

The Use of Dredge Materials
in Abandoned Mine Reclamation

Final Report on the Bark Camp Demonstration Project

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1. FORWARD

It is worth noting from the outset that abandoned coal mines have historically been the target of numerous ill-conceived disposal schemes, including the proposed dumping of unconsolidated garbage and sewage sludge. This, along with the historic acrimony between coal mining communities and mine owners has left a residue of ill feeling and suspicion around any alternate use of former mines. The existing environmental problems of abandoned mines are sometimes actually less offensive to many people than solutions that scare them. Nonetheless, if the environment can truly be healed from serious past damages in a way that benefits everyone, without passing concerns on to future generations, then such ideas warrant further scientific examination.

Abandoned mines kill people every year, creating falling, drowning and asphyxiation hazards. Mine voids collapse under towns and homes, divert streams and groundwater and acidify thousands of miles of waterways. They are the number one cause of water pollution in many states. Surface mines despoil hundreds of thousands of acres while underground mine fires can burn for decades. The reclamation of Abandoned Mine Lands nationally will require billions of tons of fill.

At the same time, environmental regulations seeking cleaner air and water are redirecting millions of tons of bulk materials to the land. Cleaner-burning coal for power generation means adding tons of lime during combustion, and collecting more of the ash that formerly went out the smoke stack. This results in 130 million tons of ash that must be managed annually, and that quantity will only grow. Sediments dredged from navigation channels, dams and reservoirs are increasingly being prohibited from aquatic disposal; and this country already produces 500 million tons of dredged materials annually. The proposed Delaware River channel deepening alone would generate nearly 100 million tons of sediments, the majority destined for 3500 acres of former and presently existing wetlands on the New Jersey shore of the Delaware River. If there is a possibility of putting these vast quantities of materials to a use that benefits the human and natural environment, it must be explored.

This project set out to demonstrate that dredged materials, amended with alkaline activated coal ash to undergo a cementitious reaction, can be practically and beneficially used to restore the devastated geology of Abandoned Mine Lands, removing physical hazards, returning surface waters to their watersheds, and restoring natural vegetation and habitat, without harm to the environment.

2. EXECUTIVE SUMMARY

This report documents the successful demonstration of the safe beneficial use of nearly half a million cubic yards of dredged materials to reclaim an abandoned coal mine in central Pennsylvania. The project was undertaken to demonstrate that sediments from standard navigational maintenance dredging operations, containing metals and organic contaminants within regulatory limits, can be processed with alkaline activated coal ash to form a low permeability cementitious fill for mine reclamation with exclusively positive environmental benefits. It also demonstrates the feasibility of this application on a practical basis; the material can be handled, processed, treated, transported and emplaced while keeping up with the production capacity of dredging operations.

2.1. INTRODUCTION

Initiated in 1995, the Bark Camp Demonstration Project is a public-private partnership among the Pennsylvania Department of Environmental Protection, the New York/New Jersey Clean Ocean And Shore Trust (a bi-state commission), and Clean Earth Dredging Technologies, Inc (a Pennsylvania environmental contracting and recycling firm). The project sought to join port economies, the need to dredge navigation channels, and the would-be waste products of coal combustion and dredging with the vast fill requirements of dangerous abandoned mine land features.

The Pennsylvania Department of Environmental Protection (PaDEP) has designated over 5600 abandoned mine features as human health hazards in need of remediation. These features, responsible for several fatalities each year, include dangerous shafts, high-walls and submerged pits, 36 underground mine fires, 800 annual incidents of land subsidence over deep mines, 250,000 acres of unreclaimed mine lands and the production of Acid Mine Drainage (AMD) that impacts 3000 miles of Pennsylvania's rivers and streams. Pennsylvania has individual strip mine features with fill requirements estimated at up to one billion cubic yards, while the total cost of these reclamations is estimated to be fifteen billion dollars. Twenty-nine (29) US states and tribal lands have catalogued over 560,000 abandoned mine land features.

An issue of similar scale is the disposal of the 500 million tons of sediments dredged on average each year from the nation's navigational channels, harbors and marinas. These volumes, which are mostly composed of water, silt, sand and clays, were typically disposed of in off-shore waters, and generally contain trace amounts of contaminants from agricultural and industrial sources. They should not be confused with the minority of highly contaminated or hazardous materials associated with 'environmental dredging' operations from industrial sites that require decontamination, and which make up a small percentage of the total volumes dredged nationally. There is however legitimate concern over the disposal of even trace contaminated materials in open water because loose sediments in aquatic habitats are consumed by bottom dwelling creatures, which over time may bioaccumulate contaminants and provide entry into the food chain. For

this reason dredged materials are increasingly used in upland applications where they are solidified and used as structural fills with no threat to the environment.

While many upland uses of dredged materials have been developed, from the construction of port islands to airport runways and use in landfill closures, sufficient portside areas are not available for the volumes involved. The cost of dredging has skyrocketed, threatening to rearrange shipping patterns with dire consequences for traffic, employment and consumer prices in the entire mid-Atlantic region. In other instances, upland placement of dredged materials has smothered valuable wetlands. On the Delaware River, the long standing practice has been to hydraulically pump dredged materials onto what were originally wetland areas of Delaware, New Jersey and Pennsylvania, covering thousands of acres. The proposed deepening of the Delaware channel would generate 93 million yards of sediments, mostly destined for existing facilities in New Jersey, as well as an additional 670 acres of its wetlands.

Another large scale problem is the US annual production of 130 million tons of coal ashes from coal burning power plants, which provide over 50% of the nation's electricity. These ashes have pozzolonic (or cementitious) properties and are similar to volcanic ashes used to perfect Roman concretes twenty centuries ago. Under alkaline conditions, these mineral products of burning react to form cementitious bonds. Modern coal ashes have been used in US construction since 1948, and 20% of the total ash generated is used in the manufacture of Portland cement. But the remainder is largely land filled or stockpiled. Their sheer volume and the portion placed in unconsolidated stockpiles are themselves causes of environmental concern.

This project sought to demonstrate the potential for the combined beneficial use of these wastes, or byproducts of US shipping and power generation while leveraging the economies of scale of each of the problems addressed. Along with their ability to form cements, the contaminant binding properties of alkaline activated coal ashes is well established, making them an appropriate binder for dredged sediments, and forming a manufactured fill for the geological restoration of the basement rock of stripped mine lands.

Historic proposals for the use of abandoned mines often focused on the planned dumping of bulk materials simply as a means of disposal, clearly attempting to fit a round peg into a square hole. However there is a real need for safe mine reclamation fill materials where such materials are not economically available, and for funding mechanisms to address that fifteen billion dollar problem. The high cost of dredged material management along with ever increasing volumes of coal ash generated to reduce air emissions, have made their beneficial use for mine reclamation economically feasible. Over 19 million dollars was provided to accomplish this project. The question to be answered was whether it was truly beneficial, without negative consequences for the environment.

2.2. THE PROJECT

In 1995 the NY/NJ Clean Ocean And Shore Trust, a bistate marine resources commission known as COAST, approached the Pennsylvania Department of Environmental Protection (PADEP) with a proposal to test the feasibility of using dredged materials from the Port of New York and New Jersey in abandoned mine reclamation. Facing the legacy of 300 years of coal mining, PADEP has been an active leader in mine reclamation research and applications. The department determined that in spite of negative public perceptions of dredged materials, the levels of contaminants involved were not excessive and well within their regulatory experience. In order to ensure that only acceptable materials were used, the Bureau of Land Recycling and Waste Management applied regulatory limits for contaminant levels from existing programs and forbade the use of any hazardous materials whatsoever.

2.2.1. The Bark Camp Mine Reclamation Laboratory

PADEP identified the existing Bark Camp Mine Reclamation Laboratory in Clearfield County as a good candidate for the demonstration site. It was an abandoned mine in a State Forest owned by the Commonwealth, the responsibility for the reclamation of which had devolved to the state.

Bark Camp as a whole is an abandoned coal mining complex that included abandoned surface and underground mines, preparation facilities and operating equipment, all with their attendant residual problems. Given that the facilities operated from the 1950s through the early 1980s, substances commonly used included PCB containing electrical transformers, a variety of fuels, solvents and other materials no longer in use today. Several reclamation and acid mine drainage abatement methods had been and continue to be tested and evaluated there, including the use of coal ash and municipal waste incinerator ash grouts.

The permitting process was begun and discussions entered into with the nearby community of Penfield in Huston Township. The township governing board formed an Environmental Committee that would work with PADEP as full partners to inspect and monitor site activities. An amendment to the existing permit for ongoing reclamation activities was approved for the inclusion of dredged materials in June 1997.

Bark Camp Run is a small stream that runs northward down a narrow headwater stream valley for about a mile and a half before entering a six foot diameter culvert under the former coal processing facility. It emerges and continues another 1.75 miles to where it joins a larger stream. The entire inside rim of the valley upstream of the culverted area was strip mined about 50 feet above the valley floor to reach thin layers of coal outcropping there. A bench was cut about 100 feet into the hillside creating a vertical cliff or highwall, with the pyritic overburden being dumped downhill. The project area is that bench and highwall along the west side of the stream which stretches from near the stream's headwaters almost to the culverted area. Approximately one third of this stretch of highwall has a second highwall above the first one at the downstream end. The reclamation achieved in this project involved replacing the stripped out overburden

with the manufactured fill, placed in lifts until the original contours of the hillside were restored, then covered with topsoil and planted.

Since the stripped pyritic overburden ringing the valley is below the project level and was not remediated, it has and will continue to impact the upper portion of the stream with acid drainage parameters. Prior to the project, surface and groundwater in the project area exceeded Pennsylvania Chapter 93 water quality criteria and/or drinking water standards for lead, cadmium, aluminum, Iron, manganese, sulfate, pH, and phenols. The area's coal beds, exposed on the valley walls by the strip mine, tilt down northwestward at twice the pitch of the descending streambed, intersecting the valley floor at the processing area and continuing downward beyond it. Two deep mines had been historically tunneled into the hills on either side of the valley at the processing site, and were now flooded and generating 180,000 gallons of acid mine drainage daily into the stream below the former entrances, impacting the downstream portion of Bark Camp Run. The use of materials with minimal contamination during the demonstration was never likely to further degrade the already impacted stream.

During the course of the project, many interested people visited the site and discussed the various activities and their merits. They represented a wide range of backgrounds and interests and included state and Federal agencies both within and outside of Pennsylvania, news media, elected officials (both municipal and state representatives), national and state environmental organizations and watershed groups, academic researchers, private business concerns and local citizens.

Analysis was regularly posted and available on the PADEP website during the course of the project.

2.2.2. Permitting, Sampling and Analysis

Each step of the process, beginning prior to dredging through the processing and placement of dredged materials, and including all components of the fill materials used, are regulated by permits and approvals issued by the relevant state and federal authorities. Dredged materials and all additives had to meet specific bulk chemistry and leachate testing standards to gain approval for their use. Prior to the acceptance of any sediments, core samples from proposed dredging projects were analyzed for bulk chemistry, volatile and semi-volatile organic compounds, pesticides, PCBs, dioxins and metals before being approved for use in the demonstration. A single proposed dredging project was rejected for exceeding allowable contaminant limits. All admixture elements were required to meet regulatory standards as well.

In addition to the minimum testing standards for inclusion of any materials in the project, a series of confirmatory tests were also required to ensure that no unauthorized materials were being included anywhere along the processing line. Samples were regularly obtained at the port-side dredged material processing facility after pre-amendment and just prior to shipping, and random samples were also obtained from rail cars upon arriving at Bark Camp. Samples were taken of the final pugmill mixture as

well, before emplacement in the highwall. These samples were subjected to the entire chemical testing protocol for all analytes.

Over 50 surface and ground water monitoring points have been established over the course of the mine reclamation laboratory in the past decade. These include the monitoring of a mine pool, multiple acid drainage seeps and a collection system beneath a lined area of municipal waste incinerator ash grout removed from the demonstration. Several of these were established for, or continued to be monitored during, this project. Surface water monitoring points were established in Bark Camp Run and its tributaries above, along and downstream of the demonstration project, and 6 monitoring wells were drilled along its length at the toe of the lower highwall, rather than the standard 100 feet away, to monitor groundwater. A small ravine separated the project into two phases near its middle, with three of the wells along each phase. Additionally, domestic wells in the general vicinity of the off-loading site on the rail siding were monitored to detect any changes during operations. Water samples were taken at the monitoring points at first monthly, and then quarterly, beginning prior to operations on the site. The samples were tested for a comprehensive suite of organic compounds and metals, which are listed in the report appendix.

2.2.3. Operations

Dredging is accomplished by using clam shell buckets mounted on cranes. The sediments are grabbed from the bottom of the waterway and placed in hopper scows for transfer to Clean Earth Dredging Technology's (CEDT) port side processing facility. Dredged sediments are over 60% water, and must be stabilized for shipping. After decanting excess water rising to the surface of the scows, the material is screened to remove debris and blended with approximately 15% coal ash before being loaded into 110 ton gondola railcars and covered with tarpaulins for transport to the mine site. The addition of coal ash is sufficient to bind any free water in the material. CEDT processed and shipped up to 4300 tons of amended dredged materials per one-shift day.

Although Bark Camp was an appropriate site for demonstration purposes, it was never logistically ideal, requiring a long haul from the port and multiple re-handling of materials. On arrival at Bark Camp, the railcars were unloaded into off-road trucks for the nearly two mile trip from the rail siding to the processing pad at the mine site. The now pre-amended dredged material was further mixed with coal ash and lime kiln dust in proportions necessary to initiate pozzolonic reactions, taken to the high walls and placed in piles while they begin the curing process. The material was spread in one to two foot lifts and roller compacted. In this project the fill was engineered to achieve a minimum compressive strength of 35 pounds per square inch within 28 days (enough to support construction machinery), a permeability of less than 1×10^{-6} centimeters per second (nearly the low permeability of a clay cap) and to withstand freeze/thaw cycles.

Each lift was placed in a width slightly narrower than the one immediately below it to reconstruct the original contours of the hillside. When that was accomplished, the surface was covered in approximately 18 - 20 inches of manufactured topsoil made

from local shale, paper fiber cellulose, organic material from a vegetable tannery, coal ash and lime. The surface was planted in a mixture of grasses.

The first material to be placed was a total of 40,000 tons of amended dredged material in May 1998. Placed in the upper highwall, its side slope was covered and planted, but the entire top surface was left uncovered to monitor the effects of weathering. The site was monitored for two years from initiation before additional materials were brought to the project. In two years of surface and groundwater monitoring there was not a single detection of a volatile or semi-volatile organic compound, pesticide, PCB or dioxin. No metal was detected other than the background already present due to mine drainage. Yet the flat expanse of shale and severe highwall was diminishing through the reclamation efforts, the planted slope had established a lush growth, and there was no detectable change in the stream below the length of the project. A negligible amount of chloride from the salt water (sodium chloride) in the material was detected in the lowest elevation monitoring well (34 mg/L). However, no chlorides were detected beyond background levels in the surface water monitoring point below the site.

Manufactured fill placement resumed in July, 2000. In May 2001, three years after the project began and the emplacement of over a quarter million tons of dredged sediments, a biological survey by the Pennsylvania Fish and Boat Commission showed over-wintering trout in the stream below and along the site. In spite of the fact that the entire Commonwealth is under a fish consumption advisory due to contaminants like mercury and PCBs, the fish samples from Bark Camp Run met the standard for unlimited consumption. A total of 435,000 cubic yards of dredged materials were amended and emplaced by spring 2002, with a three month winter hiatus in operations.

