RECEIVED
CLERK'S OFFICE

FEB - 9 2004

STATE OF ILLINOIS
Pollution Control Board

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
Petition of Noveon, Inc.	)	
	)	**AS 02-5**
	)	
for an Adjusted Standard from	)	
35 Ill. Adm. Code 304.122	)	

NOTICE OF FILING

Dorothy M. Gunn, Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street
Suite 11-500
Chicago, IL 60601

Deborah Williams
Assistant Counsel
Division of Legal Counsel
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
Springfield, IL 62794-9276

Bradley P. Halloran
Hearing Officer
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street
Suite 11-500
Chicago, IL 60601

PLEASE TAKE NOTICE that on **Monday, February 9, 2004**, we filed the attached **EXHIBITS TO WRITTEN TESTIMONY OF T. HOUSTON FLIPPIN** with the Illinois Pollution Control Board, a copy of which is herewith served upon you.

Respectfully submitted,

NOVEON, INC.

By: ______________________
One of Its Attorneys

Richard J. Kissel
Mark Latham
Sheila H. Deely
GARDNER CARTON & DOUGLAS LLP
191 N. Wacker Drive – Suite 3700
Chicago, IL 60606

THIS FILING IS SUBMITTED ON RECYCLED PAPER

CERTIFICATE OF SERVICE

The undersigned certifies that a copy of the foregoing **Notice of Filing** and EXHIBITS TO WRITTEN TESTIMONY OF T. HOUSTON FLIPPIN was filed by hand delivery with the Clerk of the Illinois Pollution Control Board and served upon the parties to whom said Notice is directed by

Dorothy M. Gunn, Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street
Suite 11-500
Chicago, IL 60601
(personal delivery)

Deborah Williams
Assistant Counsel
Division of Legal Counsel
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
Springfield, IL 62794-9276
(first class mail and electronic delivery)

Bradley P. Halloran
Hearing Officer
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street
Suite 11-500
Chicago, IL 60601
(personal delivery)

on Monday, February 9, 2004.

CH02/22292364.1

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
Petition of Noveon, Inc.	)	
	)	**AS 02-5**
	)	
for an Adjusted Standard from	)	
35 Ill. Adm. Code 304.122	)	

EXHIBITS TO SUBSTITUTED WRITTEN TESTIMONY OF T. HOUSTON FLIPPIN

Respectfully submitted,
NOVEON, INC.

By: ______________________
One of Its Attorneys

Richard J. Kissel
Mark Latham
Sheila H. Deely
GARDNER CARTON & DOUGLAS LLP
191 N. Wacker - Suite 3700
Chicago, IL 60606

CH02/22292376.1

Exhibit A

EXHIBIT A

RESUME OF T. HOUSTON FLIPPIN, P.E., DEE

Principal Engineer
Wastewater Department

T. Houston Flippin, P.E., DEE

Assignment

Capacity Evaluation

Education

M.S., Environmental and Water Resource Engineering, Vanderbilt University, 1984

B.E., Civil and Environmental Engineering, Vanderbilt University, 1982

Registration

Professional Engineer: Tennessee, Illinois, Kentucky, and Michigan

Diplomate: American Academy of Environmental Engineers

Experience

20 years

Joined Firm

1984

Relevant Expertise

- Developing site specific operating guidelines and treatment capacities.
- Developing cost savings for treatment plants.
- Training client staff in process operations and troubleshooting.

Experience Summary

Houston Flippin has 20 years of experience in industrial and municipal wastewater management. Mr. Flippin is particularly adept at maximizing treatment process performance. This is due to years of conducting, evaluating, and developing full-scale process design and operating guidelines from bench-, pilot- and full-scale wastewater treatment studies. These studies have evaluated both biological and physical/chemical processes for treating waters, wastewaters, and sludges laden with conventional pollutants, priority pollutants, and aquatic toxicants. Mr. Flippin has used this experience to both develop treatment cost savings (capital and operating) while maintaining reliable effluent compliance and to negotiate more reasonable effluent limits. His "hands on" experience and his talent for communication has made him a frequent workshop lecture, client staff trainer, and negotiator. Recent work on the industrial side has involved developing innovative, reliable and cost-effective pretreatment processes and minimizing upgrade costs of treatment lagoon systems. Recent work on the municipal side has involved rerating capacities of POTWs using site-specific data, developing cost saving actions for aeration and sludge handling, and developing staff reorganization plans to enhance productivity. Mr. Flippin also has experience in potable water treatment, stormwater permitting, wasteload surveys, and waste minimization.

Organic Chemicals, Herbicides and Pesticides

Process Design, Start-up Assistance and Operator Training, Ciba-Geigy Corporation

Lead Engineer and Author. Responsible for an on-site treatability studies, process design development, and final report for the treatment of wastewaters discharged from Ciba-Geigy Corporation's largest U.S. organic chemicals manufacturing complex including pesticides. The project began by evaluating conversion of the existing aerated lagoon system to activated sludge. This conversion was necessary to meet effluent requirements under higher loading conditions and to meet RCRA closure requirements of on-site surface impoundments. This evaluation involved an activated sludge treatability study evaluating the impact of varying total dissolved solids concentrations (0.5 percent to 2.5 percent), temperatures (8°C to 20°C) and RCRA regulated stream discharge contributions. A process design for the aerated lagoon/activated sludge conversion was developed, presented, and implemented. Mr. Flippin developed materials for and assisted in the operator training course which preceded startup of the activated sludge plant. A follow-up treatability study was conducted and focused on TKN, TOC, acute toxicity and color reduction through the use of PACT® treatment as compared to tertiary GAC treatment. Special batch treatability

BROWN AND CALDWELL

testing evaluated alternative source control methods for a highly colored wastestream. A process design was developed to meet revised treatment objectives, a final report was issued, and a new WWTF was constructed. Startup assistance and operator training were provided for both WWTFs.

Process Design, Rhodia, Mount Pleasant, Tennessee

Lead Engineer and Author. Responsible for an treatability studies, process design development, and final report for the treatment of herbicide wastewaters. Treatments evaluated impact of photolytic decomposition, carbon adsorption, and macroreticular resins. Solution implemented included minor treatment and recycle of waters. Site converted to a nearly zero discharge operation.

POTW Impact and Discharge Negotiations, American Cyanamid, Barceloneta, Puerto Rico

Lead Engineer and Author. Responsible for an treatability studies that evaluated impact of herbicide and pesticide wastestreams on POTW. Testing indicated no adverse impact on BOD removal, nitrification, and sludge quality at the desired discharge rates. Results of testing were used to negotiate allowed discharges of these wastestreams to the POTW without pretreatment.

WWTF Troubleshooting, Zeneca Fine Chemicals, Mount Pleasant, Tennessee

Lead Engineer and Author. Responsible for treatability studies that evaluated impact of various organic chemical, herbicide and pesticide wastestreams on site's biological wastewater treatment facility (WWTF). Developed approach for screening impact of new wastestreams on the WWTF. Prescribed maximum allowable discharge rates of each process waststream to prevent upset of the WWTF.

Pulp and Paper

Comprehensive Wastewater Management Plan, Chesapeake Corporation, West Point, Virginia

Lead Engineer, Field Team Manager, and Author. Developed a comprehensive wastewater management plan for a Chesapeake Corporation 1,800 tpd integrated mill. Wastewater characterization studies defined sources and distribution of waxes through the pulping and paper making process, the impact of secondary fiber production on WWTF solids management, the impact of bleaching process chlorine substitution on influent wasteloads, effect of separate and combined settling of pulp mill and paper mill wastewaters, and impact of various equalization basin sizes and modes of operation on influent load dampening. Batch treatability tests evaluated alternative primary clarification schemes, alternative site applications of dissolved air flotation (DAF) for wax removal and solids recovery, impact of CO_2 stripping/coagulation and flocculation on pure oxygen activated sludge settleability and impact of secondary fiber on activated sludge settling properties. Continuous flow treatability studies evaluated the effects of secondary fiber production, secondary fiber wastestream DAF pretreatment, aeration basin temperatures, slimicide loadings and bleaching plant chlorine substitution on pure oxygen activated sludge plant performance (particularly sludge settleability). The continuous flow treatability studies also involved evaluation of several types of biological selectors to control filamentous sludge bulking: aerobic, two-stage aerobic, anoxic/anaerobic, and extended anoxic/anaerobic. Elements of this project were presented by Mr. Flippin at the 1992 TAPPI Environmental Conference.

Lagoon Modeling and Upgrade Evaluation, Confidential Client, Midwest

Lead Engineer. Developed alternative upgrade measures for a wastewater treatment lagoon system to accommodate increased wasteload while not exhibiting H_2S emissions. One alternative was based on operating the lagoons without oxygen and nutrient deficiencies and thus achieving greater BOD removal rates. This alternative was based on treatability data. The second alternative was based on operating the lagoons under oxygen and nutrient limitations, which decreased BOD removal rates but minimized upgrade requirements. Extensive full-scale system data was used to develop a model for evaluating system performance under alternative conditions. The project is currently in the final design stage.

Hazardous Waste

Groundwater Remediation Process Design, FLTG, Incorporated, Crosby, Texas

Project Manager and Lead Engineer. Responsible for a groundwater remediation project for a company formed by 80 principle responsible parties. This Superfund site groundwater treatability investigation considered how best to upgrade the existing treatment facility. Air stripping, peroxidation, ozonation, ultrafiltration, carbon adsorption, resin adsorption, and anaerobic degradation separately and in conjunction with activated sludge treatment were considered. Following a series of batch and continuous flow treatability tests, activated sludge treatment followed by granular activated carbon treatment was selected as the most cost-effective means of achieving discharge targets. In addition, a cost-effective sludge treatment and disposal plan were developed.

Textiles

Toxicity Reduction Evaluation/Toxicity Identification Evaluation, Globe Manufacturing, Gastonia, North Carolina

Project Manager, Lead Engineer, and Author. Managed a wastewater pretreatment project where the industrial discharge was cited as the source of the POTW's effluent aquatic toxicity problem. Treatability tests were conducted which screened the effects of the following treatment processes on effluent toxicity reduction: air stripping, cation exchange resin, activated silica, macroreticular resin, granular activated carbon, and biohydrolysis.

Results of these tests and further desktop evaluations indicated the biotoxicant was ethylene diamine and that activated sludge treatment would provide the most cost-effective treatment. Continuous flow treatability studies were used to develop the process design for the selected process. Submitted design basis report for the pretreatment facility, reviewed final design drawings and specifications, and provided startup assistance. The pretreatment facility eliminated all acute and chronic toxicity associated with the wastestream discharge at its flow contribution to the POTW. Elements of this project were published in *Water Science Technology*, Volume 29, No. 9 (1994).

Food Processing

Waste Minimization, Quaker Oats, Newport, Tennessee
Project Manager, Lead Engineer, and Author. Developed a waste minimization plan for a Quaker Oats facility. On-site wastewater characterization studies coupled with interview of site personnel were used to develop practical, cost-effective waste minimization recommendations. Implementation of the plan resulted in significant reduction of product losses and sewer pretreatment surcharges.

Combined Municipal/Industrial Wastewater Management

ISP Chemicals, Calvert City, Kentucky

Principal Engineer/ Site CSM: Investigation of the impact of eight waste streams on the onsite activated sludge process.

Clariant Corporation, Elgin, South Carolina

Provided alternative treatment system analyses prior to the construction of a Greenfield wastewater treatment facility.

Cooperative and Cost Effective Wastewater Treatment, Ryan Foods Company, Murray, Kentucky
Project Manager and *Principal Engineer.* Worked with City of Murray and industry to develop a "win-win" strategy for minimizing wastewater treatment costs for both the City and industry. Early estimates by the City's consultant had indicated that the POTW would have to spend approximately $10 million to accommodate the discharge wasteload on the POTW with Ryan Foods at maximum loading (and without pretreatment). Estimates indicated that Ryan Foods would have to spend $3 million to meet the limits requested by the City if pretreatment were to be installed. A review of pertinent information indicated the opportunity for significant savings by both parties. Treatability studies were conducted and POTW performance data were reviewed. This work indicated that a much less costly approach could be taken. A final design was developed for the pretreatment facility and installed at a cost of $1.6 million. The pretreatment facility reduced the wasteload by approximately70 percent. However, the remaining wasteload to the POTW exceeded the "rated capacity" of the POTW. A site-specific analysis was conducted and used to

rerate the capacity of the POTW. A major component of this analysis was sludge stabilization and alternative disposal methods. This rerating allowed the POTW to gain an additional 29 percent in rated capacity for a cost of $0.7 million. So, in the end, the City of Murray and Ryan Foods both saved more than $1 million each. The City also received definition of alternative sludge disposal methods and a description of the incremental upgrades that would be required in the future as the "real rated capacity" of the POTW was approached.

Municipal Wastewater Management

Change Management Program, Metro Water Services, Nashville, Tennessee

Assistant Task Manager for Operations Group. Worked with client to identify cost-saving action items to reduce annual O&M costs at two water treatment plants and three wastewater treatment plants. The purpose in these reductions was to render the plants' operating costs competitive with that estimated by private contractors and thus "stave off privatization." Annual savings of greater than $1,000,000 were identified. Currently serving as advisor to teams implementing savings regarding sludge thickening and dewatering and aeration. In addition to this work, have assisted client in process troubleshooting which has allowed client to avoid effluent non-compliance.

