Help Instruction File:

Polymer Module Overview

Provided by the Office of Surface Mining Reclamation and Enforcement (OSMRE), the Pennsylvania Department of Protection (PADEP), the U.S. Geological Survey's (USGS) and the West Virginia Department of Environmental Protection (WVDEP).

Polymer Module Overview

Table of Contents

1.0 Objective

The objectives of this overview are to: (1) Provide an understanding of the application of polymer in mine drainage treatment and (2) Provide an overview of the Polymer module to guide users in developing an estimate of the cost to construct, operate, and maintain the polymer component of mine drainage treatment systems. The module can also be applied to reverse cost model the polymer component of an existing treatment system to establish and evaluate future financial and investment decisions. The information is presented in two sections, **Overview and Application** and **Polymer Module Overview**.

2.0 Overview and Application

A basic understanding of the chemical and physical properties, the application, and equipment requirements of the polymer component of a mine drainage treatment system are required to develop a treatment strategy using the AMDTreat software. These topics are discussed below before discussing the module interface and functionality to provide the necessary context. The Overview and Application section is organized into three parts: (1) Physical and Chemical Properties and (2) Benefits/Drawbacks, Equipment and Typical Treatment Configurations, and (3) Application and Financial Analysis.

2.1 Physical and Chemical Properties

The most common type of polymer products used in mine drainage treatment are synthetic (man-made) anionic polyacrylamide flocculant polymers, which are organic compounds used as flocculants. Polymers are manufactured in different forms but the most common three used in mine drainage treatment include a dry granular material, emulsion, and pre-diluted polymer. These types of readily available polymers are classified as non-hazardous substances by the Occupational Safety and Health Administration (OSHA). However, some of the hazards indicated on polymer material safety data sheets (MSDS) consist of (1) skin irritant and (2) eye irritation. Polymer is also extremely slippery, particularly in liquid form, and should be cleaned up based on the manufacturer's recommendations if spilled. A system designed with a small containment concrete curb or similar containment structure will greatly facilitate cleanup of spilled polymer and minimized associated slip and fall hazards. Please see the MSDS for additional information on the applicable polymer product. **This help file and AMDTreat Polymer Module does NOT comprehensively address the overall site safety precautions that must be considered when designing, operating or maintaining a polymer component of a treatment system. System designers and operators must consult with qualified and knowledgeable chemical and equipment providers in order to adequately address site and personnel safety concerns.**

Polyacrylamide polymers are chains of organic molecules made up of smaller molecules referred to as monomers. Anionic polymers have a negative charge and are commonly used in applications to settle inorganic solids such as metals, clays, and silts as they are effective at the separation of mineral-based liquid-solid applications. Cationic polyacrylamide polymers are also organic in composition but possess positive charged surfaces and are much less commonly used in most mine drainage treatment applications. Polymer manufacturers offer a variety of different molecular weight and charge density configurations. Typically, polymer sales technicians will assist treatment plant designers and operators in selecting the best performing polymer for their particular application through on-site testing of the treated mine water.

Metal precipitates (solid) that form when either alkaline addition is performed increasing the pH for net acidic mine drainage or oxygen is added to net alkaline mine drainage may hold a surface charge that prevent the individual floating particles from combining to form larger particles allowing them to more readily settle out of the water. In the case of mine drainage this is most commonly a net positive surface charge. Consequently, anionic polymers which by definition have negatively charged surfaces are the preferred choice. This is apparent particularly where a net alkaline mine drainage source surfaces, is introduced to oxygen through aeration and is observed in multiple settling ponds in series appearing to be a cloudy orangish color due to the suspended iron precipitates that have formed from ferrous iron being oxidized to ferric iron. If sufficient retention time is not provided for the suspended iron particles to eventually floc naturally in order to settle out of the water or if surfaces such as those present in wetland vegetation are available for the iron particles to adsorb/attach then the suspended iron particles will discharge from the treatment system. There are a number of examples where polishing wetlands have been employed as components of both passive and active treatment systems to enhance flocculation and settling. In much the same manner as anionic polymers, surfaces of wetland plants are net negatively charged which promote removal of suspended iron and other positively charged metal particles. The following weblink to OSMRE's Flight 93 webpage provides a much more detailed discussion of enhanced solids removal by polishing wetlands:
https://www.arcc.osmre.gov/programs/TDT/flight93.shtm

Polymer functions by allowing the iron particles to floc together, bonding to the oppositely charged polymer surface, forming larger particles that will settle out of the water. There are many different manufacturers of anionic polymer flocculant products and it is important to conduct the appropriate jar tests or bench scale testing using the water to be treated with any perspective polymer product to confirm the effectiveness at settling the precipitated solids, desired solution strength of polymer, and the dosage that works the best. The anionic polymer flocculant product is most commonly applied prior to the mine water entering the settling pond or clarifier in order to maximize the floc formation by causing the precipitated metal solids to combine or "floc" forming larger particles that will more readily settle out of the water. The polymer increases the rate of sedimentation of the solids producing a dense sludge in the settling pond/clarifier allowing the water to contain low suspended solids upon discharge from the settling unit. The resulting sludge when polymer is applied is also more readily dewatered for disposal.

The type of polymer product selected is important since it will dictate the type of equipment needed to prepare the polymer for addition to the mine drainage treatment process. In general, polymer is water soluble and has a finite shelf life depending on the type of polymer to be used. *Dry Polymer* contains the highest amount of active flocculant ingredient, normally greater than 90%, and is expected to last up to 2 years if kept dry until it must be used. For a *Dry Polymer* product, the product will need to be mixed with water as part of a process referred to as make down in order to dissolve the polymer product and to be stored in a holding tank for use. The made down polymer product is normally made with a solution strength less than or equal to 0.5% by weight (% wt). If solution strengths of the made down polymer are greater than 0.5% wt and the initial high energy mixing process is not efficient, the solution will result in the formation of "fish-eyes", which are unhydrated polymer particles surrounded by a gelatinous layer of hydrated polymer, rendering the unhydrated particles ineffective at carrying out the role of the polymer. "Fish-eyes" can also create clogging issues in the feedlines and equipment. The made down polymer is then mixed with what is commonly referred to as "push water" in order to provide further dilution to create the desired solution strength of 0.1% or less and transport the polymer solution to the application point with the mine water. In-line static mixers are often utilized to further promote mixing of the polymer (neat) solution with the additional push water. The lowest solution strength practically achievable is the objective as this will promote mixing of the polymer/push water solution with the mine water as the mine water density and solution density will closely approximate one another. At the point of polymer application to the mine drainage the correct volume of polymer must be added to result in the target dosage commonly expressed in parts per million (ppm) in the mine drainage. Typical target dosing rates for anionic *Dry Polymer* in mine drainage are between 0.5 and 1.0 ppm. Please note, in this module it is assumed that the *Dry Polymer* will be delivered as a solid in either *55 lb Bags* or *1,650 lb Super Sacks* (bulk). The product must then be made down on site in order to create the necessary solution strength for the dosage rate needed with the mine drainage, which requires a clean water source at the treatment site for both the make down process and to use as push water. Clean water sources are not necessarily limited to potable or purchase water sources. In many cases treated effluent is utilized for both the make down and push water components. However, suspended solids concentrations must be low and ideally Total Dissolved Solids (TDS) concentrations of the source water should not be excessively high. Low TDS water is most applicable for the initial make down of *Dry Polymer*, or as in the case of emulsion polymer for the initial polymer inversion step and much less of a consideration for push water applications.. System designers should also note that in sizing storage tanks for the made down neat polymer solution several factors must be considered. First, neat solutions made from *Dry Polymer* should be allowed to "age" for approximately 24 hours before use for peak efficiency. Secondly, neat polymer solutions made from *Dry Polymer* will have a shelf life and ideally should be fully utilized no longer than 2 to 3 days after make down. Otherwise, the organic molecules within the polymer will significantly degrade. *Emulsion Polymers* and the dilute solutions made from them do not requiring aging to achieve maximum efficiency and are not as susceptible to shelf-life degradation concerns. Please see Section 3.4 of Help File for assumptions.