As previously noted, there were ongoing reclamation projects at the site before this demonstration was proposed; permits had been issued for the use of coal ash grouts, manufactured soil and finally, municipal waste incinerator ash (MWIA) grouts. MWIA went through a full permitting process in 1996 and was shown to exhibit low permeability and pozzolonic activation. Regional competition for qualifying, bidding and contracting for dredged material delayed completion of this project until arrival of MWIA in April, 2001. CEDTI began amending the alkaline activated ash and dredged material mixtures with MWIA in May, placing most of that material in Phase Two and another area removed from the project. For several months in 2002 after final placement of dredged materials, MWIA grouts were used to complete the final sections of the Phase Two highwalls.

2.2.4. Physical and Chemical Processes

The factor that makes this application safe and beneficial for mine reclamation is the physical and chemical changes undergone by the constituent materials. More than 20 years of increasingly sophisticated scientific investigations have established an understanding of the long known ability of alkaline activated bituminous coal ashes to form very strong cementitious bonds. Cementitious properties occur among the mineral fraction remaining after coal combustion because they are converted by the heat of combustion, in the presence of lime injected to reduce the generation of acid rain, into

highly reactive compounds with stored chemical energy. When mixed with water at high pH, they initiate cementitious reactions breaking their chemical bonds and forming new ones. Most of the water present becomes divided into hydrogen and oxygen, and is chemically bound into the minerals of the new cement matrix. Both fly ashes and dredged sediments (sand, silt and clay) are mostly composed of silicon, aluminum and oxygen compounds, which along with calcium, are the core constituents of cementitious reactions.

Cement mineral structures or matrices are extremely tight and leave only tiny pore spaces that may contain water in excess of pH 12. Because of chemical reactions with calcium, this pore water remains extremely alkaline, and maintains a very strong buffering capacity, being able to neutralize acids over long periods of time. Several things happen to metals and organic compounds present during these reactions, including:

Precipitation: most metals that are in soluble form are transformed in the high pH environment into insoluble forms that precipitate out of solution, just as iron dissolved by acid drainage precipitates out in streams when the mine drainage is diluted by fresh water.

Since the pore water has the capacity to buffer acids, these substances remain immobilized and less vulnerable to leaching out of the matrix.

Isomorphic Substitution: contaminants may be chemically incorporated into the new compounds formed as the solid mineral phase develops from the slurry, they may also stick to the surface of the new compounds or be absorbed into their three dimensional structure (*adsorption* and *absorption*).

Physical Encapsulation: contaminants are surrounded by a strongly bonded matrix from which they can not escape.

Metal and organic contaminants are physically and chemically bound at the molecular level and are not released when the concrete matrix is broken up. Once a contaminant is incorporated into the mineral phase of the cement, that matrix must be chemically destroyed to release them. The specific regulatory testing that the manufactured fill in this demonstration must pass is the Toxicity Characteristic Leaching Procedure (TCLP) testing, where a sample is pulverized, then tumbled in acidic solution for 18 hours, the equivalent to an extremely long duration of exposure to acid rain attack.

Aside from these complex mineral interactions at work, a more common effect is taking place as well: the massive reduction in surface area. When disposed of in the ocean, dredged materials are literally consumed in large quantities over time by mud-dwelling marine organisms; their digestive systems processing every grain of sediment, and any contaminants thus available. But when solidified into a low permeability monolithic mass, the area available to chemical attack, compared to the massive volume enclosed, is infinitely reduced. The fine particle sizes of both ashes and sediments make for very low permeability materials when compacted, and water can only move through them at

a very minute rate. When considering the ability of these mixes to buffer naturally mildly acidic rainfall, along with their extremely low hydraulic conductivity, they are calculated to remain stable through geological time periods.

2.2.5. Results and Conclusions

Analysis of sediments before dredging and along the processing train showed that trace contaminants within permitted levels were present in the fill material prior to placement. Yet in the more than five years of monitoring ground and surface water impacts after placement began, the substances of public health concern - PCB's, pesticides, volatile and semi-volatile organic compounds, dioxins and furans- were not detected in any of the surface and groundwater monitoring points. Similarly, metals remained at the background levels present before the project and were not impacted by the manufactured fill. No hazardous materials were ever detected in regular confirmatory and random sampling of transported materials.

The demonstrated effects were predicted by an extensive body of research and are due to the well established physical and chemical binding properties of pozzolonic materials, the low permeability of the fill, a relatively low level of commonplace contaminants in the manufactured fill constituents, and the small surface area to volume ratio of the restoration. Correctly proportioned blends of dredged sediments, coal combustion ash and kiln dusts, properly applied, will not leach contaminants to ground or surface waters due to their inherent physical characteristics and the chemical bonds formed upon their proper blending.

This demonstration has proven the feasibility of this application on a practical basis; the material can be handled, processed, treated, transported and emplaced while keeping up with the production capacity of dredging operations.

The only statistically significant water monitoring impact detected over the course of the entire project was the appearance of chlorides from common salt, which fluctuated in relation to project activities and demonstrated the effectiveness of the water monitoring plan. While some chlorides were expected due to the presence of salt water in marine dredged materials and a period of surface washing off the hardened material, elevated chlorides were correlated with the use of municipal waste incinerator ash as a pozzolonic amendment in the later stages of the project and its placement as a grout, its use having been permitted prior to this project.

At the height of activity during exclusive placement of dredged material fill, chloride levels in the area of Bark Camp Run affected only by the project (and not a source of drinking water) briefly reached 44 mg/L, well below impact levels for fish and other aquatic organisms. During placement of MWIA grout, chlorides briefly exceeded the EPA suggested drinking water standard (for aesthetics and not health) of 250 mg/L in a single round of testing (282 mg/L) and then declined. While these levels correlated well with four of the six ground water monitoring wells, two of them showed inexplicably high levels of chlorides, not reflected in the stream data. An examination of the site configuration lead to a series of physical and chemical tests on the monitoring wells as

well as expanded water sampling on the site, and correlation of the results with a geological cross section of the underlying strata. The wells in question were revealed to be so situated that they were collecting elevated chlorides as an artifact of their placement and site configuration coincidences, and not reflecting actual ground water concentrations of chlorides, which otherwise exceeded the drinking water level only on a single occasion.

While such projects are typically done near acid drainage impacted waters that require time to recover after remediation, a short period of elevated chlorides would be inconsequential. However, projects in potentially sensitive freshwater areas must be designed and managed to take this phenomenon into account, employing appropriate sediment and runoff management. Careful mix design and project management can reduce the amount of free water remaining un-bound by hydrating reactions in the cured material, thereby reducing any mobilization of chlorides. PADEP will continue to closely monitor the project to quantify this trend. While incinerator ash is being tested and monitored at another area of Bark Camp, its use in environmentally sensitive areas should be restricted until testing is completed.

Analysis of Domestic Wells in the vicinity of the rail siding where materials were off-loaded indicate that, removed from the project and the site, there is a source of contamination originating at some far distance away from the siding and migrating toward it. The effected wells are all within the influence of multiple residential sewage discharges and several are within the influence of a large farm field that has had contamination issues in the past. Further, the wells closest to the railroad, indeed the one directly below and adjacent to the unloading area, have lower values of detected elements.

A dangerous high wall in a state forest, adjacent to state game lands was eliminated. Water is now flowing overland to the stream rather than back into and along the highwall. Flat expanses of bare shale and pyritic rock have been restored to a meadow habitat frequented by bear, deer, elk, bobcat and turkey. The survey of Bark Camp Run by the Pennsylvania Fish and Boat Commission in May 2001, three years after the project began, cited significant water quality improvements with increasing numbers of macroinvertebrate taxa and some common fishes at a downstream station in Bark Camp Run which was formerly sterile due to the mine drainage impacts left behind by the bankrupt mining operation.

The survey further reported over wintering trout in the upper section of Bark camp Run, directly below the fill project area. Pennsylvania has a state-wide precautionary one meal per week fish consumption advisory due to the prevalence of trace contaminants in the environment. And while there is a one meal per month advisory for PCB contaminated fish and a two meal per month advisory for mercury contaminated fish, all the fish tissue samples from Bark Camp met the standards for unrestricted consumption, including for mercury and PCBs.

Community outreach and participation were vital to the success of this project. Local communities must be closely worked with and included in the projects to dispel

misconceptions and build cooperation. As would any major reclamation project, this work also provided significant employment and financial resources to the host area.

The appearance of moderately elevated chlorides during this demonstration corresponds with the introduction of municipal waste incinerator ash (MWIA) into the manufactured fill. About 253,000 tons of MWIA was placed in Phase 2 of this demonstration, and also on the western side of the Bark Camp site as a whole, an area separate and distinct from the dredge demonstration project. Although MWIA ash is known to release chlorides, its use at Bark Camp was as a pozzolonic material incorporated into the manufactured fill. As such, the manufactured fill would be expected to release a finite amount of chlorides as well. The extent and degree to which the chloride levels have increased in various monitoring points at Bark Camp over time with the placement of material containing MWIA, indicates a clear need for caution in the use of this material in a similar project. PA DEP, therefore, has decided that Municipal Waste Incinerator Ash will not be considered for use in mine reclamation projects. Any other potential use of this material would require a more extensive review and separate examination with the appropriate permitting agency which is not within the scope of this report.

The key to the successful use of this concept is thoroughness. The capabilities of properly made ash mixes were utilized in ancient times, and over the last 70 years. Over 80% of the surface and groundwater analytes tested for, at significant cost, were reported as undetected. The proper characterization of raw materials, and the imposition and monitoring of appropriate performance criteria for compressive strength and low permeability, along with sound project design and operations, are more important than continually analyzing bulk chemistry for contaminants during operations.

3. INTRODUCTION

The Bark Camp Mine Reclamation Project involves aspects of three major issues, Abandoned Mine Lands, Dredged Material Management and the management of Coal Ash.

3.1. ABANDONED MINE LANDS

Most Americans are not aware of the indispensable role coal mining has played in the development of this country, the immense physical scale at which it was accomplished, or the human and environmental legacy it has left us.¹ Nearly one-third of all the coal produced in the United States was mined in Pennsylvania, and at the cost of over 50,000 lives.² Since its discovery in Pennsylvania over 300 years ago, more than ten billion tons of coal have been removed from this state alone.³

Today, combustion of coal provides over half of the electricity generated in this country. Although coal mining was historically undertaken at times indiscriminately over a vast geographical area, it is much more carefully regulated now than in the past.⁴ Strip or surface mining (fig. XXX) chased coal hundreds of feet into the ground, creating massive pits. In deep mining, thousands of shafts were drilled for prospecting, ventilation and the movement of miners and coal, exploiting seams up to 2000 feet deep and many square miles in area. Nine thousand (9000) of these mines in Pennsylvania alone were simply abandoned when mining was no longer economically viable, leaving a truly vast inventory of degraded physical features.

One quarter of a million acres of Pennsylvania are unreclaimed mine lands, and 5600 abandoned mine features have been identified by PaDEP as posing hazards to human health and safety.⁵ Many of these pits draw garbage dumping, or fill with water and become 'attractive nuisances' drawing youths, and resulting in fatalities from falls and drowning. On average, four people are killed each year in Pennsylvania's abandoned mines. Garbage fires from dump sites have transferred to coal seams resulting in 36 ongoing underground mine fires. In the town of Centralia, one such fire required the relocation of 530 homes and businesses. Eight hundred (800) times each year deep mine collapses transfer to the surface below towns and homes, crumbling foundations.

¹Especially since the discovery of high quality anthracite in eastern Pennsylvania, coal provided the compact energy source that allowed large scale urbanization, the expansion of railroads, fueled the nation's war efforts and the Industrial Revolution. Nearly twice the amount of coal mined is still underground in that state.

² Hornberger et.al. 1990

³ 4.6 billion tons anthracite and 9.3 billion tons bituminous since 1984. Typically, several times the amount of coal produced is removed in overburden, as much as 30 times the volume of coal. Gray and Bruhn, 1984.

⁴ The Surface Mining Control and Reclamation Act (SMCRA) of 1977 establish the Abandoned Mine Land (AML) program to restore eligible lands and waters by collecting fees from existing mining operations.

⁵ Pennsylvania Department of Environmental Protection (PaDEP), Bureau of Abandoned Mine Reclamation (BAMR).

Holes opening in back yards and parking lots turn out to be old shafts hundreds or thousands of feet deep. In extreme cases, entire streams are “captured” by mine subsidence, disappearing down shafts and faults to mine pools deep below, emerging miles away, sometimes even in other watersheds as polluted mine drainage.

This historic rearrangement of geology on a massive scale has had even more severe consequences. Much of Pennsylvania’s coal is associated with pyritic rock. Drilled and shattered by dynamite, these minerals oxidize while exposed to air. After the mines were abandoned and subsequently flooded, the water reacted with the oxidized rock to create sulfuric acid. This water emerges as Acid Mine Drainage (AMD) with a pH as low as 2.3, making 2500 miles of rivers and streams in Pennsylvania uninhabitable to fish and unusable to people.⁶ Dissolving iron and clay, AMD covers many stream beds feet-thick for miles in bright orange iron oxides (locally named “yellow boy,” fig. 2) or white slicks of aluminum, toxic to fish. Acid Mine Drainage is the number one cause of water pollution not only in Pennsylvania, but also in every Appalachian coal mining state.

Pennsylvania maintains five water treatment plants solely to treat AMD impacted waters. It is estimated that, left untreated, acid drainage will continue to be generated in eastern Pennsylvania for another 800 to 3000 years.

PADEP’s re-mining regulations begin by stating that “in all likelihood, government funded reclamation of abandoned mine lands will not solve the estimated \$15 billion in environmental problems caused by past mining in the Commonwealth.”⁷ Nationally, over 560,000 abandoned mineland features have been catalogued by the Bureau of Land Management in 29 states and tribal lands.⁸

3.2. DREDGED MATERIAL

Most navigable channels, bay inlets and marinas in this country require periodic dredging: the physical removal of the mud, sand and silt that naturally accumulate in them from the erosion of upstream sediments. One cubic yard of mud (weighing approximately one ton) picked up from a river bottom will typically consist of over 60% water, the remaining fraction being made up of various sized particles: gravel, sand, silt and clay, and up to 7% organic material (decaying plant matter). Debris that has made its way into the water will be present in areas closer to shore.

The United States annually removes over five hundred million tons of dredged materials from its navigable waters. In the case of the Port of New York/New Jersey, harbor waters only reach a natural depth of 17 feet while container vessels can draw nearly 50 feet of water. The Delaware River must also be dredged to a serviceable channel depth. Channels are cut and must be maintained to allow these ships to use the harbor. Being a river port, the harbor is subjected to a high rate of silting which must be regularly

⁶ United States Geological Survey, Coal mine drainage projects in Pennsylvania. An additional 500 miles of waterways are considered ‘impaired’ in the Commonwealth.

⁷ PA Bulletin, Vol. 15 No. 26, June 29, 1985, p2379

⁸ Department of the Interior, Bureau of Land Management.

removed. Additionally, shipping channels are being increasingly deepened to 50 feet to accommodate the newest generation of container ships. The Panama and Suez canals will themselves be deepened to accommodate the newest generation of container shipping.