Petrochemical and Synthetic Fuels

Safety Kleen Corporation, East Chicago, Indiana

Lead Engineer, Project Manager, and Author. Responsible for on-site wastewater treatment facility (WWTF) process troubleshooting and training to facilitate compliance with pretreatment limits at this facility, one of the largest oil re-refineries in the world. Treatability studies and process design were required for WWTF modifications to accommodate increased production and more stringent pretreatment limits.

Brown and Caldwell provided sampling and analytical procedures modified for cyanide, ammonia, and orthophosphate analyses. A more comprehensive and site-specific procedure was implemented to evaluate the chemical conditioning requirements of the mixed liquor. "In situ" oxygen transfer was determined to assess upgrade requirements.

Treatability studies were conducted. The effects of operating temperature (30°C to 60°C) and F/M ratio (0.1 lb COD/lb MLVSS • day to 0.7 lb COD/lb MLVSS • day) on activated sludge settleability and effluent quality were evaluated. The effects of steam stripping, as a pretreatment step, on activated sludge system performance were evaluated. Metals precipitation with lime, alum and caustic was studied as a pretreatment and post treatment process. High pH air stripping and breakpoint chlorination were examined as effluent NH_3-N reduction technologies. Effluent peroxidation and ozonation were evaluated as a means of providing effluent total phenolics reduction. The use of a biological selector and chemical conditioning (e.g., coagulation and flocculation) were investigated as means of improving sludge settleability.

A process design to upgrade the existing WWTF was provided and included a four stage, aerobic biological selector, temperature and pH control, coagulation, flocculation, increased RAS pumping capacity, breakpoint chlorination and tertiary filtration. Final design guidance was provided on selection of equipment for the biological selector and tertiary filtration.

Booth Oil Company, Buffalo, New York

Lead Engineer and Author. Responsible for wastewater sampling program to define treatment process limitations under increased future loading conditions. Treatability testing was conducted to evaluate alternatives for controlling total phenolics discharge. Both improvements in oil/water separation and hydrogen peroxide treatment were considered. A report presenting alternatives for upgrading WWTF operations and for prioritizing capital improvements was presented.

Groundwater Remediation Process Design, FLTG, Incorporated, Crosby, Texas

Project Manager and Lead Engineer. Responsible for a groundwater remediation project for a company formed by 80 principle responsible parties (almost exclusively petrochemical industries and refineries). The groundwater at this site exhibited an influent COD of approximately 600 mg/L and had free product present. A groundwater treatability investigation was conducted to determine how best to upgrade the existing treatment facility. Air stripping, peroxidation, ozonation, ultrafiltration, carbon adsorption, resin adsorption, and anaerobic degradation separately and in conjunction with activated sludge treatment were considered. Following a series of batch and continuous flow treatability tests, activated sludge treatment followed by granular activated carbon treatment was selected as the most cost-effective means of achieving discharge targets. In addition, a cost-effective sludge treatment and disposal plan were developed.

Reilly Industries, Lone Star, Texas

Lead Engineer, Project Manager and Author. Responsible for a two-tiered project at this coal tar plant. Treatability studies were conducted and process designs were developed for alternative wastewater treatment facility upgrades that would allow plant to meet more restrictive pretreatment limits. A work plan was developed in cooperation with TNRCC that would allow the POTW to seek permit relief which in turn would allow the plant to not require WWTF upgrades.

Permitting

Hunt Foods (formerly Quaker Oats), Newport, Tennessee
Project Manager and *Principal Engineer* on project involving wasteload minimization, pretreatment facility design and negotiation of pretreatment limits.

Laidlaw (formerly Osco, Inc), Nashville, Tennessee
Project Manager and Principal Engineer on project involving pretreatment facility design, startup, troubleshooting, and pretreatment permit negotiations.

J. Hungerford Smith, Humboldt, Tennessee
Principal Engineer on project involving pretreatment facility design, POTW upgrade design, and pretreatment permit negotiations.

Ryan Foods Company, Murray, Kentucky
Project Manager and *Principal Engineer* on project involving pretreatment facility design, construction management, startup, operator training, POTW upgrades, pretreatment permit negotiations, and negotiation of re-rated capacity of POTW with Kentucky Division of Water.

BF Goodrich Performance Materials, Henry, Illinois
Project Manager and Principal Engineer on project involving treatment facility design, startup, operator training, treatment facility troubleshooting and NPDES permit negotiations with Illinois EPA. Meeting with Illinois Water Pollution Control Board is pending.

ISP Chemicals, Texas City, Texas
Project Manager and Principal Engineer on project involving modifying existing NPDES permits for stormwater and wastewater. Project also involved conduct of testing to get adjusted metals limits.

OxyVinyls (formerly Geon Canada), Niagara Falls, Ontario, Canada
Project Manager and Principal Engineer on project involving treatment facility troubleshooting, operator training, and "NPDES equivalent" permit negotiations.

Confidential Client, Barceloneta, Puerto Rico
Project Manager and Principal Engineer on project involving treatability testing and pretreatment permit negotiations.

Toxicity Reduction

Thiokol Corporation, Brigham City, Utah
Lead Engineer on effluent toxicity identification evaluation (TIE) followed by toxicity reduction evaluation (TRE) as a part of treatability studies for a newly designed WWTF. The new WWTF replaced two existing WWTFs that were abandoned. Acidification, air stripping, alkalinization, chemical

reduction with sodium thiosulfate, filtration, granular activated carbon, ion exchange (anion and cation), macroreticular resin, and metal complexing with EDTA, were evaluated as a means of achieving effluent toxicity reduction for a selected wastestream. High salinity was identified as the toxicant. The client decided to blend the selected wastestream with other wastestreams causing a decrease in wastewater salinity and an increase in wastewater BOD. Activated sludge treatment followed by ozonation as a means of toxicity reduction and disinfection was determined to provide consistent compliance with effluent BOD and toxicity limits. A process design was provided. The newly designed WWTFs included grit removal, equalization, activated sludge treatment, granular media filtration and ozonation. The final design for the WWTF was reviewed for consistency with the process design.

Confidential Client, Indiana

Lead Engineer and Project Engineer A Toxicity Identification Evaluation (TIE) was conducted for a large-volume producer of metal ingots and sheet aluminum. The TIE used Phase I laboratory characterization procedures, single stream toxicity testing, and resynthesis testing with major wastestreams treated for toxicity removal. Both *Ceriodaphnia* and the fathead minnow were used in acute tests throughout the study. Study results indicated that adsorptive organic compounds associated with an internal waste treatment process were primarily responsible for toxicity. Pure chemical tests with the wastewater treatment polymer used at the site indicated that the polymer may play a role in effluent toxicity.

A Toxicity Reduction Evaluation (TRE) work plan was also conducted for the client to develop a means to cost-effectively reduce effluent toxicity as required by the State. Services included wasteload characterization and wastewater treatment facility (WWTF) optimization.

Memberships

National Society of Professional Engineers (NSPE)

Technical Association of the Pulp and Paper Industry (TAPPI)
  Water Quality Committee Member

Water Environment Federation
  Pretreatment Committee Member

Chi Epsilon - National Civil Engineering Honor Society

Publications/Presentations

"Enhanced Activated Sludge Treatment of High Strength Bio-inhibitory Industrial Wastewater" with R. Rhoades, 10th Annual WEF Industrial Wastes Technical and Regulatory Conference, Philadelphia, Pennsylvania, August 2004.

"Treatment Alternatives for Removing Ammonia-Nitrogen from Landfill Leachate" with R.E. Ash and B.N. Card, Annual Tennessee Solid and Hazardous Waste Conference, Gatlinburg, Tennessee, April 2004.

"Alternative Considerations in Sizing Aeration Basins" with W. W. Eckenfelder, Design, Performance and Operation of Biological Treatment Processes Pre-Conference Workshop, Vanderbilt University and USEPA Conference, "Industrial Wastewater and Best Available Treatment Technologies: Performance, Reliability, and Economics", Nashville, Tennessee, February 2003.

"Modifying Equalization to Provide Pretreatment of High Strength Wastewaters" with D.A. Moye, 19th Annual North Carolina AWWA/WEF Conference Proceedings, Winston-Salem, North Carolina, November 2002.

"Benefits of Using Nitrate as Nutrient in Activated Sludge Treatment Systems" with W. W. Eckenfelder and D.A. Moye, 8th Annual WEF Industrial Wastes Technical and Regulatory Conference, Atlantic City, New Jersey, August 2002.

"Biological Treatment of High TDS Wastewaters," with W. W. Eckenfelder and V. J. Boero, Water Environment Federation- Industrial Waste Technical and Regulatory Conference, Charleston, South Carolina, August 2001.

"Competitive Performance for Water and Wastewater Utilities," with J.L. Pintenich, Nashville Quality Forum, Nashville, Tennessee, October 1999.

"Reclaiming POTW Capacity," with M.L. Roeder, American Society of Civil Engineers-Tennessee Section Annual Meeting, Nashville, Tennessee, October 1999.

"Batch Activated Sludge Testing to Determine The Impact of Industrial Discharges on POTW Performance", with J.S. Allen, *Proceedings of 1998 WEF Industrial Wastes Specialty Conference*, Nashville, Tennessee, March 1998.

"Economics of Treating Poorly Degradable Wastewaters in the Chemical Industry," with K.D. Torrens, *Proceedings of 1998 WEF Industrial Wastes Specialty Conference*, Nashville, Tennessee, March 1998.

"Effects of Elevated Temperature on the Activated Sludge Process," with W.W. Eckenfelder, Jr., *Proceedings of 1994 TAPPI International Environmental Conference*, Portland, Oregon, April 1994.

"Toxicity Identification and Reduction in the Primary Metals Industry," presented at *Spring AIChE Conference*, Atlanta, Georgia, April 1994.

"Treatability Studies and Process Design for Toxicity Reduction for a Synthetic Fiber Plant," with J.L. Musterman, *Water Science Technology*, Vol. 29, No. 9 (1994).

"Granular Carbon Adsorption of Toxics," technical review of chapter four in *Toxicity Reduction in Industrial Effluents*, P. W. Lankford and W. W. Eckenfelder, Jr. (Eds), Van Nostrand Reinhold, 1992.

"Diagnosing and Solving a Pulp and Paper Mill's Poor Activated Sludge Settleability Problems Through Treatability Studies," with M. A. Bellanca, *Proceedings of 1992 TAPPI Environmental Conference*, Richmond, Virginia, 1992.

"Hydrogen Peroxide Pretreatment of Inhibitory Wastestream – Bench Scale Treatability Testing to Full Scale Implementation: A Case History," with R. L. Linneman, *Proceedings of Chemical Oxidation: Technology for 1990's*, Vanderbilt University, Nashville, Tennessee, 1991.

"Control of Sludge Bulking in a Carbohydrate Wastewater Using a Biosorption Contactor," with W. W. Eckenfelder, Jr. and M. A. Goronszy, *Proceedings of the 39th Annual Purdue Industrial Waste Conference*, 1984.

Research Topics

Biodegradation of PCBs and HCB, research conducted at ECKENFELDER INC.

Volatile Organic Compound Emissions from Activated Sludge Systems, research conducted at ECKENFELDER INC.

Performance of Selective Bacteria in Industrial Activated Sludge Systems, research conducted at Vanderbilt University

Biosorption for Improved Reactor Capacity, research conducted at Vanderbilt University

Control of Activated Sludge Bulking Through the Use of a Biosorption Contactor, research conducted at Vanderbilt University

Workshops

Instructor, Tennessee State University, "Monitoring Requirements, Operating Guidelines, Calculations, and Troubleshooting," presented during "Aerobic Biological Wastewater Treatment Workshop," Nashville, Tennessee, November 1997, April 1998, November 1998, and April 1999. N

Instructor, Mississippi Water Pollution Control Operators' Association, Inc., "Clarifier Operation and Maintenance Workshop," Tunica, Mississippi, April 1997.

Instructor, Brown and Caldwell, "Activated Sludge Wastewater Treatment Workshop, " attended by participants from over 3 municipalities and 10 industries, Nashville, Tennessee, November 1999, March 2000, May 2001, November 2002, and November 2003.

Instructor, Tulane University and Louisiana Chemical Association, "Wastewater Strategies for Industrial Compliance: Gulf Coast Issues and Solutions", New Orleans, Louisiana, December 2003.

Honors

Who's Who of Citation's Environmental Registry, 1991

Eckenfelder Inc. Technical Employee of the Year Award, 1990

Outstanding Young Men of America, 1986

Exhibit B

EXHIBIT B

PERTINENT ARTICLES FROM LITERATURE REVIEW

Nitrification Inhibitors for Corn Production

D. W. Nelson, University of Nebraska
D. Huber, Purdue University

Reviewers
K. D. Frank, Univesrity of Nebraska · *G. W. Randall, University of Minnesota*
R. G. Hoeft, University of Illinois · *W. I. Segars, University of Georgia*
D. R. Keeney, University of Wisconsin · *J. T. Touchton, Auburn University*
G. L. Malzer, University of Minnesota · *L. F. Welch, University of Illinois (retired)*
H. F. Reetz, Jr., Potash & Phosphorus Institute, Illinois

Nitrogen (N) is an essential element for plant growth and reproduction. The amounts of N taken up by corn exceed those of any other soil-derived element. Today an average 25% of plant-available N in soils (ammonium and nitrate) originates from the decomposition (mineralization) of organic N compounds in humus, plant and animal residues, and organic fertilizers, 5% from N in rainfall, and 70% from applied inorganic N fertilizers (Figure 1). In soils, organic N is converted to ammonium through microbial decomposition. Ammonium formed in soil, added as fertilizer, or in precipitation is rapidly oxidized to nitrate in the nitrification process carried out by specific bacteria. Nitrification results in the production of nitrate, a form of plant-available N which is readily lost from soils. Nitrification inhibitors are chemicals that slow down or delay the nitrification process, thereby decreasing the possibility that large losses of nitrate will occur before the fertilizer nitrogen is taken up by plants. This publication discusses N losses from soils, characteristics of nitrification inhibitors, and how nitrification inhibitors can be used to improve efficiency of corn production.

