including the following:

- Ten monitoring wells to supplement the observation well network for the CH-16 aquifer pumping tests (MW-113 through MW-122);
- Approximately 120 monitoring wells to supplement the existing shallow ground water monitoring well network and complete the delineation of ground water constituents in the shallow ground water; and
- Approximately 50 monitoring wells to establish a deep bedrock monitoring well network, and supplement the existing deep bedrock monitoring locations (FLUTe™ liner ports at wells PW-37 and CH-17).

Additionally, approximately 100 monitoring wells were installed as part of the IA RI programs to complete shallow ground water quality assessments of specific soil AOCs. These wells supplemented the pre-2007 network of approximately 167 wells at the Site.

Well installation activities proposed in the approved October 2013 Bedrock Ground Water RI Workplan Supplement 2 are ongoing and will be completed before June 2014. The results of this program will characterize the ground water quality and flow along the northern and northwestern boundaries within multiple hydrostratigraphic zones. The findings of this program will not alter the information presented in this RIR but will refine and further characterize the contamination originating from off-Site sources. The ongoing well installation activities will be documented in a future annual progress report.

For all well installations, TRC personnel provided oversight of a Roche-contracted driller and documented well installation and sample collection activities. Wells were installed by five separate drilling companies using various drilling methods, including air rotary, hollow-stem auger, and sonic drilling methods. Generally, wells installed as part of IA-related ground water quality assessments or for the shallow ground water RI were installed using 2-inch diameter PVC screens to depths of up to 80 feet bgs and PVC risers, whereas monitoring wells installed as part of the deep bedrock ground water RI were generally installed using stainless steel screens to depths ranging from 80 feet to 730 feet bgs and steel risers. All well constructions were completed in accordance with NJDEP well construction regulations (or NJDEP-approved variances). Following well installation, each well was developed using either a submersible pump or an air lift pump to remove drilling fluids, establish hydraulic connection with the surrounding formation, and remove fines generated during the drilling process. All monitoring wells were surveyed after completion by a New Jersey-licensed land surveyor. The monitoring wells installed at the Site are shown on Figure 9; their construction details are summarized in Table 3 (Existing Monitoring Well Construction Details). Monitoring well drilling and construction logs and other documentation are provided in Appendix H.

3.17 Hydraulic Gauging Studies

A ground water level gauging study of the deep bedrock aquifer system was completed from May 23 through June 14, 2013 to assess potentiometric level fluctuations over time (e.g., variations in flow configurations, hydraulic gradient reversals) and to assess for evidence of potential off-Site pumping influences (e.g., cyclic drop/rise in response to regular local ground water withdrawal). Electronic pressure transducers and data loggers (i.e., Diver®) were placed in selected deep monitoring well clusters (DW-2B/D; DW-8A/B/C/D; DW-13A/B; DW-14C; DW-15A/C, DW-16; DW-17C/D), and in shallow monitoring wells MW-60 and MW-201A to provide data on the interaction between different levels within the bedrock. Water-level measurements were collected at short time intervals (e.g., 10 minutes) in each well throughout the study. After several weeks of data collection, the data loggers were removed from the monitoring wells and the data were downloaded to a computer to generate hydrographs (water-level fluctuations over time). Precipitation data were obtained from a rain gauge in Little Falls, New Jersey (located approximately 2 miles from the Site), for comparison to the ground water gauging data collected. The hydrographs were generated to depict ground water elevations and precipitation over time (Appendix I). These hydrographs were evaluated to determine if precipitation events influenced any water levels at specific locations (e.g., increase rainfall = rise in ground water elevation).

Water levels were monitored in selected shallow monitoring wells and staff gauges along the Valley Drain and St. Paul's Brook from July 24 through September 13, 2013. Water levels were measured using logging pressure transducers (i.e. Diver®) in monitoring wells and in stilling wells installed in the streams. The data loggers collected pressure head data throughout the entire study. These data were used to better understand the influence of precipitation and the interactions of surface water and ground water (e.g., whether the stream was gaining [ground water discharge] or losing [ground water recharge]).

Monitoring wells MW-60, MW-60G, MW-102, and MW-194; piezometer PZ-05; and surface water monitoring stations VD-400 and VD-1870 were gauged to measure levels along the Valley Drain. Monitoring wells MW-30, MW-31, MW-32, MW-220, and MW-48; piezometer PZ-03; and surface water monitoring stations SPD-50, SPD-2260 were monitored along St. Paul's Brook. The water-level elevations were used to produce hydrographs to compare between ground water and surface water measurements (Appendix J).

3.18 Synoptic Hydraulic Gauging Event

Following well installation, fluid levels were routinely measured in Site monitoring wells to assess the potential for presence of free-phase product (light non-aqueous phase liquid [LNAPL] or dense non-aqueous phase liquid [DNAPL]) accumulations in the wells and to determine the depth to the ground water interface.

On September 16, 2013, water levels were measured in all of the existing monitoring wells, at the former Deluxe Check facility (off-Site), and at surface water monitoring stations established along St. Paul's Brook (Table 4). The water-level data were used to generate ground water contour maps, vertical flow nets, and calculate hydraulic gradients for the ground water flow regimes.[5] NJDEP contour map reporting forms are included in Appendix K.

3.19 Monitoring Well Sampling Activities

3.19.1 *Initial Screening Using Passive Diffusion Bags (PDBs)*

As an initial task to supplement the current understanding of Site-wide ground water quality conditions, monitoring wells that had not been previously sampled or had not been sampled in the last 3 years were sampled for Target Compound List (TCL) VOC analysis using the PDB sampling method in January 2013. The PDB sample method[6] was selected to reduce the sampling time and the volume of investigative-derived waste (IDW) associated with other sampling methods. This data set was intended to serve as an initial screening tool to guide future borehole advancement activities.

Additionally, as new wells were installed, initial PDB sampling for TCL VOC analysis was completed at newly-installed wells to assess ground water quality and guide the remedial decision-making process as it related to delineation status and source area and plume characterization.

During all PDB sampling activities, for wells previously sampled using PDBs, one PDB was deployed at the depth interval that has historically been sampled. For wells not previously sampled using PDBs, multiple PDBs were positioned within each well. Typically, one PDB was

[5] During the September 2013 synoptic hydraulic gauging event, two remediation wells (RW-51 and RW-96) and multiple building dewatering systems or building basement sumps (i.e., sump pumps located in on-Site Buildings 1, 8 [Utility Tunnel], 39, 52, 76, 85 [demolished in early 2014], 115, 116, and 118) were in operation at the Site.

[6] Ground water sampling was conducted using PDBs in accordance with the NJDEP Field Sampling Procedures Manual and manufacturer's instructions. PDBs are made of low-density polyethylene. The principal of sample collection with PDBs is based on Fick's Law of Diffusion, which states that compounds tend to migrate from areas of higher concentration to areas of lower concentration. Pre-filled PDBs are suspended below the water table interface within the screened interval of a ground water monitoring well. VOCs in the well water will diffuse across the permeable polyethylene membrane of the PDB sampler until the VOC concentration inside and outside of the PDB has achieved equilibrium. The PDBs are attached to a polyethylene line (tether) and weights are used to control PDB buoyancy. Typically, up to four PDBs (pre-filled with laboratory-grade deionized water), weights, and tethers are installed in the well in series (in 5 foot intervals, spanning a 25 feet screen interval) and left to equilibrate in the well for a minimum of 14 days. During PDB retrieval, the water in the PDBs is emptied and transferred to the sample container (for transport to the laboratory).

positioned at 2.5 feet from well bottom, one at 2.5 feet from the top of the well screen, and additional PDBs (as needed) spaced at 5 foot intervals within the well screen, as per NJDEP guidance. PDBs were deployed in the well on weighted tethers provided by the manufacturer, and left to equilibrate for a period of at least 2 weeks prior to retrieval and sample collection. Based on the findings of these ground water sampling activities, additional temporary and permanent monitoring wells were added to supplement ground water delineation.

3.19.2 *Comprehensive Sampling Event (PDB and Low Flow Methods)*

Ground water sampling activities were conducted in accordance with the NJDEP Field Sampling Procedures Manual (2005). A comprehensive event was conducted to assess the water quality of all on- and off-Site wells screening seven hydrostratigraphic zones. The large number of wells (> 400) and full baseline suite of analytical parameters (VOCs, semi-volatile organics [SVOCs], pesticides, metals) presented some challenges to implementing this comprehensive program, specifically requiring the use of multiple sampling methods (PDBs, low flow, FLUTe™), interaction/access negotiation with off-Site property owners, multiple sampling teams and several consecutive weeks of sampling to achieve completion.

The PDB method was selected for VOC parameters. PDBs were installed in all wells and allowed to equilibrate for a minimum of 14 days prior to sample collection. While PDBs provide a time-weighted VOC concentration (based on the equilibration time within the well), they are relatively easy to deploy and recover, do not require measurement of purging stabilization and produces no waste water, which reduces time, operator error and overall sampling costs.

Most wells had never been sampled for non-VOC parameters; PDBs cannot be employed for these analytes. Therefore, a second comprehensive baseline event using the low-flow sampling method was conducted for non-VOC parameters (SVOCs, metals and polychlorinated biphenyls [PCBs]/pesticides) to evaluate the presence, extent, and likely sources of these non-VOC constituents in ground water. The low-flow sampling event immediately followed the PDB VOC sample collection.

Ground water samples were also collected from off-Site monitoring wells located at the former Deluxe Check and former Nova facilities. Additionally, samples (23) were collected from two on-Site multi-port FLUTe™ liners (PW-37 and CH-17) using the low-flow sample method.

Between September 18 and 22, 2013, a comprehensive round of ground water samples were collected from equilibrated PDBs retrieved all available monitoring wells (more than 400 wells). All samples were analyzed for TCL VOCs using by Accutest Laboratory (Accutest) in Dayton, New Jersey.

From September 23 to November 4, 2013, a comprehensive sampling round (approximately 440 wells) was conducted using the low-flow sampling method to obtain samples for non-VOC parameters (filtered and unfiltered metals, SVOCs, and PCBs/pesticides). All samples were analyzed for TAL metals, TCL SVOCs, TCL PCBs and TCL pesticides by Accutest. During well purging activities, water quality measurements (temperature, pH, oxidation-reduction potential [ORP], turbidity, specific conductivity, salinity and dissolved oxygen [DO]) were collected using a field-calibrated water quality meter. Ground water sampling measurements and calculations are provided on the Field Sampling Sheets in Appendix L.

3.20 Data Reliability

The analytical methods used for the RI are provided in the QAPP and the laboratory analytical reports. The laboratory data reports and electronic data deliverables/Electronic Data Submission (EDD/EDS) for the RI data are included on compact disc in Appendix M. The sample collection summary for the recent RI ground water sampling is included in Table 1 and the analytical data for the recent RI ground water sampling are summarized in Tables 5-1 through 5-9.

Sample collection activities and laboratory analysis of ground water samples obtained from September through November 2013 were performed in accordance with the TRSR, the NJDEP-approved RI Workplans and the QAPP. Sample analysis was completed by Accutest Laboratories of Dayton, New Jersey, Orlando, Florida and Wheat Ridge, Colorado [laboratory facilities certified by the State of New Jersey].

A quality assurance review was performed on the laboratory analytical reports for the samples analyzed as part of the Site-Wide Ground Water RI. The method-specific calibrations and quality control performance criteria were met for the data generated during this investigation, except as indicated in the conformance/non-conformance summaries provided in the laboratory reports. Quality assurance issues noted in the lab reports that resulted in qualified data include the following:

Accutest Job No. JB49531 - The recoveries for endosulfan II were less than 10% in the MS/MSD analyses performed on sample DW-14C-375.75; therefore, the non-detect results for endosulfan II in this sample should not be used for decision-making purposes. Since endosulfan II is not a COC, the overall project objectives were not adversely affected.

Accutest Job No. JB49924 - The recoveries of endosulfan I, endosulfan II, 3,3'-dichlorobenzidine, 3-nitroaniline, and 4-nitroaniline were significantly low in the MS/MSD analyses performed on sample DW-18C-162.75. Therefore, the non-detect results for these compounds in this sample should not be used for decision-making purposes. Since endosulfan I, endosulfan II, 3,3'-dichlorobenzidine, 3-nitroaniline, and 4-nitroaniline are not COCs, the overall project objectives were not adversely affected.

Accutest Job No. JB47922 - The recoveries were less than 10% for Freon 113, cyclohexane, dichlorodifluoromethane, and methylcyclohexane in the MS/MSD analyses performed on sample MW-112-8.9. Therefore, the non-detect results for these compounds in this sample should not be used for decision-making purposes. Since Freon 113, cyclohexane, dichlorodifluoromethane, and methylcyclohexane are not COCs, the overall project objectives were not adversely affected.

Accutest Job No. JB48904 - The recoveries for atrazine and 3,3'-dichlorobenzidine were extremely poor in the MS/MSD analyses performed on sample MW-106B-31.2(A). Therefore, the results for these compounds in this sample should not be used for decision-making purposes. Since these compounds are not COCs, the overall project objectives were not adversely affected.

Accutest Job No. JB49173 - The recoveries were less than 10% for pentachlorophenol in the MS/MSD analyses performed on sample MW-112B-29.75(A). Therefore, the results for this compound in this sample should not be used for decision-making purposes. Since for pentachlorophenol is not a COC, the overall project objectives were not adversely affected.

Accutest Job No. JB50711 - The recoveries were less than 10% in the MS/MSD analyses for 3,3'-dichlorobenzidine and 4-notroaniline for sample MW-231C-66.75. Therefore, the results for these compounds in this sample should not be used for decision-making purposes. Since these compounds are not COCs, the overall project objectives were not adversely affected.

Data contained in the following lab packs were determined to be usable but qualified due to the presence of contaminants in the field/trip/calibration blanks:

Accutest Job No. JB50862 - All data has been determined to be useable. However, it is qualified that the usability of the VOC results for MW-223B-41.75 is questionable due to the presence of significant contamination in the trip and field blanks collected in October 3013 associated with this sample. It was recommended that sample MW-223B-41.75 be re-collected for VOCs to ensure accurate results. On November 12, 2013, a ground water sample was recollected (JB52991), the associated data laboratory package reviewed, and the COCs have been adequately addressed.

Accutest Job No. JB48743 - A review of the trip blank analysis has determined that all data is useable. However, it is qualified that the usability of the VOC results is questionable due to the presence of significant contamination in the trip blank sample TB-DC-092713-882. These wells were resampled as part of the fourth quarter 2013 sampling event and the results will be reported in the next report.

Accutest Job No. JB47907 - A review of the trip blank analysis has determined that all data is useable. However, it is qualified that the usability of the VOC results is questionable due to the presence of significant contamination in the trip blank sample. The well was resampled as part of the fourth quarter 2013 sampling event and the results will be reported in the next report.

Accutest Job No. JB51491 - All data has been determined to be useable. However, it is qualified that the usability of the VOC results is questionable due to the presence of significant contamination in the trip blank sample. On December 17, 2013, the samples were recollected (JB55852), the associated data laboratory package reviewed, and the overall data determined to be adequately addressed.

Accutest Job No. JB49615 - It is qualified that the usability of the VOC results is questionable due to the presence of significant contamination in the trip blank sample. These wells are being resampled as part of the fourth quarter 2013 sampling event and the results will be reported in the next report.

Based on a review of the laboratory reports, TRC did not further qualify any data. For the four lab reports where it was proposed that samples be recollected, the data was not used for decision making purposes [but as a general guide]. In general, the majority (> 99%) of the ground water sample data collected in association with the Site-Wide Ground Water RI are considered to be valid and useful for the intended data quality objectives and their intended purpose and no additional sampling or re-sampling beyond that being conducted as part of the fourth quarter 2013 sampling event is necessary.

3.21 Factors Influencing Data

The synoptic round of ground water and surface water elevation measurements was completed in 1 day (September 16, 2013). The data generated from this event were consistent with measurements collected prior to and after the one-day gauging event. It should be noted that during the gauging event, two remediation wells (RW-51 and RW-96) and multiple building dewatering systems or building basement sumps were in operation at the Site.

No significant events or seasonal variations are known to have influenced the sampling procedures or the results of the sampling programs presented in this RIR. Due to the large number of monitoring wells (> 440) and associated logistics challenges, the comprehensive sampling event (using passive diffusion bags for VOCs and low flow sampling methods for non-VOC parameters) spanned multiple, consecutive weeks in September and October. This larger time frame for the comprehensive sampling event did not affect data quality and local constituent variations will be eventually verified through long-term monitoring.