Ninety-five percent of US international trade moves through our ports and, nationally, more than 400 ports and 25,000 miles of navigation channels must be dredged.⁹ Container shipping is the most cost-effective and environmentally-conservative form of freight movement. The newest generation of container ships can carry the equivalent payload of fifty freight trains (of one hundred cars each) or five thousand tractor trailers. Efficient ports positively affect the region's transportation grid, traffic, wear and tear on roads and bridges, and air pollution, as well as jobs, the cost of consumer goods, and the competitiveness of US exports. The ability to bring oil tankers to berth at capacity (rather than in shifts due to shallow channels) affects not only the cost of fuel processing, but prevents the small but regular spills that take place when transferring oil to smaller vessels out in deeper waters. In the Delaware River, the port accounts for more than \$1.2 billion in annual revenue and more than \$500 million in state and local taxes, while supporting over 54,000 jobs. The proposal to deepen the Delaware channel to the Port of Philadelphia and Camden would generate an additional 93 million tons of dredged material. But for all the importance of that destination, the Port of New York/New Jersey remains the primary point of import and export for the Commonwealth of Pennsylvania.

3.2.1. Dredged Material Disposal

For over a century and until recently, dredged materials were placed in scows, towed out to sea and released. Dredged material was the last of numerous bulk substances, from bulk acids to sewage sludge, to be prohibited from disposal in the ocean over the last 70 years, and its continued dumping drew growing opposition from environmental groups.¹⁰ With the development in the 1990s of laboratory tests capable of detecting concentrations of chemical substances down to one part-per-trillion, trace amounts of chemicals from agricultural and industrial applications were detected, most notoriously trace amounts of chlorinated compounds, including dioxins and PCBs.¹¹

A re-invigorated and ultimately successful campaign to stop ocean disposal of dredged materials engendered a number of misconceptions about these sediments. The significance of preventing their disposal in aquatic environments was not that the material was "hazardous waste" (it is not) but that mud-dwelling creatures were consuming it over long periods of time.

⁹ US Army Corps of Engineers, WDC, Building and Maintaining our Underwater Highways.

¹⁰ The substances disposed of in the ocean and the years that disposal was prohibited include: municipal solid waste, 1932, acid waste, 1940, sewage sludge, 1992, dredged material, 1996.

¹¹ For an idea of how big that number is, one-trillionth of the distance from the earth to the moon is 1/64th of one inch, or, one second out of 31,710 years.

With the detection of trace metals and organic compounds in dredged material, it was felt that dumping them in a marine environment would expose benthic (bottom-dwelling) organisms that burrow in and consume the mud, like marine worms, to the biological accumulation of contaminants over time. Since these creatures serve as the basis for the marine food chain, and are consumed by fish and crabs, it was hypothesized that contaminants might work their way into the human food chain. For this reason, ocean disposal of contaminated dredged sediment material has nearly ceased.

Alternatively, dredged material from the Delaware River has been hydraulically pumped onto Confined Disposal Facilities (CDFs) created by diking wetlands along the shore. The proposed deepening of the 102-mile long Delaware River Channel to the Port of Philadelphia would cost one quarter of a billion dollars and generate 93 million cubic yards of dredged materials. Present plans call for disposal of 55 million cubic yards of this material, largely on present and former wetland areas on the New Jersey shore of the Delaware River, with the balance of the material going to the State of Delaware.¹²

In recent years however, the upland beneficial use of dredged materials has increased.¹³ Japan has constructed airports and port islands using dredged material. In the United States, dredged materials are increasingly used in construction projects and the remediation of brownfields for commercial uses. Since 1995, numerous projects have been completed in New Jersey and more recently New York involving the beneficial use of dredged materials. In New Jersey, dredged materials have been used to cap and redevelop several landfills, including the City of Linden Municipal Landfill, and to transform the Kapkowski Road Landfill in Elizabeth, New Jersey, into a 1.2 million square foot retail outlet mall facility. Other projects have involved the use of dredged material as fill for the capping of two former industrial brownfields sites, creating championship golf courses and open space in their place. In New York City, the Pennsylvania Avenue and Fountain Avenue Landfills recently utilized dredged material as fill as part of an approved capping and closure plan to help transform these landfills into a large public park.

The subject of environmental contaminants in dredged materials and any corresponding potential threats to human health and the environment is complicated, controversial, and often emotional. The majority of dredged materials are similar in composition to many commonly used raw materials. However, extensive screening and testing protocols were created and followed during this demonstration and the local community was extensively consulted in order to specifically answer such concerns.

¹² USACE Philadelphia District website. Less than 10% of the total will be beneficially used for shore nourishment and marsh restoration.

¹³ Innovative Technologies for Site Remediation and Hazardous Waste Management, Proceedings, of the National Conference, American Society of Civil Engineers, July 23-26 1995

3.3. COAL ASH

Coal formed as massive swamp deposits around 300 million years ago. The swamps contained sand, clay and other minerals while their vegetation, like all living things, gathered trace elements and metals, which became concentrated under geological conditions over time. When coal is burned, on average 10 percent of its bulk remains behind as a mineral residue known as coal ash. Since over half the electricity generated in the United States is produced by burning coal, we produce over 130 million tons of coal combustion by-products annually.

In the US, coal was burned for heat as early as colonial times, long before it was used to generate power. Its ash has been known ever since. In many towns and cities ash wastes were systematically used to “reclaim” swamps and wetlands, forming ground for human habitation.¹⁴ Before the collection of fly ash from smoke stacks, millions of tons escaped and were ubiquitously distributed in the environment.

Today, as a result of environmental regulations aimed at reducing acid rain and particulate emissions, an estimated 30 million tons of additional coal combustion waste is produced annually.¹⁵ Pulverized lime is injected into furnaces during the combustion process to reduce the amount of acid rain-causing sulfur in coal, and ‘scrubbers’ and electrostatic precipitators in smoke stacks collect much of the fine particles that formerly escaped into the atmosphere. If all currently proposed clean air legislation seeking further reductions in emissions were to be passed into law, within a decade the total of coal combustion products seeking disposal could increase by another 30 to 50 million tons annually.¹⁶ Materials prevented from dirtying the atmosphere must otherwise still be attended to, and Pennsylvania produces about 17 million tons of coal ash annually from coal fired power plants, and the burning of anthracite and bituminous coal waste.¹⁷

3.3.1. Cementitious Reactions

It has long been known that many coal combustion processes are similar in effect to cement kilns, where minerals are imparted with the potential energy to form cement under certain conditions. Cements react in the presence of water to form chemical bonds that produce very stable solids. Concrete, which is cement mixed with sand, water and an aggregate, was perfected by the ancient Romans. Many of their concrete structures and roadways (like the Pantheon and the Via Apia) exist to this day, demonstrating their high degree of permanence under severe conditions of environmental exposure over nearly 20 centuries. Part of the secret of the durability of Roman concretes is their use of volcanic ash.

¹⁴ From 1895 to 1920 the majority of New York City’s waste stream was coal ash, with mandatory household segregation from trash, and used for land ‘reclamation’ on the cities wetland periphery. “Urban Residential Refuse Composition and Generation Rates for the 20th Century”, Walsh, Daniel C., Environmental Science and Technology, Volume 36, pg 4936, 2002

¹⁵ Utility Solid Waste Activities Group, WDC.

¹⁶ Ibid

¹⁷ Scheetz, Air and Waste Mgmt. Assoc. presentation, June 8-13, 1997

Volcanic ash is similar in many ways to coal ash, being the mineral product of a high heat process (volcanoes) acting on native rock. Neither coal ash nor volcanic ash will undergo cementitious reactions in the presence of water alone, as cements do, but will react under high pH (alkaline) conditions. Such materials are said to be 'pozzolonic,' named after the Italian town of Pozzuoli near Naples, from where the Romans first mined their volcanic ashes. The Romans used ash amended concretes for particularly high wear environments, like submerged bulkheads in salt water ports. Fly ash produces a concrete with a very low porosity and very fine pores, which is responsible for its low permeability and high resistance to chemical attack, a property which of the Romans seem to have been aware.¹⁸

3.3.2. FBC Coal Ash

The pozzolonic ash of interest to this project is derived from the burning of bituminous coal mining waste (locally known as gob) that was discarded during mining operations over the past century. The gob consists mostly of shale (mixed with coal) that occurred as layers in the coal seam, or was mined with the coal along its margins; it includes large amounts of quartz and clay. Only three out of every eight tons of the material is coal. Hundreds of millions of tons of coal waste despoil Pennsylvania's coal mining areas, looming over towns as black hills, resisting re-vegetation and generating billions of gallons of acid drainage. Currently 12 facilities in Pennsylvania mine this waste and burn it in Fluidized Bed Combustor facilities to produce electricity.

A fluidized bed combustor (FBC) burns the crushed coal waste along with ground limestone suspended in an upward flow of air that circulates the particles in a 'fluidized bed.' The limestone is added to react with acid rain-causing sulfur from the pyritic rock, which generates acid drainage in coal wastes. The limestone (CaCO_3) breaks down into lime (CaO) which may make up 30% of the ash, and (in water) gives the ash a pH of 12.5

In contrast to pulverized coal utility plants that burn mostly pure coal, FBC plants mostly process native minerals in a modest heat environment, transforming clays into highly reactive mineral compounds of calcium, aluminum, and silica (SiO_2). Cements are also compounds of calcium, aluminum and silica, the difference from pozzolons being that they are formulated to react with water (undergoing hydration), while pozzolons may require additional lime or other alkaline activators to initiate their cementitious reactions. The amount of calcium in these materials provides their ability to buffer them against acid attack for very long periods of time.¹⁹ When compacted coal ashes react they may form a dense, low permeability fill that tenaciously binds the elements, compounds and metals within them. Modern cement research started in the late 1800s, and fly ash research began more than 50 years ago. The exact nature of the reactions responsible

¹⁸ Used in cement mixes, fly ashes' spherical shape and high surface area provide flowability, high surface areas for reaction, and continue to react within the cement matrix, filling and closing off pore spaces, providing the cured cement with resistance to chemical attack.

¹⁹ A buffer is a compound that has the ability to neutralize both acids and bases, keeping pH constant in a solution

for binding contaminants is well understood and described in the Cementitious Reactions section below.

3.3.3. Beneficial Use of Coal Ash

Given the volumes available and their well known cementitious properties, fly ashes have been beneficially used for decades. 20% of the coal ash produced each year in the United States is used either in the manufacture of Portland cement or as a partial substitute for it.^{20,21} An early large scale beneficial use of coal ash was in Montana's Hungry Horse Dam in 1948, where 35% of the Portland cement for its 2.5 million cubic yards of concrete was substituted with fly ash. In 1983, the U.S. Environmental Protection Agency issued "Procurement Guidelines for Cement and Concrete Containing Coal Fly Ash," which encouraged increased use of concrete containing coal fly ash in federally-funded projects. The Washington D.C. Metro system in the 1980s and the 1996 Atlanta Olympic Stadium also used fly ash concretes. Recently, York University in Toronto, using "green" building practices constructed a new computer center out of concrete that was 50% fly ash. Replacing cement in concrete mixes not only reduces cost and increases performance, but also contributes to the reduction in the release of carbon dioxide. Cement manufacture is fuel intensive and its compounds release greenhouse gases; one ton of carbon dioxide is released into the air for every ton of cement produced.²² This means that the use of fly ashes as a replacement for cement prevents the emission of over 20 million tons of greenhouse gases in the US annually.

The use of coal ash in mine reclamation is not new. Since 1988 Pennsylvania's 12 waste coal plants have consumed over 88 million tons of coal wastes to produce electricity, removing the acid drainage causing refuse piles. The 58 million tons of FBC coal ash produced was then used to reclaim 3,429 acres of mine lands.²³

Fluidized bed combustion ash has also been demonstrated to effectively sequester acid drainage-causing mine waste buried at former mine sites. The 100-acre McClosky Site in Clearfield County, north-central Pennsylvania had been reclaimed in the 1970s under then-existing regulations, backfilling the pit with acidic mine spoil. Though re-contoured, covered with topsoil and planted, the spoil backfill proved to be generating acid drainage as low as pH 2.2 from infiltrating rainfall. About 700,000 tons of alkaline activated FBC ash was mixed with water and used to create a 36 inch cap over the site, laid in 6 inch roller compacted lifts. Permeability became comparable to a clay cap (10-7 cm/sec), the topsoil was replaced and the site planted with grasses.²⁴ After the capping

²⁰ This limit is be more of a reflection of old construction codes and resistance to changing old habits.

²¹ Up to 35% replacement of cement in the US; this is used in applications where lower heats of hydration are required during high temperatures.

²² York University uses High-Volume Fly Ash Concrete for Green Building, D.S. Hopkins A. et al

²³ ARIPPA

²⁴ Permeability is the degree to which water can pass through the material. While glass is impermeable, even solid rock will allow tiny amounts of water to slowly enter into it. This is measured at a speed, usually in the millionths of a centimeter per second, a very low permeability.

was completed, the acid discharges ceased and fish returned to waters at a site that would otherwise require decades of continuous passive mine drainage treatment.²⁵

The Fran Contracting site also in north central Pennsylvania, was a similarly reclaimed surface mine where the operator had backfilled the pit with acid generating coal refuse before reclamation, developing an acid discharge that destroyed over five miles of native trout stream below it. Remote sensing techniques determined that the material was present in discrete pods throughout the mine site. Those pods identified through magnetometry as pyritic were targeted for pressure injection of alkaline activated FBC grout into and around the pods to isolate them from infiltrating air and water. The FBC ash encapsulated the pods and solidified into weak cement with a permeability of 10^{-7} centimeters per second. The targeted grouting of 5% of the total area resulted in a 40% reduction in acid mine drainage and up to a 65% reduction in trace metals.²⁶

In spite of these beneficial uses, the US lags behind other nations in the recycling of coal ash, with the majority still landfilled or stockpiled at an annual cost of \$1.3 billion. The Netherlands and Germany have a 100% recycling rate for their coal ashes in construction, reclamation and road base uses, while Bermuda imports as much coal ash as it can for reef construction. But in the US there has not been a concerted public education and outreach effort, and the regulatory inconsistency across affected states serves to discourage the positive development of beneficial uses beyond present levels.

3.3.4. Physics and Chemistry of Binding Reactions

It is important to establish a common baseline of communication in complex and contentious issues; otherwise they can acquire a private language of their own. People have become used to thinking of lead, arsenic and uranium as 'contaminants,' no matter where they are, or in how small a quantity, even though they are actually very common substances. Here, the term 'contaminant' is used to describe substances that are present beyond normal background levels and that may cause health or environmental concerns. Specifically, we use the term to refer to certain heavy metals and complex organic compounds not normally present in the local environment, or present beyond background levels.

3.3.5. Contaminant Binding

The well known ability of pozzolons to form very strong cementitious bonds permits them to be used in an increasing range of applications from mine reclamation through concrete construction. A cubic foot of concrete can support half a million pounds; but it is their noted ability to strongly bind metals and contaminants that is vital to the application demonstrated at Bark Camp. More than 20 years of increasingly

²⁵ Hellier, William W., Abatement of Acid Mine Drainage Pollution to Upper Three Runs, paper presented at W. Virginia Surface Mine Drainage task force Symposium, April 7-8, 1998.

²⁶ Schueck, Joseph et.al. Water Quality Improvements Resulting from FBC Ash Grouting of Buried Piles of Pyritic Materials on a Surface Coal Mine, paper presented at 1996 Annual Meeting of the American Society for Surface Mining and reclamation, Knoxville, TN, May 19-24, 1996

sophisticated Investigations, including x-ray diffraction and electron microscopy, has established an understanding of those processes and are here briefly summarized.