The second option for anionic polymer products to use in mine drainage treatment is *Emulsion Polymer*. The *Emulsion Polymer* product is a liquid consisting of coiled chains of polymer suspended in water droplets dispersed in oil. The percent activity of *Emulsion Polymers* ranges from 20 to 50% wt, requiring a dose of *Emulsion Polymer* two to three times greater than that of *Dry Polymer* (90% active). *Emulsion Polymer* is most commonly supplied in 275-gallon totes at mine drainage treatment sites. The *Emulsion Polymer* is then pumped from the tote to a mixing unit where it is first mixed with a clean water source to provide inversion, and then mixed with additional push water for dilution before conveyance to the application point with the mine drainage. Most *Emulsion Polymers* contain an inverting surfactant that assists with the inverting phase from a coiled polymer dispersed in oil to coiled polymer dispersed in push water. Many of these inverting surfactants contained in *Emulsion Polymers* are intended to start inversion when the polymer is diluted to a concentration between 1 to 2% wt. As a result, some treatment sites will first pump the *Emulsion Polymer* into an aging tank where water is added to the polymer to produce a solution strength of 1 to 2% wt for inversion and then pumped to a mixing unit where it is blended with push water to further dilute the polymer to a 0.1% wt solution strength. However, many of the more recent *Emulsion Polymer* pump skids and mixing units are designed to pump the *Emulsion Polymer* directly into the mixing unit where it is mixed with push water using sufficient energy to promote inversion of the product without the use of the aging tank step. Typical dosing rates of *Emulsion Polymer* in mine drainage treatment is 2.5 to 3.5 ppm. If kept airtight in a tote, *Emulsion Polymer* can be stored roughly 6 months before it must be used.

Pre-Diluted Polymer is the third and final type of anionic polymer used in mine drainage treatment, particularly at remote sites where electricity is not available. Similar to *Emulsion Polymer*, *Pre-Diluted Polymer* is most commonly provided in 275-gallon totes. The *Pre-Diluted Polymer* is made by chemical distribution companies by dissolving *Dry Polymer* into water to produce a 1.0 to 1.25% wt solution.

Some companies produce *Pre-Diluted Polymer* products using a brine solution to allow the polymer to dissolve but not fully uncoil in order to allow an extended shelf life of more than 3 months. The most common application of pre-diluted polymer in mine drainage treatment is to pump or gravity feed with a needle valve the polymer solution directly into the mine drainage. Alternatively, where the mine drainage source is pumped, static mixers are used to more thoroughly mix the mine water and polymer solution. Target dosing rates for *Pre-Diluted Polymer* is the same as made down *Dry Polymer*, ranging from 0.5 to 1.0 ppm.

Table 1 provides characteristics of the three types of polymers used in the module including the default values for each item in the Anionic Polymer Flocculant Information section.

Polymer Type	Product Container from Supplier	Target Dose (ppm)	Product Density (lbs/gal)	Activity (%)	Desired Strength of Made Down Polymer (% wt)	Desired Strength in Push Water (% wt)	Product Unit Cost ($/lb)
Dry Polymer	55 lb Bags, 1,650 lb Super Sacks	0.5-1.0	6.68	90	$\leq$0.5	0.01	$1.65 (55 lb Bags), $1.55 (1,650 lb Super Sacks)
Emulsion Polymer	275 gal Tote	2.5-3.5	8.59	30	N.A.	0.05	$1.17
Pre-Diluted Polymer	275 gal Tote	0.5-1.0	8.34	90	0.08	N.A.	$0.24

Table 1: Specifications for three most common polymer products used in mine drainage treatment.

Ferrous Iron is the primary multi-valent contaminate in flooded underground coal mines in the eastern U.S., although some underground mines also require manganese and aluminum treatment. An operator can consider using polymer to maximize the settling of any precipitated solids within a mine drainage treatment system. For net acidic mine drainage, following the addition of alkalinity and aeration (oxygen), the goal is to oxidize the ferrous iron (Fe^{2+}), dissolved aluminum (Al^{3+}) and dissolved manganese (Mn^{2+}) forming solid precipitates of each. Historically, operators have used lime or caustic soda addition in active treatment systems and limestone in passive systems to increase pH in order to precipitate metals. This is then followed by the addition of polymer prior to or within the settling pond or clarifier to promote settling of the solids, forming a sludge layer that is ultimately removed for disposal. The polymer is effective at removing the solids from the mine drainage within the settling unit to achieve effluent standards (Figure 1). However, if the mine drainage source is net alkaline, the role of polymer remains the same in that it aides in removing the solids following aeration, forming a sludge layer within the settling pond or clarifier.

2.2 Benefits/Drawbacks, Equipment and Typical Treatment Configurations

This section summarizes some of the benefits, drawbacks, equipment, and treatment configurations of the polymer systems used at mine drainage treatment sites.

2.2.1 Benefits:

The major reason why polymer is popular is its ability to promote the formation of floc from individual metal precipitates, enhancing the settleability of the particles and creating an effluent with low suspended solids. The benefits of using polymer as a component of a mine drainage treatment system include:

1. Quick reacting allows for precise dosage and reduced size of the settling pond/clarifier.
2. Can be effectively mixed with mine drainage using passive mixing, like turbulent flow, provided that solution density differences between the dilute polymer and the treated mine water are minimal.
3. Works very well at promoting flocculation of target mine drainage constituents, improving their settleability and removal from the water within a settling pond/clarifier prior to discharge.
4. Maximizes sludge production by generating larger, more dense sludge particles, and may enhance the dewatering of sludge upon removal for disposal.
5. Depending on the type of polymer selected, the lower the capital costs the higher the annual costs and vice versa (higher capital costs may have lower annual costs).
6. Minimal maintenance, with the dose pump and electric mixer being the only mechanical parts.
7. Relatively small equipment footprint (automatic *Dry Polymer* systems that utilize *1,650 lb Super Sacks* have the largest footprint of polymer types, whereas *Dry Polymer* systems using *55 lb Bags* have a comparable footprint to most *Emulsion Polymer* systems).
8. Relatively stable chemical (*Dry Polymer*) allows for long-term storage in instances of ephemeral or periodic treatment.
9. The use of *Pre-Diluted Polymer* is possible at remote sites where electricity is not available, which is common for many mine drainage treatment systems.
10. Depending upon preference, systems can be highly automated or very basic (manual) in design philosophy.