3.22 Deviation from the Technical Requirements and Guidance

All activities were conducted in compliance with the approved RI work plans, the TRSR and applicable guidance documents. As such, there were no sampling methods or procedures deviated from the TRSR and applicable guidance.

4.0 SITE-WIDE GROUND WATER RI FINDINGS

This section presents the findings of the RI activities conducted between 2007 and 2013. The methods and procedures employed during the RI activities are presented in Section 3.0 (Technical Overview). The laboratory data packages and the electronic data deliverables associated with these RI activities are included on compact disc(s) in Appendix M.

Ground water primarily occurs in the bedrock fractures/partings beneath the Site. The top of bedrock typically occurs within 20 feet bgs. Based on geophysical logging observations across the Site, most of the bedrock fractures are oriented northeast to southwest and are cross-cut by a subordinate, north-northwest to south-southeast trending fracture system. The greatest frequency of fractures is found in the central portions of the Site within the shallow and deep bedrock (specifically near the Valley Drain and St. Paul's Brook). This fracture system is associated with a documented regional fault system. The local and regional system of fractures and faults constitute the structural framework affecting local and regional ground water flow.

Ground water in Zone S1 flows under water table conditions from the northern and northwestern portions of the Site to the south and southeast, with some localized flow being influenced by the Valley Drain, St. Paul's Brook, and Springer Brook. There is a significant downward vertical flow component from Zone S1 to the underlying intervals (Zones S2 and S3) throughout portions of the Site. Within the highly fractured portions of the Site, vertical hydraulic gradients are significantly lower and include both downward and upward gradients. Ground water in Zones D1, D2 and D3 flows from the northwest to the southeast, similar to the shallow ground water flow system. Under natural (non-pumping) conditions, the flow field conforms to the regional drainage basin with the northern boundary of the Roche property being hydraulically upgradient of the rest of the Site.

Ground water sampling results confirm the presence of VOCs, SVOCs, pesticides and metals contamination in the shallow ground water across the Site. The vertical and horizontal extent of ground water contamination has been fully delineated at on- and off-Site locations. Chlorinated VOCs are the primary COCs that have been detected throughout the shallow and deep ground water zones across and along the boundaries of the Site. The distribution of chlorinated VOCs in ground water correlates with the ground water flow paths defined within the bedrock aquifer system. Sources of contamination have been identified at on- and off-Site locations, with the greatest impacts attributed to off-Site contributors. Based on the information presented in this GWRIR, it is concluded that the Site-wide ground water RI has achieved the program objectives within the statutory deadline (May 7, 2014) and is considered complete.

The following subsections provide greater details on the findings of the RI activities conducted between 2007 and 2013.

4.1 Site Geology Findings

Appendix B provides the drilling logs for the boreholes and wells completed at the Site.

4.1.1 *Lithologic Descriptions*

4.1.1.1 Overburden

The overburden (unconsolidated materials) directly under the Site's surface consists of artificial fill and glacial deposits. While the thickness varies across the Site, the overburden tends to be between 5 and 20 feet thick. The artificial fill is the shallowest unit within the overburden and is composed of a heterogeneous mixture of sand, silt, clay, gravel and man-made materials (e.g., bricks, glass, concrete, coal/ash, wood, and metal debris). The artificial fill is underlain by glacial deposits (Rahway Till). The glacial deposits are composed of poorly sorted sandy silt to clayey silt, with occasional lenses of pebbles and cobbles.

4.1.1.2 Bedrock

The Site is underlain by reddish brown sandstone and siltstone of the Passaic Formation. A weathered bedrock zone ("transition zone") has been characterized by TRC using over 200 stratigraphic logs created during numerous drilling events spanning 1987 to 2012. TRC has observed that the "weathered bedrock zone" varies in thickness across the Site (with a maximum thickness of 45 feet). This zone typically displays unconsolidated, sub-angular pieces of weathered rock in a clayey matrix. Below the weathered bedrock zone, competent bedrock (unweathered) and occasional zones of less competent bedrock or "soft bedrock" (exceptionally quick drilling) have been encountered.

4.1.2 *Structural – Shallow Bedrock*

4.1.2.1 Geomorphologic Analysis of Site Features

Figures 1 and 4 depict the regional and local topography surrounding the Site. As shown on these figures, the Site is located in a valley between two northeast-southwest trending ridges (parallel to the regional strike of the bedrock bedding planes), with Site drainage controlled by St. Paul's Brook. The western and central portions of the Site are relatively flat, with a gentle slope to the south. On the eastern edge of the Site, a small ridge (with a northeastern axial trend) extends from the northern property boundary toward the southern property boundary, and terminates at St. Paul's Brook. To the north of the on-Site eastern ridge lies a second ridge (located north of Route 3) with the same axial trend. Further south of St. Paul's Brook, another small ridge (northeastern axial trend) extends in a southward direction. St. Paul's Brook flows through the gap between these two eastern ridges, eventually discharging to the Third River, which drains into the Passaic River. The Valley Drain, an on-Site stream that has been buried (culverted) beneath the existing Site grade, lies in the center of the Site and is oriented parallel to the eastern ridge.

The ridge features and the Valley Drain are in alignment with a set of northeast-trending faults (mapped by the NJGS), located approximately 1 mile north of the Site. These structural features (local streams and ridges) and mapped faults are related to an extensional fault system throughout the Newark Basin. The Newark Basin is highly fractured in response to early Mesozoic rifting and subsequent wrench faulting of the eastern North American margin (Herman, 2005).

4.1.2.2 Visual Survey of Local Rock Outcrop

Rock outcrops can offer information on the lithology and structure (orientation of bedding and fractures, fracture frequency) of shallow bedrock. Figure 7 provides a map showing the location of exposed rock outcrops (surface expression of shallow bedrock) in the vicinity of the Site. In 2013, TRC performed reconnaissance to locate mapped rock outcrops in the area of the Site. The largest outcrop exposures found during this survey were located along the railroad tracks (both sides) and south of the Nichols Park dam. Appendix N provides photo-documentation of identified structural features. As shown in Appendix N, some areas of outcrop displayed evidence of structural deformation (e.g., attributed to the regional fault system), including intensely fractured zones and "*slickensides*[7]" on fracture surfaces. TRC collected orientation measurements using a Brunton compass from bedding and fractures identified at outcrop locations. Of the measurements collected, the majority of fractures displayed a north to northeastern orientation, consistent with the regional trend of structural features.

4.1.2.3 Surface Geophysical Surveys

Between August and October 2013, a surface geophysical survey program (2-dimensional electrical resistivity imaging, microgravity, and multi-channel analysis of surface waves) was conducted at the Site by Quantum Geophysics under the direction of TRC. Appendix C provides the Quantum Report for this program. This program was undertaken to identify the presence of near-surface bedrock fractures associated with the regional fault zone that may be influencing ground water flow and contaminant distribution in the bedrock aquifer system.

[7] A geologic term. A **slickenside** is a smoothly polished surface caused by frictional movement between rocks along the two sides of a fault. The surface of the slickenside is normally striated (linear furrows) in the direction of movement. See photos under Appendix N.

Fifteen survey transects were conducted in accessible areas along the two suspected permeable fracture zones (St. Paul's Brook, Valley Drain). Figure 10 provides a map depicting the location of the survey transects. For most transects, two geophysical methods were employed to complement data sets, yield better resolution of the identified features, and optimize the effort in the event of interference with a given method (e.g., buried utilities and piping).

Of the three surface geophysical methods conducted at the Site, only shallow seismic (MASW) and microgravity methods performed well enough to provide compelling evidence of major structural elements in the bedrock. ERI was unsuccessful due to interference from metal objects (e.g., fencing, railroads, and buried utilities).

The combined analysis of the two successful surface geophysical methods resulted in 41 fracture-like anomalies being traced across multiple survey lines to infer nine fracture traces (designated as PF#1 through PF#9 on Figure 10). These fractures traverse the entire Site, extending to depths greater than 70 feet and displaying widths up to 100 feet. Five fracture traces (PF#1 through PF#5) enter the Site near the Route 3 guard shack, trending roughly north-south, following the route of the original course of the Valley Drain. Four fracture traces (PF#6 through PF#9) are parallel with St. Paul's Brook and the railroad trending northwest-southeast.

These nine fracture traces are clearly extensions of the regional fault system associated with the Newark Rift Basin. The bedrock fracture/fault systems along St. Paul's Brook and the Valley Drain structurally control the location of surface streams and have influenced ground water flow paths and contaminant distribution.

4.1.3 ***Structural – Deep Bedrock***

4.1.3.1 <u>Borehole Geophysical Surveys</u>

The dominant fracture system in the region displays a northeast trend with subordinate joints trending to the northwest and north. To assess whether the dominant fracture orientation was expressed locally in the deeper bedrock and to identify transmissive (hydraulically conductive) zones, downhole geophysical logging was completed on numerous open boreholes. Appendix D provides the ARM Geophysics Inc. reports and logging results for these bedrock boreholes. Structural data derived from the optical televiewer (OPTV) logs were imported into geologic computer software (Rockworks) for data reduction and analysis of the fracture occurrence, frequency, and orientation.

Rose diagrams and contoured equal-area nets generated from borehole logging data highlight the dominant (most prevalent) orientation of the fractures observed for each borehole (Appendix D and Figure 10). The northeast-trending, regionally dominant fracture system is clearly evident on the Rose diagrams.

As shown in Appendix D, the bedrock beneath the Site exhibits three primary joint (planar fracture) sets. Joint Set 1 has a mean orientation of N33^{o}E (strike) and a dip of 8^{o}NW. This set displays the dominant mean strike of the low angle (<15°) bedding plane fractures identified from the logged boreholes. The other two joint sets represent high angle fractures that cross-cut the bedding planes and display mean orientations of N35^{o}E (strike), 71^{o}NW (dip), and N33^{o}E (strike), 73^{o}SE (dip).

Geophysical logging was also performed to aid in the identification of transmissive water-bearing zones within the rock formation at these well locations. Based on the recent and historic geophysical logging results, open fractures and fractures displaying evidence of flow were selected for packer testing and sampling. The packer samples were intended to support a vertical assessment of relative permeability and ground water quality within the bedrock boreholes and to aid in the selection of future monitoring well screen intervals.

4.1.3.2 Borehole Fracture Frequency and Transmissive Zones

Conceptually, bedrock stratigraphic zones (or regions) with the greatest open fracture frequency should be relatively conductive and provide higher hydraulic yields. These zones were specifically selected for packer testing/sampling and well screen placement, given the likelihood that ground water flow and contaminant transport would be highest within these intervals. To evaluate whether fracture frequency changes with increasing depth or by region, TRC constructed histograms and cross-sections of borehole fracture information.

Figure 11 provides a composite histogram (graph) displaying fracture frequency with borehole depth for the entire Site. As shown on Figure 11, hydrostratigraphic Zones D1 and D2 (0 to 250 feet below msl) showed the highest fracture frequency, with a dramatic decrease in Zones D3 and D4. The high frequency of fractures is indicative of intense brittle deformation and faulting in these depth intervals (Zones D1 and D2) in the bedrock.

Appendix N provides geologic cross-sections depicting the number of open bedrock fractures (encountered in 50-foot increments) that support the fracture frequency evaluation conducted across the Site. The cross-sections traversing the central portion of the Site, in particular sections A-A’, B-B’ and E-E’, highlight regions with numerous open fractures, often coincident with fracture traces identified by the surface geophysical program.

The geologic cross-sections (Appendix N) also show hydraulic conductivity (K) values derived from packer testing of discrete fracture intervals. For reference, the potentiometric surface contour lines (lines of equal water-level elevation) have also been included on these cross-sections. Interpreted regions of higher K are highlighted (in blue) on the cross-sections. As shown on these sections, zones of relatively high K tend to be coincident with the greatest number of open fractures (e.g., Zones D1and D2) and the fracture traces identified by the surface geophysical program.

4.1.3.3 Evidence of Faulting

The results of the surface and borehole geophysical programs have provided evidence indicating the presence of a regional fault system traversing the Site. The bullets below list other observations that support the presence of the regional fault system:

- Slickensides on a rock outcrop along the rail road tracks south of IA-11;
- Slickensides on rock fragments noted while drilling Well DW-7 (within the central zone, north of Route 3);
- Borehole collapse attributed to high degree of fracturing and void/soft zones reported at three locations within the Site interior (i.e., CH-6/DW-20D, CH-10/DW-21D and CH-15).
- Lithologic unit displacement, noted as "fault" by ARM on OPTV log for DW-16 (located near St. Paul's Brook and the former Deluxe Check facility); and
- Boreholes within the central portion of the Site display high pumping yields during drilling (increased availability of water, >100 gpm), especially boreholes DW-7, DW-9, DW-21D, and DW-22D.

4.1.3.4 Conceptual Model Implications

Structural data collected across the Site suggest that vertical fracturing and the regional fault system play a greater role in the rock structure at the Site than had been initially anticipated. Other researchers, specifically, Knapp (1904), Veccholi (1965), and Spayd (1985), have documented similar findings at some sites where steeply dipping fractures serve as the major conduits for ground water recharge, storage and flow (Herman, 2010).

Borehole data collected at the Site indicates that the high frequency of vertical fractures facilitates hydraulic communication from the shallow to deeper bedrock zones. As such, discrete aquifers (bedding plane fracture zones) are less important in contaminant transport than the totality of the fractured aquifer system. Monitoring wells do not need to be installed in discrete units (A,B,C) to trace contaminant transport but instead can be constructed in any depth interval and would be expected to encounter some level of contamination (within the plume), due to the high degree of fracture interconnectivity (hydraulic communication) of the bedrock system. This perspective permits the use of a continuum flow ground water model for most of the Site, as opposed to a discrete fracture flow model[8] (i.e., the LMAS model, *Michalski and Britton).*

4.2 Site Hydrogeology Findings

4.2.1 ***Structural Framework***

The local and regional system of bedrock fractures and faults constitute the structural framework affecting local and regional ground water flow. Below are some key observations/clarifications:

- Borehole data indicates that the highest density of fractures occurs at depths between msl (0 feet msl) and 250 feet below msl (spanning Zones D1 and D2).

- The fracture frequency at most boreholes tends to increase with depth, with a maximum fracture density in the D1 and upper D2 layers and then decreases as depth increases. In other words, within the deepest depth zones there are fewer fractures, which decreases the potential for fracture interconnectivity. As such, zones D3 and D4 are significantly less conductive than the bedrock in the shallower zones.

- The bedrock to the east and southeast of the Site has a much lower hydraulic conductivity than the bedrock immediately under the middle of the Site. This permeability contrast has a controlling influence on ground water flow, the distribution of ground water constituents, and the shape of the chlorinated VOC plume.

4.2.2 ***Ground Water Hydrology***

4.2.2.1 Monitoring Well Installation Rationale

Table 3 provides a summary of well construction details and the technical rationale (or basis) for monitoring well construction design and locations across the Site. Figure 9 provides the location of the monitoring wells installed at the Site (which screen the overburden and shallow and deep bedrock systems).

[8] However, it is important to note that under pumping conditions, the areas around some extraction wells do exhibit anisotropic behavior in response to the pumping stresses, suggesting that specific bedding plane fracture zones may transmit relatively more water along strike in response to such stresses.

Roche monitoring wells have been constructed with a screen or open interval (up to 25 feet in length) in one of the following hydrostratigraphic zones[9]:

- **Zone S1** (includes 226 wells screened higher than 80 feet above msl);
- **Zone S2** (includes 85 wells screened at 80 to 50 feet above msl);
- **Zone S3** (includes 62 wells screened at 50 to 0 feet above msl);
- **Zone D1** (includes 26 wells screened at elevation 0 to 100 feet below msl);
- **Zone D2** (includes 19 wells screened at elevation 100 to 250 feet below msl);
- **Zone D3** (includes 20 wells screened at elevation 250 to 400 feet below msl); and
- **Zone D4** (includes 3 wells screened 400 feet below msl).

4.2.2.2 Ground Water Flow Regime - Synoptic Well Gauging Event

On September 16, 2013, fluid-level measurements were collected from all accessible monitoring wells completed in six hydrostratigraphic zones (S1 through S3, and D1 through D3). Table 4 presents the ground water elevation data collected on September 16, 2013. The ground water elevation measurements across the Site ranged from 36.45 (DW-18D) to 129.65 (MW-61) feet above msl. The average depth to ground water in the shallowest wells was 10.35 feet bgs for this event. The synoptic water-level data from this gauging event were used to calculate hydraulic gradients, construct potentiometric surface maps and develop hydrologic cross-sections (vertical flow nets) for the shallow and deep ground water flow system.