As stated above, pozzolonic properties occur among the mineral fraction of coal combustion products that remain behind as ash. This is because the aluminum, silicon, oxygen and calcium in the sand, clay and limestone are converted by the heat of combustion into highly reactive compounds with stored chemical energy. In the presence of water at high pH, the compounds dissolve into a gel phase. The water serves first as a vehicle for raising the pH by dissolving the lime present in the mix, initiating the cementitious reaction; then as the source of H and OH (hydroxide) for the hydrating reactions that form the new chemical bonds. Note that the water has been divided into its constituent elements (hydrogen and oxygen) and chemically bound into the minerals of the new cement matrix. Though not exactly a crystal, cement mineral structures or matrices are extremely tight and leave only tiny pore spaces that may remain filled with water. Because of chemical reactions with calcium, this pore water remains extremely alkaline, and maintains a very strong buffering capacity, being able to neutralize acids for very long periods of time. The cementitious reaction initiates slowly and depending on the specific substances present may achieve their design strength within hours or days, and then continue to react for long periods of time.

Several things happen to metals and organic compounds present during these reactions:

First: organic degradation by alkaline attack. Organic molecules are known to decompose under high pHs, including otherwise resistant PCBs, where their complex carbon ring structures are broken open. The pore water in concrete may remain as high as pH 13.4, continuing to degrade organics that are present in the concrete. When 'quick lime' is used in these processes, extremely high heats of hydration further destroy organics

Second: Precipitation. Contaminants that are dissolved in acid waters are transformed to insoluble forms that precipitate out of solution. This is the reason that iron, dissolved by acid drainage, precipitates out in streams when the low pH mine drainage is diluted by fresh water. Since the pore water within the cement matrix is extremely alkaline, and have the capacity to buffer acids, these substances remain immobilized and less vulnerable to leaching out of the matrix.

Third: Sorption: adsorption (or ion exchange) is the adhering of contaminants to the surface of a clay or fly ash glass sphere, and the more familiar; physical absorption, when contaminants interact with a solid and go within it, like water into a sponge.

Fourth: Isomorphic Substitution (also called isomorphous substitution): When chemical reactions initiate, they do not always occur neatly as they are written out on a blackboard; elements and compounds convenient to the reaction are grabbed and incorporated as handy substitutes for the nominal reactants as the solid phase develops from the slurry. Quartz is a good example of this; all quartzes are compounds of silicon

and oxygen (SiO_2 , silica) yet there are hundreds of color variations. This is because of 'impurities' being incorporated into the quartz crystal matrix.

Fifth: Physical encapsulation. In physical encapsulation, contaminants are surrounded by a strongly bonded matrix from which they cannot escape, like pebbles in asphalt. Once a contaminant is incorporated into the mineral phase of the cement, the mineral matrix must be destroyed to release them.

It is important to note that the sequestration of contaminants does not rely on the macro-physical structure of cementitious compounds; in other words, such contaminants are not released when the concrete block is broken up. The specific regulatory testing for the materials used in this demonstration is the Toxicity Characteristic Leaching Procedure (TCLP) testing, where a sample is pulverized and tumbled in acidic solution for 18 hours, vastly multiplying the surface area of sample subject to chemical attack.

3.3.6. Surface Area

Given the above binding mechanisms, it should be pointed out that another more mundane phenomenon is at work as well: surface area. Surface area is a vital aspect of any physical or chemical reaction. We chew our food to increase the surface area available to acid attack for our stomach's digestive process. For a chemical reaction to occur, say, between a substance and acidic rainfall, the acidic water must literally come in contact with each molecule in order to affect it. The more volume that is incorporated into a monolithic body, the smaller the relative surface area it has; the outside of a one-half gallon milk carton has less surface area than the combined total outside surfaces of 8 single-serving milk cartons, even though they contain the same total volume of milk. The solidification of dredged material and ash into a monolithic hillside or pit restoration dramatically reduces the surface area of dredged material and ash particles that are exposed to the environment, on the order of trillions of times compared to loose dredged sediments scattered in aqueous environments.

3.4. PROJECT CONCEPT

When enough coal ash is added to the dredged material and the pH is raised by the addition of alkaline lime kiln and cement kiln dust, a pozzolonic reaction takes place where the coal ash particles dissolve into a gel phase and chemically recombine with the available water into a cementitious matrix. The metal and organic contaminants of concern are precipitated into insoluble forms, combined into new compounds, or bound into the cement matrix. The small amount of free water remaining in the pore spaces is extremely high pH and the material achieves a very low permeability. The reaction begins slowly and increases in rate over time, reaching its engineered specifications of compressive strength and low permeability at 28 days.

3.4.1. Process Longevity

The question of the longevity of this process naturally arises; how long will the described physical and chemical bonds remain effective? Very specific research has taken place to determine a quantitative answer. We have seen that the chemical binding mechanisms do not rely on the physical integrity of the fixed material. Even when ground up and subjected to acid bath testing, the material does not readily leach contaminants. Not only are the strong chemical bonds responsible for this, but the buffering capacity of the calcium compounds resist a lowering of the pH of the material, preventing the release of contaminants in solution. The key then in judging long-term stability of these fill materials in the environment is their resistance to chemical attack, and their ability to buffer acidic rainfall. Atmospheric carbon dissolves in rainwater, making it a very mild carbonic acid. Rainwater will also dissolve nitrogen and sulfur oxides from air pollution to form both dilute nitric and sulfuric acid. This phenomenon is mimicked in the SPLP leaching tests described elsewhere in this report.

In other studies, a very conservative calculation was made based on the results of extensive laboratory testing of artificially contaminated soils subjected to acid environments.²⁷ It was calculated that, in a solid slug of material immobilized by alkaline materials (ignoring its true hydraulic conductivity), if one meter of naturally acidic rainfall were to *completely pass through it each year*, the material would have enough chemical buffering capacity to neutralize the acidity for 76,000 years. Given that in reality it would take water thousands of times longer to pass through a low-permeability material, then it follows that properly mixed, placed and cured fly ash amended fill will last through geological time- as long as the surrounding topography will last.

²⁷ Innovative Technologies for Site Remediation and Hazardous Waste Management, Proceedings of the National Conference, American Society of Civil Engineers, July 23-26 1995

4. THE BARK CAMP PROJECT

In September 1995 the bistate marine resources commission between the states of New York and New Jersey, Clean Ocean And Shore Trust (COAST) contacted the Pennsylvania Department of Environmental Protection (PADEP) regarding the possible use of dredged material in abandoned mine reclamation.²⁸ After a 6-month examination of the issue by the Dredged Material Management Team of the New Jersey executive branch, COAST was charged with formulating an environmentally sound approach to the large volume of material that would no longer be placed in the ocean.²⁹ Headquartered at Rutgers University's Institute of Marine and Coastal Sciences, and Columbia University's Earth Engineering Center, COAST is oriented to broad regional environmental issues.

An initial meeting was held with PADEP in October, 1995.³⁰ Given the history of schemes that had been proposed for Pennsylvania mines in the past, and the vast public perception of dredged material initially formed during the campaign to ban ocean disposal, the initial reaction was one of intrigued skepticism. A detailed examination of the bulk chemistry of dredged material sampled within the Port of New York /New Jersey by representatives of PADEP's Bureau of Land Recycling and Solid Waste Management indicated the dredged materials were well within the experience of state regulators and nothing extraordinary.

PADEP is the state agency in charge of regulating dredging needs in the Commonwealth, which included not only maintenance dredging of the state's waterways, but also the maintenance dredging of individual hydro power dams that are silted up on the Susquehanna River. As discussed below, PADEP had been working with fly ash grouting of deep mine voids for several years, and felt that perhaps dredged materials would be a suitable aggregate in the large volumes of fill they required. In theory, alkaline ashes mixed with the fine grained dredged material would create a very low permeability solid fill that would bind any metals and organic contaminants present and make them insoluble. Since fly ash grouts expand as they set (the property which limits their use as a replacement for Portland cement to 20%) the fill should also seal mining voids and surfaces from acid-producing air and water. The prevention of Acid Mine Drainage, rather than its perpetual treatment after being generated, was seen as a much more desirable solution to the problem. The attendant improvement in impacted waterways and wetlands, along with the volumes of fill available for reclamation and funding from massive port economies was an interesting opportunity.

Samples were obtained from the Army Corps of Engineers and bulk chemical analyses by EPA certified laboratories were examined. Dr. Barry Scheetz from Penn State University's Materials Research Laboratory, who had already completed much research

²⁸ www.nynjcoast.org

²⁹ Report of the Dredged Material Management Team, Final Report to the Governor, January 1st, 1995

³⁰ With the directors of the bureaus of Abandoned Mine Reclamation, and Land Recycling and Waste Management, scientific staff, marine scientists, port and COAST officials.

on the use of fly ash grouts, was engaged by CEDTI to perform preliminary bench scale mixes of dredged material and alkaline activated fly ash and found the process to be feasible. Over the next year, many meetings were held with state and federal agencies, scientists, regulators and mine reclamation field staff to sketch out a basic project design, identify potential demonstration sites, and to obtain funding for the project. In January 1997, PADEP and the New Jersey Department of Environmental Protection signed a Memorandum of Understanding regarding cooperation and information exchange in dredged material and solid waste issues.

Siting requirements were identified as necessitating a project that could be remediated in a short space of time, could be monitored adequately, and which already had some baseline environmental monitoring in place. These criteria lead to consideration of the Bark Camp site, despite the fact that it was logistically far from ideal--Bark Camp is nearly 350 miles from the Port of NY/NJ and has a two-mile gap between rail access and the actual surface mine site. Therefore, imported fill material would have to be re-handled and trucked to the site. After establishing that the project was in theory safe, and likely to be beneficial the question of public perception and trust had to be addressed.

4.1. PUBLIC PERCEPTION AND PARTICIPATION

From the outset it was recognized that the Demonstration Project might gain an association with the out-of-state waste importation issue in Pennsylvania, where communities with permitted municipal landfills were accepting large volumes of municipal solid waste from other states in exchange for significant tipping fees. Such importation generated a very unfavorable public perception, largely in connection with waste disposal trucks on the highways and the negative image of waste importation. It also generated political and regulatory opposition because it threatened to severely shorten the lifespan of already permitted disposal capacity in the Commonwealth.

Notwithstanding, the Governor's Office and PADEP felt that the potential for remediating devastated mine lands outweighed political perceptions and believed the idea deserved further consideration and study. But before any commitments were made, it was decided that DEP officials would meet with the local residents near the site, explain the project in detail and address any concerns raised, and then open the site for inspection to any resident who would be interested.

A public outreach effort commenced with a public meeting held at the Penfield Grange Hall in Huston Township on May 22, 1997. The residents of Penfield were invited, as were local sportsmen's groups, government officials and service organizations. Understandably, local citizens raised concerns about material that was considered "contaminated" being brought to their area, the negative effects of excess truck traffic, and the potential for water pollution from the site. From the discussions, two (2) particular issues emerged as the primary concerns of the community. First, local residents wanted assurances that the materials brought to the site would not be hazardous. Secondly, and most sharply felt, was that no hazardous materials could be

mixed with the dredged material at any place along the transportation route and that there could be no “midnight dumping” of wastes at the site.

Several important results came from the town meeting. The Huston Township supervisors (the local governing body) appointed an Environmental Committee of interested citizens to oversee work at the site. PADEP agreed to provide full access to the site day or night to any resident who wanted to inspect the facility, and arranged for CEDT to provide funds for the community to hire their own inspector and for chemical analysis of any samples collected by them at a lab of their choice.

The sampling and analysis plan for the Demonstration Project, as detailed below, was specifically designed and modified to answer the community’s concerns, providing for confirmatory testing of materials arriving at Bark Camp, as well as unannounced random sampling by the community and the PADEP site inspector.

The township committee became a full participant in the project and PADEP included them in all decisions regarding site plans. CEDT was required to submit a detailed operational plan for day-to-day activities including unforeseen contingencies. The environmental committee reviewed the plan and its revisions, and participated in meetings with CEDT, leading to final approval of the project. Because the environmental committee was given a voice in the decision-making process, potentially contentious issues were resolved to everyone’s satisfaction. The Huston Township Environmental Committee will continue to be consulted until final reclamation of the site is complete.

On June 6, 1997, PADEP issued Amended Beneficial Use Order No. BU40030, permitting the use of dredged materials from the Hudson-Raritan Estuary and the Delaware River for the reclamation of the Bark Camp Abandoned Mine Site. In 1998 the New Jersey State legislature authorized an expenditure of up to \$20 million for the demonstration from the 1996 Port Development Bond Fund, and the first delivery of pre-amended dredged material arrived at Bark Camp on May 28, 1998.

4.2. BARK CAMP

Bark Camp is a hilly and wooded area in the Moshannon State Forest just west of central Pennsylvania in Clearfield County (fig. 3). It is three miles due north of Interstate Route 80 and two miles south of the nearest community, Penfield, in Huston Township. Bark Camp is likely named for an old tree bark gathering camp for a bark tannery and is adjacent to a state game land. The area is frequented by sportsmen and hunters.

The area’s watershed and underlying coal beds tend to dip downward to the north and northwest. The stream at the site, named Bark Camp Run, follows this drainage pattern and empties into the Bennett Branch to the west. The main feature of interest for this project is the hillside rising about 300 feet above Bark Camp Run to the west and running due north about a mile and a half (fig. 4 to be composed). The entire area is underlain by twin layers of coal beds which, with time and erosion are now above the stream and outcropping along the hillsides, one 40 feet above the other.

In the 1950s the coal seams (only about 30 inches thick) were 'chased' back into the hillside on either side of the valley by deep mining; tunnels and galleries being dug to follow the dip of the coal beds that descend westwards about 300 feet vertically towards the Bennett Branch. A map of the abandoned mines is shown in Figure 5. From the 1960s a surface mining operation attacked the face of the hillsides surrounding and sloping down to Bark Camp Run. Because the seams or beds were not very close to the top of the hill, the overburden was stripped to expose the coal beds only as far back into the hillsides as feasible, dumping the overburden into the valley below, creating a bench along the entire 11,000 foot length of the hill.³¹ In part of this area, a second, upper bench was also stripped on a separate coal seam.

The mine operator had constructed a coal preparation plant and loading facility at a site about halfway up the valley at the deep mine entrances. A steel culvert was placed in the stream and covered with spoil material and coal refuse to create a 5-acre working area. Coal from the underground mines was processed at the site and trucked along Bark Camp Run to a railroad siding at the mouth of the valley near Penfield.

In 1988, the mine operator declared bankruptcy and the responsibility for the mine site, along with the cost for its reclamation, devolved to the Commonwealth. The operator abandoned the site, leaving behind the coal preparation plant, mountains of coal waste (silt and refuse), old mining equipment and rusting vehicles. Figure 6 (not pictured yet) is an aerial photo of the processing pad before any reclamation began, but after the initial site cleanup, facing due south. The double high wall is visible at top, partly covered in trees. It curves around the hill to the left and continues for about two miles. The piles of coal refuse generated acid drainage during rain events, visible here as three orange pools.

The coal seams, being relicts of geological time, differ in contour from the surface. The former coal processing facility (and now the dredge processing facility) was located in the curve of Bark Camp Run because that is the point where the tilted plane of the seams, descending from within the hills above the valley to the southeast, intersect the valley floor, from where they continue downward below the stream bed. The upper end of the coal seams lie at about the 1700 foot contour near the head of the valley and fall to an elevation of 1120 feet at its mouth, dipping almost 600 feet to the stream's 300 feet over the same linear distance.