2.2.2 Drawbacks:

The drawbacks of using polymer as a mine drainage treatment chemical include:

1. Annual cost, polymer is a relatively expensive chemical and depending on the needs of the system it can be a considerable cost component of the annual costs. *Pre-Diluted Polymer* is the most expensive polymer product used in mine drainage treatment on a cost per active ingredient basis since you are purchasing primarily water, therefore this type of polymer should be reserved for remote sites where electricity is not available and it is the only option when polymer is needed.
2. The polymer system and product should be stored within a temperature-controlled building or structure in order to prevent freezing and inconsistency issues with the product, especially during the cold weather months.
3. The capital costs and footprint associated with the equipment options for *Dry Polymer* can be significant compared to other polymer types, especially for an automatic system for use in mine drainage treatment.
4. *Emulsion Polymer* systems tend to require more frequent maintenance than *Dry Polymer* systems. Typically, several hours per week of downtime maintenance is needed to clean injection ports, nozzles and lines associated with the emulsion pump mechanism.

2.2.3 Equipment and Typical Treatment Configurations:

2.2.3.1 Dry Polymer - The module assumes the *Dry Polymer* will be delivered in either *55 lb bags* or *1,650 lb Super Sacks* (bulk). The *Dry Polymer*, which is most common in a granular form but may be delivered as a powder depending on the manufacturer, must be made down (diluted) at the treatment site using either a manual or automatic make down system. The two types of *Dry Polymer* systems that the user must choose between in the Polymer module are assumed to have standard components for each.

Manual System

For a manual *Dry Polymer* system, the make down equipment is composed of an extra-large HDPE (XLHDPE) day tank with a low revolutions per minute (RPM) mixer. The XLHDPE day tank size can be estimated by the software, based on calculating the volume of diluted polymer solution required to achieve the user-defined target polymer dose for a 24-hour period (why it's called a day tank) and provide an additional 20% volume as a safety factor for the tank size. Alternatively, the user can specify a *Custom* cost for a known day tank size and mixer. This manual make down system assumes the operator will add water to the XLHDPE day tank and manually add the *Dry Polymer*, preferably into a Hootonanny Eductor (see Figure 4) for pre-wetting, into a vortex created by a low RPM (less than 400 RPM) mixer and mixed for approximately 30 minutes to fully dissolve the *Dry Polymer*. The made down polymer in the day tank is then processed through a separate pump and mixing equipment system, which consists of two diaphragm pumps (one primary and one back-up) that pump the made down polymer from the day tank to two inline static mixers where the diluted polymer solution is mixed with either additional dilution water (push water) or with the mine drainage. The user can select to allow the module to Estimate the cost of the diaphragm pumps and inline static mixers using the default unit cost or to provide a known Custom cost for this portion of the manual polymer system. Either component of the manual *Dry Polymer* system can be excluded by the user as deemed appropriate for the specific application.

Automatic System

For an automatic dry polymer system, the make down equipment is composed of a stainless-steel (or fiberglass) blending/aging tank, piping, and a hopper that continuously makes a diluted polymer solution. The hopper gravity feeds *Dry Polymer* into a pre-wetting chamber where the *Dry Polymer* is mixed with water with high shear agitation to pre-wet polymer granules to prevent unwanted agglomeration, referred to as 'fish-eyes', and ensure proper activation of the active polymer ingredient. Note that if the *1,650 lb Super Sacks* are the selected delivery method (bulk) for *Dry Polymer* in the module, an option is automatically included in the equipment section for a bulk bag (Super Sack) feeder option. However, the user can choose to deselect this option in the *Automatic Dry Polymer Equipment* section by unchecking the corresponding box. Following the pre-wetted chamber, the polymer and water are conveyed into a second stage mix tank where the polymer and water are mixed in a low shear environment to produce the desired polymer solution strength set by the operator on a computer control screen for the system (*Desired Solution Strength of Made Down Polymer*). Following this mix tank, the diluted (made down) polymer is conveyed to a holding tank. As the product is pumped from the made down polymer solution holding tank, a low-level sensor in the tank automatically initiates the production of another batch of polymer solution from the hopper. The default selected dosing pump and mixing skid is responsible for pumping the made down polymer solution from the holding tank and mechanically mixing it with push water (clean water source) for further dilution to achieve a constant solution strength electronically set by the operator on the skid using the computerized controls or remotely from a 4-20 milliamp (mA) signal. The dosing pump and mixing skid unit automatically adjusts the flow of the push water and made down polymer solution from the holding tank to prevent disruptions. The dosing pump and mixing skid consists of two high quality diaphragm pumps, one primary and one back-up, and a mixing unit which are all mounted on a stainless-steel skid frame geared with computerized controls for the equipment. The user can select to allow the module to *Estimate* the cost of the pump and mixing skid, an optional item, or the user can choose to deselect it by unchecking the corresponding box, using the default unit cost, or provide a known *Custom* cost for this portion of the automatic *Dry Polymer* system.

2.2.3.2 Emulsion Polymer System - An *Emulsion Polymer* system is much less complicated and requires less equipment than what is typically required for *Dry Polymer*. The default equipment provided in the module for *Emulsion Polymer* consists of a computerized pump and blending unit mounted on a stainless-steel skid frame. The operator sets the desired solution strength for the polymer in the dilution (push) water on the computer control panel, which controls the progressive cavity pumps (2) that pump the *Emulsion Polymer* from the tote to the mixing unit. In the mixing unit, dilution (push) water is pumped to mix with the *Emulsion Polymer* to achieve the desired solution strength and additional mechanical mixing is provided to promote inversion and unwinding of the polymer chain in order to react with the mine drainage. A default unit cost is provided that can be adjusted by the user or a Custom cost for the *Blending Skid w/ Progressive Cavity Pump and Computerized Controls* unit can be specified.

2.2.3.3 Pre-Diluted Polymer System - The *Pre-Diluted Polymer* system is also less complicated and requires less equipment than what is typically required for *Dry Polymer*. The default equipment provided in the module for *Pre-Diluted Polymer* consists of two *Diaphragm Dosing Pumps* (one primary and one back-up) and two *Inline Stainless-Steel (SS) Static Mixers with Removable Mixing Fins*. *Pre-Diluted Polymer* is pumped using a diaphragm pump from the totes in which it is delivered to the site to two static inline mixers to blend the *Pre-Diluted Polymer* with the mine drainage. The static inline mixers are only used in situations where the mine drainage source is being pumped in order to provide the pressure needed for the mixers to blend the *Pre-Diluted Polymer* and water. If the mine drainage is gravity fed through the system, common at many surface mine sites, the user can deselect the line static mixers since the *Pre-Diluted Polymer* would simply be pumped directly into the mine drainage. The operator can also further dilute the *Pre-Diluted Polymer* solution by pumping it from the storage totes into the static inline mixers for mixing with push water prior to adding to the mine drainage. Default quantity and unit costs are provided for the *Diaphragm Dosing Pump* and *Inline SS Static Mixer with Removable Mixing Fins* that can be adjusted by the user, or a *Custom* cost can be entered for all of the equipment as one lump sum amount.