LNAPL Detection

During the September 2013 gauging event, no LNAPL/DNAPL detections were observed in any monitoring wells. However, in August 2013, a minor LNAPL accumulation (< 0.1 foot thick) was detected during the installation of one borehole located along the Route 3 boundary (and hydraulically downgradient of a Sunoco Service Station located on the westbound [north] side of Route 3). At that time, a sample was collected for petroleum fingerprinting and other forensic analysis by NewFields. The laboratory reported that the sample was identified as weathered leaded gasoline from the 1960s. This LNAPL appears to have migrated from the nearby Sunoco Service Station to this borehole location. Appendix O provides the laboratory report prepared by NewFields. On October 3, 2013, at the request of the NJDEP, TRC transmitted a letter to the Sunoco representative and their LSRP to provide notification of these RI findings.

[9] Additional monitoring wells (installed by other responsible parties or filed with the NJDEP under a separate Roche case #) have been assigned to hydrostratigraphic zones S1, S2, S3, D1, and D2. Refer to Section 3.5 of this document for additional information.

4.2.2.3 Vertical Hydraulic Gradients

Water levels measured at the well clusters (screening different zones) throughout the Site were used to calculate vertical hydraulic gradients. The difference in hydraulic head between selected pairs of wells, screened at different depths, was determined from synoptic measurements of water levels collected during the September 2013 monitoring event. The vertical gradient was derived by using the difference in hydraulic head divided by the vertical distance between the middle of the well screens in each pair of wells.

Table 6 provides a summary of vertical hydraulic gradients for well pairs across the Site (based on field data collected in September 2013). In general, the well clusters display downward vertical hydraulic gradients, indicating the shallow bedrock aquifer zones provide recharge to the deeper bedrock zones. In some locations, an upward vertical gradient is evident from Zone D3 to D2, possibly reflecting the higher permeability of Zones D1 and D2 relative to Zone D3. The vertical hydraulic gradients for the well pairs ranged between -0.632 to +0.611 foot/foot (downward and upward, respectively) for the September 2013 measurement event.

Shallow Hydrostratigraphic Zones (S1, S2, S3)

Ground water present in Zone S1 represents the water table interface across the Site, flowing through mixed lithologic zones (overburden-artificial fill, overburden-glacial till, weathered and fractured competent bedrock). Ground water flow in Zones S2 and S3 occurs mainly in fractured competent bedrock, although some of S2 flow occurs in the "transition zone" of weathered and competent bedrock.

Figure 12 is a potentiometric map (ground water elevation contours) of Hydrostratigraphic Zone S1. As shown on Figure 12, flow through this zone is the most complex due to the interaction of ground water with surface water, subsurface utilities, weathered bedrock and other varied aquifer materials encountered.

In general, ground water in Zone S1 flows under water table conditions from areas of higher heads in the northern portion of the Site to the south and southeast. While local influences are evident (most notably ground water "mounding" upstream of the Nichols Park dam and in IA-4), flow converges towards the center of the Site, coincident with the surface streams. The average lateral hydraulic gradient along the longest flowpath (from the northwest corner to the southeast corner) of the Site is 0.013. As shown on Figure 12, the lateral gradient is steeper at the southern end of the Site reflecting the surface topography. The spacing of the water-level contours indicates the water-bearing overburden and weathered bedrock is relatively permeable under the facility, and the permeability decreases markedly to the southeast of the Site.

Figure 13 is the potentiometric surface map of Zone S2. As shown on Figure 13, flow in Zone S2 displays less influence from surface water features. The general southerly slope of the potentiometric surface still shows flow convergence below the surface streams, but the effect is muted. The overall horizontal gradient of Zone S2 (0.014) is very similar to Zone S1. Vertical hydraulic gradients from wells screened in S1 and S2 are predominately downward (63% of measurements) and have an average of 0.098. Upward vertical hydraulic gradients are commonly found in well nests nearest the surface drainages and display an average of 0.066.

Figure 14 is the potentiometric surface map of Zone S3. The configuration of the potentiometric surface for Zone S3 is similar to Zone S2, except the effect of surface streams is less apparent. There is an area of hydraulic mounding (higher heads) in the southeast corner of IA-3. The source of this local ground water "mound" is anomalous and unknown, and will be further evaluated in future ground water gauging events.

The vertical flow nets (Figures 15 through 19) show a significant downward vertical flow component from S1 to the deeper intervals throughout much of the Site. The steepest vertical hydraulic gradients (in excess of 0.20) occur in upland areas in zone S1 and S2. The vertical hydraulic gradients then lessen dramatically in zone S3 and deeper zones. The steep vertical gradients are likely attributed to the topographic relief as well as the permeability contrast between the overburden/weathered transition zone and the competent, highly fractured bedrock.

Overall, the shallow hydrostratigraphic zones are the most dynamic beneath the Site, as a result of the shallow ground water flow regime being influenced by site topography and lithology. In some areas, shallow ground water follows relatively short flow paths discharging at surface streams. Shallow ground water has also been found to serve as a source of recharge to the deeper ground water flow system under the Site.

Deep Hydrostratigraphic Zones (D1, D2, D3, D4)

Deep ground water (extending from msl to greater than 700 feet below msl) has been subdivided into four hydrostratigraphic zones (D1, D2, D3, D4). Despite having divided the deeper aquifer system into four distinct zones for investigative purposes, it was found that these deep zones exhibit a general consistency in the overall geologic/hydrogeologic characteristics and the general ground water flow configurations.

Potentiometric surface maps for Zones D1, D2 and D3 (Figure 20, Figure 21, and Figure 22, respectively) illustrate the configuration of ground water flow within the deep bedrock zones. Flow in the deeper system is consistent with regional drainage (eastward) from the highlands west of the Site toward the Passaic River east of the Site. Ground water in the deep zones displays lateral hydraulic gradients between 0.010 and 0.014 from the northwest to the southeast, similar to the shallow ground water flow system. As shown on Figures 20, 21, and 22, the hydraulic gradients steepen markedly at the southeastern corner of the study area. The steepening gradients are somewhat consistent with the changes in surface topography, but the change in the potentiometric surface is more pronounced. This steepening of the lateral hydraulic gradient indicates that the bedrock under the ridge along the Site's eastern boundary and to the southeast of the Site is much less conductive than the bedrock under the Site; the intense fracturing under the Site apparently does not extend to the east and southeast of the Site.

In general, the vertical flow nets (Figures 15 through 19) illustrate the very gentle vertical and horizontal hydraulic gradients throughout the deep ground water system. The recharge areas in the northwest portion of the property and the southwest area of the Site are exceptions to these gentle hydraulic gradients (where the rock appears to be less permeable). The middle portion of the aquifer has very low gradients, with broadly spaced contours; in several of these sections most of the flow is lateral (i.e., flowing out of the page toward the reader).

4.2.2.4 Continuous Hydraulic Gauging Study

To assess the effects that precipitation and pumpage of supply wells (possibly occurring on neighboring properties) may have on the ground water flow regime, continuous water-level measurements were collected in selected wells using automated gauging devices. In 2013, down-hole pressure transducers/data loggers (i.e., Diver) were installed in several wells across the Site and operated for 30 days or more. Results of the continuous gauging study are provided in Appendix I.

Gauging studies of the shallow aquifer clearly indicate that overburden wells that are installed in close proximity to surface streams have a strong hydraulic communication with those streams. This was demonstrated by the strongly correlated in-well gauge responses with corresponding rises and falls in stream stages associated with precipitation events. Of particular interest are those wells installed in close proximity to culverted streams. These also showed a strongly correlated and rapid response to increased culvert flows induced by rainfall events.

Monitoring wells MW-30, MW-31, and MW-32 all show this type of rapid short-lived response, similar to the gauge responses observed in the measurement stations installed in the piped sections of St. Paul's Brook. Monitoring well MW-60 also shows a similar rapid response to rainfall events. MW-60 is located adjacent the culverted Valley Drain storm sewer and Clifton Sanitary Sewer line near the Route 3 Gate. The results from this hydraulic gauging survey establish that the culvert pipes are leaking surface drainage into the shallow ground water, and serves as a source of ground water recharge in areas adjacent to these utilities (which has significant implications for contaminant transport). Wells installed in the bedrock or transition zone show a much more muted hydraulic response (or no response at all) to short-term rainfall.

Continuous gauging of the deep wells (Appendix I) showed no evidence that the local ground water flow regime is currently influenced by the pumping of water supply wells on neighboring properties. However, in the last decade, water-level fluctuations had been observed in some on-Site monitoring wells in response to off-Site production well pumpage (e.g., the former Styertown well located north of Route 3). Refer to the figure included with Appendix T.

The gauging indicated that well clusters typically show consistent downward flow gradients, and the deeper wells show very little (or no) response to rainfall events. The DW-8 monitoring well cluster showed an upward gradient in the deep bedrock between the deepest well in Zone D3 (DW-8D) and the two wells in Zones D1 and D2 (DW-8B and DW-8C, respectively). Some locally upward gradients from Zone D3 wells to Zone D2 and Zone D1 wells in the deep aquifer were measured elsewhere, suggesting that the high permeability zone in Zones D1 and D2 is receiving ground water from above and below.

4.2.2.5 Aquifer Pumping Tests and Fracture Interconnectivity

Three long-term aquifer pumping tests (24 to 72 hour) were completed at the Roche facility to provide quantitative estimates of aquifer parameters and to develop a qualitative assessment of aquifer anisotropy and heterogeneity. Separate pumping tests were conducted using Wells MW-51, CH-1, and CH-16 as the extraction wells with numerous surrounding observation wells for each test. Fluid measurements were recorded manually (via interface probe) or by pressure transducer-data loggers[10] (e.g., InSitu Troll®). A summary of each of these tests follows.

MW-51 Pumping Test

In September 2002, a 24-hour constant rate pumping test was conducted by Roche at Zone S3 well MW-51 (currently recovery well RW-51, which screens Zone S3). The purpose of this pumping test was to obtain site-specific aquifer properties for the weathered bedrock transition zone in the IA-6 area (and to support the design of the ground water extraction system in IA-6 for the treatment of chlorobenzene impacts in ground water). Twenty-three observation wells were monitored during this pumping test. A complete report of the MW-51 pumping test is

[10] The pressure transducers were installed more than 15 feet below the surface of the water table interface in each well to ensure that the transducers were continuously submerged throughout the gauging study. The actual location of each transducer was measured and recorded from the top of casing after deployment was complete. Each unit was pre-programmed to initiate the collection of water-level measurements at the same specific time to produce comparable, uniformly collected data.

included in the IA-6 Phase II RI Report (TRC, 2004).

Well MW-51 was pumped at a constant rate of approximately 15 gpm with a maximum sustained drawdown of nearly 20 feet. The influence of pumping was demonstrated by notable drawdown observed in Zone S2 wells MW-22A and MW-50, and Zone S1 wells MW-6A and MW-52. Minimal drawdown was recorded at well MW-7C, located over 400 feet from well MW-51 in Zone S3. The effects of drawdown suggested anisotropic conditions; Zone S2 well MW-22A, located 210 feet from the pumping well, showed an immediate response to pumping, while Zone S1 well MW-6A, located approximately 25 feet away, showed no response until 25 minutes into the test. No response was observed at wells located on the west side of St. Paul's Brook but within 250 feet of MW-51. Type curves derived for a leaky confined aquifer (Hantush and Jacob, 1955) best suited the drawdown data. The transmissivity (T) was estimated at 0.57 foot^2/min to 6.92 feet^2/min and storativity (S) values ranged from 10^{-4} to 10^{-1}.

The results of the MW-51 pumping test provided evidence of fracture flow roughly aligned with regional strike and the fracture traces identified during the surface geophysical survey (Section 4.1.2.3 and Appendix C).

CH-1 Pumping Test

In November 2003, a 72-hour constant rate aquifer test was performed using CH-1 as the extraction well, pumping at a rate of approximately 300 gpm. CH-1 is a deep borehole (400 feet) located in IA-6, west of Building 76 and 86. This borehole pumping test provided estimates of transmissivity and storativity (T and S) values and constituted the first Site-wide hydrogeologic evaluation of the Site's significant water-bearing zones. Eight observation boreholes (CH-2 and CH-4 through CH-10), were installed across the Site to serve as the primary observation points utilized during the pumping test. The complete results of the CH-1 pumping test were presented in the Remedial Investigation Report, Core Hole 1 Aquifer Test (TRC, 2005).

Ground water measurements collected during the 72-hour pumping test from the boreholes located on the west side of the Roche facility yielded information showing a slightly elliptical anisotropic response in the deep bedrock aquifer. Coreholes and wells east of First Avenue showed no response to the pumping of CH-1. In addition, only a slight response to pumping was observed in the shallow bedrock and overburden wells. The dampened response in shallow wells in response to deep pumpage is a reflection of the lower overall permeability of the weathered bedrock and greater degree of fracture in-filling in Zones S1, S2, and S3 relative to Zones D1 and D2.

The 72-hour pumping test and recovery monitoring were used to determine aquifer parameters, specifically, the induced capture area, the distance of influence, and the extent of influence in shallower water-bearing zones. Quantitative analysis of the drawdown and recovery data yielded T estimates that ranged from 0.3 $foot^2$/min to 4.4 $feet^2$/min in the bedrock and 2.0 $feet^2$/min to 18.2 $feet^2$/min in the shallow wells and overburden. Estimates of storativity (S) ranged from $2.9x10^{-5}$ to $2.2x10^{-3}$ in the bedrock to $2.9x10^{-3}$ to 0.3 in the shallow aquifer. These values are generally on the high end of the range of published data for the Brunswick Aquifer System (which includes the Passaic Formation).

CH-16 Pumping Test

In May 2010, a 72-hour constant rate pumping test was performed on corehole CH-16, located in the eastern part of the Roche facility. A complete report on the CH-16 aquifer pumping test (and historic production wells operated at the Site) is presented in Appendix F. The objectives of the pumping test at CH-16 were to determine aquifer parameters east of First Avenue, to assess the hydraulic connection between the shallow and deep ground water under the east side of the facility, and to assess the capacity of this pumping well (CH-16) to induce hydraulic capture across the eastern side of the facility.

The 72-hour constant rate aquifer test at CH-16 was conducted at a rate of approximately 157 gpm. The maximum drawdown in the extraction well (CH-16) was 79 feet. Transducers were deployed in 86 wells during the CH-16 pumping test. All of the boreholes (CH-1 through CH-20), former production well PW-37, and all of the 80-foot deep, upper bedrock monitoring wells (MW-113 through MW-122) (currently assigned to Zone S3) were utilized during the CH-16 pumping test as observation wells. In addition, 57 shallower bedrock monitoring wells (Zones S1 and S2) were used as observation wells. The maximum area of pumping influence extended as much as 1,000 feet north of the extraction well. During the test, many deep observation wells displayed drawdown in excess of 10 feet.

The drawdown configuration created during the pumping test suggested anisotropy in the aquifer. The axis of the elliptical cone of depression was generally parallel to strike, with another component to the west (or down dip). The down dip component, however, is also asymmetrical, suggesting even greater anisotropy. The results of the CH-16 pumping test indicate that deep bedrock wells east of First Avenue displayed the greatest amount of drawdown response (influence from pumping). Shallow wells experienced a more muted response to pumping, with only a few wells exhibiting 5 feet or more of drawdown. This behavior is consistent with what was observed in the CH-1 test (i.e., a dampened response in shallow wells during the pumpage of the D1 and D2 zones).

Aquifer Test Conclusions

The three pumping tests suggest that, under pumping stresses, the bedrock aquifer will locally display anisotropic behavior due to the bedrock structure (e.g., preferential flow along a northeast-southwest orientation of significant bedding plane partings and extensive steeply dipping fractures [with the same strike]). Under pumping conditions, pumping wells induced flow throughout the fracture network, as the aquifer was found to be highly productive.

The MW-51 pumping test, conducted in the shallow bedrock, confirmed that wells screened in Zones S3, D1, and D2 are in direct hydraulic communication, unlike wells screened in shallower overburden and weathered bedrock.

Corehole pumping tests conducted at CH-1 and CH-16 used extraction wells that screened hundreds of feet of open borehole(s). These two tests provided an average profile of the aquifer response to pumping, simulating the aquifer response to the Site's historic production wells when they were in operation. These tests confirmed that pumping the deeper bedrock had a muted response in the shallow bedrock and overburden, suggesting that the deeper intervals show slow leakage during the short duration of these tests or are at least semi-confined by the less permeable "transition zone" of weathered bedrock.