THE NITRIFICATION PROCESS

Ammonium (NH_4^+) added to soils or formed by decomposition of organic N compounds is oxidized to nitrite (NO_2) by *Nitrosomonas* bacteria, and nitrite is further oxidized to nitrate (NO_3) by *Nitrobacter* bacteria in a process termed nitrification (Figure 1). Nitrate is normally the form of N taken up by plants; however, most plants can also assimilate ammonium. In most soils, nitrification of applied ammonium is rapid (2-3 weeks), but nitrification rates are greatly reduced by cool soil temperature (50°F), low pH (5.5), and waterlogged conditions. Nitrification converts ammonium, a positively charged ion that is bound to clay and organic matter, to nitrite and nitrate, negatively charged ions that are free in the soil solution and are readily lost from the plant rooting zone of soils.

N LOSS FROM SOILS

Only about 50% of the applied N is taken up by corn during the year following fertilizer addition. About 25% is immobilized during residue decomposition or remains in the soil as nitrate. The remaining 25% is lost from the plant rooting zone by leaching and/or dentrification. (See Table 1 for a generalized estimate of the fate of fertilizer N added to soils.) Some of the immobilized N will be mineralized (5% per year) and will be available to subsequent crops. Nitrate remaining in the profile at the end of the cropping season will be available to the succeeding crop unless lost over the winter and spring by leaching or dentrification.

Leaching is important in coarse-textured soils. Nitrate may be leached from naturally well-drained or tile-drained soils by percolating water. One inch of infiltrating water will move nitrate 1 to 2.5 inches downward in clay loam and sandy soils, respectively. Thus, during periods of excess rainfall, leaching may move nitrate out of the effective rooting zone of plants.

Denitrification (the microbiological conversion of nitrate and nitrite to gaseous forms of N) is the major pathway of N loss from most fine-textured soils. It normally occurs in soils that become waterlogged by

IOWA STATE UNIVERSITY
University Extension

NCH 55 Revised February 1992
Electronic version July 2001

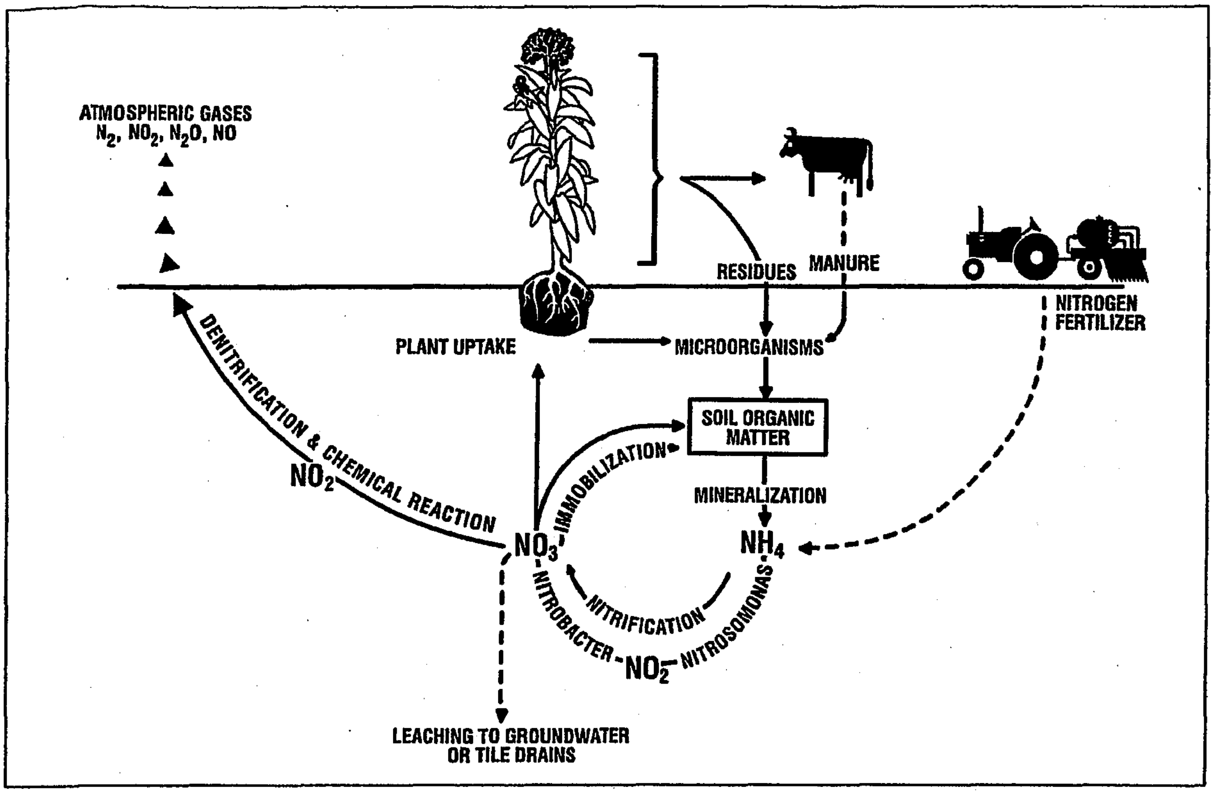


Figure 1. The nitrogen cycle in soils (adapted from Nitrogen in Agricultural Soils).

excessive rainfall or irrigation. Denitrification occurs at maximum rates when soils are warm (60°F), pH values are high (7), nitrate is plentiful, and an energy source (carbon) is available. In waterlogged soils, more than 100 lb. of nitrate N per acre can be denitrified within a 5-day period. However, in cold soils (40°F) or soils with low pH values (5), denitrification rates are slow.

TYPES AND USES OF NITRIFICATION INHIBITORS

Nitrification inhibitors (NI) are chemicals that reduce the rate at which ammonium is converted to nitrate by killing or interfering with the metabolism of *Nitrosomonas* bacteria (Figure 1). The loss of N from the rooting zone can be minimized by maintaining applied N in the ammonium form during periods of excess rainfall prior to rapid N uptake by crops. A number of compounds have been shown to inhibit nitrification in laboratory and field studies (Table 2); however, only N-Serve® and Dwell® have U.S. Environmental Protection Agency approval for use on cropland in the United States. Additional compounds are used in Japan and other countries; and registration is expected for additional compounds in the U.S.

N-Serve is currently labeled for corn, sorghum, wheat, cotton, rice, and other crops and is sold in emulsifiable and nonemulsifiable formulations. Dwell was registered as a nitrification inhibitor in 1982, but it is uncertain if the product will be marketed. Both chemicals are effective nitrification inhibitors when 0.5 lb. of active ingredient (a.i.) per acre is used in a band application with anhydrous ammonia or N solution fertilizers.

N-Serve and Dwell may also be impregnated on solid fertilizers or mixed with N solution fertilizers prior to broadcast applications. However, incorporation of the nitrification inhibitor-treated fertilizer must occur shortly after application because both compounds are volatile. Higher rates (2 to 4 times band applications) of N-Serve and Dwell are often required to control nitrification of broadcast ammoniacal fertilizers. Recent studies have shown that NI can also be effectively used with liquid animal manures and sewage sludges that are injected into the soil.

Table 1. Generalized Fate of Fertilizer Nitrogen Applied to Corn.[1]

Fate of applied N	Soil texture: coarse	Soil texture: medium and fine
	------% of applied N------	
Plant uptake (first year)	40 - 60	50 - 60
Remains in soil as organic and inorganic N	20 - 25	25 - 30
Lost from root zone:		
Denitrification	5 - 10	15 - 25
Leaching	15 - 20	0 - 10

[1] Average values over years for soils in the Cornbelt and southeastern U.S. and irrigated soils of the Great Plains and western valleys.

Table 2. Compounds Marketed or Proposed as Nitrification Inhibitors.

Chemical name	Common or trade name	Manufacturer	Registered in the U.S.A.
Produced commercially:			
2-chloro-6-(trichloromethyl)-pyridine	N-Serve	Dow Chemical Co.	Yes
5-ethoxy-3-trichloromethyl-1, 2, 4-thiadiazol	Dwell, Terrazole (etradiazol)	Uniroyal Chemical	Yes
Dicyandiamide	DCD	SKW Trostberg AG	No
2-amino-4-chloro-6-methyl-pyrimidine	AM	Mitsui Toatsu Co.	No
2-mercapto-benzothiazole	MBT	Onodo Chemical Industries	No
2-sulfanilamidothiazole	ST	Mitsui Toatsu Co.	No
Thiourea	TU	Nitto Ryuso	No
Proposed as nitrification inhibitors:			
2,4-diamino-6-trichloromethyl-5-triazine	--	Amer. Cyanamid Co.	No
Polyetherionophores	--	Amer. Cyanamid Co.	No
4-amino-1, 2, 4-triazole	--	Ishihara Industries	No
3-mercapto-1, 2, 4-triazole	--	Nippon Gas Indus.	No
Potassium azide	--	Pittsb. Plate Glass Co.	No
Carbon bisulfide	--	Imperial Chem. Indus.	No
Sodium trithiocarbonate	--	Imperial Chem. Indus.	No
Ammonium dithiocarbamate	--	FMC	No
2, 3, dihydro-2, 2-dimethyl-7-benzofuranol methyl-carbamate	Furadan (carbofuran)	FMC	No
N-(2, 6-dimethylphenyl)-N-(Methoxyacetyl)-alanine methyl ester	--	Olin Corp.	No
Ammonium thiosulfate	--	--	No
1-hydroxypyrazole	--	BASF	No
2-methylpyrazole-1-carboxamide	CMP	GDR	No

EFFECTS OF NITRIFICATION INHIBITORS

A number of studies throughout the United States have demonstrated that NI effectively retards the conversion of ammonium to nitrate in a variety of soils. Results indicate that application of NI delays the conversion of ammonium to nitrate for 4 to 10 weeks, depending upon soil pH and temperature. With fall applications of N fertilizers, NI minimize nitrification until low soil temperatures (40°F) stop the process. With spring applications, NI prevent the formation of nitrate during the late spring when rainfall is high and uptake of N by crops is low.

Corn yields are often increased as N losses from soils are reduced by the application of NI with both conventional tillage and reduced tillage systems (Table 3). The potential benefit from NI application depends on a number of site-specific factors, such as soil type, climate, cultural practices, and N management program. Highest probability of yield response from NI occurs with excessively drained or poorly drained soils because of N losses from leaching and denitrification, respectively. For example, a study in Indiana with fall-applied anhydrous ammonia showed that N-Serve application increased corn yields by 300% with a very poorly drained silty clay soil and 1% with a well-drained sandy loam soil. Significant corn yield responses from NI addition have also been observed with irrigated sandy soils (Table 4). Yield responses from NI are more frequent with fall N applications than with spring applications because of lower N losses from denitrification normally experienced when fertilizers are applied nearer to the time of crop need. There have been consistent yield responses from NI added to ammoniacal fertilizers for corn produced with a no-till system, presumably because of larger N losses from denitrification normally experienced with this production method.

The increased availability of inorganic N and the presence of ammonium in the soil resulting from NI addition also have been shown to increase the protein concentration of corn grain (Table 5). The feeding value of corn increases as the protein level increases. The application of NI to inorganic and organic N fertilizers also has reduced the severity of *Diplodia* and *Gibberella* stalk rots of corn, likely because of altered N metabolism in plants assimilating the ammonium form of N (Table 6). Corn stalks in areas receiving NI-treated fertilizers tend to remain green later in the growing season and have thicker rinds, both of which reduce pathogen effects and lodging. Grain moisture content at harvest is unaffected by NI addition to fertilizers.

The amounts of nitrate leached into groundwater and ozone-destroying nitrous oxide (N_2O) emitted into the atmosphere through denitrification are reduced by NI application. The use of NI also gives great flexibility in timing the application of N fertilizers. For example, with most Cornbelt soils all of the N needed for a corn crop can be applied as anhydrous ammonia during

Table 3. Effects on Grain Yields of Corn Grown with Conventional and No-Till Systems from Addition of Nitrification Inhibitors to Fall- and Spring-Applied Ammoniacal Fertilizers.[1]

Location	Time of application	No. of experiments	No. of yield increases from NI[2]	% Yield increase from NI[3]
Indiana	Fall	24	17	12.5
	Spring	51	29	5.8
	Spring (no-till)	12	9	10.0
No. Illinois	Fall	12	5	5.0
	Spring	14	2	-1.0
So. Illinois	Fall (NH_3)	7	7	4.6
	Spring (NH_3)	9	7	4.6
	Spring (no-till)	2	2	8.5
	Fall (N solution)	5	4	3.3
	Spring (N solution)	5	2	-1.2
Kentucky	Spring (no-till)	8	7	14.3
Wisconsin	Fall	2	1	4.7
	Spring	2	0	1.5

[1] Adapted from R. G. Hoeft 1984. Current status of nitrification inhibitors. In R. O. Hauck (ed.) Nitrogen in Crop Production. Am. Soc. of Agronomy, Madison, WI.
[2] Significant at 95% probability level.
[3] Average percent yield increase across all N rates and locations.

the previous fall if a NI is used, thereby reducing the workload in the critical spring planting season. The use of NI permits early spring application of N in many areas of the United States where N losses are a consistent problem.