2.3 Application and Financial Analysis

Polymer is typically used as a flocculant to improve settling of iron, aluminum and manganese precipitates in mine drainage. It is used to cause suspended particles of metal precipitates to combine, forming larger particles that are more readily settled. To achieve this the diluted polymer solution is added to the mine drainage as it is conveyed to the settling unit, most commonly a clarifier or less often a settling pond. The most common solid precipitates in mine drainage are $Fe(OH)_3$, $Al(OH)_3$, and MnO_2. The selected polymer product can be based on the preference of the design engineer or the operator or as determined by a cost analysis for the capital and annual costs of the three anionic polymer options. Polymer is typically selected for use at a mine drainage treatment site based on:

1. The need for rapid settling of suspended metal precipitates within the settling unit (e.g., clarifier).
2. Fast reaction time.

3.0 Polymer Module Overview

3.1 Layout and Workflow

In general, inputs are on the left-hand side of the module and calculated outputs are on the right. The module inputs on the left-hand side are arranged into six sections: (1) Water Quality and Flow Input, (2) Anionic Polymer Flocculant Information, (3) Equipment and System Installation, (4) Annual Cost Input, (5) Other Capital Items, and (6) Other Annual Items. The workflow for the module is for users to start at the top left-hand side. Enter the *Typical Flow* (gpm) and *Density of Water* in lbs/gal. Under the Anionic Polymer Flocculant Information enter the *Target Polymer Dose* (ppm) followed by selecting the specific polymer product (*Dry Polymer*, *Emulsion Polymer*, or *Pre-Diluted Polymer*). If *Dry Polymer* is selected, the user must select either *55 lb Bags* (non-bulk) or *1,650 lb Super Sacks* (bulk), followed by accepting the default values or specifying the *Density of Dry Polymer*, *Activity of Dry Polymer*, *Desired Solution Strength of Made Down Polymer*, and *Desired Strength of Made Down Polymer in Dilution (Push) Water*. If *Emulsion Polymer* is selected, the user can accept the default values or specify the *Density of Emulsion Polymer*, *Activity of Emulsion Polymer*, and *Desired Strength of Emulsion Polymer in Dilution (Push) Polymer*. Finally, if *Pre-Diluted Polymer* is selected, the user can accept the default values or specify the *Density of Pre-Diluted Polymer*, *Activity of Polymer*, and *Solution Strength of Pre-Diluted Polymer*. AMDTreat uses this information along with the typical flow to estimate the polymer consumption, based on the specified operational times.

Next, users can accept default values or provide custom costs in the Equipment and System Installation section for the polymer treatment equipment. Based on the selected polymer product in the Anionic Polymer Flocculant Information section, the applicable product equipment is shown in the Equipment and System Installation section. If *Dry Polymer* is selected, the user must select either *Manual* or *Automatic Dry Polymer Equipment*. If *Manual Dry Polymer Equipment* is selected, the items *XLHDPE Day Tank & Low RPM Mixer (Make Down Equipment)* and *Two Diaphragm Pumps, Feeder Tube, & Two Inline SS Static Mixers* are included. For each of these two items the user can select to exclude either item, have the software estimate the sizing and cost for each (default) or the user can enter a *Custom* cost for each item if that information is already known for an existing system. If *Automatic Dry Polymer Equipment* is selected, the items *Automatic Dry Polymer Make Down Unit (Stainless steel blending/aging tank, piping, hopper)* and *Polymer Dosing and Diaphragm Pump Skid with Computerized Controls* are included. If the user selected *1,650 lb Super Sacks* (bulk) for the *Dry Polymer*, an additional item, *Bulk Bag/Super Sack*

Feeder Option is automatically included with the *Automatic Dry Polymer Equipment* items. For each of these two or three items the user can select to exclude any of the items, have the software estimate the sizing (excludes *Bulk Bag/Super Sack Feeder Option*) and cost for each (default) or the user can enter a *Custom* cost for each item if that information is already known for an existing system. If *Emulsion Polymer* is selected, the default item includes a *Blending Skid with Progressive Cavity Pump and Computerized Controls*. For this item the user can select to exclude it in addition to have the software estimate the cost (default) or the user can enter a *Custom* cost for the item if that information is already known for an existing system. If *Pre-Diluted Polymer* is selected, the default items include *Diaphragm Dosing Pump* and *Inline SS Static Mixers with Removable Mixing Fins*. For these items the user can select to exclude it in addition to have the software estimate the cost (default) based on the desired quantity and unit cost or the user can enter a *Custom* cost for the item if that information is already known for an existing system.

The Annual Cost Input section allows the user to specify the polymer and water (dilution/push) unit costs, operational periods, and electrical unit cost to ensure polymer and water consumption and electrical costs are correctly estimated. Based on the user selected polymer product, the default unit cost is activated for the applicable polymer product, which can be adjusted by the user. Finally, users can specify additional capital and annual costs not considered by the module under the Other Capital Items and Other Annual Items headings.

Module output is provided on the right-hand side of the module. Module outputs on the right-hand side are arranged into four sections: (1) Sizing Summary, (2) Capital Cost, (3) Annual Cost, and (4) Net Present Value (NPV). The Sizing Summary section provides estimates based on the selected polymer product such as the dose corrected for percent activity, polymer consumption at different rates based on user-specified operational times, push/dilution water volumes, tank sizes where applicable, pump rates, and product refill frequency. The estimated cost to construct and operate the polymer component of a treatment system is provided under the Capital Co*st* and Annual Cost headings. Lastly, users can opt to conduct a NPV analysis to obtain the total cost to operate and maintain the polymer system for a defined time period.

A general overview of the module input and output sections is presented below, however, users are directed to the numerous tool tips located in the module that provide additional detailed information, such as definitions of terminology. In most cases, the tool tips are accessed by clicking on the information icon (ℹ) in each of the subheadings in the module.

3.2 Module Inputs

3.2.1 Water Quality and Flow Input

The Water Quality and Flow Input section is where users specify the *Typical Flow* and *Density of Water* values. These values are used to (1) estimate the polymer consumption and (2) estimate the size of various equipment items such as the day tank for *Dry Polymer*.

The definitions for *Typical Flow* and *Density of Water* can be found in the tool tip for this section. Click on the information icon (ℹ) on the right side of the Water Quality and Flow subheading. In short, *Typical Flow* is the flow rate "typically" experienced at the site. This flow rate is used to calculate the polymer consumption, so one must take careful consideration to calculate this value.

Density of Water represents the density of water to be treated with polymer as specified by the user for use in calculating polymer consumption rates.