4.3 <u>Passive Soil Gas Survey – IA-10</u>

Historic ground water analytical data from the monitoring wells located near the former gasoline service station (413 Kingsland Avenue, south of the Site) indicated the presence of chlorinated VOCs (primarily TCE) in excess of the NJDEP GWQS. To assess the potential presence of a VOC soil source area in the southeastern corner of IA-10, a passive soil gas survey was conducted using technology developed by W.L. Gore over a wide area in the this portion of IA-10. In 2013, approximately 200 passive soil gas modules (GoreSorbers) were installed on a grid (with 15 to 25-foot centers) extending along the southern property boundary (north of the former 413 Kingsland Avenue Gas Station). The survey area encompassed the Nutley sewer line that traverses through IA-10. After a 14-day equilibration period, the modules were retrieved and submitted to W.L. Gore laboratory analysis for VOC analysis. Appendix P provides the passive soil gas report prepared by W.L. Gore for this survey. As shown in Appendix P, two soil gas anomalies were identified within Parking Lot 900 of IA-10, in the area of the Nutley sewer line (PCE, TCE), and along the northern boundary of the parking lot (TCE). Shallow monitoring wells (i.e., MW-205 and MW-210) were installed near these anomalies to assess the presence of ground water contamination at those locations. Of the wells installed within the soil gas survey grid, the highest chlorinated VOC concentrations were detected in the well closest to the Nutley sewer line (TCE 11.2 µg/L in MW-205). Ground water sampling results are discussed further in the following sections.

4.4 Ground Water Quality Assessments

In compliance with the MOA (October 1992), the Roche Baseline Ground Water Monitoring Report (September 2002) documented quarterly ground water monitoring conducted at the facility from 1987 to 2000. Thereafter, quarterly ground water monitoring reports have been submitted to the NJDEP annually from 2001 to 2011. Since 2012, ground water quality conditions at the Site have been intensively investigated on an individual AOC basis. These activities have been documented in individual IA RI reports submitted to the NJDEP. The scope of the Site-wide ground water RI builds on completed RI activities documented in these individual IA RI reports and past ground water RI programs, combining ground water information for the IAs on a Site-wide basis.

4.4.1 *IA Ground Water Assessment*

Soil and ground water impacts for each IA have been investigated and documented in separate IA RI Reports. A summary of all of the IAs and their soil and ground water COCs by AOC is included as Appendix Q. Table 7 provides a comprehensive summary of the Site contaminants by IA and AOC. Figure 5 provides a map showing the IAs and AOCs across the Site. As shown in these documents, the ground water assessment and delineation status of each AOC is provided for reference (as the details have been documented in the individual IA RI Reports).

Of the more than 190 AOCs investigated at the Site, only a few IAs/AOCs were identified to possess soil impacts (related to former Roche operations) that directly resulted in ground water contamination. The most notable for these areas include the former tank farm in IA-2 (AOC 85), the pipeway in IA-9 (AOCs 67, 106, and 116), and the former Building 15 in IA-6 (AOC 155). However, it is important to note there are also other non-Roche sources of ground water contamination (not related to former Roche operations) that have been identified at the Site, including a petroleum discharge from Sunoco service station (north of Route 3), municipal sewer discharges in IA-12, the former Deluxe Check facility (west of the Site), and others north and west of the Site.

4.4.2 *Site-Wide Ground Water Assessment*

Between 2007 and 2013, multiple boreholes and monitoring wells were installed at on- and off-Site locations to characterize ground water flow and water quality conditions. Figure 9 provides a monitoring well location map. These RI activities were completed in compliance with the NJDEP-approved work plans (2007 Phase One RIWP, 2012 Site-Wide Deep Bedrock

RIWP/Supplements 1 and 2, and Site-Wide Shallow Ground water RIWP/Supplements 1 and 2).

There is presently a network of more than 440 monitoring wells installed at on- and off-Site locations to determine the extent of ground water contamination. Roche continues to install additional wells to refine the delineation described in the following sections, and to develop a more thorough understanding of ground water flow and quality conditions upgradient of the Site.

4.4.2.1 Comprehensive Sampling Event (September-October 2013)

Figure 9 provides a map depicting the location of all monitoring wells installed on- and off-Site (through September 2013). Table 1 provides a summary of the sample collection for each monitoring well. The combined comprehensive event (employing two sampling methods) was conducted to assess the water quality of all on- and off-Site wells screening the seven hydrostratigraphic zones.

Between September 18 and 22, 2013, a comprehensive round of ground water samples were collected from equilibrated PDBs retrieved from all available on- and off-Site monitoring wells. All samples were analyzed for TCL VOCs by Accutest in Dayton, New Jersey. From September 23 to November 4, 2013, a second comprehensive sampling round was conducted using all available on- and off-Site monitoring wells (including on-Site multi-port FLUTe™ wells PW-37 and CH-17) using the low-flow sampling method to obtain samples for non-VOC parameters. All low-flow samples were analyzed for TAL metals (filtered and unfiltered), TCL SVOCs, TCL PCBs and TCL pesticides by Accutest. Ground water samples were also collected for analysis from off-Site monitoring wells located at the former Deluxe Check and former Nova facilities.

4.4.2.2 Ground Water Sample Results (September-October 2013)

The ground water quality data are provided in tables and on maps categorized by hydrostratigraphic zone. Tables 5-1 through 5-7 provide individual summaries of the analytical results for each zone. Figures 23 through 35[11] provide a comprehensive summary of ground water sampling results (VOCs, SVOCs, metals, pesticides) for the comprehensive September/October 2013 sampling event. Figures 36 through 46 provide additional data representations and summaries to illustrate the contaminant distribution across the Site.

[11] Figures depicting VOC concentrations: Many of the wells sampled in September 2013 had more than one PDB deployed, set at different depth intervals within the well screen. The data boxes on these maps are a compilation of the highest detection of each compound in all of the PDBs installed in that particular well. The contouring of VOC concentrations on these figures reflects the total of the highest concentrations of PCE, TCE, cis-1,2-DCE, and VC. However, any VOC that exceeded the GWQS is shown in the data boxes. For figures showing SVOCs, pesticides and 1,4-dioxane, the hydrostratigraphic zones were combined into one data summary map due to the limited number of detections found in one or more zones.

Appendix M provide the laboratory reports and electronic data deliverables for the analyses performed. All ground water sample results were compared to the NJDEP GWQS (N.J.A.C. 7:9-6).

As required, duplicates, field blanks and trip blanks were collected during each sampling phase/event for the same analytical parameters to assess and validate the quality of the data generated. Duplicate, field blank, and trip blank sample results are presented with the analytical results of the corresponding samples in Table 5-1 through Table 5-7. As previously discussed, TRC did not further qualify or reject any data points.

Based on a review of the conformance/non-conformance summaries contained in the laboratory reports, it is concluded that these data are useable for its intended purposes. Future sampling activities should verify these analytical results, and resolve any anomalies and/or potential discrepancies identified within this data set.

4.4.3 *Ground Water Constituents of Concern*

As shown in Tables 5-1 through 5-7, VOCs, SVOCs, metals and pesticides have been detected in the ground water at the Site at concentrations exceeding the GWQS. The following table lists these Site-specific ground water COCs:

VOCs	SVOCs	Pesticides	Metals
1,1,1-Trichloroethane	1,4-Dioxane	Dieldrin	Aluminum
1,1-Dichloroethane	2-Methylnaphthalene	Lindane	Antimony
1,1-Dichloroethene	2-Methylphenol	Chlordane	Arsenic
1,2-Dichloroethane	3&4-Methylphenol		Barium
1,2-Dichloropropane	bis(2-Ethylhexyl)phthalate		Beryllium
2-Butanone (MEK)	Benzo(a)anthracene (BaA)		Cadmium
Benzene	Benzo(a)pyrene		Chromium
Chlorobenzene	Benzo(b)fluoranthene		Cobalt
Chloroform	Benzo(k)fluoranthene		Iron
cis-1,2-Dichloroethene	Dibenzo(a,h)anthracene		Lead
Cyclohexane	Hexachlorobenzene (Hbenz)		Manganese
Methylcyclohexane	Indeno(1,2,3-cd)pyrene		Nickel
Methylene chloride	Pentachlorophenol		Sodium
Tetrachloroethene	Tentatively Identified Compounds (TICs)		Thallium
Toluene			Zinc

VOCs	SVOCs	Pesticides	Metals
trans-1,2-Dichloroethene			
Trichloroethene			
Vinyl Chloride			

4.4.4 *Ground Water Contaminant Distribution*

The ground water beneath the Site has a complex distribution of contamination, both in its areal and vertical extent across the Site, through the seven hydrostratigraphic zones (S1 through S3 and D1 through D4). Figures 23 through 46 illustrate the contaminant distribution across the Site.

The sections below discuss the ground water COCs by chemical category.

4.4.4.1 Chlorinated VOCs

The most prevalent ground water COCs at the Site are chlorinated VOCs, specifically PCE, TCE and their degradation products, cis-1,2-DCE and VC (and to a lesser extent 1,1-DCE, 1,1,1-TCA, and 1,1-DCA). The Zone S1 chlorinated VOC map (Figure 23) provides the most direct indication of where chlorinated VOC releases have occurred within the area of study. As shown on Figure 23, the chlorinated VOC distribution in ground water (darkest red color on the map) indicates that chemical discharges have occurred in IA-9 (within a Roche process pipe corridor); in the area along the Clifton-Allwood Sanitary Sewer that enters and traverses the Site (north of Route 3, and in the northern portion of IA-12); in the area along Roche process and waste piping in IA-7, IA-11, and IA-15; and near a former loading dock in IA-10 (former Building 104). There are other VOCs in deep ground water that appear to have originated on off-Site properties west and possibly northwest of the Site. The historic release of chlorinated VOCs in ground water is evident off-Site (former Deluxe Check facility) along the western Site boundary. VOC plumes emanate from and extend beyond these discharge (source) areas, either being isolated (e.g., IA-9) due to lithologic or structural controls, or migrating further and commingling with other VOC plumes (IA-7, IA-11, and IA-15) (See Figures 23 through 28).

The following subsections provide a discussion of these individual VOC plume areas in greater detail.

IA-9 Process Pipe Corridor

The highest PCE concentration (35,200 µg/L) was detected on-Site in well MW-170 (Zone S1 well) located in IA-9, in the northern central portion of the property. The PCE concentrations detected in wells surrounding MW-170 are significantly lower (S1 wells ranging from non-detection [MW-217, MW-151] to 30 µg/L [MW-152]; S2 wells ranging non-detection [MW-168B] to 9.3 µg/L [MW-170B]), and serve to delineate the horizontal and vertical extent of this small PCE ground water plume area.

IA-12 (Wells MW-60 and MW-80)

The second highest PCE concentration (16,100 µg/L) was detected on-Site in well MW-60 (Zone S1 well), located in the northern portion of IA-12. MW-60 is located near the Clifton-Allwood Sanitary Sewer and the Route 3 guard house. Historically, PCE concentrations detected in well MW-60 and nearby well MW-80 (also near the Route 3 guard house) have ranged as high as 10,000 µg/L to 60,000 µg/L (representing 7% to 40% of the aqueous solubility of PCE).

These high concentrations approach the aqueous solubility of PCE, which is 150,000 µg/L (Pankow, J.F., et. al, 1996). For site characterization purposes, PCE concentrations greater than 1% of the solubility (1,500 µg/L) suggest the presence of PCE in the form of DNAPL (product) either now or in the past. Thus, data from the wells that display (or historically displayed) PCE concentrations at concentrations greater than 1,500 µg/L suggest that they are located in close proximity to a DNAPL source area. As documented in the RI Report for IA-12 (TRC, July 2013), the source investigation concluded that the DNAPL release was related to a collapsed section of the Clifton-Allwood Sanitary Sewer at the northern edge of the Roche property, just south of Route 3. This area is north and upgradient of any Roche operations. In some areas along the Valley Drain/Clifton-Allwood Sanitary Sewer utility corridor, cis-1,2-DCE is found at the highest concentrations, which is indicative of reductive dechlorination/biodegradation of PCE and/or TCE.

Clifton-Allwood Sanitary Sewer North of Route 3 (Off-Site)

Roche investigated ground water quality off-Site (north of Route 3) near the Clifton-Allwood Sanitary Sewer by installing three shallow Zone S1 wells (MW-201A, MW-202, and MW-203) and four deeper wells in close proximity to this municipal utility: one in Zone S2 (MW-201), one in Zone D1 (DW-7B), one in Zone D2 (DW-7C), and one in Zone D3 (DW-7D). The highest PCE concentrations in these off-Site wells were detected in Zone S2 MW-201 (1,410 µg/L) and in Zone D2 DW-7B (953 µg/L). The PCE concentrations detected in deeper wells DW-7C (37.9 µg/L) and DW-7D (5.6 µg/L) display a decreasing concentration gradient with increasing depth.

Based on the elevated PCE concentrations in these off-Site wells (as high as 0.9% of PCE's solubility in Zone S2) and associated breakdown products (TCE, cis-1,2-DCE, and VC), it appears that this area represents a likely second release of VOCs attributable to the impaired sewer, north of Route 3. The release(s) north of Route 3 have created a second deeper chlorinated VOC plume that appears to vertically extend from the water table down to Zone D2, and laterally commingles with the VOC plume beneath the sewer breach in IA-12 (see Figures 24 through 28).

IA-7 and Former Sanitary Sewer

In the central portion of the Site, the municipal sanitary line extends from IA-12 southward into the Site interior. In IA-7, there is a former sanitary sewer line that branches off in an easterly direction between Buildings 115 and 123 (Figure 23, in gold brown color) and then turns south towards IA-11. The highest PCE concentration (313 µg/L) found in IA-7 was detected in well MW-218 (Zone S1 well), near the former municipal sewer line (Figure 23) and located west of Building 100. Elevated concentrations of TCE (189 µg/L), cis-1,2-DCE (973 µg/L), and VC (65 µg/L) were also detected in well MW-218. The VOC distribution suggests that MW-218 is located near a point source (sanitary sewer), creating a small plume that extends into IA-11. VOC concentrations detected in wells surrounding well MW-218 are significantly lower (Zone S1 wells ranging from non-exceedance [MW-25, MW-125, and MW-195A] to 8.4 µg/L PCE and 4 µg/L TCE [MW-219] and serve to delineate the horizontal extent of this small PCE plume area. There are no Zone S2 wells in the immediate area of MW-218. There are Zone S2 wells in IA-11 located hydraulically downgradient from well MW-218, and the VOCs detected in these wells (S2 wells: MW-63 with 193 µg/L PCE and 24 µg/L TCE; MW-74 with 60.8 µg/L PCE and 2.9 µg/L TCE).

A second smaller PCE plume (inclusive of breakdown products) was detected in Zone S1 well MW-139 (4.4 µg/L PCE, 11.9 µg/L TCE, 211 µg/L cis-1,2-DCE and 4.2 µg/L VC) which is also located proximal to the former sanitary sewer line, south of Building 115. The VOC distribution in this area also suggests that there is a point source near MW-139. Below this area in Zone S2, elevated VOC concentrations (86.1 µg/L PCE, 105 µg/L TCE, 437 µg/L cis-1,2-DCE, 1.8 µg/L VC) were detected in well MW-235B (Zone S2), which is hydraulically downgradient from S1 well MW-139. There are also two S3 wells in the area of well MW-139 displaying elevated VOC concentrations, specifically wells MW-212C (147 µg/L PCE, 23.6 µg/L TCE, 1.2 µg/L VC) and MW-253C (193 µg/L PCE, 45.3 µg/L TCE, 88.2 µg/L cis-1,2-DCE).

IA-11 and Interim Remedial Measures

The ground water within IA-11 (Parking Lot 903) contains chlorinated VOCs in concentrations exceeding the GWQS in overburden and bedrock aquifers. The chlorinated VOCs in ground water mainly include PCE, TCE, cis-1,2-DCE, 1,1-DCE and VC. As shown on Figures 23, 24 and 25, the areal limits of the shallow chlorinated VOC plume in IA-11 have been defined. Along the southern boundary, the chlorinated VOC plume extends from IA-11 and IA-15 into Nichols Park in Zones S2, S3, and D1 (Figures 24 through 26); however, in Zone S1 the chlorinated VOC plume does not extend beyond St. Paul's Brook in Nichols Park (Figure 23). However, in the deeper zones (Figures 24 through 26), the chlorinated VOC plume extends beyond St. Paul's Brook and Cottage Place (residential street) and is projected to terminate before High Street. The extent of the plume will be empirically confirmed in later phases of the project.