Data in Table 3 show that NI addition does not result in yield increases in all soils and climatic conditions. In fact, in some situations there is a low probability of a corn yield increase from NI. Since the purpose of NI application is to increase the efficiency and amount of N available to plants by reducing N losses, no response to NI will be obtained during seasons or with soil types having little or no N loss. Little or no N loss occurs during seasons with below average rainfall following N application because N loss through leaching and denitrification is directly related to the amount and distribution of rainfall and the drainage characteristics of the soil.

No yield response will be obtained from NI addition when N rates used are far in excess of those required for maximum yield. For example, if maximum corn yields could be obtained with 150 pounds of N per acre but 300 pounds per acre are applied, as much as one-half of the applied N could be lost before a decrease in yield occurs. Late side-dress injections of N may reduce yield through mechanical damage to the root system and increased root rot. Immobilization of late-season applied N with a NI may further exacerbate this condition.

In sandy soils with very low cation exchange capacities, the addition of NI to ammoniacal fertilizers may not reduce N loss or increase crop yield because of differential movement of ammonia and NI from the zone of placement. Some studies have shown that ammonium ions were leached below the NI treated zone by rainfall and irrigation water. In this situation, nitrification deeper in the profile produced nitrate that was subsequently removed from the rooting zone by leaching.

Table 4. Effects of Nitrification Inhibitors on the Yield of Irrigated Corn Fertilized with Urea. (Hubbard Loamy Sand).[1]

N rate	Nitrification Inhibitor		
	None	N-Serve	Dwell
lb/acre	------corn yield, bu/acre------		
0	59	--	--
60	89	119	98
120	105	151	145
180	136	170	171
240	171	182	186

[1] Taken from G. L. Malzer, T. J. Graff, and J. Lensing. 1979. Influence of nitrogen rate, timing of nitrogen application and use of nitrification inhibitors for irrigated spring wheat and corn. In Univ. Minn. Soil Series 105 Report on Field Research in Soils.

Table 5. Effect of a Nitrification Inhibitor on Corn Grain Protein Concentration.[1]

N applied	Treatment	
	NH_3	NH_3 + N Serve
lb/acre	------grain protein, %------	
0	6.76	--
60	7.76	9.24
120	9.38	10.60
180	10.80	11.71

[1] Study conducted in Indiana using B73 x Mo17 corn hybrid.

Table 6. Effects of a Nitrification Inhibitor on Stalk Rot of Corn.[1]

No. of studies	N source	Treatment	
		N	N + N Serve
		------% plants with stalk rot[1]------	
3	NH_3	38	16
4	Swine manure	54	23

[1] Average values for all locations, years, and N rates from studies in Indiana.

WHERE SHOULD NITRIFICATION INHIBITORS BE USED?

The response of corn to applications of NI with ammoniacal fertilizers varies greatly throughout the United States because of major differences in N loss potential from differing climate, soils, and production systems. A summary of research results on corn yield responses from NI addition for various corn production regions is presented in Table 7, and the probabilities for obtaining a yield response from NI for several combinations of region, soil texture, and time of fertilizer application are given in Table 8. The addition of NI to fertilizer should be looked upon as insurance against N loss, and, thus, a decision to use NI should be based on the probability of obtaining yield increases over a period of time, e.g., 5 years. The usefulness of NI for corn production in three general regions of the United States is discussed below.

Southeast

The response of corn to NI applications in the southeastern United States has been mixed. The relatively high soil temperatures during the winter result in nitrification of fall-applied N and subsequent leaching or denitrification of the nitrate that is formed. The addition of NI does not alleviate this problem because of the limited longevity of the currently registered inhibitor compounds in soil and the long period of time between N application and crop uptake of the nutrient. Thus, yield responses to NI added to fall-applied fertilizers have not been consistently observed. A number of studies have shown modest corn yield increases from the addition of NI to spring-applied N even though inhibitor persistence is limited by high soil temperatures. Overall, the probability of corn yield response from currently available NI in the southeastern U.S. is poor for fall-applied N and fair to poor for spring-applied N.

Eastern Cornbelt

The response of corn to NI application has been more consistent over years in the eastern Cornbelt than other portions of the United States because of high rainfall, finer textured soils, and cold soil temperatures during the winter. However, overall only about 50 and 70% of the trials with spring- and fall-applied N have shown yield response from NI. Yield responses have been obtained with both spring- and fall-applied N in Indiana, Kentucky, Ohio, and southern Illinois. The consistency of yield responses to NI has been less in Michigan, Wisconsin, Missouri, central and northern Illinois, and Iowa than in other eastern Cornbelt states. However, all states in the eastern Cornbelt have studies showing corn yield increases from NI addition, and the largest and most consistent increases are normally observed with fall-applied N or with non-tillage programs.

There is a good probability of obtaining a yield increase from application of NI to fall-applied ammoniacal fertilizers in the eastern Cornbelt because of the large N loss normally associated with fall applications. The use of NI will allow producers to apply N fertilizers somewhat earlier than generally considered feasible (50°F is traditionally considered the maximum soil temperature for application of ammoniacal fertilizers in the fall without a NI). Fall application of N is not recommended for low CEC coarse-textured soils because of the possibility of ammonium leaching.

The probability is good that NI added to spring-preplant N will increase yields of corn growth on fine-textured soils of the eastern Cornbelt because of the likelihood of N losses by denitrification after fertilization. Only a fair probability exists for a yield response to NI added with spring-preplant N applied to silt loams and coarser textured soils. The probability of loss in such soils depends upon the nitrification rate following fertilization, the internal drainage of the soil, and the distribution and intensity

Table 7. Regional Summary of Corn Yield Responses from Nitrification Inhibitors Added to Ammoniacal Fertilizers Appled at Varying Times.[1]

Region	Time of application	% of studies with yield increase	% yield increase[2]
Southeast (GA, MD, NC, SC, TN)	Fall	17	14
	Spring	43	15
Eastern Cornbelt (IL, IN, OH, KY)	Fall	69	9
	Spring	51	3
	Spring (no-till)	82	13
Northern Cornbelt (MI, MN, WI) not irrigated	Fall	25	5
	Spring	17	12
Western Cornbelt (KS, MN, NE) irrigated coarse-textured soils	Spring	52	30
Western Cornbelt (KS, NE) irrigated medium- and fine-textured soils	Spring	10	5

[1] Data taken from a variety of research progress reports and published materials.
[2] Average increases obtained in experiments where NI addition gave significant yield increases.

of rainfall. Heavy rains occurring 2 to 8 weeks after fertilization may result in extensive N losses and yield responses to NI application. However, if a below average rainfall period follows fertilization, little N loss or response to NI will occur.

Western Cornbelt

Few yield responses to NI have been observed with dryland corn or irrigated corn produced on fine-textured soils in Minnesota, North Dakota, South Dakota, and other states west of the Missouri river. However, the use of NI has resulted in increased yields in areas where preplant N is applied to irrigated corn grown on sandy soils. Data from Minnesota (Table 4) illustrate the type of responses that are sometimes obtained when a NI is used to reduce nitrate leaching in irrigated sandy soils.

There is poor probability of yield response with spring-applied fertilizer for dryland corn production in the western Cornbelt; however, with irrigated coarse-textured soils the probability of a yield increase improves. There is a fair probability of a response to NI with fall applied fertilizer on finer textured soils. Fall application of ammoniacal fertilizers is not recommended for sandy soils.

ADDITIONAL CONSIDERATIONS WHEN USING NITRIFICATION INHIBITORS

More consistent yield responses have been obtained with no-till grown corn than with conventional tillage systems fertilized in the spring (Tables 3 and 8). This finding results from greater infiltration rates, higher water contents, a higher population of denitrifying bacteria in no-till soils and, thus, increased N losses from leaching and/or denitrification.

The probability of yield responses to NI added to spring-sidedress-applied N is considered low for all soils because the fertilizer is added close to the time of plant uptake. However, a few investigators in the eastern Cornbelt have observed significant yield increases from NI added to early sidedressed N fertilizers. Additional studies are needed at several locations in all corn-growing regions to determine the long-term probability of a response to NI application with sidedress N should exist on coarse-textured soils receiving excess rainfall or irrigation water.

The commercially available NI have properties that affect how they can be added to various types of fertilizers. N-Serve and Dwell can be impregnated on solid fertilizers, or an emulsifiable formulation may be mixed with N solution fertilizers. N-Serve can be added directly to bulk anhydrous ammonia because of its high solubility in liquid ammonia. However, Dwell is not soluble in ammonia, but can be added to anhydrous ammonia with a small electric pump that meters the compound into the ammonia stream between the nitrolator and the manifold system on the applicator.

Table 8. Probability of Corn Yield Increase from the Addition of NI to Ammoniacal Fertilizers Applied at Varying Times.

Soil texture	Application time	Region of the U.S. Southeast	Eastern Cornbelt	Western Cornbelt
		—Probability of corn yield increase[1]—		
Sands	Fall	Poor	Poor	Poor
	Spring	Fair	Fair	Fair[2]
Loamy sands, sandy loams, and loams	Fall	Poor	Fair	Poor
	Spring	Fair	Fair[3]	Fair[2]
Silt loams	Fall	Poor	Good	Fair
	Spring	Fair	Fair[3]	Poor
Clay loams and clays	Fall	Poor	Good	Fair
	Spring	Fair	Good	Poor

[1] Poor = less than 20% chance of yield increase at any location any year; fair = 20-60% chance of increase; good = greater than 60% chance of increase.
[2] Fair for irrigated soils, poor for dryland corn.
[3] Good for no-till production systems.

Reference to products in this publication is not intended to be an endorsement to the exclusion of others which may be similar. Persons using such products assume responsibility for their use in accordance with current directions of the manufacturer.

A publication of the National Corn Handbook Project

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Stanley R. Johnson, director, Cooperative Extension Service, Iowa State University of Science and Technology, Ames, Iowa.

File: Agronomy 2-2

Exhibit C

EXHIBIT C

SUMMARY DOCUMENT OF EFFLUENT AMMONIA-NITROGEN REDUCTION EVALUATIONS FOR NOVEON-HENRY PLANT

BROWN AND CALDWELL

MEMORANDUM

TO: Mark Latham, Esq. **JOB NO:** 27-21522.001

FROM: T. Houston Flippin, P.E., DEE

DATE: May 17, 2002

SUBJECT: Ammonia-Nitrogen Treatment Alternatives Support Exhibit

Brown and Caldwell is providing below a summary of information intended to support the discussion of ammonia-nitrogen (NH_3-N) treatment alternatives described in the Petition For Adjusted Standard. This information is the product of treatability testing, full-scale plant testing, and data provided by the Noveon-Henry Plant staff.

In order to develop treatment alternatives, a "design influent and effluent wasteload" was required. This wasteloads were developed based on individual wastestream data gathered in 1995 and effluent data gathered in 1999 through 2000 and are summarized below in Tables 1 and 2. A flow schematic is provided in Attachment A of the wastewater treatment facility (WWTF) provided at the Henry Plant.

Table 1. Influent Wasteload Used In Developing Treatment Alternatives

Parameter	PVC Tank	PC Tank	C-18 Tank	Holding Pond/ Well No. 3 Waters	Total
Flowrate, gpm					
Average	401	107	6	46	560
Peak	499	150	15	105	769
SCOD, lbs/day					
Average	2,650	8,280	1,320	50	12,300
Peak	4,330	10,840	2,940	50	18,160
Estimated BOD, lbs/day					
Average	795	2,485	395	15	3,690
Peak	1,300	3,250	880	15	5,445
TKN, lbs/day					
Average	459	494	82	3	1038
Peak	640	693	198	7	1537
NH_3-N, lbs/day					
Average	295	62	27	1	385
Peak	411	87	66	3	571

Table 2. Effluent Wasteload Used In Developing Treatment Alternatives

Parameter	Effluent Value
NH_3-N, lbs/day	
Average	909
Peak	1408

The following treatment alternatives were considered for ammonia reduction. Illustrations of each are provided in Attachment A.

- alkaline air stripping of PC Tank contents with off-gas collection and treatment (No. 1)
- alkaline air stripping of PVC Tank contents (No. 2)
- alkaline air stripping of secondary clarifier effluent (No. 3)
- struvite ($NH_4MgPO_46H_20$) precipitation from combined influent (No. 4)
- breakpoint chlorination of secondary clarifier effluent (No. 5)
- nitrification of PVC Tank wastewater (non-PC wastewaters) (No. 6)
- nitrification of combined wastewater (No. 7)
- ion exchange treatment of final effluent (No. 8)
- ozonation of final effluent (No.9)
- nitrification of secondary clarifier effluent (tertiary nitrification) (No. 10)

A summary of conceptual level capital costs for each of these alternatives are summarized in Table 3. The total costs presented in this table are considered accurate to within ± 30 percent.