3.2.2 Anionic Polymer Flocculant Information

3.2.2 Anionic Polymer Flocculant Information: After specifying the *Target Polymer Dose*, users can select from three different polymer products including *Dry Polymer*, *Emulsion Polymer*, or *Pre-Diluted Polymer*. After selecting the polymer product, the user can adjust specific input parameters based on the polymer product selected. For *Dry Polymer*, the user must first select the preferred delivery product either *55 lb Bags* or *1,650 lb Super Sacks*. The remaining items in this section can be adjusted or the user can accept the default values, these items are *Density of Dry Polymer*, *Activity of Dry Polymer*, *Desired Solution Strength of Made Down Polymer*, and *Desired Strength of Made Polymer in the Dilution (Push) Water*. *Emulsion* and *Pre-Diluted Polymer* are typically only available in 275-gallon totes delivered to the site, so no options are provided for delivery method. The items in the *Emulsion Polymer* section can be adjusted or the user can accept the default value for *Density of Emulsion Polymer*, *Activity of Emulsion Polymer*, and *Desired Strength of Emulsion Polymer in the Dilution (Push) Water*. *Pre-Diluted Polymer* has very similar items to *Emulsion Polymer* that can be adjusted in this section, which include *Density of Pre-Diluted Polymer*, *Activity of Polymer*, and *Solution Strength of Pre-Diluted Polymer*. It is assumed 100% of the dosed polymer reacts in the mine drainage; therefore, mixing efficiency is not a parameter that is considered in this module.

3.2.3 Equipment and System Installation: This section allows users to design and select a polymer system setup. Polymer systems are straightforward, after the user decides which polymer product to utilize, they can decide which equipment items to include as part of the design. The software provides the common components for each polymer type by default including unit costs. The system will estimate the equipment and associated costs, unless the user has specific cost information for an existing system. The following subsections discuss these items:

3.2.3.1 Dry Polymer Equipment - The module assumes that if the user selects *Dry Polymer* that the solid polymer will be mixed onsite; therefore, the *Dry Polymer* equipment items are only available when the user selects *Dry Polymer*. Users have two options to choose from when selecting *Dry Polymer*, either *Manual* or *Automatic Dry Polymer Equipment*.

<u>Manual Dry Polymer Equipment</u>

Since *Manual Dry Polymer Equipment* is selected by default, we will review the calculations for it first. The volume of the XLHDPE day tank is estimated by determining the required daily pump rate volume (gal/day) of made down polymer at the user specified made down solution strength multiplied by a conservative surplus volume factor of 1.2, using Equation (1).

$$XLHDPE\ Day\ Tank\ Volume = Daily\ PumpVol_{DP} * 1.2 \quad \textbf{(1)}$$

Where:
Daily $PumpVol_{DP}$ = Daily pump rate volume of made down dry polymer in gal/day of specified % solution strength.
XLHDPE Day Tank Volume = Calculated volume of XLHDPE day tank for made down dry polymer solution.

The user can edit the *XLHDPE Day Tank & Low RPM Mixer* unit cost of $8.50 per gallon (day tank volume) accordingly in order to get an accurate capital cost for these items. The default unit cost of $6,500 for the *Two Diaphragm Pumps, Feeder Tube & Two Inline Stainless-Steel Mixers* is provided, and the user can adjust this unit cost or provide a custom cost for this equipment if known. Two diaphragm pumps are recommended in order to have a primary and back up pump on-site.

Automatic Dry Polymer Equipment

If the user selects *Automatic Dry Polymer Equipment*, the first item is the make down unit that includes a stainless-steel blending/aging tank, piping, and a hopper. The volume of the blending/aging tank is estimated using the same equation as shown above (Equation 1) for the XLHDPE day tank volume. A low-level sensor is provided in the blending/aging tank that automatically initiates the production of another batch of made down polymer. The user can edit the *Automatic Dry Polymer Make Down Unit* default unit cost accordingly in order to get an accurate capital cost for these items. Default unit costs are also provided for the other two items included for an *Automatic Dry Polymer System*, including a *Polymer Dosing and Diaphragm Pump Skid with Computerized Controls*. If the user selects *1,650 lb Super Sacks* for *Dry Polymer* (Anionic Polymer Flocculant Information section) a *Bulk Bag/Super Sack Feeder Option* is included by default to hold and dispense the *Dry Polymer* from the super sacks. If the user selects *55 lb Bags* for the *Dry Polymer* then the *Bulk Bag/Super Sack Feeder Option* is not provided in the *Automatic Dry Polymer Equipment* section. The *Polymer Dosing and Diaphragm Pump Skid with Computerized Controls* is used to control and regulate the pumping of the made down and diluted polymer from the stainless-steel blending/aging tank and mechanically mix it with dilution/push water to generate a constant solution strength electronically set by the operator on the skid or remotely from a 4-20 mA signal. This diluted polymer solution is then applied to the mine drainage source. The user can select if they prefer not to include any of these items using the check boxes for each and adjust the unit costs or provide a *Custom* cost for this equipment if known.

3.2.3.2 Emulsion Polymer Equipment - If the user selects *Emulsion Polymer*, the *Emulsion Polymer Equipment* includes a *Blending Skid with Progressive Cavity Pump and Computerized Controls* with a default cost of $25,000 for the entire skid unit. The user can select if they prefer not to include this item using the check box and adjust the unit costs or provide a *Custom* cost for this equipment if known. The operator specifies the desired solution strength on the computer control panel of the skid for the progressive cavity pumps to pump the *Emulsion Polymer* from the 275-gallon tote from which it is delivered to the mixing unit where it is mixed with dilution/push water to create the desired solution strength for addition to the mine drainage.

3.2.3.3 Pre-Diluted Polymer Dosing Equipment - If the user selects *Pre-Diluted Polymer*, the *Pre-Diluted Polymer Dosing Equipment* allows the user to select the *Estimate* option using default equipment including *Diaphragm Dosing Pumps and Inline Stainless-Steel Static Mixers with Removable Mixing Fins* or select the *Custom* option where the cost for the equipment, if known, can be specified such as for an existing polymer system. The default values for the *Diaphragm Dosing Pumps* include a quantity of two (2) and a unit cost of $1,700 per pump. The default values for the *Inline Stainless-Steel Static Mixers with Removable Mixing Fins* include a quantity of two (2) and a unit cost of $1,300 per mixer. All default quantities and unit costs can be adjusted by the user as needed. The basic premise of the default equipment for *Pre-Diluted Polymer* is to use a diaphragm pump, one primary and one back-up, to pump the *Pre-Diluted Polymer* from the 275-gallon tote to two static inline mixers to mix with the mine drainage stream if the water is also pumped such as from an underground mine. However, if the *Pre-Diluted Polymer* is simply pumped into a gravity fed mine discharge such as what is common for many surface mine sites, the user can deselect the inline stainless-steel static mixers since they are not applicable and not include the cost.