The current water quality in IA-11 has improved over time in response to historic interim remedial measures (IRMs). On November 24, 2008, the NJDEP approved a long-term Permit-By-Rule (PBR) Discharge to Ground Water Authorization. The PBR authorization was part of a Remedial Action Workplan that included an Enhanced In-Situ Bioremediation (EISB) Injection program as an IRM to address the chlorinated VOCs in shallow ground water associated with IA-11. Accordingly, several rounds of amendment injections have been completed as listed below:

- March 2006: Round 1 Pilot Test Injection with Hydrogen Release Compound (HRC®) amendment;
- October 2009: Round 2 IRM Injection with HRC®;
- December 2010: Round 3 IRM Injection with HRC®;
- November 2011: Round 4 IRM Injection with HRC®-Advanced;
- May 2013: Round 5 IRM Injection with Electron Donor Solution- Extended Release™ and TerraSystems Incorporated Dechlorinating (TSI DC) Bioaugmentation Culture™; and
- December 2013: Target polishing injection of Emulsified Vegetable Oil near wells MW-33A/MW-33B.

Prior to 2013, all injection events targeted the bedding of the sewer pipeline or impacted overburden soils. Performance monitoring data during the period between 2006 and 2012 indicated that biodegradation of chlorinated VOCs in shallow ground water has occurred within the targeted injection areas.

Chlorinated VOC concentrations have been greatly reduced by the EISB IRM that began in 2006. Examination of the current Zone S1 chlorinated VOC map (Figure 23) shows the area centered on monitoring well MW-62 that has been remediated. Significant reductions in chlorinated VOC concentrations (PCE, TCE, cis-1,2-DCE, and VC) have been observed over the years in shallow ground water within IA-11 due to the injection program. For example, the most recent ground water sampling results collected from well MW-62 (September 2013) indicates a PCE concentration of 1.1 µg/L. This represents 99.99% removal of PCE compared to the elevated PCE concentrations of 11,900 µg/L (February 2006) detected prior to the initiation of injections. Furthermore, the total chlorinated VOC concentrations in MW-62 drastically reduced from greater than 14,000 µg/L (December 2005) to 42.7 µg/L (September 2013), which represents 99.7% removal of total chlorinated VOCs.

In Zone S1, only two wells display elevated PCE concentrations, specifically MW-219 (8.4 µg/L) and MW-21 (21.8 µg/L). However, in deeper zones of IA-11, PCE concentrations display an increasing trend in Zone S2 wells: MW-63 (193 µg/L), MW-74 (60.8 µg/L), and MW-75 (50.7 µg/L); in Zone S3 wells/ports: MW-119 (236 µg/L), and CH-17 Port 1 (609 µg/L); in Zone D1 ports: CH-17 Port 2 (76.4 µg/L), and Port 3 (155 µg/L). This trend eventually changes in the deeper zones as shown in Zone D2 Ports: CH-17 Port 5 (345 µg/L), Port 7 (100 µg/L), Port 8 (35 µg/L), and Port 9 (17.1 µg/L). These PCE concentrations (as well as other VOCs in this area indicated on Figure 23 through 25), serve to demonstrate a vertical decreasing concentration gradient, which supports the completion of delineation.

Western Border of IA-10 and Former Deluxe Check Facility

Along the western portion of the Site (Figures 23 through 27), ground water quality has been impacted by the presence of PCE, TCE, cis-1,2-DCE, and VC originating from an upgradient off-Site source, the former Deluxe Check facility (NJDEP Program Interest No. 021924). The former Deluxe Check facility has been the subject of ground water investigation and remediation since the late 1980s, and its impacts to ground water conditions on Roche property have been documented in previous Roche submissions to the NJDEP. The bulk of the chlorinated VOC contamination at the former Deluxe Check property originates from a source area on the east side of the former Deluxe Check building, where one or more buried drums with the bottom cut off were discovered, and in an area where a former subsurface waste fluid tank received solvent wastes. Chlorinated VOCs were detected at high (>1,000 µg/L) concentrations 10 years ago in shallow (Zone S1) monitoring wells on Roche property adjacent to the former Deluxe Check facility. In addition to PCE and its breakdown products, the releases at the former Deluxe Check site included 1,1,1-TCA and its breakdown products.

Historically, high chlorinated VOC concentrations have been detected in Zone S1 wells at the western edge of IA-10, near the property boundary with the former Deluxe Check facility (e.g., MW-17AW and MW-15W); the VOC concentrations in these wells have dropped to low levels (non-detection and 1.4 µg/L, respectively), in response to the remediation of the primary shallow contaminant source area (buried, open bottom drums) on the former Deluxe Check property.

However, elevated PCE concentrations (5,750 µg/L and 1,250 µg/L) were recently detected in the area of former Deluxe Check well MW-20 (Figure 23). Given the number of industries in this area west of the railroad tracks and also north of Route 3 along the tracks, and the historical pumping that occurred both on the Roche property and off-Site, other sources cannot be ruled out for the ethene and ethane suites of VOCs found in the wells today.

In IA-10 (near the border of the former Deluxe Check facility), the highest chlorinated VOC concentrations detected on-Site were in Zone S1 well MW-259A, which is in the vicinity of the loading dock of former Building 104 (near the western border of the Roche Site). As shown on Figure 23, well MW-259A displays detections of PCE (10.3 µg/L), TCE (40.2 µg/L), cis-1,2,-DCE (97.8 µg/L), and VC (2.3 µg/L), which may be related to historic activities in former Building 104. There are no wells proximal to MW-259A in the deeper zones (S2, S3, and D1 through D3). Therefore, it is likely that these two VOC plumes (the off-Site impact emanating from the former Deluxe Check property and on-Site impacts near former Building 104) commingle at depth under the Roche property.

Southern Region of IA-10

As shown on Figure 23, a broad plume area of low chlorinated VOC concentrations (less than 100 µg/L) is observed in IA-10, extending from former Building 103 southward to the intersection of Kingsland Street and Bloomfield Avenue. The chlorinated VOC plume in IA-10 extends off-Site to the former gas station at 413 Kingsland Street, across Bloomfield Avenue, and into the northern portion of Nichols Park. As shown on Figure 23, the extent of chlorinated VOCs in Zone S1 ground water has been completely delineated south of IA-10.

While some of the VOC detections occur proximal to Nutley sewer lines (e.g., 11.2 µg/L TCE in MW-205), there is a potential that this low-level contamination may be attributable to a combination of former operations at Roche, the former Deluxe Check facility, and/or a previous site owner.

IA-15 and Municipal/Roche Sewer

The Roche and municipal sewer lines traverse IA-15 from west to east. The VOC detections observed in the Zone S1, S2, and S3 wells in this IA could represent a VOC plume emanating from a municipal sewer discharge in IA-15.

In Zone S1, elevated PCE concentrations occur proximal and downgradient of these sewer lines. In this zone, the highest PCE concentrations were detected in on-Site well MW-112 (115 µg/L) and in off-Site well MW-171A (310 µg/L). The PCE concentrations detected in wells surrounding wells MW-112 and MW-171A are significantly lower (Zone S1 wells ranging from non-exceedance [MW-108A, MW-111A, MW-144A, MW-257A] to 15 µg/L [MW-130 and MW143A] and serve to delineate the horizontal extent of this small PCE plume area.

Below this area in Zone S2, elevated PCE concentrations were detected in wells MW-171B (459 µg/L) and MW-257B (114 µg/L). In Zone S3, elevated PCE concentrations were detected in well MW-171C (480 µg/L), which is proximal to the Site boundary, and off-Site on Cottage Road in well MW-216C (32.1 µg/L), and neighboring well MW-146C (43.1 µg/L). In this local area, there are no additional deep wells (in Zones D1 through D3) due to site access constraints. However, hydraulically downgradient from this area, a Zone D1 well (DW-4C) displays PCE at a concentration of 99.5 µg/L (and TCE at a concentration of 6.3 µg/L). As shown on Figures 25 through 28 there are wells within on-Site and in downgradient locations which serve to delineate the areal extent of this PCE plume in Zones S3 through D3.

4.4.4.2 Former Nova Electric - South of IA-15

A significant TCE release to ground water has been investigated and partially remediated at the former Nova facility southeast of the Roche Site. Very high TCE (20,000 µg/L in Nova's MW-5 [3/5/92]), and significant PCE (360 µg/L in Nova's MW-5 [3/5/92]) concentrations were historically detected in ground water at this facility. The Responsible Party undertook a source excavation remedy, excavating soils saturated with TCE and other chlorinated VOCs; this remediation has resulted in significant decreases in TCE and PCE concentrations in ground water (CRB Geological, et. al, 1996). The current extent of the Nova impact is depicted on the chlorinated VOC maps for Zones S1, S2 and S3 (Figures 23 through 25). There are wells with no exceedances in these zones between the Roche impacts and the former Nova property, indicating these impacts are distinct and are not commingled.

4.4.4.3 Other VOCs - On-Site

High concentrations of benzene, chloroform, methylene chloride and toluene were detected in ground water in Zones S1 (Figure 23) and S2 (Figure 24) under the former tank farm in IA-2. These high concentrations (greater than 1% of the individual solubilities) suggest the potential presence of current or historic LNAPL (product) in this area. The VOCs released to shallow ground water within the IA-2 tank farm have not migrated laterally beyond the boundaries of the tank farm. Only benzene was detected in Zone S1 wells downgradient of the tank farm, at concentrations less than 100 µg/L. The VOCs have migrated into the shallow bedrock beneath the tank farm; wells in Zone S2 under the tank farm show higher chloroform concentrations than the S1 wells above, and benzene, methylene chloride and toluene occurred in the mg/L range. Only benzene was detected in Zone S3 below the tank farm, at a concentration of approximately

670 µg/L.

Other VOCs have been detected in ground water in more limited and defined areas. Chlorobenzene was detected in a few locations, primarily in the vicinity of a former building in IA-6 (wells MW-51 and MW-161). Releases of several VOCs have occurred in the former tank farm in IA-2.

As shown on Figure 23, sporadic, low concentrations (< 50 µg/L) of benzene were detected in multiple locations across the Site (Figure 23), specifically in IA-4 (MW-177 and MW-182), IA-6 (MW-157), IA-9 (MW-166), IA-10 (187RI-MW-2), IA-11 (MW-62), and IA-12 (MW-60C, MW-60K, and MW-60H).

4.4.4.4 SVOCs

Several SVOC compounds were detected above the GWQS (Figures 30, 31, and 32) and these include bis(2-ethylhexyl) phthalate [BEHP], BaA, benzo(a)pyrene, benzo(f)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, Hbenz, pentachlorophenol, 2-methylnaphthalene, and 1,4-dioxane. While SVOCs have been detected within one or more of the hydrostratigraphic zones, the majority of the detections are found within Zone S1.

As shown on Figures 31 and 32, 1,4-dioxane is prevalent and has been detected in IA-1, IA-6, IA-10, and at off-Site locations. 1,4-Dioxane was detected in all six hydrostratigraphic zones (S1 through S3, and D1 through D3) above the GWQS at concentrations ranging from 11 µg/L (Zone D3 well DW-15C in IA-10/Parking Lot 905) to 80.2 µg/L (Zone S3 well MW-88D in IA-6). This compound was used as a solvent by Roche, and is also known to have been used as a stabilizer in 1,1,1-TCA.

Within Zone S1, 1,4-dioxane was detected in five wells ranging in concentrations from 19.3 µg/L (MW-23S in IA-1, near Building 46) to 35.8 µg/L (MW-177 in IA-1, near Building 46). One of the Zone S1 wells is located off-Site (west of IA-10) on the former Deluxe Check site, specifically MW-25W (21.8 µg/L 1,4-dioxane).

1,4-Dioxane was detected above the GWQS in two Zone S2 wells, one located on-Site in IA-6 (MW-50 at 11.1 µg/L) and one off-Site on Bloomfield Avenue (MW-103B at 14.1 µg/L).

Several Zone S3 wells, specifically in IA-6 (MW-54, MW-56, MW-77D, MW-79D, MW83D, MW-85D, MW-86D, and MW-88D), IA-10 (DW-13A, near Nutley Sewer), and off-Site (MW-

104C, near IA-11), displayed elevated 1,4-dioxane concentrations ranging from 20.9 µg/L (off-Site well MW-4C) to 80.2 µg/L (MW-88D, in IA-6).

Within Zone D1, 1,4-dioxane was detected in four wells ranging in concentrations from 22.8 µg/L (DW-16A in IA-10, near Building 106) to 77.1 µg/L (DW-14A in IA-10, near Building 103). 1,4-Dioxane was detected above the GWQS in three Zone D2 wells, one located on-Site in IA-10 (DW-14B at 43.4 µg/L) and two off-Site wells near the former Deluxe Check site (MW-27W at 21.8 µg/L and MW-26W at 26.7 µg/L). 1,4-Dioxane was also detected above the GWQS in two Zone D3 wells located in IA-10, specifically DW-15C (11 µg/L) and DW-14C (53.6 µg/L).

Polycyclic aromatic hydrocarbons (PAHs) (which are SVOCs) were primarily detected in Zone S1 wells at concentrations above their GWQS. However, some exceptions include selected Zone S3 wells MW-149 in IA-14 (5 µg/L BEHP) and MW-229C in IA-10 (8.8 µg/L BEHP); and Zone D3 wells DW-8C in IA-12 (3.2 µg/L BEHP), DW-2 in IA-12 (0.23 µg/L Hbenz), and DW-6D in IA-7 (0.195 µg/L BaA).

In addition, total SVOC tentatively identified compounds (TICs) were detected above criterion of 500 µg/L for total SVOC TICs in 22 wells (MW-20, MW-23S, MW-60C, MW-62, MW-64, MW-67, MW-80, MW-136, MW-137, MW-154, MW-156, MW-170, MW-170A, MW-182, MW-186-2, MW-213A, MW-233C, 179RI-MW1, 187RI-MW2, ART-MW1, ART-MW-4, ART-MW5) ranging in concentration from 545 µg/L (MW-60C in IA-12) to 6,421 µg/L (MW-64 in IA-6). Only one off-Site well displayed elevated SVOCs TICs, specifically MW-213A (located on Alexander Street, south of IA-10) with 3,373 µg/L SVOCs.

The BEHP detections are viewed as a sampling artifact. This phthalate is a common plasticizer found in tubing and other materials used during sampling. In general, the distribution of PAHs and SVOC TICs is sporadic and scattered and does not appear to be related to a specific AOC. These constituents are commonly found in artificial fill, and their detections in ground water coincide with areas of the Site where anthropogenic materials were used for fill.

4.4.4.5 Pesticides

Dieldrin, lindane, and chlordane have been detected in ground water above the GWQS in 4 areas: IA-6, IA-7, IA-10, and off-Site (Figure 30). Lindane is a pesticide used as a seed or soil treatment that was banned in 2006. As shown on Figure 30, lindane was detected in only one Zone S1 well (MW-159, in IA-6 parking lot) at a concentration of 0.14 µg/L. Chlordane is an insecticide that was used for termite control, lawn and garden care until 1988. As shown on

Figure 30, chlordane was detected in only one S1 well (MW-163, in IA-6, near the railroad) at a concentration of 0.62 µg/L.

Dieldrin was a primary ingredient in many pesticides, including termite treatments, from the 1950s to the mid-1970s. Dieldrin is more prevalent than other detected pesticides (IA-10, IA-6, IA-7 and off-Site) and was detected above the GWQS in nine Zone S1 wells, ranging in concentration from 0.031 µg/L [MW-30 in IA-10, Parking Lot 900] to 1.1 µg/L (MW-90 in IA-6, near the railroad line). Two of the Zone S1 wells are located off-Site on residential streets (south of IA-10), specifically MW-213B (0.15 µg/L dieldrin) and MW-214A (0.067 µg/L dieldrin).

Dieldrin was detected above the GWQS in five Zone S2 wells and one Zone S2 sampling port (from multiport assembly in former production well PW-37 in IA-7), ranging in concentration from 0.032 µg/L (MW-22A in IA-6, near railroad) to 1.7 µg/L (MW-82S in IA-6, near railroad). Two of the Zone S2 wells are located off-Site (South of Nichols Park) on residential streets, specifically MW-236B (0.07 µg/L dieldrin) and MW-105B (0.033 µg/L dieldrin).

Dieldrin was also detected above the GWQS in two Zone S3 wells located in IA-6 (near the railroad), specifically MW-85D (0.06 µg/L) and MW-88D (0.43 µg/L).