Table 3. Capital Cost Estimates For Treatment Alternatives

	Upgrade Costs in $ Millions for Treatment Alternative Number									
Upgrade Components	1	2	3	4	5	6	7	8	9	10
Pretreatment	0.65	0.10	0.00	0.05	0.00	0.02	0.43	0.00	0.00	0.00
Primary Treatment	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00
Secondary Treatment	0.00	0.00	0.00	0.00	0.00	1.12	1.91	0.00	0.00	0.00
Tertiary Treatment			4.21		0.75			0.57	4.6	4.00
Sub-total	0.65	0.10	4.21	0.05	0.75	1.39	2.34	0.57	4.6	4.00
Sitework/Interface Piping	0.10	0.01	0.32	0.01	0.11	0.21	0.35	0.09	0.20	0.50
Electrical/Instrumentation	0.25	0.16	0.40	0.16	0.26	0.36	0.50	0.24	0.50	0.30
Contractor Indirects (8 %)	0.05	0.01	0.34	0.00	0.06	0.11	0.19	0.05	0.37	0.32
Engin./Constr. Mgmt (18 %)	0.12	0.02	0.76	0.01	0.14	0.25	0.42	0.10	0.83	0.72
Performance Bonds (1 %)	0.01	0.00	0.04	0.00	0.01	0.01	0.02	0.00	0.05	0.04
Sub-total	1.17	0.30	6.07	0.22	1.33	2.33	3.82	1.04	6.54	5.88
Contingency (15 %)	0.18	0.04	0.91	0.03	0.20	0.35	0.57	0.16	0.98	0.88
Total Installed Cost	1.35	0.34	6.98	0.25	1.53	2.68	4.40	1.20	7.52	6.76

A summary of conceptual level operations and maintenance costs for each of these alternatives are summarized in Table 4. The total costs presented in this table are considered accurate to within ± 30 percent.

Table 4. Annual Operating and Maintenance Cost Estimates For Treatment Alternatives

	Annual O/M Costs in $ Thousands for Treatment Alternative Number									
Cost Components	1	2	3	4	5	6	7	8	9	10
Labor ($40/hour)	32	32	60	8	60	60	60	60	30	60
Electrical ($0.06/kwh)	64	29	214	0	4	10	98	10	1,363	88
Natural Gas ($0.06/therm)	18	0	0	0	0	0	0	0	0	0
Chemicals (Plant Costs)	0	1,794	575	642	1,028	218	788	147	226	459
Resin Replace. ($35/cu ft)	0	0	0	0	0	0	0	242	0	0
Off-site Disposal[a]	0	0	0	0	0	0	0	51	0	0
Maintenance Materials[b]	17	2	105	1	19	11	45	14	115	22
Sub-total	130	1,858	954	652	1,111	299	990	524	1,735	629
Contingency (10 %)	13	186	95	65	111	30	99	52	173	63
Total Annual	143	2,044	1,049	717	1,222	329	1,089	576	1,908	692

[a] Cost of disposing of spent regenerant containing 29.7 percent by weight NH_4Cl (8 percent N) assumed to be $0.10/gallon.
[b] Based on 5 percent of equipment costs.

A comparison of alternatives regarding present worth costs and ammonia removal is provided in Table 5.

Table 5. Comparison of Present Worth Costs and Ammonia Removal for Treatment Alternatives

	Treatment Alternative Number									
Components	1	2	3	4	5	6	7	8	9	10
NH_3-N Removal, lbs/day	247	147	864	217	891	423	891	891	891	891
NH3-N Removal, %	27	16	95	24	98	47	98	98	98	98
Present Worth Costs										
• Capital	1.35	0.34	6.98	0.25	1.53	2.68	4.40	1.20	7.52	6.76
• O/M[a]	0.96	13.71	7.04	4.81	8.20	2.20	7.31	3.87	12.80	4.64
• Total	2.31	14.06	14.02	5.06	9.73	4.88	11.71	5.07	20.32	11.41

[a] Based on 10 year period, 8 percent annual interest, and no salvage value.

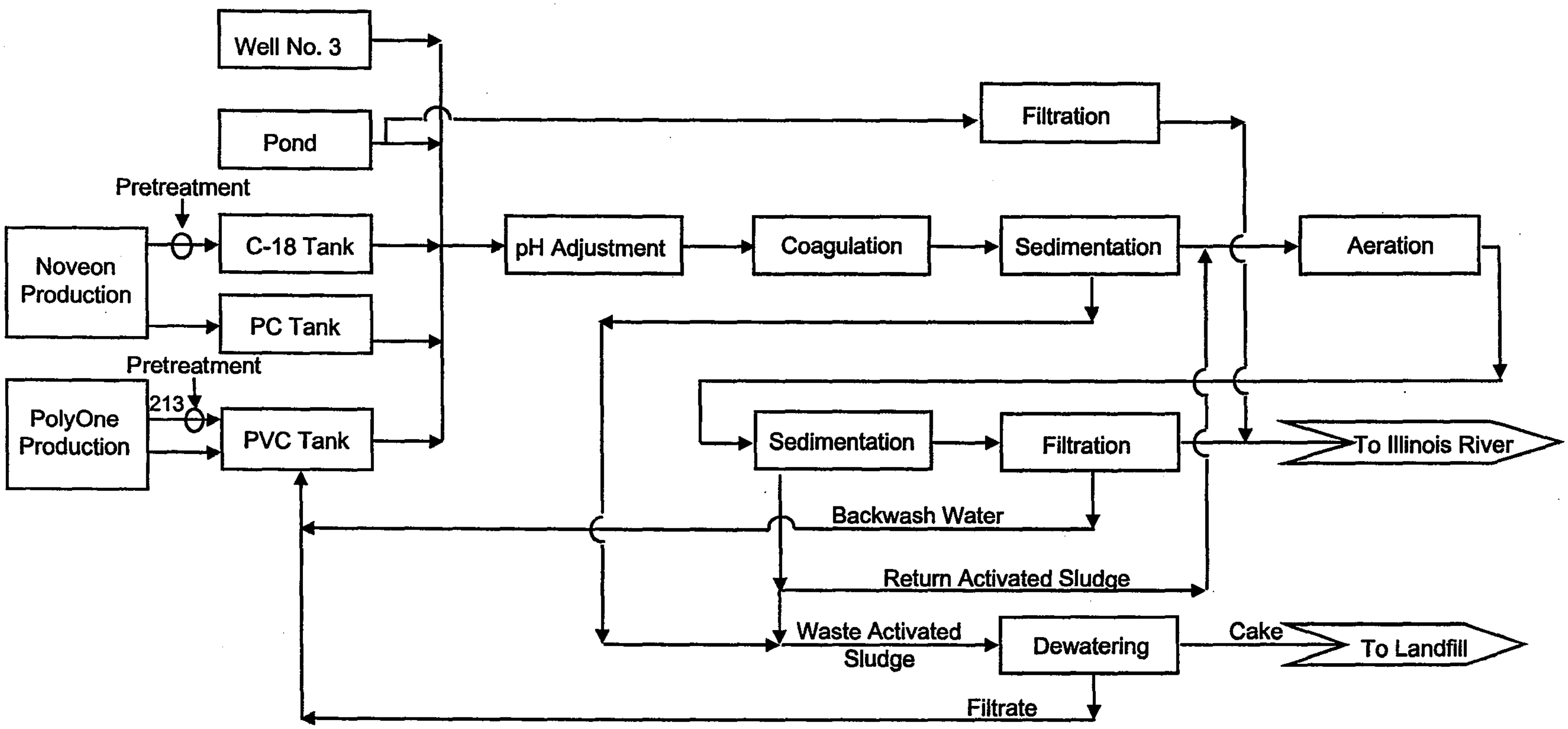


FIGURE 1

BLOCK FLOW DIAGRAM OF WASTESTREAM SOURCES AND WWTF

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 1

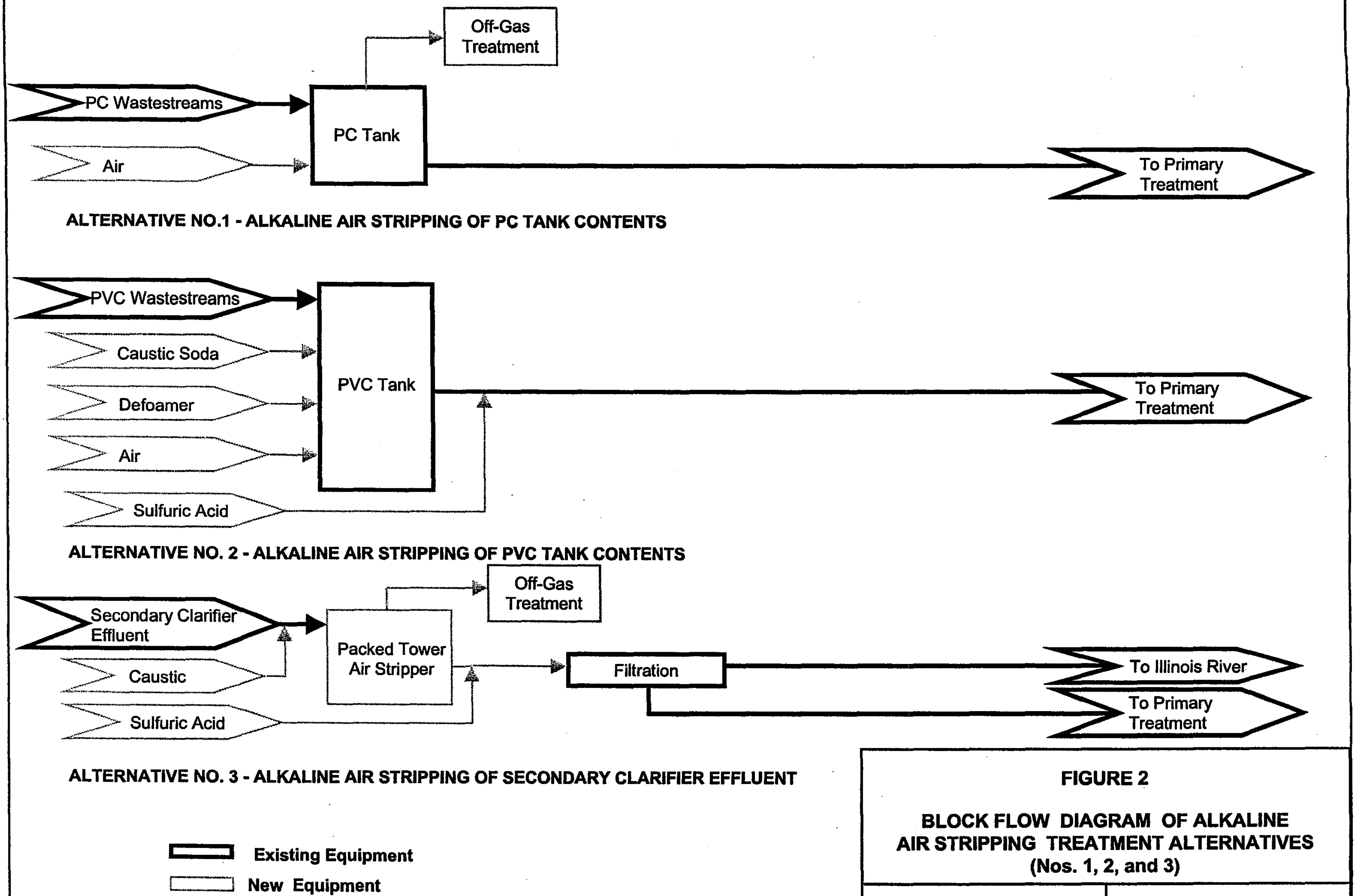


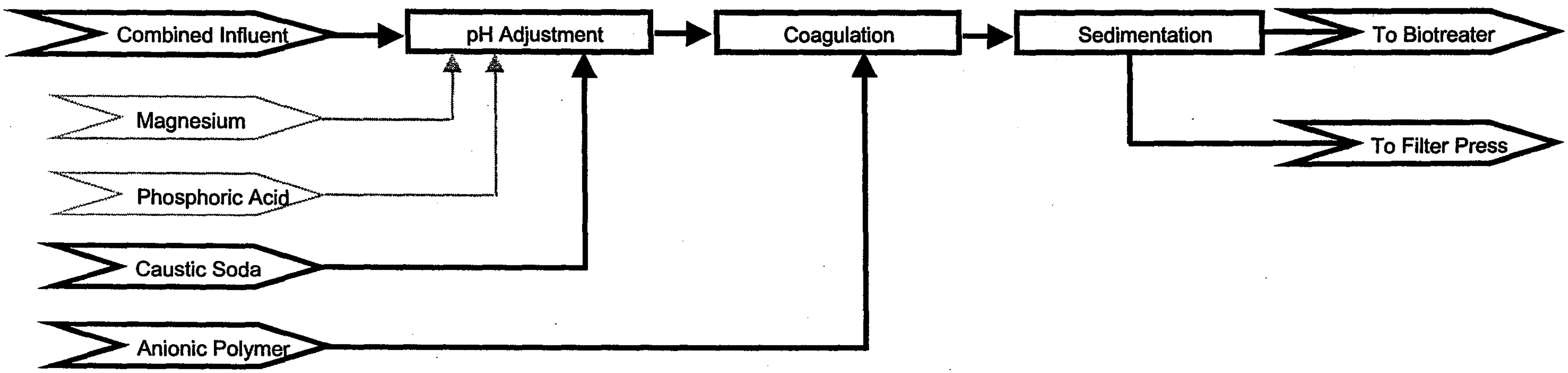
FIGURE 2

BLOCK FLOW DIAGRAM OF ALKALINE AIR STRIPPING TREATMENT ALTERNATIVES (Nos. 1, 2, and 3)

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 2



NOTE: Existing $FeCl_3$ Addition would be discontinued

Existing Equipment

New Equipment

FIGURE 3

BLOCK FLOW DIAGRAM OF STRUVITE PRECIPITATION TREATMENT ALTERNATIVE (No. 4)

