Installation Guidelines

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Notice: This document is intended for use as a general guideline for the installation of CETCO's Akwaseal Pond Liner. The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information. Installation guidelines are subject to periodic changes. Please consult our website @ www.akwaseal.com for the most recent version.

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A successful pond lining project requires both a good design and a good installation. Fortunately, the forgiving nature of Akwaseal and the active swelling and sealing properties of bentonite make it relatively easy to successfully install the liner.

1. Equipment

CETCO's Akwaseal product is heavier than typical synthetic pond liners. The installer must have the proper equipment available to offload, transport, and deploy the liner. Using improper or inadequately sized equipment can cause delays, safety hazards, and damage to the liner material. Therefore, detailed equipment requirements are provided to ensure these problems are avoided.

The liner is delivered in rolls weighing 1,500 lbs (680 kg). A core pipe is required to support the rolls. Lifting and handling equipment may be obtained from CETCO; otherwise, the core pipe should meet he properties listed in Table 1. The core pipe must not deflect more than 3 inches (75 mm) as measured from end to midpoint when a full roll is lifted.

Table 1. Core pipe requirements for safely handling Akwaseal.

Product	Roll Size, L x Diameter Ft. (m) x in. (mm)	Typical Roll Wt., lbs. (kg)	Core Pipe Length x Diameter, ft. x. in. (m x mm)	Minimum Core Pipe Strength
Akwaseal	16' x 22" (4.9 x 559)	1,500 (680)	20 x 3.5 O.D. (6.1 x 88)	160

Lifting chains or appropriately rated straps should be used in combination with a spreader bar made from an I-beam as shown in Figure 1. The spreader bar ensures that lifting chains or straps do not chafe against the ends of the roll, allowing it to rotate freely during installation. Appropriately rated straps, spreader bar and core pipe kits are available through CETCO.

Figure 1. Deployment of the liner using core pipe and spreader bar.

A front end-loader, backhoe, excavator, or other equipment can be utilized with the spreader bar and core pipe. Alternatively, a forklift with a "stinger" attachment may be used for on-site handling and, in certain cases, installation. A forklift without a stinger attachment must not be used to lift or handle the rolls. A stinger attachment as shown in Figure 2 can be specially fabricated to fit various forklift models.

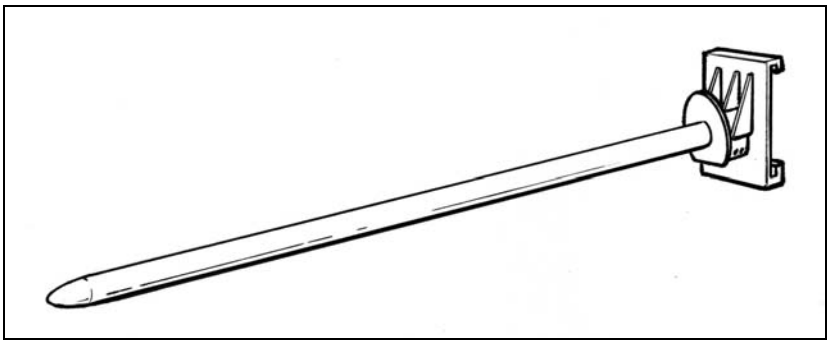


Figure 2. Typical stinger used for handling liner material. The dimensions of the mounting plate are specific to the forklift used.

Additional equipment needed for installation of Akwaseal includes:

- Utility knife and spare blades (for cutting the liner).
- Granular bentonite (for seams and for sealing around structures and details).
- Waterproof tarpaulins (for temporary cover on installed material as well as for stockpiled rolls).
- Flat-bladed vise grips (for gripping and positioning the liner panels by hand).

2. Shipping, Unloading and Storage

2.1. Shipping

To account for waste and overlaps, the area of liner ordered should exceed the lined area by approximately 15% (rounded up to the nearest roll quantity) depending on the relative complexity of the site. Two bags of accessory bentonite per roll of liner ordered is generally sufficient for overlaps, details, and penetrations. Upon receipt of the liner, all lot and roll numbers should be recorded and compared to the packing list. Each roll of liner should also be visually inspected during unloading to determine if any packaging has been damaged. Damage, whether obvious or suspected, should be recorded and marked. Major damage suspected to have occurred during transit should be reported immediately to the carrier and to CETCO. The nature of the damage should also be indicated on the bill of lading with the specific lot and roll numbers.