These wells displaying pesticide contamination above their respective GWQS are generally located along a street/road, a parking lot or near a railroad line (Norfolk Southern). The distribution of pesticide detections are sporadic and localized, and does not appear to be related to former Roche operations.

4.4.4.6 Metals

As shown in Tables 5-1 through 5-7, fifteen metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, iron, lead, manganese, nickel, sodium, thallium, and zinc) have been detected in the ground water at the Site at concentrations exceeding the GWQS. Figures 33, 34 and 35 provide the metal results for Zones S1, S2 and S3, respectively. Appendix R provides additional maps (R-1 through R-24) that depict the distribution of selected filtered and unfiltered metals (Al, Fe, Mn, Na) within the first three hydrostratigraphic zones (S1, S2, and S3).

Several metals were detected in Zone S1 ground water, including lead, thallium, chromium, nickel, antimony, beryllium, cadmium, cobalt, and zinc. These metals were detected in low-lying portions of the Site, in areas where historic fill was used for construction backfill.

Most of the elevated metal concentrations were only detected in unfiltered (total) samples and were not present in the filtered (dissolved) samples. The absence of these dissolved metals (with corresponding total metal samples) indicates the metals detected in the total samples are not truly dissolved in ground water and these detections actually reflect sample turbidity (e.g., metals absorbed to silt/clay particles) in the collected ground water samples[12].

However, dissolved metals, specifically aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, iron, lead, manganese, nickel, sodium, thallium, and zinc, were detected in one or more hydrostratigraphic zones beneath the Site. A number of these dissolved metals are naturally occurring and documented to be present in the ground water of this region and these include arsenic, aluminum, iron, manganese, and sodium.

Most of the remaining dissolved metals (with concentrations exceeding the GWQS) were found in Zone S1, with the exception of one sample in Zone S3 for dissolved chromium. Excluding the naturally occurring background dissolved metals (Al, As, Fe, and Mn), there are no dissolved metals exceedances in the lower three hydrostratigraphic Zones (D1, D2, and D3). Each of the aforementioned dissolved metals exceedances occur in less than 5% of the samples collected. The concentrations and frequency of detection of these dissolved metals is not indicative of a source release or contaminant plume.

The following subsections provide some additional statistical information on the metal detections.

Arsenic

According to the NJGS Information Circular – Arsenic in New Jersey Ground Water (M.E. Serfes, 2004), arsenic is a natural ground water quality constituent of the Passaic Formation (bedrock formation beneath the Site).

The GWQS for arsenic is 3 µg/L. Of the 444 samples collected, dissolved arsenic exceedances were found in Zones S1 (78 samples), S2 (6 samples), S3 (6 samples), D1 (3 samples), D2 (2 samples), and D3 (10 samples). The maximum concentration encountered for dissolved arsenic

[12] The NJDEP requires metals analysis to be performed on unfiltered ground water samples (pursuant to the requirements of the Safe Drinking Water Act and the Clean Water Act.). This interest in total metal concentrations (dissolved and particulate-associated metals) is based on a concern of the possible transport of metals adsorbed on mobile colloidal particles (e.g., Kaplan et al., 1995). Research indicates that significant colloid-facilitated transport of metals can occur only under a fairly specialized set of conditions (Roy and Dzombak, 1997). The problem with sampling groundwater without filtration is that particles from the well material, well slime coatings, or well pack may be sampled, and any subsequent analysis will not accurately reflect ground-water composition. To avoid such artifacts, but still permit sampling that can capture any mobile colloids present in the groundwater, monitoring wells are purged before sampling to remove the casing water and obtain representative ground-water samples. Low-flow purging and sampling techniques have been developed to minimize sample disturbances that may affect analysis (Puls,1994; Puls and Paul, 1995).

in Zone S1 is approximately 3 times greater than the maximum concentration of 57 µg/L found in the Passaic Formation (according to NJGS – Arsenic in New Jersey Ground Water). Approximately 87% of the arsenic exceedances were detected in the upper three hydrostratigraphic zones, most of which were in Zone S1.

The arsenic concentrations present in the ground water of the Roche facility are consistent with the natural background levels in the Passaic Formation ground water quality and are, therefore, not considered to be related to an on-Site release.

Aluminum

The GWQS for aluminum is 200 µg/L. Of the 444 samples collected, 38 had GWQS exceedances for dissolved aluminum. Of those 38 exceedances, 24 were in Zone S1, seven were in Zone S2, five were in Zone S3, and one was detected in Zones D1, D2, and D3 (each). The maximum concentration encountered for dissolved aluminum was 2,820 µg/L in MW-170A in Zone S1 (IA-9). This is approximately 100 times greater than the maximum concentration of 30 µg/L found in the Newark Basin (according to the Geological Survey Report GSR 35 by Serfes, 1994 [GSR 35]). Aluminum occurs naturally in soils and rock minerals and in ground water. Acid rain can dissolve aluminum in soils and minerals, allowing dissolved aluminum to be transported to surface water and ground water.[13]

Approximately 8% of the samples collected had GWQS exceedances for dissolved aluminum. Approximately 63% of those exceedances occurred in Zone S1, 18% in Zone S2, 13% in Zone S3, 2% in Zone D1, 2% in Zone D2, and 2% in Zone D3. 94% of the exceedances were confined to the upper three hydrostratigraphic zones, most of which were in Zone S1.

Dissolved aluminum detections in Zone S1 ground water appear to be scattered and relatively consistent in magnitude across the Site. The highest dissolved aluminum concentration (1,060 µg/L (in Zone S1) is from monitoring well MW-95 located in IA-6. Dissolved aluminum concentrations in Zone S2 and Zone S3 are widely scattered and range from non-detection to 567 µg/L (Zone S2 wells MW-68B, IA-9), and non-detection to 906 µg/L (Zone S3 well MW-77D, IA-6).

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[13] Aluminum is an abundant element in Earth's crust (from 7.5% to 8.1%). Clay minerals are aluminosilicates; other forms of aluminum in soils include insoluble aluminum hydroxide. The most abundant aluminum compounds are aluminum oxide and aluminum hydroxide, and these have low aqueous solubilities and readily precipitate**.** Aluminum forms during mineral weathering of feldspars, such as and orthoclase, anorthite, albite, micas and bauxite, and subsequently ends up in clay minerals. At pH values below 4.5, aluminum solubility rapidly increases, causing aluminum concentrations to rise above 5 ppm. Aluminum solubility may also occur at very high pH values (>10). The pH of ground water at the Site is from 6 to 7.5; in this pH range, aluminum has very low solubility. (http://www.lenntech.com/periodic/elements/al.htm#ixzz2wKxDMhiU).

Antimony

The GWQS for antimony is 6 µg/L. Of the 444 samples collected, seven had GWQS exceedances for dissolved antimony. All seven exceedances were detected in Zone S1. The maximum concentration encountered for dissolved antimony was 14.7 µg/L in an off-Site well (MW-60K), located on NJDOT property (immediately adjacent to the IA-12 boundary) in Zone S1. The median sample concentration of dissolved antimony is less than the method detection limit (MDL) of 1.6 µg/L. Approximately 1.6% of the samples collected had GWQS exceedances for dissolved antimony, with 100% of those exceedances occurring in Zone S1.

Barium

The GWQS for barium is 6,000 µg/L. Of the 444 samples collected, one had a GWQS exceedance for dissolved barium, which was in Zone S1. The maximum concentration encountered for dissolved barium was 6,480 µg/L in MW-178 in Zone S1 (IA-4). The median sample concentration of dissolved barium is 299 µg/L, which is less than the GWQS. Approximately 0.2% of the samples collected had GWQS exceedances for dissolved barium, with 100% of those exceedances occurring in Zone S1.

Cadmium

The GWQS for cadmium is 4 µg/L. Of the 444 samples collected, two had GWQS exceedances for dissolved cadmium, both of which were in Zone S1. The maximum concentration encountered for dissolved cadmium was 9.1 µg/L in MW-17 in Zone S1 (IA-9). The median sample concentration of dissolved cadmium is 0.3 µg/L, which is less than the GWQS. Approximately 0.5% of the samples collected had GWQS exceedances for dissolved cadmium, with 100% of those exceedances occurring in Zone S1.

Chromium

The GWQS for chromium is 70 µg/L. Of the 444 samples collected, one had a GWQS exceedance for dissolved chromium, which was in Zone S3. The maximum concentration encountered for dissolved chromium was 109 µg/L in MW-233C in Zone S3 (IA-12). The median sample concentration of dissolved chromium is 1.4 µg/L, which is less than the GWQS. Approximately 0.2% of the samples collected had GWQS exceedances for dissolved chromium, with 100% of those exceedances occurring in Zone S3.

Cobalt

The interim generic ground water quality criterion for cobalt is 100 µg/L. Of the 444 samples collected, three had GWQS exceedances for dissolved cobalt. All three dissolved cobalt exceedances were detected in Zone S1. The maximum concentration encountered for dissolved cobalt was 702 µg/L in MW-156 in Zone S1 (IA-6). The median sample concentration of dissolved cobalt is 0.5 µg/L, which is less than the GWQS. Approximately 0.7% of the samples collected had GWQS exceedances for dissolved cobalt, with 100% of those exceedances occurring in Zone S1.

Iron

The GWQS for iron is 300 µg/L. Of the 444 samples collected, 182 had GWQS exceedances for dissolved iron. Of those 182 exceedances, 125 were detected in Zone S1, 25 were detected in Zone S2, 13 were detected in Zone S3, 13 were detected in Zone D1, four were detected in Zone D2, and two were detected in Zone D3. The maximum concentration encountered for dissolved iron was 113,000 µg/L in MW-47 in Zone S2 (first water well in IA-14). This is approximately 10 times greater than the maximum concentration of 11,000 µg/L found in the Passaic Formation (according to GSR 35). Approximately 40% of the samples collected had GWQS exceedances for dissolved iron. Approximately 68% of the dissolved iron exceedances occurred in Zone S1, 13% in Zone S2, 7% in Zone S3, 7% in Zone D1, 2% in Zone D2, and 1% in Zone D3. 88% of the dissolved iron exceedances were detected in the upper three hydrostratigraphic zones, most of which were in Zone S1.

Dissolved iron concentrations greater than 10,000 µg/L have been reported in Zone S1 in portions of IA-10 (southern area towards Kingsland Street and in the northwest corner of the Site south of the Allstate Can Facility). Comparable concentrations (>10,000 µg/L) were reported in on- and off-Site monitoring wells collected in this area of IA-10. Additionally higher concentrations (>10,000 µg/L) were reported in the area of the guard house in IA-12 and in the NJDOT right-of-way along Route 3. Other areas of elevated iron concentrations in ground water (>10,000 µg/L) were reported in isolated monitoring wells in areas of IA-3, IA-6, and IA-11. In general, the iron concentrations on-and off-Site are comparable and the variable dissolved iron concentrations are attributable to naturally occurring, background conditions.

In reviewing the analytic data for iron in Zone S2, one monitoring well, MW-47 in IA-14, had a dissolved concentration over 100,000 µg/L. Three other monitoring wells, MW-71 (IA-11), MW-168B (IA-9) and MW-181 (IA-4) reported iron concentrations above 10,000 µg/L. The majority of the remaining monitoring wells are reported between non-detection and 1,000 µg/L.

Iron concentrations in ground water in Zone S3 range from non-detection to greater than 10,000 µg/L with the highest concentration (12,000 µg/L) being detected in monitoring well MW-117 (in IA-9).

Lead

The GWQS for lead is 5 µg/L. Of the 444 samples collected, seven had GWQS exceedances for dissolved lead. All seven lead exceedances were detected in Zone S1. The maximum concentration encountered for dissolved lead was 36.6 µg/L in ART-MW-5 in Zone S1 (IA-2). The median sample concentration of dissolved lead is less than the MDL of 2.4 µg/L. Approximately 1.6% of the samples collected had GWQS exceedances for dissolved lead, with 100% of those exceedances occurring in Zone S1.

Manganese

The GWQS for manganese is 50 µg/L. Of the 444 samples collected, 261 had GWQS exceedances for dissolved manganese. Of those 261 exceedances, 172 were in Zone S1, 43 were in Zone S2, 21 were in Zone S3, 14 were in Zone D1, six were in Zone D2, and five were in Zone D3. The maximum concentration encountered for dissolved manganese was 41,400 µg/L in MW-64 in Zone S1 (IA-11). This is approximately 25 times greater than the maximum concentration of 1,600 µg/L found in the Passaic Formation (according to GSR 35). Approximately 58% of the samples collected had GWQS exceedances for dissolved manganese. Approximately 66% of those dissolved manganese exceedances occurred in Zone S1, 16% in Zone S2, 8% in Zone S3, 5.5% in Zone D1, 2.5% in Zone D2, and 2% in Zone D3. 90% of the dissolved manganese exceedances were detected in the upper three hydrostratigraphic zones, most of which were in Zone S1.

Manganese concentrations exceeding the GWQS are evident across the site in Zone S1. Dissolved manganese concentrations in Zone S2 and Zone 3 were reported between non-detection and 21,000 µg/L (S2) and non-detection and 2,140 µg/L (S3), respectively. Based on the extensive soil and ground water RIs conducted at the Site, no significant sources of manganese in ground water was identified. In general, the manganese concentrations on-and off-Site are comparable and the variable dissolved concentrations are attributable to naturally occurring, background conditions.

Nickel

The GWQS for nickel is 100 µg/L. Of the 444 samples collected, two had GWQS exceedances for dissolved nickel, both of which were in Zone S1. The maximum concentration encountered for dissolved nickel was 137 µg/L in MW-156 in Zone S1 (IA-6). The median sample concentration of dissolved nickel is 4.5 µg/L, which is less than the GWQS. Approximately 0.5% of the samples collected had GWQS exceedances for dissolved nickel, with 100% of those exceedances occurring in Zone S1.

Sodium

The GWQS for sodium is 50,000 µg/L. Of the 444 samples collected, 343 had GWQS exceedances for dissolved sodium. Of those 343 exceedances, 218 were in Zone S1, 62 were in Zone S2, 32 were in Zone S3, seven were in Zone D1, nine were in Zone D2, and 15 were in Zone D3. The maximum concentration encountered for dissolved sodium was 6,860,000 µg/L in MW-42 in Zone S1 (IA-7). This is approximately 25 times greater than the maximum concentration of 270,000 µg/L found in the Passaic Formation (according to GSR 35). These elevated concentrations of sodium in ground water are most likely attributed to roadway de-icing practices performed at and around the Site.

Approximately 77% of the samples collected had GWQS exceedances for dissolved sodium. Approximately 64% of those exceedances occurred in Zone S1, 18% in Zone S2, 9% in Zone S3, 2% in Zone D1, 3% in Zone D2, and 4% in Zone D3. 91% of the exceedances were confined to the upper three hydrostratigraphic zones, most of which were in Zone S1.

Total and dissolved sodium in ground water detection are prevalent throughout the Zone S1 ground water. The highest concentrations detected in Zone S1 were in the IA-7(MW-42) and IA-11 (MW-64). Sodium in ground water reported in Zone S2 is wide spread across the Site with the highest concentrations (>500,000 µg/L) noted in a relatively concentrated area in monitoring wells MW-168B and MW-169B (IA-9), MW-226B (IA-2), and MW-181 (IA-4). Zone S3 sodium concentrations ranged from non-detection to 1,3000,000 µg/L in MW-79D (IA 6), and appears to flow in the direction of ground water in this zone.

Thallium

The GWQS for thallium is 2 µg/L. Of the 444 samples collected, 9 had GWQS exceedances for dissolved thallium. Of those 9 exceedances for dissolved thallium, 7 were in Zone S1 and two were in Zone S2. The maximum concentration encountered for dissolved thallium was 13.6 µg/L MW-160 in ART-MW-5 in Zone S1 (IA-2). The median sample concentration of dissolved thallium is less than the MDL of 1.3 µg/L. Approximately 2% of the samples collected had GWQS exceedances for dissolved thallium, with 78% of those exceedances occurring in Zone S1 and 22% of those exceedances occurring in Zone S2.

Zinc

The GWQS for zinc is 2,000 µg/L. Of the 444 samples collected, one had a GWQS exceedance for dissolved zinc, which was in Zone S1. The maximum concentration encountered for dissolved zinc was 3,640 µg/L in MW-137 in Zone S1 (IA-2). The median sample concentration of dissolved zinc is 6.3 µg/L, which is less than the GWQS. Approximately 0.2% of the samples collected had GWQS exceedances for dissolved zinc, with 100% of those exceedances occurring in Zone S1.