3.2.4 Annual Cost Input

3.2.4 Annual Cost Input: This section allows users to specify critical items needed to calculate many of the items contained in the Sizing Summary including the amounts of polymer needed, volume of dilution/push water needed if applicable, in addition to the annual cost of several items including polymer, water, and electric. The specific items included in this section that may be applicable to all of the polymer types include the following: *Polymer System Operational Time*, *Unit Cost of Water*, *Polymer Pump Power*, *Electrical Unit Cost*, and *Delivered Unit Price of Selected Polymer Product*.

3.2.4.1 Polymer System Operational Time - The operational time directly affects the estimates of polymer consumption that are provided in the Sizing Summary of the module. The operational time also affects the refill frequency of tanks and hoppers, the consumption of dilution or push water, and the electrical costs of operating pumps and other equipment associated with polymer systems. The default values for the operational times, 24 hours per day and 365 days per year, assume the polymer system will be operated continuously. However, there are situations where mine drainage treatment systems that pump and treat underground mine pools to maintain the mine pool storage can be periodically operated rather than continuously. These two input items allow the user to specify their unique operational time to more accurately estimate polymer, water consumption and electrical costs.

3.2.4.2 Unit Cost of Water - The *Unit Cost of Water* is applicable if the site requires the purchase of water from a public water supply in order to use the water for the make down process and for any further dilution and/or as push water to transport the polymer to the application point. It is important to make sure that all taxes, distribution costs, and other fees are included when calculating the *Unit Cost of Water* ($/1,000 gallons) to the site for accurately estimating the annual water cost. The best way to estimate the *Unit Cost of Water* is to review a water bill for the site and divide the bill amount by the total gallons of water used for the billing period and multiply that value by 1,000. As an example, if the water bill for a 30-day period is $60 and approximately 7,000 gallons of water was consumed at the site, then the unit cost of water would be calculated as follows:

Unit Cost of Water = ($60/7,000)*1,000 = $8.57/1,000 gallons of water

3.2.4.3 Polymer Pump Power - The *Polymer Pump Power* is the power consumption associated with the applicable pump(s) used for the specific type of polymer system selected. The default value of 130 watts is common for most polymer pumps used in mine drainage but the user can specify a value for the pump to be used if known.

3.2.4.4 Electrical Unit Cost - The unit cost of electricity is the applicable rate charged to provide electricity to the site. The value used for polymer should be the same value used for any other module where electric is required to operate that component. Make sure all taxes, distribution costs, and other fees are included when determining the *Electrical Unit Cost* in order to accurately predict the annual electrical costs. Similar to the *Unit Cost of Water*, the *Electrical Unit Cost* can be calculated by reviewing an electric bill for the site and dividing the total bill amount by the total kWhs used for the billing period that results in a $/kWh value. The *Electrical Unit Cost* is then multiplied by the power consumed by the polymer equipment and operational time to estimate the annual cost of electric for the polymer system.

3.2.4.5 Delivered Unit Price of Selected Polymer Product - The delivered unit cost for each type of polymer including default values are provided in order to estimate the annual cost of polymer consumption. Whichever polymer type the user selects in the Anionic Polymer Flocculant Information section is automatically activated in this section including which type of *Dry Polymer* delivery container is selected, *55 lb Bags* or *1,650 lb Super Sacks*, since the unit cost is different due to the bulk discount for the Super Sacks. When attempting to obtain a quote for unit cost of a polymer from a supplier make sure the unit cost includes both the purchase and delivery costs, which is the value that should be used for the *Delivered Unit Price of Selected Polymer Product*.

3.2.5 Other Capital Items: The Other Capital Items section allows users to capture the capital cost of equipment and other items that are not included in this module. For example, a small number of polymer systems have electronic weight scales to help monitor the amount of raw polymer product available in the delivered container. Since this is relatively uncommon it was not included in the module, however, users who want to include this capability can input the cost into the Other Capital Items section to capture the capital cost for such a system component.

3.2.6 Other Annual Items: The Other Annual Items section allows users to capture the annual cost of equipment and other items that are not included in this module. For example, users could include the annual subscription cost to remotely control the *Polymer Dosing and Diaphragm Pump Skid with Computerized Controls* in order to make adjustments as needed to the mixture of diluted polymer solution and push water in the Other Annual Items section.

3.3 Module Outputs

3.3.1 Sizing Summary: The Sizing Summary section displays important calculated module outputs and is specific to the type of polymer the user selects, which is denoted in the Sizing Summary title block on the right-hand side. For *Dry Polymer* the Sizing Summary includes estimated polymer dose corrected for percent activity, polymer flocculant and made down and dilution (push) water consumption per the operational time, refill frequency and annual quantities of delivered containers, made down polymer pump rates, and day tank capacity. For *Emulsion Polymer*, the Sizing Summary includes estimated polymer dose corrected for percent activity, polymer flocculant and dilution (push) water consumption per the operational time, and refill frequency and annual quantities of delivered containers. For *Pre-Diluted Polymer*, the Sizing Summary includes estimated polymer dose corrected for percent activity, polymer flocculant and pre-diluted polymer solution consumption per the operational time, and refill frequency and annual quantities of delivered containers. The refill frequency provides users with an estimate of how often the polymer product delivered container (e.g., *1,650 lb Super Sack*) will need refilled based on the estimated polymer consumption.

3.3.2 Capital Cost: This section provides the estimated costs for the various user-specified components and the total estimated cost to construct the polymer system. Based on the selected polymer type, the Capital Cost may include make down system (*Dry Polymer*), made down polymer dosing and mixing equipment, *Emulsion Polymer* blending and pump skid, *Pre-Diluted Polymer* equipment, and other capital items specified by the user in the Other Capital Items section. Users can opt to estimate the installation cost by specifying it as a percentage (cost-multiplier) of the Capital Cost or by entering a *User-Specified* cost.

3.3.3 Annual Cost: The Annual Cost section provides an estimate of the cost to operate and maintain the polymer component of the mine drainage treatment system. Users can select to have AMDTreat estimate the annual chemical (polymer) cost or specify an annual polymer cost. Specifying an annual chemical cost is often used when AMDTreat's NPV calculations are being used to estimate water treatment liability. The annual operation and maintenance for the polymer components can either be specified by the user or estimated by assuming it is a percentage of the polymer system Capital Cost. The latter method assumes that more expensive systems are more costly to maintain. The *Electric* cost for the polymer system can either be estimated using the software based on polymer pump power and *Electrical Unit Cost* or specified by the user. The estimated annual cost of water for the polymer system is important to consider especially if the source is a public water supply where consumption charges are based on a *Unit Cost of Water* ($/1,000 gallons), which is a user-specified variable. The user can choose to allow the software to estimate the *Estimated Water Cost* broken down by make down water and push water or the user can specify a known annual cost of water. Any other Annual Cost specified by the user in the Other Annual Items section would also be included.

3.3.4 Net Present Value: The NPV section determines the cost to operate a treatment system component over a specified time period. The NPV calculates the present-day financial investment required to generate the income to pay for future operation and equipment/materials replacement costs. Both **Financial Variables** and **Cost Categories** are required to calculate the NPV.