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 3

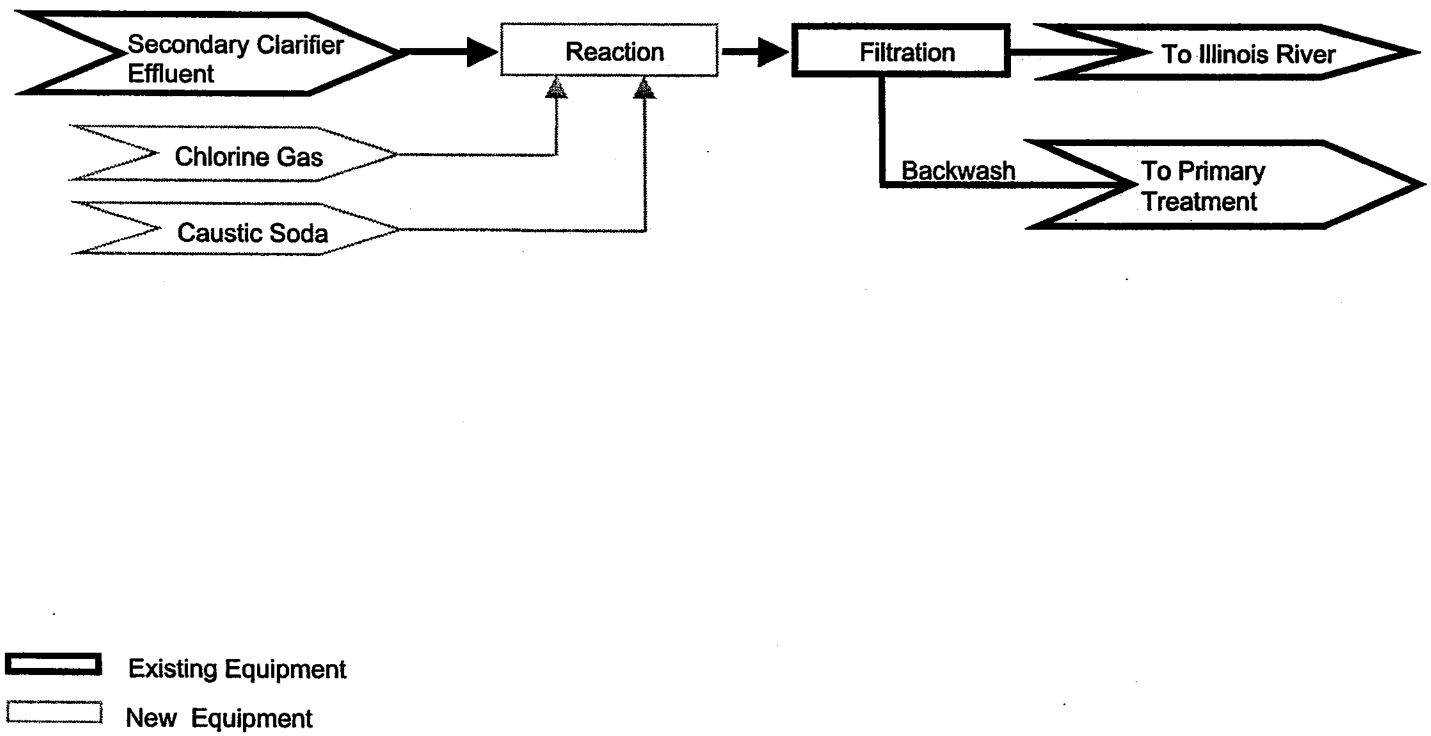


FIGURE 4

BLOCK FLOW DIAGRAM OF BREAKPOINT CHLORINATION ALTERNATIVE (No. 5)

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 4

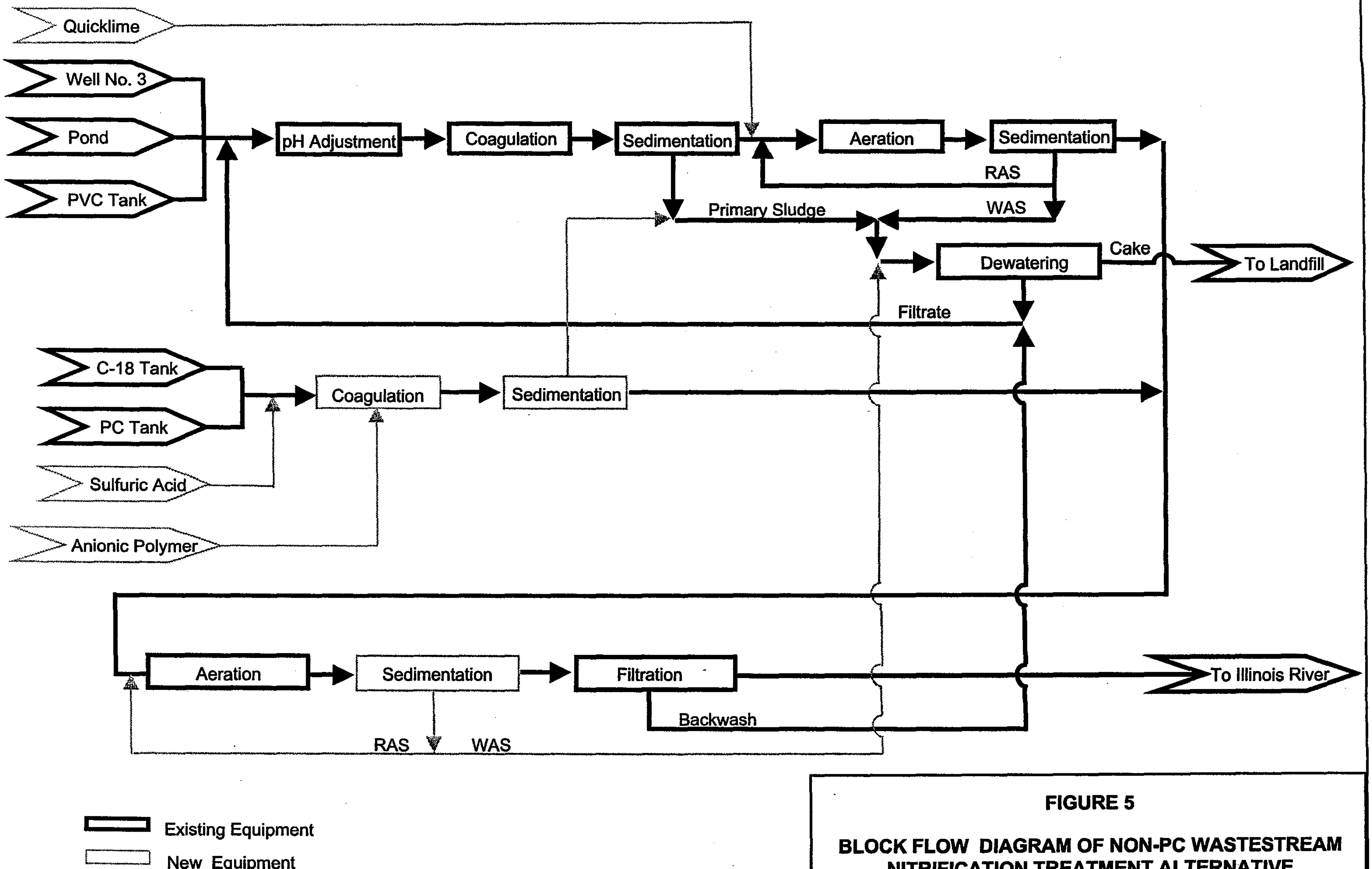


FIGURE 5

BLOCK FLOW DIAGRAM OF NON-PC WASTESTREAM NITRIFICATION TREATMENT ALTERNATIVE (No. 6)

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 5

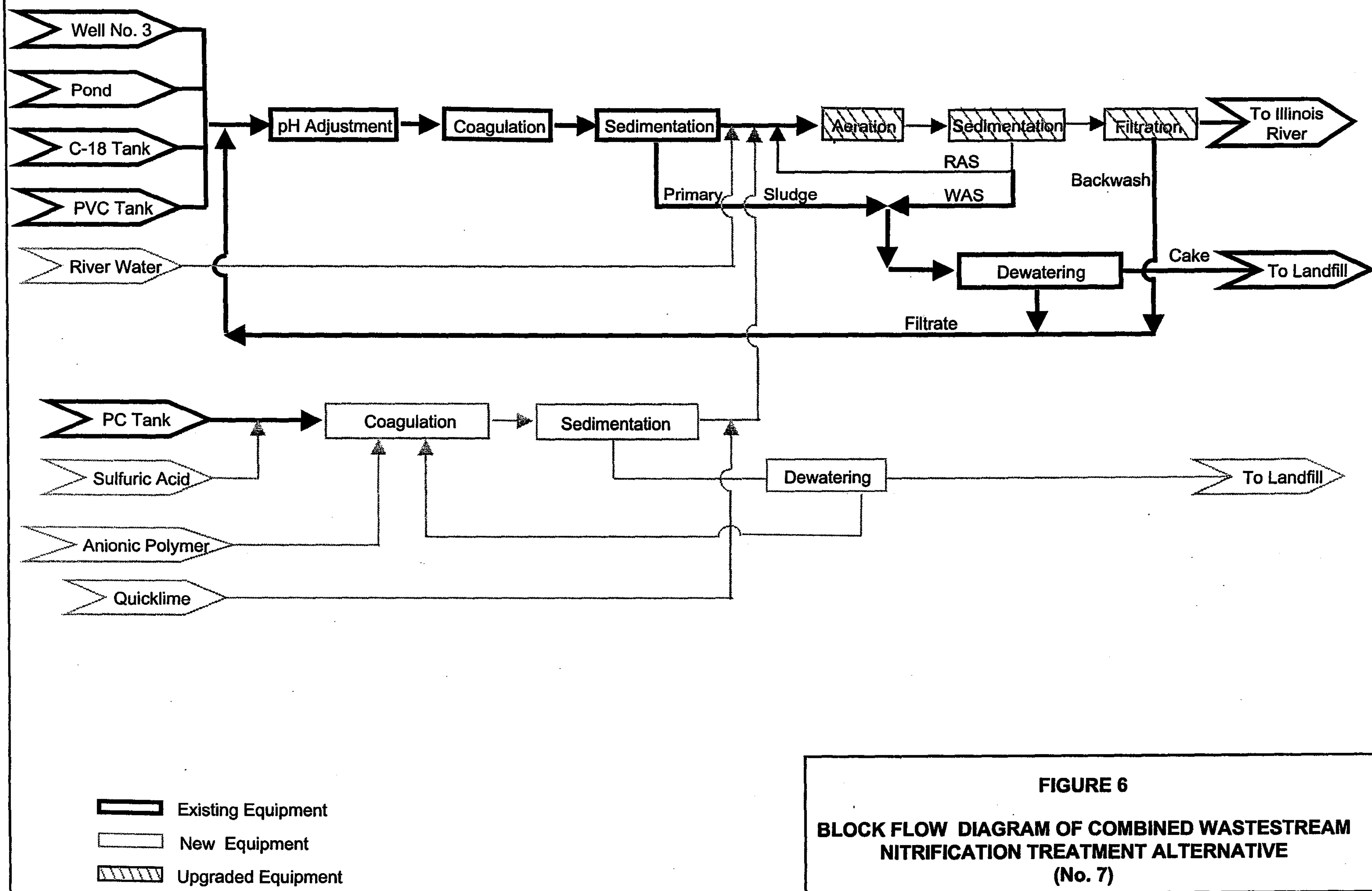


FIGURE 6

BLOCK FLOW DIAGRAM OF COMBINED WASTESTREAM NITRIFICATION TREATMENT ALTERNATIVE (No. 7)