4.4.5 ***Vertical Delineation of Ground Water Contamination***

4.4.5.1 VOCs

The vertical migration of VOCs is more wide-spread than the other chemical constituents (SVOCs, pesticides, and metals), which are generally limited to the shallow zones (S1, S2, and S3). The downward vertical extent of chlorinated VOC exceedances are depicted on maps for six hydrostratigraphic zones (Figures 23 through 29).

Figures 36 through 40 provide cross-sections that depict contaminant distribution in the vertical plane. The total VOC concentration (summation of PCE, TCE, cis-1,2-DCE, and VC) at each well sampling interval has been contoured on the cross-sections. Examination of these two sets of figures (plan view maps and cross-sections) provides insight into the vertical distribution of chlorinated VOCs. Based on the findings presented in the earlier sections and the graphic attachments, the ground water COCs have been delineated vertically.

The downward migration of dissolved VOCs from Zone S1 to Zones S2 and S3 appears to have been influenced by the strong downward vertical hydraulic gradients in portions of the Site. The vertical ground water flow nets shown on Figures 15 through 19 indicate a pronounced downward component to ground water flow throughout the studied flow regime (with the possible exception of upward flow from Zone D3 to Zone D2 in some areas), and the steepest vertical gradients occur in the uppermost 60 to 80 feet of the saturated zone (land surface to approximate sea level). Chlorinated VOC impacts appear to have migrated more downward than laterally in Zones S1 and S2, in particular along the central axis of the Site down the middle of the property. The impacts associated with the discrete release in the IA-9 pipe corridor do not appear to have migrated vertically and seem confined to the backfill within that corridor.

The highest chlorinated VOC concentrations in Zones D1 and D2 have been detected upgradient of the Site (+/- 1,000 µg/L total VOC concentration). Wells DW-7B and DW-7C had higher chlorinated VOC concentrations than any Zone D1 and D2 wells located downgradient along the central axis of the Site. In addition, the multiport well MW-20 at the former Deluxe Check facility had higher PCE and 1,1,1-TCA concentrations than any wells in the corresponding Zone D1 and D2 wells in IA-10 on the Site. In IA-12 (near the Clifton-Allwood Sanitary Sewer), the chlorinated VOC concentrations display a decreasing gradient with increasing depth, from Zone S2 to Zones S3 and D1. However, within Zone D2 in IA-12, the VOC concentrations are notably higher than the overlying zones (S2, S3, and D1). This suggests that the chlorinated VOC plume observed on-Site in Zone D2 originates upgradient of and migrates under the Site.

The vertical hydraulic gradient is gentler in Zones D1 and D2, where the hydraulic conductivity is relatively high, particularly in the eastern portion of the property. The chlorinated VOC impacts have spread over larger areas in Zones S3, D1, and D2 due to the high hydraulic conductivity of these zones under the Site.

Chlorinated VOC concentrations in Zone D3 are diminished in comparison to the overlying zones; only one well showed total chlorinated VOCs above 100 µg/L. The downward migration of chlorinated VOCs below an elevation of 400 feet below msl is apparently impeded by the diminishing number of water-bearing fractures and bulk hydraulic conductivity of the bedrock at these depths. Three deeper wells were installed into Zone D4. Two of the three deepest wells, DW-20D (560 feet deep) and DW-22D (670 feet deep), showed chlorinated VOC concentrations less than 10 µg/L, and no individual VOC constituent at a concentration above 5 µg/L. The vertical extent of the chlorinated VOC plume has therefore been approximately delineated in the vicinity of an elevation of 500 to 600 feet below msl.

In the former tank farm in IA-2, the very high concentrations of benzene, methylene chloride, chloroform, and toluene have not migrated downward below Zone S2. Of these COCs, the only VOC that migrated downward into Zone S3 is benzene, at a concentration several orders of magnitude below what was detected in shallower zones.

In IA-6, chlorobenzene concentrations are elevated (> 100 µg/L) in some Zone S1 wells. However, these concentrations are lower and less prevalent in Zones S2 and S3. In Zone S3, only one IA-6 well displayed 57 µg/L of chlorobenzene, which demonstrates a decreasing concentration gradient in this area.

4.4.6 *Areal Delineation of Ground Water Contamination*

4.4.6.1 VOCs

The horizontal migration of VOCs is more wide-spread than the other chemical constituents (SVOCs, pesticides, and metals), which are generally limited to within or proximal to the Site boundaries. The extent of chlorinated VOCs in each zone is shown on Figures 23 through 29.

Based on the findings presented in the earlier sections and the graphic attachments, the ground water COCs have been delineated areally.

As shown on Figure 23, the downgradient extent of the chlorinated VOC plume is delineated in Zone S1. Chlorinated VOC exceedances have been detected off-Site on the former gas station property (413 Kingsland Street) south of IA-10 and in Nichols Park (MW-106A and MW-171A), south of IA-11 and IA-15. St. Paul's Brook forms a hydrologic discharge boundary, preventing the Zone S1 VOC plume from migrating beyond the brook (in that zone).

In Zones S2 and S3, the chlorinated VOC plume extends further downgradient (vertically and areally) into the residential area south of IA-11, IA-15, and the southeast corner of IA-10. The chlorinated VOC plume in Zone S3 is more widely spread under the eastern portion of Roche property.

The higher concentration chlorinated VOC plume has spread through a band of high permeability bedrock under the eastern portion of the facility in Zones D1 and D2. The off-Site well cluster on Colonial Terrace (MW-258B, MW-258C, and DW-24), near Hawthorne Avenue, provides delineation of the VOC plumes in Zones S2, S3, D1, and D2 downgradient of the Roche property (Figures 24 through 27).

The eastward migration of the chlorinated VOC plume appears to have been retarded by the lower permeability of the bedrock to the east and southeast of the facility.

4.4.7 *Influence of Background Soil Conditions on Ground Water Quality*

Based on an examination of the ground water quality across the Site, it is clear that many of the contaminants detected in soil (metals, PAHs, and pesticides) have not significantly impacted the ground water quality at the Site due to the low solubilities of these chemical compounds. From a Site-wide perspective, there are certainly localized detections of these compounds at concentrations exceeding the GWQS. However, since the concentrations of these compounds are not sufficiently high to generate expansive contaminant plumes[14], it has been concluded that these localized, soil-related exceedances are associated with either natural background conditions (e.g., aluminum, iron, manganese, arsenic), the presence of artificial fill (e.g., SVOCs and other metals) or off-Site sources (pesticides along the railroad right of way and on residential properties) that are unrelated to any of the discharges investigated during this RI.

[14] The fate and transport of metals in ground water depends on the chemical form and speciation of the metal (Allen et al., 1991). The mobility of metals in ground water systems is hindered by reactions that cause metals to adsorb or precipitate, or chemistry that tends to keep metals associated with the solid phase and prevent them from dissolving. These mechanisms can retard the movement of metals and also provide a long-term source of metal contaminants (NRC, 1994).

4.4.8 ***Sources of Chlorinated VOC Contamination in Ground Water***

The RI results provide sufficient data to evaluate the sources of the ground water contamination found under the Roche Site. There is evidence that releases on the Roche property have impacted ground water quality in specific areas. In some of these localized areas, there remains significant contaminant mass sorbed to soils in the saturated zone, warranting remedial action.

The primary contaminants detected in ground water are VOCs. The most widespread are chlorinated VOCs, specifically PCE, TCE, cis-1,2-DCE, and VC, and to a lesser extent 1,1-DCE, 1,1,1-TCA, and 1,1-DCA. While the distribution of VOCs was discussed in earlier sections, the following provides a summary of VOC sources identified at the Site.

4.4.8.1 Clifton-Allwood Sanitary Sewer

The primary sources of chlorinated VOCs in on-Site ground water have been related to releases from the Clifton-Allwood Sanitary Sewer, not associated with Roche, and possibly other waste lines. Significant releases have occurred north of Route 3 (upgradient of the Roche property) and in the vicinity of the Roche guard shack in IA-12. These elevated PCE concentrations suggest that PCE was discharged from the Clifton-Allwood Sanitary Sewer as DNAPL in at least two locations, one north of the Roche property and the other on the northern edge of the Roche property.

Releases from the Clifton-Allwood Sanitary Sewer have likely also occurred further south within the Roche property. The data indicate two localized releases from the former location of this sewer in IA-7 (it was rerouted when Building 123 was constructed) and in IA-11. Additional releases have occurred in IA-15 from the Clifton-Allwood Sanitary Sewer and possibly from other process and waste lines that transect this area.

Examination of the Zone S1 map indicates that in addition to releases attributable to the current Clifton-Allwood Sanitary Sewer alignment in IA-3, IA-7, and IA-11, and to the former alignment of this sewer further east (under existing Building 123), some of the impact may also reflect some contribution from Roche process lines aligned parallel to the sewers. The Zone S1 VOC impacts are not continuous along this corridor, indicating that the backfill around these utilities is not acting as a conduit facilitating continuous migration from releases that have been documented north of Route 3 and in IA-12.

Roche contracted Paulus, Sokolowski, and Sartor (PS&S) to conduct television surveys of the Clifton-Allwood and Nutley Sanitary Sewers where they transect Roche property. These studies are provided in Appendix S. These surveys showed evidence of numerous breaches in the integrity of these pipes, some of them significant. Some of the observed high chlorinated VOC concentrations in Zone S1 (e.g., MW-60 and MW-80) correlate closely with observed breaches in the sewers.

4.4.8.2 IA-9 Process Piping

Releases of PCE appear to have occurred through breaches in a process pipe in IA-9. The elevated concentrations of PCE in soil and ground water in this localized area along the process pipeline suggest the release of DNAPL (PCE); the high proportion of PCE degradation products in the sampling results indicates the release occurred in the past.

4.4.8.3 IA-10 - Building 104 and Building 70

There is a broad area of low-level (less than 100 µg/L) PCE contamination in IA-10, with a possible "hot spot" in the vicinity of former Building 104. The source of this broad, low-level PCE contamination in Zones S1 and S2 may emanate from the former Deluxe Check facility west of IA-10 (and/or represent an on-Site commingled plume area). In the deep ground water, the contaminant suite demonstrates the impact derives from a source west of IA-10, possibly from the former Deluxe Check site, although other properties west and northwest of IA-10 could also be contributing to the observed impacts.

In the southeast corner of IA-10, the total chlorinated VOC plume in Zones S1, S2, and S3 (Figures 23, 24, and 25) is characterized by a higher proportion of TCE relative to PCE than elsewhere on the Roche property. This area of high TCE:PCE ratio begins in the vicinity of the Building 70 and extends onto the former gas station (413 Kingsland Street) and into the northwest corner of Nichols Park. The higher TCE:PCE ratio persists vertically in this area downward into Zone D3 (Figures 25 through 28). This high TCE portion of the total chlorinated VOC plume may be indicative of a separate source of ground water impact, perhaps associated with Building 70 and/or the Nutley municipal sewer (that extends south of Building 70). It should be noted that the IA-10 RI did not identify a source of TCE associated with any AOC in IA-10.

4.4.8.4 IA-6 - Chlorobenzene

Other VOCs have been detected in ground water in discrete areas with small footprints. Chlorobenzene has been detected in IA-6; the original source of this contaminant has not been determined, but may be associated with the use of chlorobenzene inside a former (now demolished) building in IA-6. Chlorobenzene has been detected in ground water samples collected from the S1, S2, and S3 Zones in this area. It should be noted that chlorobenzene has also been detected in wells proximal to the Clifton-Allwood Sanitary Sewer (north of Route 3 and along the former sewer alignment in IA-7).

4.4.8.5 IA-2 Tank Farm

Significant releases of several VOCs occurred in the former tank farm in IA-2. Benzene, chloroform, and methylene chloride (and to a lesser extent toluene) have all been detected in shallow ground water in this former tank farm at very high concentrations.

4.4.8.6 Benzene-Toluene in IA-9, IA-4, and IA-12

Benzene and toluene are associated with the chlorinated VOC release in the process pipeway in IA-9. There is benzene in ground water in the western part of IA-4; the source of this benzene is not known. The low level benzene detections along the northern edge of IA-12 are probably related to surface runoff of gasoline contamination from Route 3 entering the storm sewer system near the northern guard house.

4.4.8.7 1,4-Dioxane

There are a few discrete areas where 1,4-dioxane has been detected in the ground water. This compound was used by Roche as a solvent in certain manufacture processes; it has also been used commercially as a stabilizer for 1,1,1,-TCA. 1,4-Dioxane detections in the shallow zones (Zones S1, S2, and S3) can be attributable to former building operations (that may have used 1,4-dioxane as a solvent). However, detections of 1,4-dioxane in deep zones appear in association with 1,1,1-TCA and its breakdown products (primarily in IA-10) may be related to off-Site sources (e.g., the former Deluxe Check facility).

There is also evidence that ground water contaminated with chlorinated VOCs is migrating onto the Site from other contaminant sources west and north (and possibly northwest) of the Site. These will also be described below.

4.4.8.8 Former Deluxe Check Facility and other Potential Sources West and Northwest of Roche

There is compelling evidence of migration of chlorinated VOCs onto the Site from the west and northwest. As discussed earlier, chlorinated VOCs migrated from the former Deluxe Check facility onto the Site in Zones S1, S2, and S3 (beneath IA-10). VOC concentrations in Zone S1 wells in the west-northwestern portion of IA-10 have declined since the remediation of the primary source area at the former Deluxe Check property.

Figures 41 through 46 depict the ratios of VOCs (in a pie chart format) detected in the September 2013 ground water samples in Zones S1 through D3. As shown on Figures 44 through 46 (depicting VOC ratios for Zones D1 through D3), the COCs detected in deep ground water under IA-10 are very different from the COCs detected under the rest of the Site. The predominance of 1,1,1-TCA and its breakdown products under IA-10 indicates that this ground water impact has a different source, flowing onto IA-10 from the northwest or west. 1,1,1-TCA was historically detected in shallow ground water on the former Deluxe Check facility, and was found in its source area along with PCE. The absence of this suite of chlorinated VOCs in the shallow ground water under the Site is strong evidence that the 1,1,1-TCA and associated breakdown products originated on other properties west and possibly northwest of Roche.

The chlorinated ethenes (PCE and its breakdown products) and methyl tert butyl ether (MTBE) also appear to be present at relatively lower levels in Zones D1 through D3 under IA-10 as a result of plume migration from the former Deluxe Check facility or potentially from other off-Site sources. As shown on Figure 37 (hydrostratigraphic cross-section B-B'), the PCE (and associated breakdown products) released in the shallow former Deluxe Check source area may have migrated vertically as deep as Zone D2 on the former Deluxe Check property. Examination of this figure suggests that the impact seen under IA-10 may be due to plume migration from the former Deluxe Check facility. In accordance with Deep Bedrock RIWP Supplement 2, Roche will continue to implement additional investigative work on the western and northern boundaries of IA-10, and in the interior of IA-10. These additional investigations will provide more definition of the commingled plumes under IA-10. Roche anticipates providing a progress report to the NJDEP on the additional perimeter work and quarterly monitoring in the second half of 2014 (or later).

4.5 <u>Receptor Evaluation</u>

In February 2011, Roche submitted an updated receptor evaluation (including the RE form) for the Roche Nutley facility. Updates to the RE are required with certain remedial phase reports (e.g., with the RIR). The following sections include updated RE information applicable to the Site-Wide Ground Water RI.

4.5.1 *Receptor Evaluation - Land Use*

The Site is located in residential and commercial areas of Nutley and Clifton, New Jersey. Residences border the property to the east and south. The land use/land cover map, the landscape project map, and the state and federal wetlands map from the NJDEP's GIS database are included as Figures 2, 3, and 6, respectively. The Clifton sanitary and storm sewer system enters the Site at the Route 3 entrance, traversing the Site from north to south, eventually becoming parallel with St. Paul's Brook. A recreational park (Nichols Park) lies within 200 feet of the Site boundary to the south. There are no schools and one child care center (a Roche-owned and formerly operated facility) within 200 feet of the Site boundary.

4.5.2 *Receptor Evaluation - Ground Water*

Due to the presence of ground water impacts at the Roche Site, a well search is required pursuant to N.J.A.C. 7:26E-1.14. An initial well search was completed in 2001, and was updated in 2009. In accordance with NJDEP requirements, a 1-mile radius well record search and a 5-mile radius search of high-capacity wells was conducted using the NJDEP Bureau of Water Allocation (BWA) well record database to identify potentially active wells in the area surrounding the Site. The results of NJDEP well records database search were tabulated and mapped to summarize the records search findings. The NJDEP requested that an additional well search update be completed in conjunction with the ongoing Site-wide RI. Therefore, an updated well search was submitted to the NJDEP on April 26, 2013, as part of the RI program.