4.2.1. Pre-project Conditions

Bark Camp Run is affected by acid drainage produced by the abandoned surface mining and, to a greater extent, by the two underground mines. The stripped pyritic overburden dumped into the valley during historic mining operations is below the project level and was not remediated by it. The mine spoil has impacted the upper portion of

³¹ The Bark Camp Surface Strip Mine was operated by the Glen Irvan Corporation from approximately 1960 to 1988. Two underground deep mines, Bark Camp 1 and Bark Camp 2, were also operated at the site since the 1950s.

the stream with acid drainage parameters and will continue to do so. Prior to the project, these exceeded water quality criteria and/or drinking water standards in the upper portion of Bark Camp Run for aluminum, iron, manganese, sulfate and pH.³² Prior to any work done at the site, ground waters in the monitoring wells along the high walls exceeded water quality criteria and/or drinking water standards for lead, cadmium, phenols, aluminum, iron, manganese, and pH. The monitoring point above any project activity that serves as a control for the stream quality at the head of the valley had exceeded water quality criteria and/or drinking water standards for cadmium, aluminum, iron, manganese, and pH, and reached a chloride concentration of 120 mg/L. Five gas wells surround the upper valley above the project site may have some impacts on ground water.

When the mines were abandoned, the underground mine voids (which remain intact) flooded, forming an acid generating mine pool in the areas down-dip of the entrances.³³ The portions lying up-dip of the elevation of the entrances (more than a mile in length in places) allow groundwater collected within them to flow toward the mine pool and overflow to the surface through the original entries. The resulting discharges from both mines are acid and contained dissolved metals. The stream, with a neutral pH (around 7) upstream of the processing area, was acidic (pH 2.8 to 5.2) downstream of the processing site, rendering it sterile. Groundwater aquifers, which are used as sources for drinking water in the area, are naturally high in iron pyrite due to coal deposits in the area. These aquifers also display acidic conditions.

In April 1982, before the underground mines which were abandoned began to discharge, the Pennsylvania Fish and Boat Commission conducted a stream survey to document the condition of Bark Camp Run for trout stocking. It sampled only one station near the mouth of the stream and found it to be of fair quality. A 1990 survey by the Bureau of Water Quality Management looked at the water immediately upstream and downstream of the abandoned preparation plant area. It showed the stream above the coal preparation facility to be healthy and indicative of a naturally reproducing trout stream. Immediately below the preparation plant, water quality criteria were violated. The report states "Bark Camp Run is not supporting its CWF (Cold Water Fishery) designation downstream..." describing the stream near the mouth as a "stressed aquatic system." See figure 7 for the site as it existed just prior to the reclamation efforts.

4.2.2. Mine Reclamation Laboratory

The mine reclamation research projects conducted earlier at Bark Camp and elsewhere by DEP provided the scientific basis for several aspects of the manufactured fill project. These projects are briefly summarized here.

Mineral rights and surface rights are often separately owned in Pennsylvania. When the Bark Camp Mine operator defaulted in 1988, the Bureau of Forestry (BOF), being the

³² PA Chapter 93

³³ Confirmed by drilling and video camera placement, PA DEP BAMR, 2002

surface owner, took the initiative to improve the site. No bond funds were available for reclamation, since the mine had been active before new mining regulations requiring such bonding had gone into effect.³⁴ The abandoned mine lands problem, resulting from years of pre-law mining is so vast and resources so scarce that PADEP officials are constantly searching for innovative means of accomplishing reclamation projects.

BOF and BMR began a basic clean-up effort, using in-house labor and a 'work in lieu of fines' system to have contractors begin clearing abandoned machinery. However, such efforts were not sufficient to extend to the reclamation of either the surface or underground mines. It was estimated that 3 to 5 million tons of fill would be required to complete restoration. With no bond monies available to finance such reclamation, and with the down-slope spoil becoming well forested over time, it was apparent that the site would likely remain unreclaimed.

At about this time, BMR had received a grant from the Environmental Protection Agency to study the chemical, physical and biological mechanisms occurring in wetlands that were used to treat acid mine water. Acid drainage impacts over 3000 miles of Pennsylvania's waterways and their treatment remains a priority. BMR proposed to use Bark Camp for the research project, since the site was in need of reclamation, it was isolated from any other activities that might influence the research and it was on Commonwealth property so easements and rights-of-way were unnecessary. BMR and BOF collaborated in clearing a portion of the Bark Camp site and constructing the wetland cells, visible in the aerial photo (fig. 5, not yet shown) in the lower right. Initial water monitoring began just prior to constructing the wetlands, and is detailed below.

The main acid mine drainage impact to the site were discharges from the overflow of the Bark Camp One and Two deep mines as described above. Bark Camp One was overflowing acid drainage at a rate of about 115 gallons per minute, while Bark Camp Two had a flow of about 10 gallons per minute. The wetland cells were constructed and acid drainage from the deep mines channeled into them. BOF, being aware of the McClosky and Camp Run projects, described above, suggested the possibility of grouting the deep mines to prevent acid drainage formation and discharge into Bark Camp Run.

The first use of coal ash at Bark Camp was approved in December 1993 through a no-cost reclamation contract between the Bureau of Abandoned Mine Reclamation and a contractor, E&L Brokerage "... for reclamation of the stockpiled refuse, disassembly and removal of the coal preparation facility and demonstration of the complete backfilling of the Bark Camp No.2 deep mine using fly ash and an activator."³⁵ The contractor received payment from the ash generator, while the Commonwealth would bear no costs, and initial cleanups were begun. Monitoring wells (numbered 1, 2 and 3) were drilled on the crest of the southern hill above Bark Camp Run below the coal processing

³⁴ the Surface Mining Control and Reclamation Act of 1977

³⁵ Demonstration Project – No cost Contract; DER Contract #OSM 17 (6955) 101.1 ,issued December 20, 1993.

facility for the purpose of determining groundwater quality in, underneath, and above the Bark camp No 2 underground mine.

PADEP establishes sampling and testing requirements for any residual waste material proposed for beneficial use, formerly through the issuance of a Beneficial Use Order, subsequently replaced by a General Permit process. The Department's regulations at 25 Pa Code 287.664 define the requirements for the beneficial use of coal fly ash at abandoned mine sites. This regulation requires the generator of the ash to demonstrate to the DEP that the chemical and physical quality of the ash meets DEP certification guidelines. The user of the ash must describe how the ash is to be used and must monitor the site to evaluate the success of the beneficial use project.

When an evaluation of the deep mines indicated that their grouting was problematic (since much of their length was under water and would require much larger volumes of coal ash than were available locally) it occurred to BMR that perhaps ash could be used to reclaim the surface high walls instead, utilizing the no cost contract.

The contractor therefore began restoring the surface features of the site by placing coal ash, waste lime and coal refuse in lifts to restore the high wall just to the south of the preparation plant. A two-foot layer of an ash and waste lime mixture was placed on the floor of the abandoned surface mine, on which a layer of coal refuse was placed and compacted. The sequence was repeated until the surface mine highwall was eliminated. The ash and lime mixture hardened to a low permeability soil cement, preventing air and water from contacting the acid producing refuse. The Pennsylvania State University Materials Research Laboratory was involved in formulating the makeup of the cementing agents to insure proper proportions of ash and lime.

Subsequently E&L Brokerage submitted a permit application to PADEP for the beneficial use of municipal waste incinerator ash (MWIA) and received approval on September 12, 1996 for ash from the York County Solid Waste Authority's municipal solid waste incinerator in York County, PA, the Hempstead municipal solid waste incinerator in Long Island NY, and the Essex County municipal solid waste incinerator in Newark, NJ.³⁶ The Beneficial Use Order contained a number of conditions to control the quality of the ash material including prohibiting the use of ash material testing hazardous as defined in DEP regulations, requiring quarterly testing of the ash using EPA methodologies, TCLP leaching tests for RCRA parameters, and prohibiting ash that exhibited toxic waste characteristics as defined in DEP regulations.

DEP decided to do a small test with the municipal waste incinerator ash, on a liner with a collection system, on the opposite side of the hill from Bark Camp Run. In 2001, about 9000 cubic yards of dredged sediments from the Parker Dam State Park were combined with alkaline activated MWIA ash and placed on the liner. The Monitoring

³⁶ Beneficial Use Approval Order No. 40030 ,Nov. '97.

point from the leachate collection system is designated as Surface Water 31, and the erosion and sedimentation pond below the area is SW 32. Subsequently, MWIA grouts was used in much of Phase Two of the project site.

As areas of highwall were returning to their original contours it was apparent that large amounts of soil cover would be required. The contractor worked with Penn State University's Dr. Dale E. Baker to develop a manufactured top soil. Dr. Baker developed the American Society of Testing and Materials (ASTM) protocol for determining the soil-like qualities of materials named for him. In April 1997, a general permit (WMGR045) was issued to E&L Brokerage for the use of paper mill sludge (paper fibers that were too short for recycling) for water retention, vegetable tannery waste for organic nutrients, and waste lime and coal ash for the manufacturing of an artificial soil. The general permit prohibits the use of paper mill waste if the dioxin concentration exceeded 30 parts per trillion, prohibits the use of tannery wastes if the total petroleum hydrocarbon level exceeds one (1) percent, and prohibits the use of any materials that are hazardous as defined by DEP regulations.

In each instance an effort was made to use the properties and economics of would-be waste materials and co-products to accomplish mine reclamation that would not otherwise be accomplished. When the opportunity arose to test dredged material, at minimal cost to the Commonwealth, amending the existing permits for ongoing activities at Bark Camp was the most effective means of accomplishing the demonstration and completing the reclamation of the site.

On June 6, 1997, PADEP issued an amendment to the Beneficial Use Approval Order and the No-Cost contract between E & L Brokerage and PADEP for the use of the dredged materials in an engineered fill at the Bark Camp Mine Reclamation Project pursuant to state solid waste regulations.

4.3. PROJECT OPERATIONS

The following sections describe the operations, permitting, monitoring and testing involved in this project. Each step of the process is regulated by permits and approvals issued by local authorities. For clarity these sections are treated separately, with the attached tables detailing the permits and monitoring requirements at each step of the operation.

4.3.1. Dredging

Maintenance dredging is simply the removal of sediments from a body of water that have accumulated due to erosion in order to maintain a desired depth, as in a reservoir, dam, shipping berth, marina or navigation channel. It must not be confused with environmental dredging, which is the removal of source-specific contaminated sediments generated during an environmental cleanup operation, such as the removal of PCB laden spoils from past industrial spills.

The Demonstration Project involved navigational dredging for the maintenance of existing shipping channels and berths. Such channels are 'authorized' to be maintained

to certain depths depending on their use, by periodic dredging of the silt, sand and clay that are deposited in them.

Dredging activities have become increasingly more heavily regulated by federal and state environmental agencies in recent years. Each state has extensive regulations governing not only the dredging activity itself, but also the processing, transport, and disposal of the dredged sediments. The New Jersey guidance document entitled “The Management and Regulation of Dredging Activities and Dredged Material in New Jersey’s Tidal Waters 1997” sets out in detail the myriad requirements for dredging in New Jersey’s waters. Additional information and detail regarding the applicable permitting requirements and specified monitoring protocols for this project are presented in the Permitting section below.

For this project, the contractor is required to prepare and submit a sampling and analysis plan to PADEP, detailing the actual locations and frequency of sediment sampling points for each waterway proposed to be dredged. The ABUO requires bulk chemistry analyses and leachate testing (TCLP analyses) on each 10,000 cubic yards of material to be dredged. In general, approximately one (1) core sample must be obtained for each 4000 cubic yards of material expected to be dredged. PADEP set specific pass/fail limits for what was to be considered acceptable material for the project, and appears in [Appendix 5](#). Additionally, NJDEP (for NJ projects) or NYSDEC (for NY projects) also issue a Water Quality Certificate for the dredging activity and Acceptable Use Determinations (NJ only) for processing and beneficial use of dredged materials, including the material that was destined for Bark Camp under this project.

Prior to dredging, the area proposed to be dredged is defined by an engineer and the target area is then surveyed. From the bathymetric survey, the volume of material required to be removed for the specific project is calculated.

Subsequently, core samples of the in-place sediment are taken to physically and chemically characterize the material. For this project, a PADEP inspector was present for the initial, and most of the subsequent, in-situ dredged material sampling events to obtain split samples for analysis at an independent PADEP laboratory. The physical testing determines the grain size of the sediments, the percent moisture, and the total organic carbon content, while an entire suite of bulk chemical testing is performed for the chemical substances listed in [Appendix 6](#) and described below.

Since any contaminants primarily adhere to the fine grained particles, sediments consisting mostly of sand and gravel will likely not be associated with elevated levels of any chemical constituent. Sediments consisting primarily of silts and clays have a higher affinity for the attachment of contaminants due to their increased surface area.

The physical act of dredging can be accomplished in several ways. Here we will concentrate on the methods employed for the Demonstration Project. Due to the nature of the sediments being removed for the project, and restrictions imposed by state and federal regulatory authorities, all dredging for the demonstration project was accomplished using environmentally-friendly methods. A mechanical dredge

(clamshell) was utilized along with an “environmental bucket,” a clamshell bucket fitted with overlapping sides and a gasket seal to prevent loss of material into the water column during the dredging process. Further best management practices (BMPs) were employed during the dredging process, including limiting the line hoist speed of the crane during dredging, lowering the clamshell bucket below the sides of the hopper barge before releasing the sediments into the barge, and utilization of silt curtain around the dredging area in environmentally-sensitive locations.

After deposit of the dredged material into hopper scows, each scow was transported to a location within the dredging area waterway, or to the Claremont DMRF, for dewatering of free water from hopper scows under permit controlled conditions. In general, each scow was allowed to settle for a minimum of six hours prior to decanting (evacuating) free water that rises to the top of the scow into a separate holding vessel. The decant water is then allowed to further settle for a minimum of 24 hours within the dewatering vessel, or until the decant meets the permit requirements of discharge back to the waterway. Upon reaching the required limits for total suspended solids, the clarified water is discharged back into the adjacent waterway.

4.3.2. Processing

Clean Earth Dredging Technologies, Inc. (CEDTI) of Hatboro, Pennsylvania operates a fully permitted commercial dredged material processing and trans-shipment facility (fig. 8) on lands located adjacent to the Claremont Terminal Channel in Jersey City, Hudson County, New Jersey (the “Claremont DMRF”). The waterfront parcel consists of approximately nine acres with nearly 1000 feet of waterfront pier access and is capable of receiving numerous barges simultaneously. As contracted by PADEP, CTI was responsible for procuring the necessary dredged material projects, and for all project operations including the dewatering, processing, land transportation and upland beneficial use activities for the project.

For the individual dredging projects comprising the Demonstration Project, multiple hopper scows are used for each project. Typically, one scow will be loading at the dredge site, several scows will be in transit to the processing facility or dewatering, and one scow will be off-loading at the Claremont DMRF. The hopper scows ranged in capacity from 1700 to 4000 cubic yards of dredged material.

Upon completion of the dewatering and discharge process, each hopper scow is transported by tugboat to the Claremont DMRF where it is moored to the dock. As necessary, oversize debris (pilings, timbers, tires, etc.) is removed from the barges using a conventional hydraulic excavator equipped with a rake mechanism. The dredged material is then lifted from the hopper barge into a pugmill processing system (illus.) using a long-reach excavator equipped with a hydraulic closed clamshell bucket and placed onto a vibrating screening unit that screens the material to less than 4 inches in size. The oversize debris removed from the barges and screened in the mill is placed into roll-off containers or dump trucks for transport to an approved solid waste disposal or recycling facility.