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 6

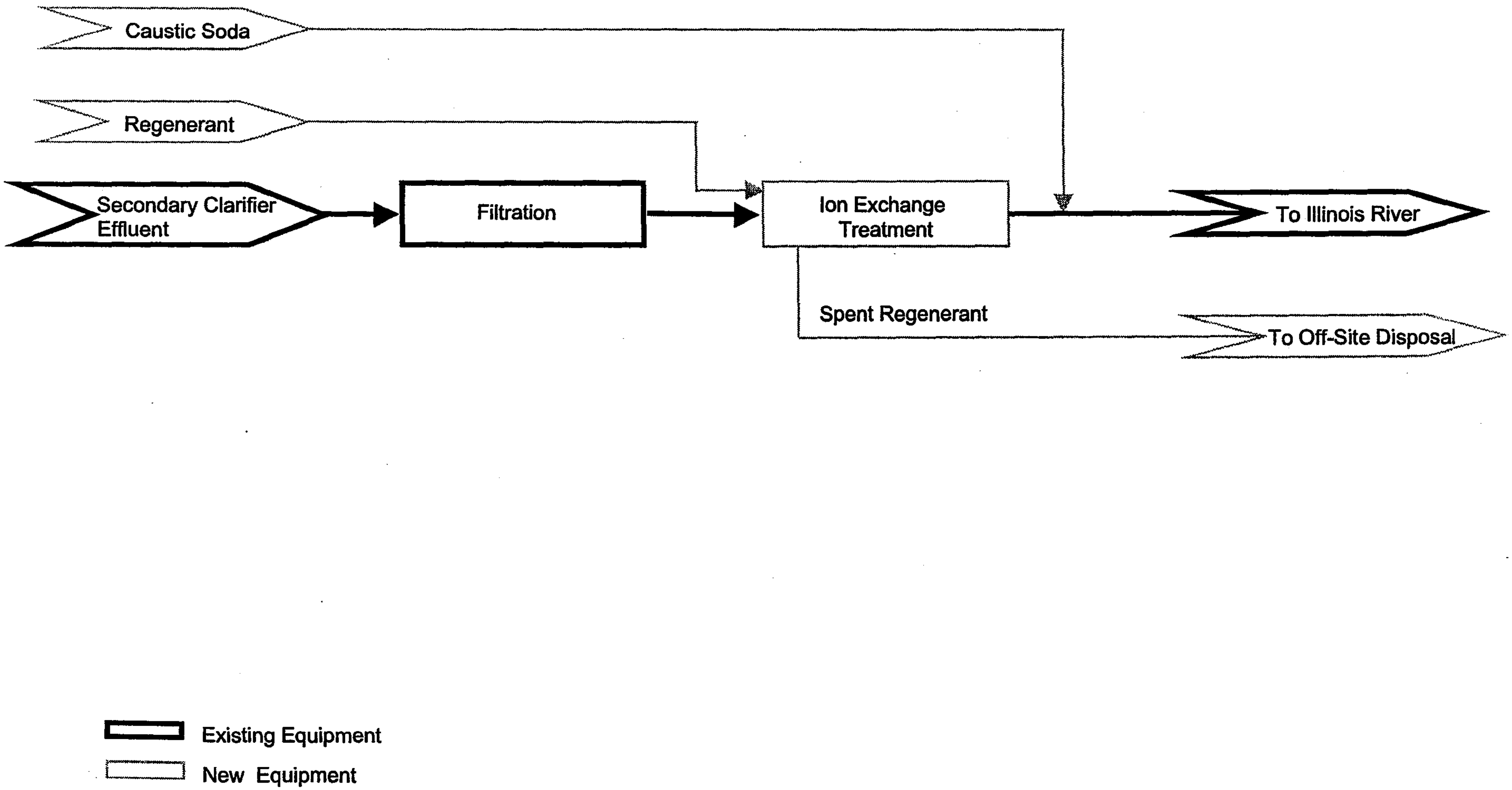


FIGURE 7

BLOCK FLOW DIAGRAM OF ION EXCHANGE TREATMENT ALTERNATIVE (No. 8)

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 7

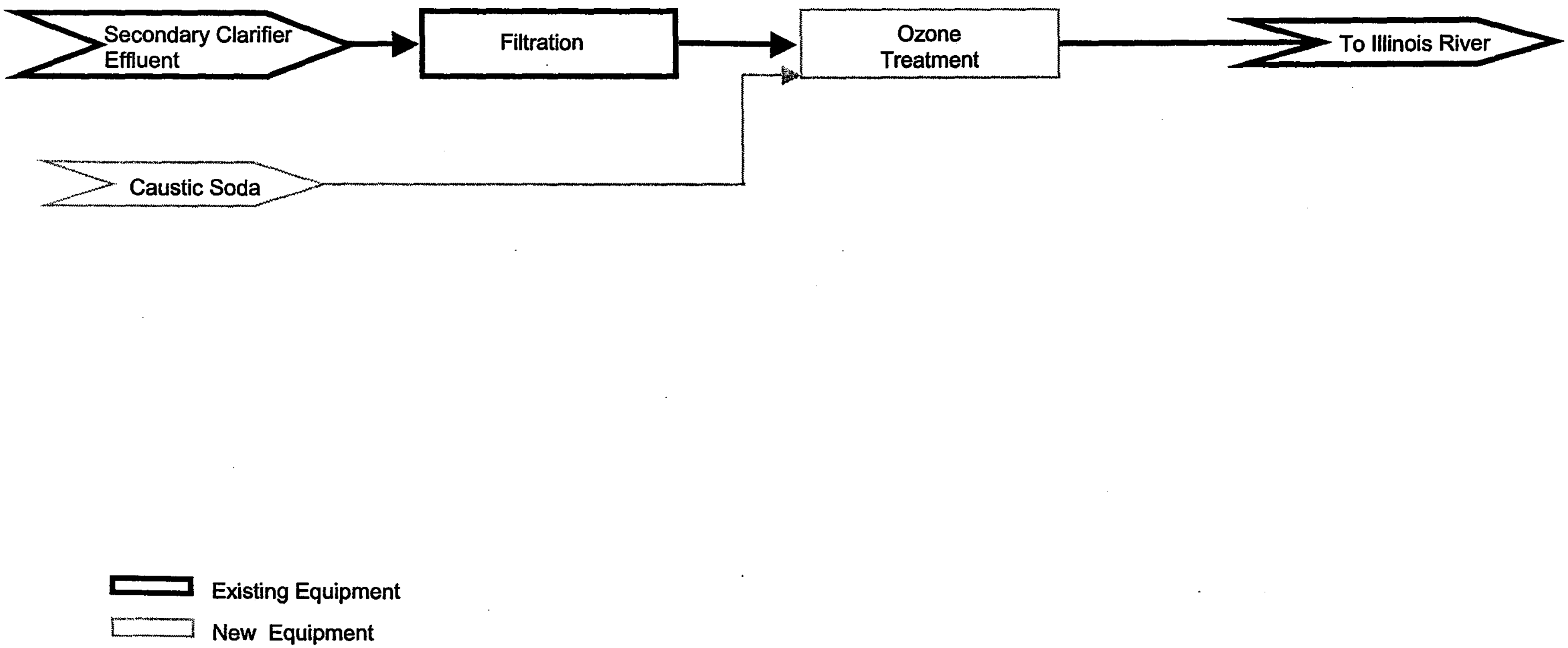


FIGURE 8

BLOCK FLOW DIAGRAM OF OZONE TREATMENT ALTERNATIVE (No. 9)

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 8

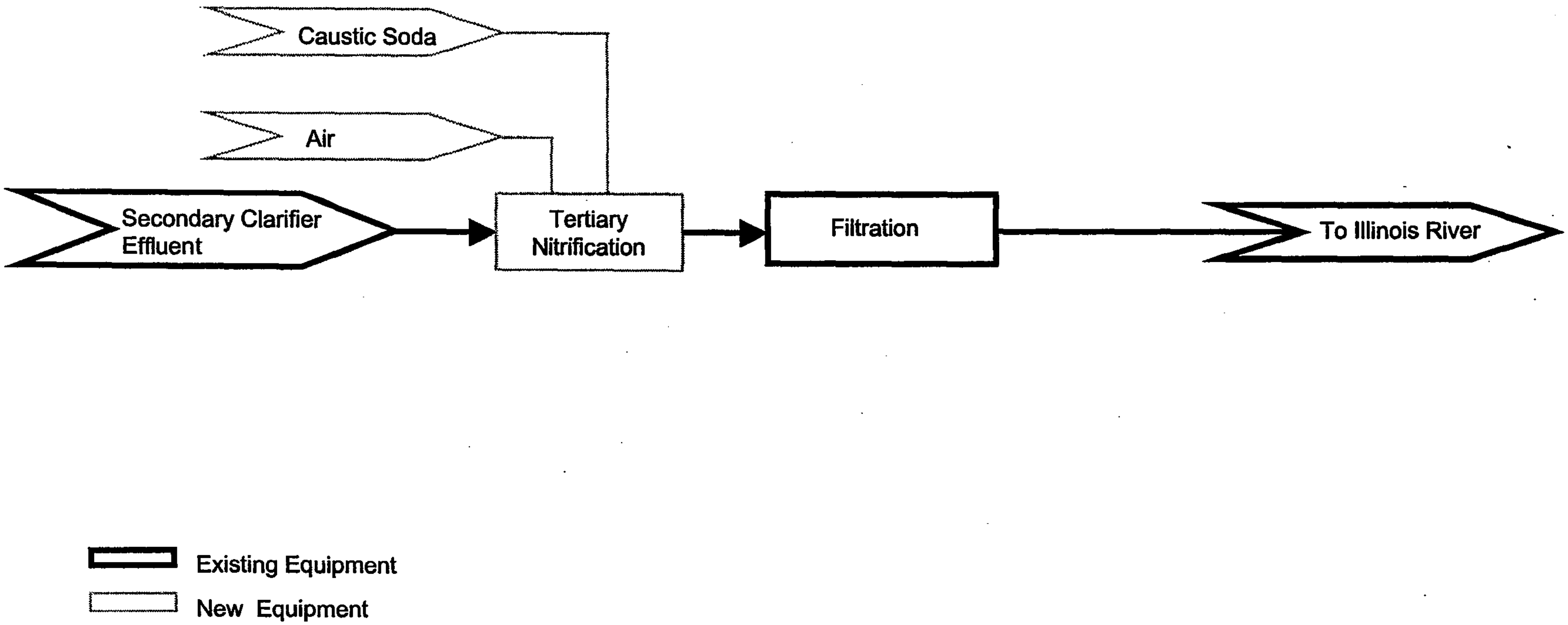


FIGURE 9

BLOCK FLOW DIAGRAM OF TERTIARY NITRIFICATION TREATMENT ALTERNATIVE (No. 10)

BROWN AND CALDWELL

Nashville, Tennessee

P:/PROJ/21522/Fig 9

Exhibit D

EXHIBIT D

SUMMARY OF COST ANALYSIS FOR PROVIDING INCREMENTAL EFFLUENT AMMONIA-NITROGEN REMOVAL AT THE NOVEON-HENRY PLANT

WWTF Component	Basis	PC Tank Stripping w/ Off-gas	PVC Tank Stripping w/o Off-gas	Effluent Stripping w/ Off-gas	Effluent Stripping No Off-gas	Effluent Stripping No Off-gas 75% removal	Effluent Stripping No Off-gas 50% removal	Effluent Stripping No Off-gas 25% removal	Struvite Precipitation	Effluent BP Chlorination	Non-PC Nitrification	Combined Nitrification
Additional Operations/ Maintenance Labor												
* Labor Hours		800	800	1500	1300	1300	1000	1000	200	1500	1500	1500
*** Annual Cost, $**	$40/hr	32000	32000	60000	52000	52000	40000	40000	8000	60000	60000	60000
Electrical Usage												
* hp		162	75	545	505	450	300	300	1	10	25	250
* kwh		1058664	490122	3561553	3300155	2940732	1960488	1960488	6535	65350	163374	1633740
*** Annual Cost, $**	$0.06/kwh	63520	29407	213693	198009	176444	117629	117629	392	3921	9802	98024
Maintenance Materials												
* Low End Equipment Costs, $		330,000	40,000	2106000	1263600	1013600	631800	379080	15000	375000	222,000	890,000
*** Annual Costs, $**	5% of E Costs	16500	2000	105300	63180	50680	31590	18954	750	18750	11100	44500
Chemical Costs												
* 50 % NaOH, $ year	$240/ton	0	1770431.04	434000	434000	434000	217000	108500	0	955541	217772	742484
* 98% H2SO4, $/year	$46/ton	0	24238	141000	119850	119850	70500	35250	0	0	0	45333
* 75 % H3PO4, $/year	$335/ton	0	0	0	0	0	0	0	407160	0	0	0
* 62 % Mg(OH)2, $/year	$220/ton	0	0	0	0	0	0	0	235205	0	0	0
* 98% HCl, $/year	$70/ton	0	0	0	0	0	0	0	0	0	0	0
* Chlorine Gas, $/year	$50/ton	0	0	0	0	0	0	0	0	72681	0	0
*Annual Costs, $/year		0	1794669	575000	553850	553850	287500	143750	642365	1028222	217772	787817
Annual Resin Replacement, $/year	$90/cu ft	0	0	0	0	0	0	0	0	0	0	0
Annual Off-site Disposal, $/year	$0.10/gal											
Natural Gas Cost, $/ year												
Annual Cost, $/ year	$0.06/therm	18240	0	0	0	0	0	0	0	0	0	0
Subtotal Annual Costs, $/year		130260	1858076	953993	867039	832974	476719	320333	651507	1110893	298674	990341
Contingency (10%),$/yr		13026	185808	95399	86704	83297	47672	32033	65151	111089	29867	99034
Total Annual Cost, $/year		143286	2043884	1049393	953743	916271	524391	352367	716657	1221982	328542	1089375
Present Worth of Annual Costs $	10 years 8 percent interest	961448	13714462	7041424	6399617	6148181	3518665	2364380	4808771	8199501	2204516	7309707
Capital Costs, $		1,345,138	344,023	6,983,076	4,522,426	3,770,418	2,453,930	1,541,358	253,748	1,526,625	2,676,729	4,397,370
Total Present Worth, $		2,306,586	14,058,484	14,024,500	10,922,043	9,918,598	5,972,595	3,905,738	5,062,519	9,726,126	4,881,245	11,707,077
Average NH3-N Removal, lbs/day		247	147	864	864	648	432	216	217	891	423	891
Average NH3-N Removal, %		27.2	16.2	95.0	95.0	71.3	47.5	23.8	23.9	98.0	46.5	98.0
Present Worth Cost, $/lb NH3-N		2.56	26.13	4.45	3.47	4.20	3.79	4.96	6.39	2.99	3.16	3.60