3.3.4.1 Financial Variables - The *Term of Analysis*, *Inflation Rate*, and *Rate of Return* are three variables used in the NPV calculations. The default values for these terms are shown under the Net Present Value section of each module. Users must access the Net Present Value menu at the top of the main user interface to change the default values as they would apply to all modules used for an entire mine drainage treatment system. While NPV is determined for each AMDTreat module activated by the user, the goal is to determine a total NPV for an entire mine drainage treatment system project (a collection of cost estimates for individual modules creates a treatment system project in AMDTreat). Therefore, a single value for *Term of Analysis*, *Rate of Return*, and *Inflation Rate* is applied to all modules and cannot vary between modules.

- <u>Term of Analysis</u>: The time period used by the NPV calculation to determine the financial investment required to pay for all future costs of the treatment system.

- <u>Inflation Rate</u>: Represents the average price increase of goods and services over time. AMDTreat uses the inflation rate to calculate the future cost of the annual operation and maintenance (O&M) and recapitalization items.

- Rate of Return: Describes the expected profit on an investment.

3.3.4.2 Cost Categories - For each treatment module, AMDTreat provides a list of recommended equipment and materials that require recapitalization. In addition, AMDTreat provides recommendations (default values) for *Life Cycle* and *Replacement Percentage*. Users can click on the default values for *Life Cycle* or *Replacement Percentage* and use the +/- buttons to change the default values. In addition, users can select *Custom Cost* and enter a new cost to represent the current cost of the equipment. Users can add new recapitalization items or deactivate/delete existing items for calculating the NPV.

An example of how the recapitalization variables are used to determine NPV is to consider the following hypothetical scenario. Assume a vertical turbine pump has a *Life Cycle* of 50 years but requires the pump motor to be rebuilt every 20 years. Assume the present-day cost to purchase the motor is $500,000, and the cost to remove, rebuild, and reinstall the pump motor is $20,000. Now assume we want to determine the amount of investment required today (NPV) to generate the income to pay for the future cost of rebuilding the pump motor over a 50-year *Term of Analysis*, which is also equal to the *Life Cycle* of the pump. Assume an *Inflation Rate* of 5.0% and *Rate of Return* of 8.1%. The goal is to place the money in a relatively secure investment vehicle to generate 8.1% annually. The NPV will calculate the size of investment required to generate income for future costs.

There are several ways to model the replacement cost. One way is to replace 4% of the present-day cost of the pump (4% of $500,000 = $20,000) with a *Life Cycle* of every 20 years. If the *Term of Analysis* is 50 years, then the entire pump would not require recapitalization since the *Life Cycle* of the pump is 50 years. However, the motor would require two replacements (50 years / 20 years = 2.5 rounded down to 2).

To determine the NPV to recapitalize rebuilding of the motor, AMDTreat calculates the future cost to rebuild the motor at each *Life Cycle*, 20 and 40 years. The program uses the *Inflation Rate* to inflate the present-day default cost to rebuild the motor in 20 and 40 years from now. While the present-day cost to rebuild the pump motor is $20,000, the future cost to rebuild the motor in 20 years at a 5.0% *Inflation Rate* is $53,065 and $140,799 in 40 years (Equation 2). Assuming an 8.1% *Rate of Return*, the 50-year NPV for the pump is $17,422. In other words, an initial investment of $17,422 is needed at an annual *Rate of Return* of 8.1% to generate the investment income required for the two motor rebuilds over the 50-year *Life Cycle* of the pump.

$$\textit{Cost to rebuild pump motor in 20 years} = \textit{Present Day Cost} \times (100\% + \textit{Inflation Rate})^{20} = \$20{,}000 \times (100\% + 5\%)^{20} = \$53{,}065 \quad \textbf{(2)}$$

- Annual Operation and Maintenance Cost: By default, AMDTreat transcribes the annual O&M cost from the Annual Cost section to the Net Present Value section. The program assumes the module is being used to estimate the Annual Cost for a treatment system component, so it automatically transcribes the Annual Cost to the NPV section. If this is not the case or the user wants to use some other Annual Cost, the *Use Custom* box can be selected to allow the user input of a different Annual Cost to utilize in the NPV calculation.

- Recapitalization Cost: Certain treatment system components, especially mechanical and water conveyance equipment, require periodic replacement. The recapitalization cost of an item is an estimate of the amount of money required to pay for future replacement costs for the item. In addition to the Financial Variables described above, three additional values are required to calculate the NPV of recapitalization costs, the Present-Day Equipment Cost, the *Life Cycle*, and the *Replacement Percentage*.

- Default Cost: This represents the current cost to purchase the equipment or material.

- Life Cycle: The time frame between equipment or material replacement is termed as its *Life Cycle*. Some equipment manufacturers provide recommended *Life Cycles* for their equipment to provide consumers with an estimate of how long the equipment is expected to be operational. Some *Life Cycles*, such as those used for treatment media (limestone), are based on best professional judgement. Some operators prefer to periodically purchase and replace equipment before failure to preserve the continuity of operations, while others wait until failure to replace an item.

- Replacement Percentage: The *Replacement Percentage* is an adjustment factor to the default cost to accommodate situations where the entire piece of equipment or all the material does not require recapitalization. For example, a passive treatment component may be designed to contain enough limestone to neutralize the acidity load for 20 years, however, the accumulation of metal hydroxide precipitates within the void space of the limestone layer may require that 25% of the limestone be replaced every seven years to prevent hydraulic failure such as plugging or short-circuiting. For this scenario, the initial cost of the limestone making up the limestone layer is discounted by 75% and assigned a *Life Cycle* of seven years to determine the amount of money required to cover the cost of replacing 25% of the limestone layer every seven years over the *Term of Analysis*.

3.3.4.3 Rationale for Recapitalization Recommendations - Recapitalization recommendations are based on professional experience of the AMDTreat Team and may not apply to all situations. Users are encouraged to customize the recapitalization assumptions to their treatment scenario. AMDTreat Team members are located in Pennsylvania and West Virginia and have collective experience in design, funding, and/or operation/maintenance for over 100 passive and active treatment systems. Users may have different experience and opinions than those listed.

By default, AMDTreat includes a list of between three and five recapitalization items based on the polymer type selected in the Polymer module. However, the items the user selects to include in the module will also determine which items are included in the NPV section. Users can delete or modify any of the default recapitalization items by either deselecting the item or by setting the *Replacement Percentage* to zero. If the item is deselected, the *Total Cost* for the item will still be shown but the cost will be subtracted from the NPV, shown in the NPV heading. For example, the default value for the *Life Cycle* of a Diaphragm Pump (*Dry Polymer*) is seven years due to basic wear and tear. However, users may opt to increase the *Life Cycle* if the pump will be used intermittently as determined by the user specified operational time. Users are free to fully customize the replacement items, including adding new items or deleting default items.

Dry Polymer:

Manual Dry Polymer Make Down System: The manual *Dry Polymer* make down system default *Life Cycle* is 20 years with 100% replacement. This will depend on the day tank type and material (HDPE). The user can adjust these values accordingly.