4.3.3. Pre-amendment

Dredged sediments are mostly water (about 60%) when dredged, but their clay and silt components make their mass adhere together. Depending on how long they have been allowed to consolidate in the channel after their deposition, they may be fairly stiff like clay, yet at the same time have no structural integrity, remain flowable, and continually release water over time. In order to make the material suitable for rail transportation it must be 'pre-amended' at the port site (in respect to their 'final amendment' at the mine reclamation site). The addition of admixtures including approximately 15% by volume of ash and in some cases, small percentages of alkaline admixtures, at this stage binds any free water in the material, prevents it from 'sloshing' in the rail cars, and makes it easier to handle. The first several dredging projects, as detailed below, were pre-amended with coal combustion ash only. The ash arrived at the facility in closed tanker trucks and was pneumatically blown into the storage and feed silos visible in the photo of the processing system. After mid-2001, screened municipal waste incinerator ash (MWIA) was used as the pre-amendment material.

After passing the debris removal system, the screened dredged material falls directly into a receiving hopper which feeds a low-incline conveyor belt delivering dredged material directly to a twin-shaft pugmill (an enclosed box with counter-rotating paddles). The pugmill is also fed by ash silos and conveyors containing the necessary admixtures. All conveyors are equipped with spill containment systems. In the pugmill, the dredged material is mixed with the admixtures, which are introduced to the pugmill chamber via an enclosed delivery system. Emissions from the pugmill and additive delivery system are controlled by three separate bag-house dust-collection devices. The entire dredged material processing system is covered by a General Air Quality Permit and an Air Pollution Control Permit. The pugmill blending system is controlled by a programmable logic controller (PLC), a computer that uses weigh bridges on the feed conveyor belt to measure the weight of dredged material entering the system on a real-time basis. As the material is weighed, conveyor line speeds and flow rates of each admixture are controlled by the computer to ensure that a consistent, pre-determined percentage of each admixture is being blended with the dredged material on a real-time basis through the "continuous batch" process.

After mixing, the amended dredged material empties from the pugmill onto a radial stacking conveyor. This is simply a conveyor belt gantry that can swivel in an arc from the pugmill, with its end mounted on wheels. It can be positioned directly over gondola type rail cars lined up on a series of tracks parallel to the mill, or stockpile the material for re-handling to trucks, railcars, or hopper scows.

A major goal of this project was to prove the feasibility of this application on a practical basis; that the material can be handled, processed, treated, transported and emplaced while keeping up with capacity of the in-water dredging operations. CTI's dredged material processing facility processed and shipped up to 4300 yards of material per day, and it is estimated that the present facility is capable of stabilizing up to 6,000 cubic yards daily.

4.3.4. Transportation

CEDT maintained a leased fleet of up to 400 rail cars for use in shipment to the Bark Camp site over the course of the Demonstration Project. Each car holds a payload of approximately 110 tons of material. The cars are covered with a watertight tarpaulin to exclude rainwater and to deter the addition of foreign material to the cars during shipping. Transportation from the Claremont DMRF in Jersey City, New Jersey is by Conrail Shared-Asset Railroad to the Norfolk Southern Railroad to its terminus at Driftwood, Pennsylvania. From there, the Pittsburgh & Shawmut short line Railroad delivers the train to a dedicated siding at the mouth of the Bark Camp valley.

As noted previously, Bark Camp was not logistically ideal, partly because of the distance between the rail and the mine site, necessitating re-handling into off-road trucks with a bridge-mounted hydraulic excavator (fig. 9). At the off-loading site, the cars were untarped, and the pre-amended dredged material was excavated from the rail cars and transferred onto site dump trucks for shipment to the process area at Bark Camp. The material arriving at the Bark Camp process site was stockpiled adjacent to the pugmill on a graded and bermed pad. Surface water run-off from the Bark Camp process pad flows into a sediment trap for solids removal before discharge to Bark Camp Run

4.3.5. Final Processing

The final processing and amendment of the dredged material takes place at another pugmill system constructed by CEDT on the site of the former coal processing facility at Bark Camp, pictured in figure 10. The pre-amended dredged material, various coal combustion ashes and alkaline activators are stockpiled on the processing pad and placed by loaders and excavators into individual feed hoppers. Each feed hopper is controlled by a computer-monitored conveyor belt weigh-scale system that meters the materials using variable speed systems according to a set mixing regimen programmed by the pugmill system operator. As at port process site, the material exits the pugmill mixing system onto a radial stacking conveyor. Off-road site dump trucks are loaded with the amended dredged material and carry the manufactured fill material to the mine high wall, where each load is dumped into 'soldier piles,' and optimally allowed to sit for up to three days to allow the pozzolanic reactions to dry the material to near optimum moisture content. At this stage, the manufactured fill material is then placed and compacted in one- to two-foot lifts using standard earthmoving equipment including bulldozers and a vibratory roller (fig. 11, 12). Each successive vertical lift is placed parallel to the high wall, and is slightly narrower than the previous one, mimicking the original contour of the hillside until the top of the stripped high wall and the natural contour of the hill is reached.

When the final grade is achieved with the fill, an 18 - 20-inch layer of manufactured topsoil (described above) is placed over the fill and planted with a mine reclamation meadow mix specified by the BOF. As previously mentioned, the manufactured topsoil

has exhibited a remarkable ability to sustain lush growth even during periods of drought, as in the summer of 2000, and the project area now maintains a dense grass cover. The series of photos on Page Y illustrate the process sequentially from pre-reclamation through to completion.

As seen in the series in figure series 13, 14 and 15, the stripped portion of the hillside was transformed from having two exposed shale ledges, with precipitous drops along their length, back to its original contour before mining. The Pennsylvania Bureau of Forestry had expressed its desire to keep the area as a meadow habitat. The surface road visible along the middle of the restoration has been planted, and will be preserved as a fire road for access into the valley.

The manufactured fill project took several years for actual implementation. The first dredged material arrived at Bark Camp on May 28, 1998, nearly three years from the first contact between COAST and DEP. Five years have passed and 424,710 cubic yards of dredged material have been brought to the Bark Camp site, out of the 550,000 yards permitted for the demonstration.

4.4. PERMITTING

4.4.1. Permitting, Port Side

After processing the initial pilot project of 19,000 cubic yards of material at a temporary facility in 1998, CDTI established its Dredged Material Processing Facility on the Claremont Channel in Jersey City, New Jersey. The following regulatory approvals and permits were obtained from the New Jersey Department of Environmental Protection (NJDEP) to operate the facility:

NJDEP Waterfront Development Permit/Water Quality Certificate No. 0906-96-0001.6 issued May 10, 1999.

- New Jersey Pollution Discharge Elimination System/Discharge to Surface Water Permit (NJPDES/DSW) No. NJ0134015 issued July 30, 1999.
- NJDEP Bureau of Air Quality General Permit (Activity ID No. GEN990001, Facility ID No. 12115) for Ash Management Equipment issued July 20, 1999.
- Hudson County Soil Conservation District Soil Erosion & Sediment Control Plan Permit No. 99-H-1386 issued August 1, 1999.
- PADEP Amended Beneficial Use Order No. BU40030 issued June 6, 1997 for the reclamation of the Bark Camp Abandoned Mine Site located in Clearfield County, PA.

Each of the seven individual dredging projects that went to Bark Camp required permits from the relevant federal, state and local jurisdictions in New York and New Jersey.

The management of dredged materials generated, processed, disposed of or beneficially used, in the state of New Jersey is regulated by the New Jersey Department

of Environmental Protection, Office of Dredging and Sediment Technology. During October 1997, NJDEP produced and adopted a technical manual that specifies New Jersey's rules and regulations regulating the management of dredged materials. The manual is titled, The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters, October 1997.

4.4.2. Permitting, Pennsylvania

In the years before the dredged material project, several permits had been considered and issued for prior mine reclamation operations at Bark Camp:

The first use of coal ash at Bark Camp was approved in December 1993 through a no-cost reclamation contract (OSM17 (6955) 101.1) between the Bureau of Abandoned Mine Reclamation and the contractor, E&L Brokerage.

E&L Brokerage received approval (BUO 40030) in September, 1996 for the beneficial use of municipal waste incinerator ash (MWIA) from the York County, Pa. Solid Waste Authority's municipal solid waste incinerator the Hempstead, Long Island municipal solid waste incinerator in NY, and from the Essex County municipal solid waste incinerator in Newark, NJ.

In April 1997, a general permit (WMGR045) was issued to E&L Brokerage for the use of paper mill sludge, vegetable tannery sludge, waste lime and coal ash for the manufacturing of an artificial soil.

The first permit allowing dredged sediment to be used for this project was issued by PADEP on June 6, 1997, as an amendment to the Beneficial Use Approval Order and the No-Cost contract between E & L Brokerage and PADEP for the use of the dredged materials in an engineered fill at the Bark Camp Mine Reclamation Project, pursuant to state solid waste regulations. The order reiterated the conditions of the original order and also detailed conditions to control the quality of the materials used for the manufactured fill. The Beneficial Use Order (BUO) specifies the terms and conditions for the acceptance of any dredged materials, predicated upon PADEP's review and approval of the physical test results and chemical analysis. Each dredging project considered for Bark Camp required an Approval of Analyses of Specific Dredged Material Source upon completion of testing.

Additional permits for operations at Bark Camp included:

- PADEP NPDES General Permit No. PA R-304802 (1997), Authorizes Industrial Activities Stormwater Discharges.
- PADEP NPDES Permit No. PA S - 101714 (1998) - Authorizes Construction Activities Stormwater Discharges.

The use of municipal waste incinerator ash (MWIA) was required to undergo the complete permitting application/ approval process. The use of MWIA at Bark Camp was approved by DEP in September 1996. The Beneficial Use Order requires quarterly sampling and analyses on all MWIA received at Bark Camp. Testing must include an analysis of the toxicity characteristics as set forth in the Toxicity Characteristics Leaching Procedure (TCLP). Further, the formulation of MWIA and activator must be analyzed using the Synthetic Precipitation Leaching Procedure (SPLP).

4.4.3. Coal Ash

The beneficial use of coal ash in Pennsylvania is regulated by The Solid Waste Management Act, the Surface Mining Conservation and Reclamation Act, the Clean Streams law and the Coal Refuse Disposal Act. Specific permitting requirements, procedures, performance standards, inspection requirements, enforcement procedures and penalties are in 25 PA Code, Chapter 287.

5. RESULTS

Analysis of sediments before dredging and along the processing train showed that trace contaminants within permitted levels were present in the fill material prior to placement. Yet in the more than five years of monitoring ground and surface water impacts after placement began, the substances of public health concern - PCB's, pesticides, volatile and semi- volatile organic compounds, dioxins and furans - were not detected in any of the surface and groundwater monitoring points. Similarly, metals remained at the background levels present before the project and were not impacted by the manufactured fill.

Pre-screening of dredging projects eliminated one candidate from use at Bark Camp for exceeding permitted levels of contaminants, while random testing of rail cars and pug mill samples at Bark Camp confirmed that no hazardous substances had been added to the materials during shipping and handling.

The only statistically significant water monitoring impact detected was the appearance of chlorides from common salt, which fluctuated in relation to project activities and demonstrated the effectiveness of the water monitoring plan. Chlorides in Bark Camp Run (not a source of drinking water) remained below any action level or water quality standard during the three years of exclusive placement of amended dredged materials. After placement of municipal waste ash grouts, chlorides exceeded recommended drinking water standards on one occasion. Higher chloride levels in two wells were determined to be artifacts of their placement and not a reflection of groundwater levels. However, even though these wells were found to be collecting water from across large areas of the site due to road and well configurations, they did not exhibit a single detectable contaminant other than already present mine drainage metals.

The extensive physical changes wrought on the site, described below, include the restoration of the entire project area to its approximate pre-mining contours (fig. 15).

The dangerous double high wall, located in a state forest adjacent to a state game land, was eliminated removing a significant human health threat. On what were wide benches of bare pyritic rock and shale, the slope has been restored, covered with soil and planted, creating a meadow habitat visited by bear, turkey, bobcat, deer and elk. The project was accompanied by significant employment opportunities as well as other positive inputs more fully treated below.

The entire data set collected during the project will be available through the [NY/NJ COAST](#) website.

6. DISCUSSION

6.1. ORGANICS AND METALS

Prior to dredging, trace levels of contaminants were present in the project sediments. Volatile and semi-volatile organic compounds, pesticides, PCBs and dioxins, as well as lead, mercury, chromium, cadmium and arsenic were detected, although within permitted levels. It is again important to distinguish between sediments such as these, containing trace contaminants within permitted levels, and the environmental remediation of heavily contaminated hazardous substances that require decontamination, and which are prohibited from this application. PCBs barely exceeded one fourth of the permitted standard, and dioxins never exceeded one half.

The manufactured fill was placed during two periods between May 1998 and August 2002 separated by a hiatus of nearly two years. Water monitoring for all parameters began prior to the placement of materials: testing for metals beginning in October, 1997 and for organics in March of 1998. Samples were at first collected monthly and then quarterly.

Water samples were analyzed for general chemistry parameters, metals semi-volatile and volatile organic compounds, pesticides, PCBs and dioxins and furans. The sampling protocol is listed in Appendix 7. The most dramatic results are impressive yet expected: no detected organics or heavy metals from the project whatsoever in over five years of surface and groundwater monitoring. Metals typical of acid mine drainage (especially iron and manganese) were present before the project began and continue to be, due to the pyritic mine spoil rimming the floor of the valley, dumped during historic stripping operations. Since it is below the project area, it was not remediated during this application and continues to generate acid drainage.

As detailed in the relevant section, bituminous coal ashes, especially from fluidized bed combustors, have been demonstrated to bind metals and contaminants into insoluble forms inside a low permeability cementitious matrix. The trace organic contaminants, shown to be present in the pugmill samples, are expected to be sequestered, but they may also be subject to alkaline attack within the high pH matrix, and may no longer exist intact.

Time trends in each potential contaminant were explored through (a) smoothed scatter plots, and (b) using the non-parametric annual and seasonal Mann-Kendall test for

monotonic trend. Variables for which the trends were statistically significant at the 90% level were identified. The spatial consistency and homogeneity of these trends was then analyzed. Chloride was the only parameter to show a statistically significant trend in every location.

6.2. CHLORIDES

Other than a general downstream improvement of mine drainage impacts from the former mining operations, the only statistically significant trend observed during monitoring was the appearance of chlorides from sodium chloride (common salt), validating the placement of surface and groundwater monitoring points. In correlating chloride concentrations against sodium, total dissolved solids, and specific conductivity, sodium chloride was identified as the source of chlorides.

6.3. MONITORING POINTS DATA

The behavior of chlorides in surface and ground water monitoring points over five years is illustrated in [Graph 1](#) and [Graph 2](#) [SW Cl vs. Projects], while the placement of the monitoring points is illustrated in [Appendix 8](#). A brief review of the monitoring points is necessary to understand the recorded effects.