WWTF Component	Basis	Effluent Ion Exchange	Effluent Ion Exchange	Effluent Ion Exchange	Effluent Ion Exchange	Ozonation	Tertiary Nitrification	Tertiary Nitrification	Tertiary Nitrification	Tertiary Nitrification
			75% removal	50% removal	25% removal			75% removal	50% removal	25% removal
Additional Operations/ Maintenance Labor										
* Labor Hours		1500	1500	1500	1500	750	1500	1500	1500	1500
*** Annual Cost, $**	$40/hr	60000	60000	60000	60000	30000	60000	60000	60000	60000
Electrical Usage										
* hp		25	18.75	12.5	6.25		225	168.75	112.5	56.25
* kwh		163374	122531	81687	40844	22727273	1470366	1102775	735183	367592
*** Annual Cost, $**	$0.06/kwh	9802	7352	4901	2451	1363636	88222	66166	44111	22055
Maintenance Materials										
* Low End Equipment Costs, $		284000	227200	170400	85200	2300000	444000	355200	266400	133200
*** Annual Costs, $**	5% of E Costs	14200	11360	8520	4260	115000	22200	17760	13320	6660
Chemical Costs										
* 50 % NaOH, $ year	$240/ton	129861	97396	64930	32465	226145	458660	343995	229330	114665
* 98% H2SO4, $/year	$46/ton	0				0	0			
* 75 % H3PO4, $/year	$335/ton	0	0	0	0	0	0	0	0	0
* 62 % Mg(OH)2, $/year	$220/ton	0	0	0	0	0	0	0	0	0
* 98% HCl, $/year	$70/ton	17044	12783	8522	4261	0	0	0	0	0
* Chlorine Gas, $/year	$50/ton	0	0	0	0	0	0	0	0	0
*Annual Costs, $/year		146905	110179	73453	36726	226145	458660	343995	229330	114665
Annual Resin Replacement, $/year	$90/cu ft	242449	181837	121224	60612	0	0	0	0	0
Annual Off-site Disposal, $/year	$0.10/gal	50727	38045	25363	12682					
Natural Gas Cost, $/ year										
Annual Cost, $/ year	$0.06/therm	0	0	0	0	0	0	0	0	0
Subtotal Annual Costs, $/year		524083	408772	293462	176731	1734781	629082	487921	346761	203380
Contingency (10%),$/yr		52408	40877	29346	17673	173478	62908	48792	34676	20338
Total Annual Cost, $/year		576492	449650	322808	194404	1908259	691990	536713	381437	223718
Present Worth of Annual Costs $	10 years 8 percent interest	3868259	3017150	2166041	1304450	12804419	4643251	3601346	2559441	1501151
Capital Costs, $		1,198,024	1,095,472	787,814	480,157	7,523,300	6,762,000	6,223,800	4,264,200	2,304,600
Total Present Worth, $		5,066,283	4,112,621	2,953,855	1,784,607	20,327,719	11,405,251	9,825,146	6,823,641	3,805,751
Average NH3-N Removal, lbs/day		891	668	445	223	891	891	668	445	223
Average NH3-N Removal, %		98.0	73.5	49.0	24.5	98.0	98.0	73.5	49.0	24.5
Present Worth Cost, $/lb NH3-N		1.56	1.69	1.82	2.20	6.25	3.51	4.03	4.20	4.68

Exhibit E

EXHIBIT E

SUMMARY TABLE COMPARING COST, EFFLUENT AMMONIA-NITROGEN REDUCTION PERCENTAGES, RELIABILITY, AND PROS AND CONS OF ALTERNATIVE EFFLUENT AMMONIA-NITROGEN REDUCTION PROCESSES FOR THE NOVEON-HENRY PLANT

Comparison of Costs and Removals of Effluent NH_3-N Removal Processes for the Noveon-Henry Wastewater Treatment Facility with 10-Year Project Life

Process	Capital Cost ($ millions)	Annual Operating Cost ($ millions/year)	Present Worth Cost[a] ($ millions)	Present Worth Cost[a] ($/lb NH_3-N removed)	Effluent NH_3-N Removal (Average %)
PC Tank Stripping with Off-gas Control	1.35	0.130	2.21	2.45	27
	1.31	0.125	2.15	4.60	14
PVC Tank Stripping without Off-gas Control	0.344	2.04	14.1	26.13	16
	0.317	2.03	14.0	51.89	8
Effluent Stripping with Off-gas Control	6.98	1.05	14.1	4.42	95
Effluent Stripping without Off-gas Control	4.52	0.894	10.5	3.34	95
	3.77	0.850	9.5	3.83	75
	2.45	0.483	5.7	3.44	50
	1.54	0.332	3.8	4.59	25
Struvite Precipitation	0.254	0.669	4.74	5.99	24
	0.254	0.539	3.87	6.53	18
Effluent Breakpoint Chlorination	1.53	1.22	9.73	2.99	98

Comparison of Costs and Removals of Effluent NH_3-N Removal Processes for the Noveon-Henry Wastewater Treatment Facility with 10-Year Project Life

Process	Capital Cost ($ millions)	Annual Operating Cost ($ millions/year)	Present Worth Cost ($ millions)	Present Worth Cost ($/lb NH_3-N removed)	Effluent NH_3-N Removal (Average %)
Non-PC Nitrification	2.68	0.329	4.88	3.16	47
Combined Single-Stage Nitrification	4.40	1.09	11.7	3.60	98
• MBT Removal Process	0.86	0.441	3.82		Less Than 25
• WWTF Upgrades	3.54	0.649	7.88		0
Effluent Ion Exchange	1.20	0.688	5.82	1.79	98
	1.10	0.533	4.67	1.88	75
	0.79	0.379	3.33	2.01	50
	0.48	0.222	1.97	2.38	25
Effluent Ozonation	7.52	1.91	20.3	6.25	98
Tertiary Nitrification	6.76	0.692	11.4	3.51	98
	6.22	0.536	9.83	4.03	75
	4.26	0.381	6.82	4.20	50
	2.30	0.223	3.81	4.68	25

[a]10 years at 8% interest.

Comparison of Costs and Removals of Effluent NH_3-N Removal Processes for the Noveon-Henry Wastewater Treatment Facility with 20-Year Project Life

Process	Capital Cost ($ millions)	Annual Operating Cost ($ millions/year)	Present Worth Cost[a] ($ millions)	Present Worth Cost[a] ($/lb NH_3-N removed)	Effluent NH_3-N Removal (Average %)
PC Tank Stripping with Off-gas Control	1.35	0.130	2.63	1.46	27
	1.31	0.125	2.54	2.72	14
PVC Tank Stripping without Off-gas Control	0.344	2.04	20.4	18.90	16
	0.317	2.03	20.2	37.43	8
Effluent Stripping with Off-gas Control	6.98	1.05	17.3	2.71	95
Effluent Stripping without Off-gas Control	4.52	0.894	13.3	2.12	95
	3.77	0.850	12.1	2.44	75
	2.45	0.483	7.2	2.17	50
	1.54	0.332	4.8	2.90	25
Struvite Precipitation	0.254	0.669	6.8	4.30	24
	0.254	0.539	5.5	4.64	18
Effluent Breakpoint Chlorination	1.53	1.22	13.5	1.08	98

Comparison of Costs and Removals of Effluent NH_3-N Removal Processes for the Noveon-Henry Wastewater Treatment Facility with 20-Year Project Life

Process	Capital Cost ($ millions)	Annual Operating Cost ($ millions/year)	Present Worth Cost ($ millions)	Present Worth Cost ($/lb NH_3-N removed)	Effluent NH_3-N Removal (Average %)
Non-PC Nitrification	2.68	0.329	5.9	1.91	47
Combined Single-Stage Nitrification	4.40	1.09	15.1	2.32	98
• MBT Removal Process	0.86	0.441	5.2		Less Than 25
• WWTF Upgrades	3.54	0.649	9.9		0
Effluent Ion Exchange	1.20	0.688	8.0	1.23	98
	1.10	0.533	6.3	1.27	75
	0.79	0.379	4.5	1.36	50
	0.48	0.222	2.7	1.63	25
Effluent Ozonation	7.52	1.91	26.3	4.05	98
Tertiary Nitrification	6.76	0.692	13.6	2.09	98
	6.22	0.536	11.5	2.36	75
	4.26	0.381	8.0	2.46	50
	2.30	0.223	4.5	2.76	25

[a]20 years at 8% interest.

Comparison of Removals and Reliability of Effluent NH_3-N Removal Processes for the Noveon-Henry Wastewater Treatment Facility

Process	Effluent NH_3-N Removal		
	(Average %)	Reliability Rating[1]	Comments
PC Tank Stripping with Off-gas Control	27	8	Involves adding surface aerator, oversized withdrawal fan, off-gas collection and thermal oxidation of off-gas. Off-gas collection and treatment are needed for VOC control. No chemical addition required since PC Tank contents are normally pH 11 s.u. Simple to operate. Performance will vary as volatile amine content varies in wastewater. Average removals of 0 to 27 percent could be achieved by varying the size of the surface aerator placed in the tank.
PVC Tank Stripping without Off-gas Control	16	7	Involves adding caustic addition and surface aerator to PVC tank contents. Acid addition in primary system will be required to lower pH to 9.0 s.u. Simple to operate. Strong foaming potential in PVC Tank which would reduce effectiveness. Performance will vary based on production discharges of NH_3-N and volatile amines, and NH_3-N returned in sludge dewatering filtrate and tertiary filter backwash. Removals of 0 to 16 percent could be achieved by varying the size of the surface aerator placed in the tank. Will increase effluent TDS.
Effluent Stripping with Off-gas Control	95	7	Involves pumping sand filter effluent through two packed towers in series. Caustic is added to increase pH to 11.5 s.u. and acid is added to lower the treated effluent pH to 8 s.u. Off-gas is directed to an acid scrubber for recovery of $(NH_4)_2SO_4$. Scrubber discharge would be disposed off-site. Complex to operate. Equipment must be housed in heated building to prevent freezing. Fouling of tower media with precipitants is anticipated. Removals of 75 to 95 percent would be achieved by treating the whole effluent through different sized columns. Removals of 25 to 50 percent would be achieved by treating only a portion of the final effluent. Will increase effluent TDS.

Comparison of Removals and Reliability of Effluent NH_3-N Removal Processes for the Noveon-Henry Wastewater Treatment Facility (Continued)

Process	Effluent NH_3-N Removal (Average %)	Reliability Rating[1]	Comments
Effluent Stripping without Off-gas Control	95	8	Same as above but without off-gas collection and treatment. NH3-N would be discharged to atmosphere. Will increase effluent TDS.
Struvite Precipitation	24	6	Involves feeding magnesium hydroxide and phosphoric acid to existing primary treatment system. Simple to operate. However, the precipitant is prone to foul pumps and piping. Removal could be varied between 18 and 24 percent depending upon the quantity of magnesium hydroxide added. Performance will vary strictly as a function of influent NH_3-N load. Will increase effluent TDS.
Effluent Breakpoint Chlorination	98	9	Involves routing secondary clarifier effluent through chlorination step prior to tertiary filtration. Caustic is fed to maintain pH control. Reliable process. Creates safety concerns and may form chlorinated organics. Will increase effluent TDS.
Non-PC Nitrification	47	7	Involves using existing activated sludge system to provide BOD removal and nitrification of PVC wastewater. Treated effluent from this system would be combined with PC wastewater and treated in new activated sludge system. Complex system to operate. Two WWTFs that would be subject to upset. Performance would vary as a function of PVC NH_3-N and amine loading. Will increase effluent TDS.

Comparison of Removals and Reliability of Effluent NH_3-N Removal Processes for the Noveon-Henry Wastewater Treatment Facility (Continued)

Process	Effluent NH_3-N Removal (Average %)	Reliability Rating[1]	Comments
Combined Single-Stage Nitrification	98	7	Involves adding pretreatment system to remove MBT and possibly other inhibitors from the PC tank contents with acid addition and precipitation at pH 2 s.u.. The precipitant is separately dewatered and disposed. Caustic is added to the treated PC wastewater. This wastewater is blended with wastewater and river water and undergoes biological nitrification in an expanded WWTF. River water addition is provided to maintain a set PC wastewater flow contribution. Additional aeration equipment, aeration tankage, and sand filtration would be required. Complex to operate with two separate sludge dewatering operations in service. Performance would vary with success of pretreatment facility in removing inhibitors. Will increase effluent TDS.
Effluent Ion Exchange	98	6	Involves pumping sand filter effluent through two resin columns in series. Caustic is added to neutralize effluent from strong acid resin treatment. Resins would be regenerated daily using acid and spent regenerant (high cation content NH_4CL solution) would be disposed off-site. Complex to operate. Equipment must be housed in heated building to prevent freezing. Fouling of media with precipitants and biomass is anticipated. Removals of 25 to 95 percent would be achieved by treating only a portion of the whole effluent. Should have little net effect on effluent TDS.

Comparison of Removals and Reliability of Effluent NH_3-N Removal Processes for the Noveon-Henry Wastewater Treatment Facility (Continued)

Process	Effluent NH_3-N Removal (Average %)	Reliability Rating[1]	Comments
Effluent Ozonation	98	8	Involves routing secondary clarifier effluent through ozonation step prior to tertiary filtration. Caustic is fed to maintain pH control. Very complex system requiring active monitoring and safety controls. Will increase effluent TDS.
Tertiary Nitrification	98	7	Involves pumping secondary clarifier effluent into separate biological treatment tank containing fixed film media. Magnesium hydroxide is added for alkalinity control. Simple to operate. Removals of 25 percent to 95 percent would be achieved by treating the whole effluent through varying sized reactors. Performance would vary with the success of the upstream WWTF in removing inhibitors. Will increase effluent TDS.

[1] Reliability Rating based on a relative assessment of mechanical and process performance reliability to achieve the average percent removal (10 being highest reliability). Reliability means the ability of the treatment process to achieve the predicted effluent ammonia-nitrogen (NH3-N) concentrations on a routine basis.