Polymer Low RPM Mixer Motor Rebuild: The low RPM electric mix motor component of the manual *Dry Polymer* make down system requires being rebuilt with a default *Life Cycle* of seven years. The *Life Cycle* may be adjusted based on the quality of the motor.

Diaphragm Pumps: As part of the *Manual Dry Polymer Equipment*, the diaphragm pumps that convey the made down polymer from the day tank to mix with the dilution push water have a *Life Cycle* of seven years before the equipment requires replacement. The *Life Cycle* may be adjusted based on the quality and usage of the pumps.

Automatic Dry Polymer Make Down System: The automatic *Dry Polymer* make down system default *Life Cycle* is 30 years with 100% replacement. This will depend on the day tank type and material (SS). The user can adjust these values accordingly.

Polymer Dosing and Pump Skid: The default *Life Cycle* is 30 years for the polymer dosing and diaphragm pump skid unit with computerized controls at 100% replacement. The user can adjust these values accordingly.

Emulsion Polymer:

Emulsion Polymer Blending Unit: The default *Life Cycle* is 30 years for the *Blending Skid with Progressive Cavity Pump and Computerized Controls* at 100% replacement. The user can adjust these values accordingly.

Pre-Diluted Polymer:

Diaphragm Dosing Pump: The default *Life Cycle* for the *Diaphragm Dosing Pumps* that convey the *Pre-Diluted Polymer* from the tote to the application point is seven years at 100% replacement. The user can adjust these values accordingly.

Inline Stainless-Steel Static Mixers with Removable Fins: The default Life Cycle for the *Inline SS Static Mixers with Removable Fins* is 25 years at 100% replacement. The user can adjust these values accordingly.

3.4 Assumptions of Design Sizing and Costs

AMDTreat is a cost estimation model that uses assumptions to provide treatment sizing and both capital and annual cost estimates. While there are many assumptions in the program, the assumptions that follow are important for the Polymer module.

1. Polymer functions by allowing charged suspended particles to floc together, bonding to the oppositely charged polymer surface, forming larger particles that will settle out of the water. There are many different types and manufacturers of polymer flocculant products. Consequently, it is important to conduct the appropriate jar tests or bench scale testing using the water to be treated with any perspective polymer product to confirm the effectiveness at settling the precipitated solids, desired solution strength of polymer, and the dosage that works the best. The AMDTreat development team has designed the polymer module with a primary focus toward treatment applications in which the most common mine drainage constituents (Fe, Mn and Al) are targeted for removal within a typical treatment pH range of 6.0 to 9.0. Users should be aware that in other instances, for example where a very high treatment pH is required or where additional mine drainage constituents such as trace metals are targeted, significant differences in polymer type, application rate and cost may exist.
2. In both passive and active treatment applications polishing wetlands have been proven to be an effective strategy for removal and retention of low concentrations of suspended solids. In certain treatment applications polishing wetlands may eliminate the need for, or significantly reduce the operational costs of, a polymer system.
3. Users should be aware that adequate and efficient mixing of the polymer solution with the treated water is critical for achieving optimal performance at minimal cost. While not specifically included within the module, the user should be aware that many mine drainage treatment facilities employ additional mixing strategies such as the use of multiple polymer dose points and or slow mix tanks or compartments within the treatment train in order to optimize polymer mine water mixing opportunities.

4.0 References

5.0 Figures

Figure 1: Blending skid with progressive cavity pump and computerized controls for emulsion polymer used at a site for flocculating iron hydroxide sludge and dewatering in Geotubes.

Figure 2. Emulsion polymer totes (275-gallon) for use at a mine drainage treatment facility in Pennsylvania.

Figure 3. Super sack (1,650 lbs) feeder option as part of an automatic dry polymer make down system that automatically dispenses dry polymer product to produce a made down solution.

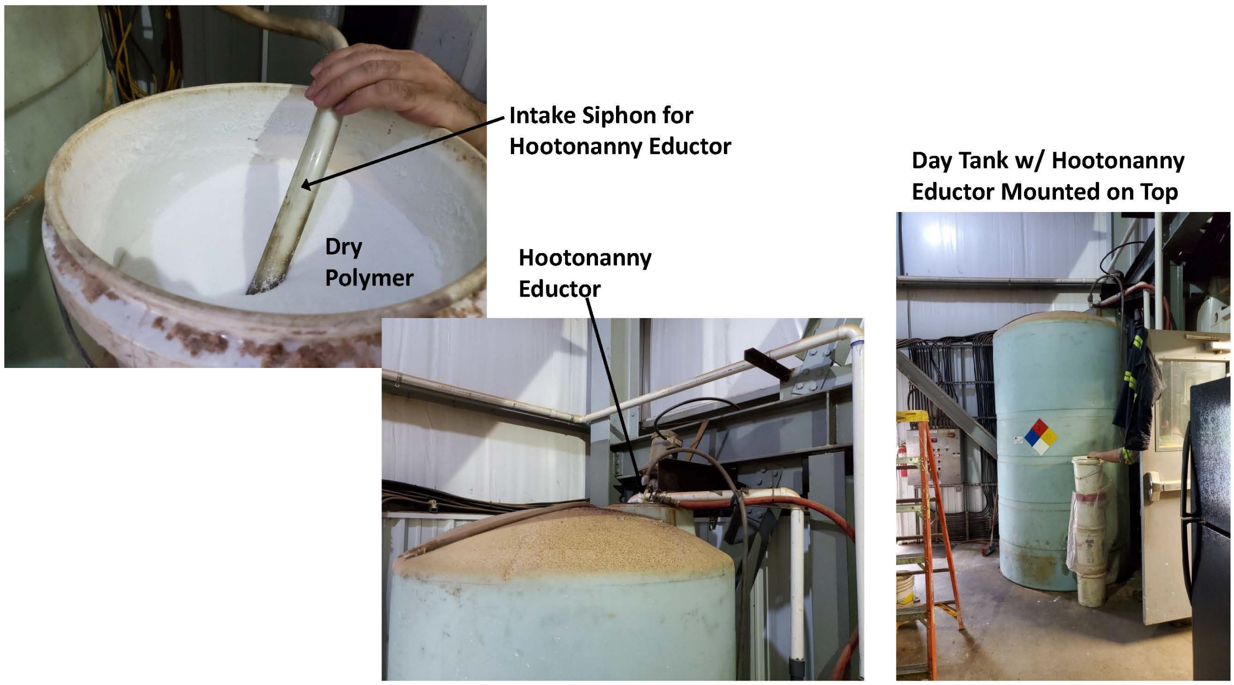

Figure 4. Manual make down of dry polymer into day tank using Hootonanny Eductor system on top of tank at a mine drainage treatment facility.

Figure 5. Stainless steel blending/aging tank for made down dry polymer solution with mixers mounted over the tanks.

Figure 6. Pumps and inline static mixers for mixing the made down polymer solution with push (dilution) water prior to addition to the mine drainage source.

Figure 7. Photo of two pumps as part of the dosing skid component of a dry polymer automatic system.

Figure 8. Application point of polymer into the mine drainage at a treatment facility.