Surface Water (SW) Monitoring Points. Surface Water 1 (SW-1) is near the head of the valley, above any impact from the project fill, and serves as a reference point for the ambient water quality of the stream. It generally runs at a small rivulet of about 1 to five gallons per minute (gal/min.), but up to 20 gal/min. in rainy weather. Surface Water 3 is taken from an intermittent tributary to Bark Camp Run which flows in the ravine dividing the project into two phases. A culvert located there supports the road over the small ravine and sample collection was performed directly below the culvert. SW 3 runs intermittently at about 1 to 5 gal/min. and is often dry (thus the reduced number of samples available from there). SW-5 is the furthest downstream monitoring point affected exclusively by the project. It is located where the stream curves northwestward towards the processing pad, just below the extreme edge of the fill area, and runs at about 1000 to 2000 gallons per minute. Surface Water 7 is several hundred feet downstream from the processing pad and receives contributions from not only several other tributaries draining the valley, but 180,000 gallons daily from the two deep mine drainages as well. Miscellaneous other sampling points will be discussed below.

Monitoring Wells (MW). Six monitoring wells were drilled along the length of the valley, directly below the fill area, at the edge of the lower bench. Monitoring Well 9 (MW-9) is near the southern end of the project and along with MW 8 and MW 7 is in Phase 2. A small ravine bridged by a culverted road beyond MW 7 separates the two phases. Monitoring wells MW 6, MW 5 and MW 4 are spaced further along the valley within Phase 1.

Chloride is most familiarly known as half of the common table salt molecule, sodium chloride (NaCl), and is a negative ion, or anion. Sodium is a positively charged atom, or

cation, and the oppositely charged atoms attract each other electrically to form a loose ionic bond. Ionic bonds are weak magnetic attractions as opposed to the extremely strong chemical bonds that take place in pozzolonic reactions, where electrons are shared among atoms. Sodium chloride is extremely soluble and readily dissolves in water. The ions disassociate and are detected separately. While sodium fairly readily binds with other compounds, chlorides are extremely unreactive and are therefore very mobile in solution.

Prior to the use of Municipal Waste Incinerator Ash (MWIA), low levels of chloride (below 50 mg/L) were detected in surface waters during the exclusive placement of dredged materials amended with alkaline activated coal ash. Given that the dredged materials used contained salt water they would be expected to release some sodium chloride during processing, handling and the curing period. Some chlorides would be expected to appear from salt dissolving during surface washing of the manufactured fill and then decline.

Since most of the water present during pozzolonic reactions is chemically broken up and bound as hydrogen and oxygen compounds in the cementitious matrix, only a small amount of liquid water remains in the pore spaces. Coal ashes and dredged materials are mostly made up of very fine particles, when the manufactured fill is roller compacted and cured, it forms a very tight solid that water does not easily enter or move through. It would literally take many tens of thousands of years for water to pass through properly mixed and placed material. This low permeability and low hydraulic conductivity reduces the amount of chlorides that could subsequently become available.

Immediately after setting up, a certain amount of salt would be liberated by surface washing of the monolithic fill. Water would penetrate the topsoil layer and hit the low permeability surface, moving along it down slope, collecting easily dissolved salts on its surface, the area of which, as discussed above, is very small compared to the enclosed volume. Also, as the layers of fill become higher, the weight of the top portion would squeeze a certain amount of pore water out of the lowest portion. Chlorides would afterwards be reduced to moving across a concentration gradient, diffusing extremely slowly out of the cementitious matrix. Thus, chlorides, which exist in a finite amount and become less available over time, are expected to make an early appearance and then drop off in concentration.

The appearance of *elevated* chlorides during this demonstration corresponds with the introduction of municipal waste incinerator ash (MWIA) into the manufactured fill. Though unconsolidated MWIA ash is known to release chlorides, it is a pozzolonic material and would be expected to release a finite amount of chlorides as well. About 253,000 tons of MWIA was placed in Phase 2, and the western portion of the former mine site in an area removed from this project, which is across the hilltop and away from Phases 1 & 2 of the project.

The USEPA recommended ambient freshwater water quality criteria for chloride are:

- 860 mg/L for acute exposure, and 230 mg/l for prolonged exposure.³⁷
- USEPA also recommends a level of 250 mg/L under the Safe Drinking Water Act for potable water sources, which Bark Camp Run is not.
- 25 Pa Code Chapter 93 Water Quality Standards is 250 mg/L, which is also intended to protect the potable water supply.

Again according to the USEPA, salt is not acutely toxic to rainbow or donaldson trout but becomes toxic at 6777 mg/L.³⁸ During the three years of exclusive placement of amended dredged materials, stream chlorides in the section below the project very briefly rose to 44 mg/L then declined, clearly a level well below any action level or water quality standard.

After placement of incinerator ash grouts however, stream levels rose to a high of 282 mg/L below the project and has declined ever since. Chlorides rose to 309 mg/L below the processing area in the more heavily acid mine discharge impacted portion of the stream. While these levels correlated well with four of the six monitoring wells, two of the wells showed inexplicably high levels of chlorides, not reflected in the stream data. While the highest level of chlorides ever reached in the stream below the site was 282 mg/L, one well indicated a chloride concentration of 1900 mg/L, the other a high of 864 mg/L. For a diffusing groundwater measurement to reach such a level in that well, a much higher concentration of available chlorides would have to be the source. It was hypothesized that either the manufactured fill was improperly mixed above those two areas or the wells were somehow registering an artificial concentration of chlorides. If the fill was not behaving as designed, then there would had to have been at least some trace of metals or organics in the same wells, which was not the case, nor was their any physical failure of the slope. An examination of the site configuration indicated the second possibility.

It had already been suspected that MW 7 was located in a fracture, since the well chemistry showed that it was a full pH unit more acidic than the other wells and only 15% of their alkalinity. Mine drainage related metals (iron, manganese and aluminum) in MW 7 were 1.5 to 10 times the concentration in the other wells. Water sampling was expanded at the site and the wells underwent physical and chemical testing. The results were compared to a geological cross section of the site constructed from the drilling logs, where each strata and their thickness had been recorded.

The wells in question were revealed to be so situated that they were collecting elevated chlorides as an artifact of their placement and site configuration coincidences, and not reflecting actual ground water concentrations of chlorides.

³⁷ EPA 440/5-88-001 and at 53 FR 19028 and <http://www.epa.gov/ost/pc/revcom.pdf>

³⁸ Pesticide Action Network database

Site examination revealed several factors that could be influencing the well chlorides. All the wells had been drilled in 1997 prior to operations, and placed along the downhill edge of the lower highwall bench. Topographic analysis showed that the wells were in steadily declining altitudes in succession, descending along the highwall above the stream, each well lower than its predecessor. Since mining had ceased some 20 years before, the surface of the mine spoil that had been dumped downhill during historic strip mining had become well forested and was indistinguishable from that of the overall surface. Drilling logs revealed that, as a consequence, all of the 6 wells were actually drilled through from 7 to 46 feet of spoil before encountering native rock. The native surface below the spoil is a hydraulically highly transmissive layer known as a “weathered regolith” and readily transmits water to a depth of 30 to 60 feet.³⁹ Additionally, after operations were begun, construction crews sought slight widenings of the lower pit floor bench for the placement of sedimentation and erosion traps, just as the drilling crews did for well placement. Consequently, each well was closely associated with a sediment trap near its surface, four of them actually on the edge of the ponds.

Furthermore, construction roadways were established at the edge of the upper and lower highwalls for hauling material. In the case of the lower wall, the road ran past the wells and sediment ponds. As a safety measure, a three to four foot tall safety berm had been required by inspectors along the downhill side of the road, and was placed along the length of the project, on the downhill side of the wells and sedimentation ponds. Since the berm and roadways were channeling water to the ponds, it was suspected that the runoff water, concentrated in the ponds, was influencing the wells through the crushed layer of mine spoil connecting their surfaces.

6.4. PUMP TESTS

Each well was mechanically pumped while electronically measuring their rate of well water recharge. Water samples to be tested for chloride levels were taken at each well prior to pumping, after three well volume evacuations (the normal sample gathering point) and after an additional 10 evacuations, or after the well ran dry if 10 evacuations were not reached. Each sediment pond was also sampled and analyzed for chlorides. The results appear in [Appendix 9](#). The results were compared along with a geological cross section of the strata along the line of wells.

A small culverted ravine separates the length of the valley into two approximately equal phases, with three wells along each phase. From the head of the valley at the highest elevation in Phase 2 are Monitoring Wells 9, 8 and 7, followed by the small culverted ravine, and then by wells 6, 5 and 4 in Phase 1.

³⁹ PADEP Act 54 Report, Geology and Hydrology of the Bituminous Coalfields, VII-7 1999

It was the lowest well in each phase that exhibited the high chloride levels; well 7 at the lowest end of Phase 2, and well 4 at the lowest end of Phase 1. Pumping data from the two higher elevation wells in each phase, 9 and 8 in Phase 2, and 6 and 5 in Phase 1, showed slow recharge rates indicating sealed wells being recharged from rock strata.

Well 7 however proved to be totally unconfined. Beginning with a standing water depth of 80 feet, even after pumping 13 well volumes from it, the water level only dropped 6 inches. Water was flowing into well 7 as quickly as it was being pumped out of it. On closer examination, a seep was observed being emitted from the hillside below well 7; all evidence supported the finding that it had been situated in a fracture and was open to all surrounding influences.

Pumping data for well 4, at the lowest edge of the project at the bottom of Phase 1 was also exceptional, in that, even though pumped dry, it recovered extremely quickly, regaining 13 feet of water in 10 minutes. Drilling logs showed that well 4 was the only one to be drilled deeply enough to hit the next layer of coal, from immediately above which layer it was recharging. Recall that all coal seems in the region dip northwestward, away from the stream. Well 4 was collecting water from above an impermeable barrier and which was not heading into the stream.

Wells 7 and 4 were being influenced by factors other than recharge of groundwater heading toward the stream. An examination of the chart showing well chloride levels at 0, 3 and 13 purges explains the measured artifact. The square above the bar chart for each well indicates the chloride concentration in the sediment ponds above or nearly above each well. They indicate that chlorides were achieving relatively high concentrations in the ponds due to pooling and channeling of the water along the length of each phase over the constantly disturbed road bed. Chlorides in the sediment pond over well 9 were 4234 mg/L, and by the time the water had pooled above well 8 they were 6244 mg/L. The geological chart, along with drilling log data indicating the strata of water bearing layers, shows that the main aquifer is the sandstone layer trending downward along the valley. The strata diagram also shows that wells 9, 8 and 7 are all connected by a layer of mine spoil. Salt is so soluble that it will dissolve easily in water. The larger salt-bearing area covered by water, the higher the concentration of salt.

Recall that after two years from the start of the project, where material was placed above well 5, a slight elevation in chlorides appeared in MW 4, diagonally and downhill from the area, and not well 5 directly below it. Water was clearly also moving down along the valley through permeable strata rather than just perpendicularly into the stream. High chloride water, elevated because of the increased length of contact with the surface, pooling, and movement along the disturbed road were migrating through the mine spoil from the sediment ponds above wells 9 and 8 and being intercepted by the fracture around well 7. While sediment pond chlorides were high over wells 9 and 8, with no corresponding level in the wells below them, the sediment pond chloride level above well 7 was only 394 mg/L, while the well level was over 1900. there is a slight rise in the road heading towards well 7, which interrupted surface flow of the pooled sediment pond waters, but allowed them the pass below through the permeable strata.

The sediment pond at the lowest edge of Phase 2, after well 7 and just above the ravine separating the phases, had a chloride concentration of 680, showing that along-wall movement of water over the roadways was still concentrating chlorides, but interrupted over well 7. The ravine between phases prevented their uninterrupted movement down gradient into Phase 1.

Similarly, the sediment pond chloride levels over wells 6, 5 and 4 in Phase 1 were 333/mg/L, 1630 and 3105 respectively, growing in concentration downhill. A clay lens above well 5, just below the spoil layer probably further aided in moving water along the spoil towards well 4. Well 4, collecting water from a deep impermeable layer (an aquatard) that moved water away from the stream, was the recipient of recharge of chloride enriched water moving down gradient through the mine spoil layer.

All reclamations and remediations are engineered specifically to shed water off their surfaces. In this case, road safety precautions and the coincidental placement of wells in mine spoil, in areas ideal for sediment ponds, mitigated to collect, channel and pool water along the length of the entire project. Thus the higher than expected chloride concentration in these wells are a result of surface processes that inadvertently channeled water along the length of the two phases and pooled it directly over the monitoring points placed in a permeable strata. Since the saturation point for chlorides is extremely high, artificially channeling water over greater lengths had the accidental affect of magnifying chlorides in a fairly small volume of water, appearing in two wells, and not reflected in the stream.

6.5. CORRELATION OF CHLORIDES AND MONITORING POINT DATA

The extensive body of test results clearly illustrates that site impacts were tracked by chlorides registering at relevant monitoring points. A schematic is included for reference at each point in the project timeline, showing the areas worked and the monitoring points discussed.

6.5.1. Project 1, May 1998

The first material placed on the site was 40,000 tons of dredged material, coal ash and lime kiln dust, at the southern end of the upper bench between May 28 and September 9, 1998 (fig. XXX).

The sloping contour edge of the fill, in line with the restored slope of the hillside, was covered with manufactured topsoil and planted, while the flat upper surface was left exposed for two years and allowed to weather. After two years of exposure, only the top inch acquired the crumbly texture of soil while the rest of the material below remained compact and solid. The area lies above Monitoring Well 5, and upstream of Surface Water monitoring points 5 and 7, all of which could be expected to be impacted. No effects were observed for any of those three points. For the two years that the material exclusively occupied the highwall area, and afterwards, PCB's, pesticides, volatile and

semi-volatile organic compounds and dioxins were not detected. Metals remained at background levels present before the project was begun.

From the start of monitoring, SW 7, below the processing pad, showed a constant background chloride level of around 15 mg/L, both in the presence and absence of project activity. Historic monitoring indicated chloride levels at 90 mg/L in the Bark Camp #2 deep mine, and SW 7 may be indicative of the mined area's background levels. MW 5, below the project area, as well as Surface Water 5 downstream of the site, remained at around 2 mg/L during the entire period. The only detected impact was a very gradual rise in chlorides over a two year period in Monitoring Well 4, to 46 mg/L. This suggests that the groundwater drainage trends more diagonally along the length of the project rather than perpendicularly straight down toward the stream. Certainly that is the way the bedding planes of the coal seams trend. Surface Water 1, above any impact of the project, showed a chloride level of 120 mg/L at one point during monitoring. Two gas wells are situated above that area. Gas wells have been shown to occasionally emit salt brines from deep geological layers. Five such wells ring the valley, and may have a small influence on background chloride levels.

6.5.2. Project grouping 2, July 2000

Two years passed from the beginning of the first project before any additional material was brought on site, with no detection of organics whatsoever, or metals other than already present at background levels. The succeeding dredged material projects overlapped each other through to the completion of operations at the end of 2002. With the renewal of operations in July of 2000, dredged material mixed with coal ash and lime kiln dust was used to continue the upper bench reclamation begun in Project 1. Since the manufactured fill needed adequate time to allow for the curing process to advance at least enough to support the construction equipment being used, enough area had to be available to leave a layer of emplaced and compacted material undisturbed for a period before adding an additional lift. Operations expanded to the lower bench in Phase 1 and were alternated between the upper and lower benches until the completion of both. These activities were above Monitoring Wells 6, 5 and 4 and upstream of Surface Water monitoring points 5 and 7. Phase 1 reached to near the edge of the ravine separating the two phases, where the intermittent stream was being sampled just below the lower bench and designated Surface Water 3.