The well search (1-mile and 5-mile radius from the Site) was conducted using the NJDEP BWA well record database to identify potential active wells in the area surrounding the Site. In addition, an inquiry was made with the Nutley and Clifton Health Departments to obtain any existing local or county records of wells in the vicinity of the Site.

Appendix T provides a copy of the updated well search that was previously submitted to the NJDEP (April 2013). Based on the findings of the April 2013 well search, there are one non-public well, two public non-community wells, 16 domestic wells, four irrigation wells, and 14 industrial wells within 1 mile of the Site. The well record documentation provided by the NJDEP BWA is provided in Appendix U.

Throughout the ground water investigation process, Roche has continued to update the well search. New information has been obtained since the April 2013 submission. An updated well search submission is being prepared and will be submitted to the NJDEP as part of a forthcoming Site-wide Receptor Evaluation Report update.

In 2013, TRC and Roche collected water samples from one active potable well (4 Hawthorne Avenue, Nutley Township) and obtained recent analytical results from the owner of another active potable well (30 Alexander Avenue, Nutley Township) identified in the vicinity of the Roche Site. The laboratory results were previously provided to the NJDEP, the Nutley Health Department, and the owner of the 4 Hawthorne Avenue well. The laboratory results for these potable well samples indicated an absence of any Site-related contaminants in the water sample collected at the 4 Hawthorne Avenue property or in the laboratory data package provided by the

30 Alexander Avenue property owner. TRC and Roche met with Nutley Township officials to provide recommendations to abandon these wells and have the residents connected to public water supply system.

4.5.3 *Receptor Evaluation - Vapor Intrusion*

The objective of the vapor intrusion (VI) evaluation and investigation is to determine whether vapors from materials discharged to the environment are migrating into nearby occupied or potentially occupied structures, both on Roche property and in off-Site areas in the direction of plume migration, in accordance with the NJDEP's March 2013 Vapor Intrusion Technical Guidance (VITG) and required by TRSR N.J.A.C. 7:26E-1.15. Roche has been evaluating the VI exposure pathway since 2012 in accordance the TRSR and the VITG. Investigation of potential VI receptors is ongoing. Criteria driving the evaluation include:

- Whether an occupied or potentially occupied structure lies within 30 feet of petroleum VOCs and 100 feet for all other VOCs;
- Whether shallow ground water contains VOCs concentrations greater than the NJDEP's VI Ground Water Screening levels[15] [GWSLs];
- VOC contaminated soil in the unsaturated zone;
- The presence of LNAPL; and
- The proximity of buildings not otherwise included in the evaluation to buildings with confirmed VI pathways.

An evaluation of Site-wide shallow ground water data has been performed to identify investigation triggers; new ground water analytical results are continually evaluated by TRC as they are reported by the laboratory to determine if additional investigation is warranted. Based on the results of ground water sampling conducted through the third quarter of 2013, all potential receptors within the NJDEP-required VI investigation distance criteria have been evaluated. In accordance with the TRSR, Roche has been providing the analytical results with an explanation of findings to the NJDEP Case Manager, the owners and occupants of off-Site buildings (that have been sampled as part of this investigation), and the local health departments as the investigation has progressed. The analytical results from VI sampling conducted since January 2013 has additionally been provided to the New Jersey Department of Health. A total of 33 on-Site and 19 off-Site buildings have been evaluated due to their proximity to potential VI sources. Of the on-Site buildings that have been evaluated, 23 were sampled, eight do not require sampling due to their construction, personnel access restrictions (i.e., building is a confined space requiring supplied air of respirator use), or future-use considerations (i.e., the

[15] Per the NJDEP's March 2013 *Master Table – Generic Vapor Intrusion Screening Levels.*

building is scheduled for demolition in the next few months). The need to sample is being evaluated for the two remaining buildings. For off-Site buildings, 16 have been sampled, two require initial sampling (residences are currently unoccupied), and access was denied by the owner/occupant of one residence.

Only one building (on-Site utility tunnel known as Building 8) has a confirmed vapor concern condition; additional evaluation of this building is ongoing. The VI pathway for all other buildings sampled is incomplete and, as a result, either does not require additional confirmatory investigation or additional monitoring is proposed.

A comprehensive summary of the VI evaluation will be provided in a forthcoming Receptor Evaluation Report. This report will document the investigation efforts completed to date and provide details about VI investigation results.

4.5.4 *Receptor Evaluation - Ecological*

According to the NJDEP's TRSR, an Ecological Evaluation includes an assessment of (1) ecologically sensitive natural resources on, adjacent to, or in the influence of the subject site; (2) contaminants of ecological concern present on-Site; and (3) the presence of migration pathways from areas of contamination to adjacent sensitive areas.

Per the TRSR, Environmentally Sensitive Natural Resources (ESNRs) include environmentally sensitive areas such as wetlands, surface water, and other environmentally sensitive areas identified in NJDEP's Discharges of Petroleum & Other Hazardous Substances Regulations (N.J.A.C. 7:1E-1.8). To identify ESNRs, TRC is reviewing threatened and endangered species database search information for the Site and surrounding area provided by the New Jersey Natural Heritage Program. In addition, the NJDEP's GIS database resources are being reviewed (including land use/land cover maps, federal and state wetland maps, and landscape project maps), and a Site-wide inspection has been conducted to identify ESNRs present on or adjacent to the Site. The results of the Ecological Evaluation will be documented and submitted to NJDEP in a separate, Site-wide ecological report.

5.0 CLASSIFICATION EXCEPTION AREA

In accordance with the NJDEP Compliance Attainment Guidance (2012), once ground water delineation is complete, a Classification Exception Area (CEA) is required to be established pursuant to N.J.A.C. 7:26E-4.9(a)7 and N.J.A.C. 7:26C-7.3 for all ground water impacted by contamination originating from the site.

CEAs are established in order to provide notice that the constituent standards for a given aquifer classification are not or will not be met in a localized area due to natural water quality or anthropogenic influences, and that designated aquifer uses are suspended in the affected area for the term of the CEA. The intent of this action is to ensure that the uses of the aquifer are restricted until standards are achieved.

The NJDEP establishes the CEA based on their review of site-specific hydrogeologic support documentation. Appendix V provides supporting documentation (maps defining extent of contamination and CEA boundaries and work sheets to calculate CEA duration) required to allow the NJDEP to establish the CEA for Site ground water.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Since the early 1990s, Roche has completed a series of investigative activities designed to characterize the ground water flow and quality conditions on- and off-Site, identify sensitive receptors and to evaluate potential sources of environmental impact. The investigation activities completed included: file research and review, well search and survey, geologic mapping survey, geophysical surveys (surface, borehole), packer testing and sampling, monitoring well installation, periodic and continuous hydraulic gauging, aquifer testing and multiple ground water sampling events.

Through the completion of these activities, Roche has gained an understanding of the structural framework of the bedrock and in defining the areal and vertical extent of the ground water contamination within the bedrock. Contaminant transport is governed by zones of intense fracturing with a high degree of interconnectivity where the dominant orientation of interconnected bedrock fractures dictates the primary flow paths.

The ground water contamination within the overburden and bedrock aquifer zones has been delineated areally and vertically on- and off-Site. In addition, through the installation of temporary and permanent monitoring wells in the overburden and shallow bedrock aquifer zones within source areas, greater resolution of contaminant distribution and the extent of source impacts has been achieved. At this time, the COC delineation is sufficient to complete the ground water RI.

The following sections provide conclusions regarding the conceptual hydrogeologic model, the nature and extent of ground water contamination, recommendations on the status of the ground water RI, and proposals for future/planned activities to support remedial design efforts.

6.1 Conclusions

1) **Lithology:** Over 440 boreholes and monitoring wells were installed within the overburden and bedrock across the Site to assess ground water flow and quality conditions at the Site. The overburden consists of artificial fill and glacial deposits from the ground surface and up to 30 feet bgs. Beneath the overburden, the Site is underlain by weathered and competent reddish-brown sandstone and siltstone of the Passaic Formation.

2) **Geologic Structure:** The Site lies within the Newark Basin. Based on borehole geophysical logging observations across the site, most of the bedrock fractures are oriented northeast to southwest and are cross-cut by a subordinate, north-northwest to

south-southeast trending fracture system. Vertical fractures are numerous and extensive in some parts of the Site, and interconnect the low-angle bedding plane fractures in these areas. The greatest frequency of fractures is found in the central and southwestern portions of the Site within the shallow, intermediate and deep bedrock. This intense fracture system is associated with a documented regional fault system. The local and regional system of fractures and faults constitute the structural framework affecting local and regional ground water flow.

3) **Ground Water Occurrence:** Ground water is present in the overburden and fractured bedrock and is typically found within 15 feet of the ground surface.

4) **Hydrostratigraphic Model:** Initially, the generic conceptual site model for bedrock in the Newark Basin (LMAS) was employed, but based on Site evidence (high frequency of fractures, fracture interconnectivity) the site model was modified with the establishment of seven, elevation-based hydrostratigraphic zones (S1 through S3 and D1 through D4) that extend from the ground surface to greater than 700 feet bgs. These zones correlate with the elevation of the constructed monitoring well screen intervals throughout the Site network.

5) **Ground Water Flow:** Ground water in the shallowest zone (Zone S1) flows from the northern portion of the Site to the south and southeast with localized flow to/from surface water features such as streams. There is a significant downward vertical flow component from Zone S1 to the deeper intervals (Zones S2 and S3) throughout much of the Site where there is significant vertical fracturing, with the exception of largely lateral flow in the near surface intervals. Ground water in Zones D1, D2 and D3 flows from the northwest to the southeast.

6) **Local Pumping Influences:** Hydraulic gauging studies have shown that there is currently no significant influence (e.g., gradient reversal) on the ground water flow regime from locally active supply wells.

7) **Ground Water Constituents of Concern:** Ground water sampling results confirm the presence of VOCs (PCE, TCE, cis-1,2-DCE, VC, benzene, chlorobenzene, and 1,4-dioxane) SVOCs, pesticides and metals contamination in the shallow ground water across the Site. VOC contamination (and some metal contamination) is present in the deeper ground water zones but is largely attributed to upgradient off-Site sources or background conditions.

8) **Contaminant Plume Delineation:** Through the installation of an extensive network of on- and off-Site monitoring wells (S1 to S3 and D1 to D4), the vertical and horizontal extent of ground water contamination (VOCs, SVOCs, pesticides, and metals) has been delineated at on- and off-Site locations.

9) **On-Site Sources of Ground Water Contamination:** Based on the sampling results, the following on-Site sources have been identified:

- Former Roche Operations: **IA-9-Bldg 73 Piping Corridor (Chlorinated VOCs, Benzene, Toluene)**;
- Former Roche Operations: **IA-2-Tank Farm (Benzene, Chloroform, Methylene Chloride)**;
- Former Roche Operation: IA-6-Former Building Sump (Chlorobenzene, 1,4-Dioxane);
- Former Roche Operations: IA-10-Former Building 104 Loading Dock/Building 70 (Chlorinated VOCs);
- Former Roche Operations: Utility Corridor in IA-7, IA-3, IA-11 and IA-15 (Chlorinated VOCs);
- Former Roche Operations: Historic Fill (SVOC, Metals, Pesticides);
- Former Roche Operations: non-point source release (Na);
- *Non-Roche Source*: Releases from Clifton Sanitary Sewer thru IA-12 (Chlorinated VOCs);
- *Non-Roche Source*: Release(s) from Nutley Sanitary Sewer thru IA-10/South of Building 70 (Chlorinated VOCs);
- *Non-Roche Source:* historic fill placed prior to Roche ownership (SVOCs, metals); and
- *Non-Roche Source*: Native Soil (naturally occurring Al, As, Fe, Mn, etc.).

The sampling results from on-Site monitoring wells indicate that the most significant on-Site sources (displaying the highest VOC contamination attributed to former Roche operations) were discharged in IA-9 and IA-2 (in bold above), both of which are limited in their horizontal and vertical extent.

10) **Off-Site Sources of Ground Water Contamination:** Based on the sampling results, the following off-Site sources have been identified:

- **Clifton Sanitary Sewer north of Route 3 (Chlorinated VOCs)**;
- **Former Deluxe Check site (VOCs)**;
- Sunoco Service Station (VOCs, LNAPL);

- Other industrial sites/potential sources north and west of Site (VOCs);
- Former Nova Electric site, south of Site (Chlorinated VOCs);
- Neighboring properties (dieldrin spraying by others); and
- Native Soil (naturally occurring Al, As, Fe, Mg, etc.).

The sampling results from off-Site monitoring wells indicate that the most significant off-Site source (displaying the highest VOC contamination) were discharged north of Route 3 and at the former Deluxe Check facility (in bold above). PCE has been discharged from compromised sections of the municipal sanitary sewer (off-Site and on-Site) which is north of and traverses the Roche Site. The localized release areas display PCE degradation products (TCE, cis-1,2-DCE, VC) and deep vertical plume penetration (from Zone S2 to D2 [50 feet above msl to 250 feet below msl]).

6.2 Ground Water Remedial Investigation – Completion Status

Based on the information presented in this GWRIR, it is concluded that the Site-wide ground water RI complies with the TRSR and applicable technical guidance, and as such, has met the regulatory requirements for the completion of the ground water RI.

Therefore, the ground water RI is deemed complete (for the purposes of achieving the May 7, 2014 SRRA deadline) and is sufficient to facilitate the selection of remedial alternatives and support future remedial design.

In some boundary areas, delineation of specific ground water contaminants has been inferred using data extrapolation of defined contaminant concentration gradients. As required by the NJDEP Compliance Attainment Guidance (i.e., constituent delineation to less than GWQS), it is recognized that a response action outcome (RAO) cannot be issued until the ground water contamination has been fully delineated in these areas/locations.

6.3 Recommendations

Consistent with the approach defined in the approved Remediation Road Map, multiple remediation activities are in progress, designed to further characterize Site conditions for remedial design purposes and facilitate and expedite the implementation of remedial actions to address identified Site contamination. We recommend the continuation and/or implementation of the following list of activities related to ground water.

- **Quarterly Ground Water Sampling Program –** A comprehensive ground water sampling event was conducted in September/October 2013 and presented in this

GWRIR. A second sampling event was conducted in December 2013. These events are part of a quarterly sampling program that will be continued into the future. The object of this program is to monitor and document ground water quality and ground water flow conditions across the Site over time. Data collected from these sampling events may be used to assist future remedial action decisions and may provide evidence and documentation to support a monitored natural attenuation (MNA) proposal for portions of the chlorinated VOC plume.

- **Background Water Quality Investigation –** The work proposed in the approved October 2013 Bedrock Ground Water RI Workplan Supplement 2 is ongoing and will be completed before the 2nd quarter of 2014. The results of this program will characterize the ground water quality and flow along the northern and northwestern boundaries within multiple hydrostratigraphic zones. The findings of this program will not alter the information presented in this RIR but will refine and further characterize the contamination originating from off-Site sources. In addition, these findings may be employed to guide the scope of future pre-design remedial characterization activities and will support the final remedy selection process.

- **Aquifer Testing -** A series of short-term aquifer tests were undertaken in November and December 2013 to quantify aquifer coefficients for shallow ground water zones. The findings of this aquifer testing will not alter the information presented in this RIR but will refine and further characterize the conditions in specific regions of the Site and be used to guide and support future remedial action decisions.

- **Pre-Design Investigations (PDIs) –** This RIR has documented multiple areas of ground water contamination. Pursuant to N.J.A.C. 7:26E-1.10, Roche plans to implement Pre-Design Investigation (PDI) Workplans (including environmental sample collection, bench-scale and pilot-scale test activities) to collect supplemental data and information required to design the appropriate Site remedy/remedies. The scope and duration of each remedial action or interim remedial measure (IRM) will be defined in IA/AOC-specific work plans (reviewed/approved by LSRPs) and regulatory permits will be acquired prior to full-scale implementation. It is anticipated that these work plans will include a description of the remedial technology, identification of regulatory permits and details on the infrastructure required to implement these programs. Proposals for baseline and long-term ground water sampling will be defined to document initial and post-remediation conditions.

- **Annual Ground Water Progress Report –** The aforementioned activities as they relate specifically to ground water remediation (and in support of the RI Report) will be documented in a future annual progress report. It is anticipated that the report will be submitted to the NJDEP in the late summer or fall of 2014.

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