Operations proceeded into the winter of 2000-2001. As the material approached the tops of the highwalls, the narrowing surface area available for placement made work difficult; therefore, amended material was stockpiled on the western side of the former mine site until it could be placed in the Spring. Two important milestones occurred in April of 2001. The small ravine was crossed into Phase 2, emplacing material above monitoring wells 7 and 8 and eventually 9, and municipal waste incinerator ash (MWIA) began arriving on the site, and used as a pozzolonic amendment for the dredged materials.

As described in the site history, MWIA had gone through the full permitting process and been approved for use at Bark Camp in 1996, before Bark Camp had been identified as

the site for the dredged material demonstration. The difficulty of timing bids, contracts and operations now resulted in joining the two materials at Bark Camp. Operations reached the area above Monitoring Well 9 in September 2001 and proceeded into January. The difficulties of the previous winter due to site limitations had convinced PADEP to halt operations until spring, stockpiling arriving materials at the processing area and to its west.

Operations in Phase 2 ceased through February, March and April of 2002. With their resumption in May, MWIA grout was used as a road base to recondition the upper road along Phase 1. The final quantity of dredged materials amended with MWIA, coal ash and lime kiln dust, was used to finish small areas in Phase 1, and then went on to Phase 2. After May only lime activated MWIA grouts were used until September. After May, no further dredged material came to the site and only lime activated MWIA grout and coal ash was used until September. Thus, all the material in Phase 2 had been amended with MWIA ash, while Phase 1 was mostly coal ash and lime amended dredged material, with some minor placement of MWIA grout as road base and dredged material amendments.

6.5.3. Group 2 Project Chloride Results

Summer 2000

[Graph 1](#) and [graph 2](#) illustrate monitoring point chloride levels along with placement milestones.

After a two year period from project initiation during which the only measurable impact was a slow rise in chlorides in monitoring well 4, elevated chloride levels may be correlated with specific activities above relevant monitoring sites. With the renewed activity of the Group Two projects in Phase 1, surface water points SW3, 5 and 7 all reflect surface activities with a modest rise in chlorides. SW 5 peaks at 45 mg/L within two months of renewed activity, SW 7 peaks at 48 mg/L a month later, and SW 3 at 24 the month after that. SW 3 is sampled from a very low volume of water that gains contributions from both project phases over a relatively large surface area channeled into its ravine. Its delay in showing chlorides until after SW 5 and 7 is consistent with the initial work taking place further south along the upper bench, and arriving near SW3 only later in the season. After reaching these peaks in the fall, chloride levels at SW 3 and 5 decline through winter and spring to 1.6 and 13 mg/L respectively. Chlorides at SW 7 decline to a lesser degree and hover around 40 mg/L, continually impacted by winter activities at the processing pad.

Monitoring Well 4, at the lowest portion of Phase 1 (which exhibited a slow rise in chlorides to 50 mg/L over the initial two years) rises more sharply with the group 2 projects; through winter and spring to 295 mg/L. This is now interpreted as being a result of the above described chloride magnification effect of the site. MW 5 chlorides begin rising slowly with the group 2 projects reaching 14 mg/L in the spring, while MW 6 only reaches 9 mg/L by that time.

6.5.4. MWIA Amended Materials, May 2001- January 2002

The addition of municipal waste incinerator ash to the manufactured fill after April, 2001, and its preponderance in Phase 2 provides a contrast with its relative absence in Phase 1. Chlorides in Surface Water 3, in the ravine dividing the two project phases, had fallen to background levels of less than 2 mg/L after its initial jump to 24 with the advent of Group 2 projects. But one month after arrival of MWIA ash, chlorides jumped to 103 mg/L, rising to 274 by January 2002, when operations broke for winter. Surface Water 5 climbed from 9 mg/L to 90 during that same time, while SW 7, downstream of the processing pad, rose to 179 by October, then declined, along with SW 5 through the winter hiatus.

Phase 1 Monitoring Wells appear to react to the minor placement of MWIA amended fill after April 2001, with chlorides in MW 5 and 6 trending slightly upwards; in MW 5 from 14 mg/L to 49 through March 2002, and in MW 6 from 9 mg/L to 80 during that time. MW 4 however, trends downward from its high of 295 mg/L to 49 by December.

Monitoring Well 7, the first well in Phase 2 to be affected, goes from background levels, around 1 mg/L, to 47 in the first month of work, reaching 381 by September and peaking at 1013 mg/L in December. This is seen as an artifact of the placement of that well in a fracture. Chlorides in MW 8 only rose to 5 mg/L, and in MW 9 to 2 mg/L during that time. With a winter of inactivity, MW 7 dropped in chloride concentrations to 70 mg/L, MW 8, which rose to 35 by March dropped back down to 5 mg/L, and MW 9 remained at about 5.

6.5.5. Spring 2002 – October 2003

Relatively higher chloride levels in March 2002 at MW 4 (319) and MW 7 (833) may well be an artifact of spring thaw runoff, as both points decline sharply afterwards. With the resumption of operations in late spring 2002, the upper road in Phase 1 received an MWIA grout roadbed, and the last dredged material, amended with MWIA was emplaced above Monitoring Wells 5 and 6, leaving only coal ash and lime amended MWIA grout to be emplaced in Phase 2. After the final placement of MWIA grouts in late August 2002, the surface of Phase 2 was covered with manufactured soil and planted.

6.5.6. Surface Water

These combined activities are reflected in the highest surface water peaks during the monitoring period, SW 3 reaching 372 mg/L in June, and SW 5 and SW 7 hitting 282 and 309 mg/L in November, respectively. After these all time highs, SW 3 dropped to 167 mg/L by October 2003, SW 5 descended to 78 and then rose to 110 by October 2003, and SW 7 descended to 78 and again rose to 170 by October 2003.

6.5.7. Monitoring Wells Phase 1

Monitoring Wells in Phase 1 appear to register the additional MWIA amended material placement. Chlorides in MW 6, near the border with Phase 2, go from about 80 mg/L to 443 in November 2002, ending up at 66 mg/L in October, 2003. MW 5 rises to 136 mg/L in March 2003 and descends to 57 by September 2003 and climbed again to 124 in October, 2003. Chlorides in MW 4 seem to trend upwards from 61 in November 2002 to a high of 864 mg/L in June 2003, and descending to 680 by October, 2003, which again, is a magnified value.

6.5.8. Monitoring Wells Phase 2

Chlorides in Phase 2 Monitoring Wells show a small rise at MW 9 to 16 mg/L by October, 2003. MW 8 rises to 65 mg/L in June 2003, and to 97 by October, 2003. MW 7 rises steadily from the resumption of work in April 2002, at 70 mg/L up to 1903 mg/L in September 2003, a magnified value.

6.5.9. Domestic Well Monitoring

In addition to the various monitoring points located on and around the reclamation site proper, sampling was also performed on eleven residential wells and one spring serving as water supplies, which are located approximately two miles downstream of the site. These wells are all rather shallow, being drilled in a valley bottom floodplain. Most are not used as a source of drinking water given past exposure to contamination from a variety of sources, including domestic sewage, mining and farming. Some are treated for other uses, drinking water is generally carried in, although not entirely.

These supplies are located in the general vicinity of the rail siding where dredged material, coal ash and municipal waste incinerator ash arrived at the site during periods of project activity. Monitoring was performed to detect any significant changes to these supplies and, if so, to evaluate whether or not the changes were attributable to the unloading activities. The wells are arrayed along a major highway with most being approximately one quarter mile distant (south, southwest) from the actual unloading point. A few are fairly close in a westerly direction. An examination of these supplies over time reveals the increase of chloride and/or barium in four wells. These particular supplies, however, tend to be the more distant from the unloading point. Review of the location of the four wells involved and their relative locations to each other, and to the unloading point, show that the wells having higher concentrations of these parameters before the project began are the most distant from the unloading point. Further, as the parameters continued to increase, the greater increases occurred at the most distant points, with smaller increases in those wells located closer to the unloading area. Other than natural ground water quality fluctuation, which is also observed, it appears as though some source or sources to the south or southwest are involved in this phenomenon, which may be slowing spreading northwest toward the unloading area.

The one well located immediately adjacent to, and down-gradient of, the unloading point displays the least variation and no discernable increases in chloride or barium. Most other wells, arrayed along the highway, at varying distances from the highway, are certainly susceptible to long time exposure to the use of road salt through winter periods. Likewise, the railroad itself has existed at this location for years with varying degrees of use, primarily hauling coal from this siding and others along the line. Fuel and other petroleum-based materials were used in the vicinity for as long as the railroad has existed. The conclusion drawn is that the project unloading activity has had no effect on these residential supplies.

7. CONCLUSIONS

Appropriately characterized dredged materials with acceptable levels of organic and metal contaminants, properly amended and processed with alkaline activated coal ash, can be used as a manufactured fill for abandoned mine reclamation with exclusively positive environmental benefits.

Such materials, including correctly proportioned blends of dredged sediments, coal combustion ash and kiln dusts will not leach contaminants to ground or surface waters due to their inherent physical characteristics and the chemical bonds formed upon their proper blending.

Based on the chemical analyses of dredged sediment used at Bark Camp, from nine different project locations in the Hudson – Raritan Estuary, a significant, perhaps predominant percentage of maintenance dredge material available for beneficial upland use will meet required threshold contaminant levels low enough to be used in similar applications with no adverse impacts.

In over five years of surface water and ground water monitoring, there was not a single detection of semi-volatile or volatile organic compounds, pesticides, PCBs, dioxins, or metals other than those attributable to mine drainage. This is due to the well established physical and chemical binding properties of pozzolonic materials, the low permeability of the fill, a relatively low level of commonplace contaminants in the manufactured fill constituents, and the small surface area to volume ratio. Significantly higher levels of contaminants have been successfully sequestered using this technology.

This demonstration has proven the feasibility of this application on a practical basis; the material can be handled, processed, treated, transported and emplaced while keeping up with the production capacity of dredging operations. During this project, CEDTI portside dredged material processing facility processed and shipped up to 4300 yards of material per one shift day, and it is estimated that the present facility is capable of stabilizing up to 6,000 cubic yards daily.

No hazardous materials were ever detected in regular confirmatory and random sampling of transported materials.

The concept was to use the economic strength of port economies to pay for reclamation that would otherwise not be possible. This site might never have been remediated without this project. However, given the ongoing need of the Port of NY/NJ, 435,000 cubic yards of dredged material was transported, processed and placed at a cost of \$19,400,000 or \$45 per survey cubic yard, exclusive of dredging. While Bark Camp was a good location for the purposes of this demonstration, it was never logistically ideal for such a project, requiring a very long haul and multiple re-handling of the material.

As would any major reclamation project, this work provided significant employment and financial resources to the host area: 37 people were employed at an annual payroll of \$840,000; there were annual total payables to vendors and suppliers at Bark Camp of \$2,935,000, and; \$2,100,000 was invested in site development. The solidification and stabilization of would-be waste materials in a sound and beneficial manner made this project possible, while sparing steadily decreasing permitted landfill capacity for unconsolidated materials.

A dangerous high wall in a state forest, adjacent to state game lands was eliminated. Water is now flowing overland to the stream rather than back into and along the highwall. Flat expanses of bare shale and pyritic rock have been restored to a meadow habitat frequented by bear, deer, elk, bobcat and turkey. A survey of Bark Camp Run by the Pennsylvania Fish and Boat Commission in May 2001, three years after the project began, cited significant water quality improvements with increasing numbers of macroinvertebrate taxa and some common fishes at a downstream station in Bark Camp Run which was formerly sterile due to the mine drainage impacts left behind by the bankrupt mining operation. The survey further reported over wintering trout in the upper section of Bark camp Run, directly below the fill project area.

Pennsylvania has a state-wide precautionary one meal per week fish consumption advisory due to the prevalence of trace contaminants in the environment. And while there is a one meal per month advisory for PCB contaminated fish and a two meal per month advisory for mercury contaminated fish, all the fish tissue samples from Bark Camp met the standards for unrestricted consumption, including for mercury and PCBs.

The key to the successful use of this concept is thoroughness. The capabilities of properly made ash mixes were utilized in ancient times, and over the last 70 years. Over 80% of the surface and groundwater analytes tested for in this demonstration, at significant cost, were reported as undetected. The proper characterization of raw materials, and the imposition and monitoring of appropriate performance criteria for compressive strength and low permeability, along with sound project design and operations, are more important than continually analyzing bulk chemistry for contaminants.

Coals and their ashes vary in terms of chemical, mineralogical and physical properties depending on their source and the conditions of combustion. Therefore every source of fly ash needs to be adequately characterized prior to use. Proper physical and chemical characterization of fly ashes, dredged materials and alkaline activators are necessary for successful application and should significantly reduce the frequency of highly expensive analytical testing. Proper inspection and random sampling protocols should adequately guard against tampering of materials during shipping. The practicality and efficiency of rail transport of materials has been adequately demonstrated and should be employed when possible to reduce impacts on road networks and contact with the public.

Community outreach and participation was vital to the success of this project. The interest and activity of the citizens of Penfield and the community's Environmental Commission was constructive, positive and effective.

The only statistically significant trend observed during monitoring was the appearance of chlorides from sodium chloride (common salt), validating the placement of surface and groundwater monitoring points. Prior to the use of Municipal Waste Incinerator Ash (MWIA), low levels of chloride (below 50 mg/L) were detected in surface waters, and slightly exceeded the recommended drinking water standard in a well monitoring the site during the exclusive placement of dredged materials amended with alkaline activated coal ash. Given that the dredged materials used contained salt water they were expected to release some chloride during processing, handling and the curing period. Some chlorides would be expected to appear from salt dissolving during surface washing of the manufactured fill and then decline.

The appearance of moderately elevated chlorides during this demonstration corresponds with the introduction of municipal waste incinerator ash (MWIA) into the manufactured fill. About 253,000 tons of MWIA was placed in Phase 2 of this demonstration, and also on the western side of the Bark Camp site as a whole, an area separate and distinct from the dredge demonstration project. Although MWIA ash is known to release chlorides, its use at Bark Camp was as a pozzolonic material incorporated into the manufactured fill. As such, the manufactured fill would be expected to release a finite amount of chlorides as well. The extent and degree to which the chloride levels have increased in various monitoring points at Bark Camp over time with the placement of material containing MWIA, indicates a clear need for caution in the use of this material in a similar project. PADEP, therefore, has decided that Municipal Waste Incinerator Ash will not be considered for use in mine reclamation projects. Any other potential use of this material would require a more extensive review and separate examination with the appropriate permitting agency which is not within the scope of this report.

While project site choices should be evaluated carefully from this perspective, it should be of little concern in areas which are heavily impacted by mine drainage that may well require natural hydrologic flushing over many years' time to restore stream conditions. Projects in potentially sensitive freshwater areas, however, must be designed and managed to take this phenomenon into account, employing appropriate sediment and runoff management. Careful mix design and project management can reduce the amount of free water remaining un-bound by hydrating reactions in the cured material, thereby reducing any mobilization of chlorides. PADEP will continue to closely monitor the project to quantify this trend.

Analysis of Domestic Wells in the vicinity of the rail siding where materials were off-loaded indicate that, removed from the project and the site, there is a source of contamination originating at some far distance away from the siding and migrating toward it. The effected wells are all within the influence of multiple residential sewage discharges and several are within the influence of a large farm field that has had contamination issues in the past. Further, the wells closest to the railroad, indeed the

one directly below and adjacent to the unloading area, have lower values of detected elements.