2.2. Unloading

The party directly responsible for unloading the liner should refer to this manual prior to shipment to ensure that they have the proper unloading and handling equipment. In most cases, the liner is delivered on flatbed trucks. To unload the rolls from the flatbed using a core pipe and spreader bar, first insert the core pipe through the core tube. Secure the lifting chains or straps to each end of the core pipe and to the spreader bar mounted on the lifting equipment. Lift the roll straight up and make sure its weight is evenly distributed so that it does not tilt or sway when lifted. NEVER PUSH ROLLS OFF THE SIDE OF THE FLATBED TRUCK.

The liner can also be delivered with two 2” x 12’ (50 mm x 3.65 m) Type V polyester endless slings on each roll. Before lifting, check the position of the slings. Each sling should be tied off

in the choke position approximately 1/3 the distance from the end of the roll. Lift the roll straight up so that it does not tilt or sway when lifted.

In many cases, rolls will be stacked in three pyramids on flatbed trucks. If slings are not used, unloading can be accomplished with a stinger bar and extendible boom fork lift such as a Caterpillar TH83 or equivalent with 8,000 lbs (45 kN) lifting capacity. Spreader bars will not work in this situation because of the limited space between the ends of the rolls. To unload liner rolls oriented in this way, guide the stinger bar as far as possible through the core tube before lifting the roll from the truck.

Figure 3. Proper storage of Akwaseal on site.

2.3. Storage

Rolls should be stored at the job site away from high-traffic areas but sufficiently close to the active work area to minimize handling. The designated storage area should be flat, dry and stable. Moisture protection of the liner is provided by its existing packaging; however, an additional tarpaulin or plastic sheet should be placed over the rolls for additional protection of the liner (Figure 3). Rolls can be stored indefinitely if these procedures are implemented. Rolls should be stored with the directional arrows oriented in the same direction to save materials handling time during installation (Figure 5).

The material should be stacked in a manner that prevents them from sliding or rolling. This can be accomplished by frequent chocking of the bottom layer of rolls. Rolls should be stacked no higher than the height at which they can be safely handled by laborers (typically no higher than four layers).

3. Subgrade Preparation

The subgrade is the foundation for the liner, and its importance cannot be overemphasized. Proper subgrade preparation will greatly improve the chances for a successful outcome. Conversely, deploying liner over a poor foundation can easily lead to trouble. Every attempt should be made to adhere to the following subgrade preparation procedures.

Subgrade surfaces consisting of rocky soils or gravel may not be acceptable due to their puncture potential. The finished surface should be firm and unyielding, without abrupt elevation changes, voids, cracks, ice, or standing water. Additionally, the subgrade surface must be smooth and free of vegetation, sharp-edged rocks, stones, sticks, construction debris, and other foreign matter that could contact the liner. The subgrade should be rolled with a smooth-drum compactor (Figure 4)

to remove any wheel ruts, footprints, or other abrupt grade changes. All protrusions extending more than 0.5 inch (12 mm) from the subgrade surface shall be manually removed, crushed, or pushed into and flush with the surface. The liner may be installed on a frozen subgrade, but the subgrade soil in the unfrozen state should meet the above requirements.

Figure 4. Use of a smooth-drum compactor for subgrade preparation.

4. Liner Deployment

4.1 Basic Placement Guidelines

Rolls should be taken to the work area of the site in their original packaging. The orientation of the liner (which side faces up) is important. Unless otherwise recommended, Akwaseal is installed with the GEOTEXTILE SIDE FACING UP and the GEOMEMBRANE SIDE FACING DOWN (the product will "naturally" unroll in this fashion). The arrow sticker on the plastic sleeve indicates the direction in which the roll will naturally unwind when placed on the ground (Figure 5). Prior to deployment, the packaging should be carefully removed without damaging the liner.

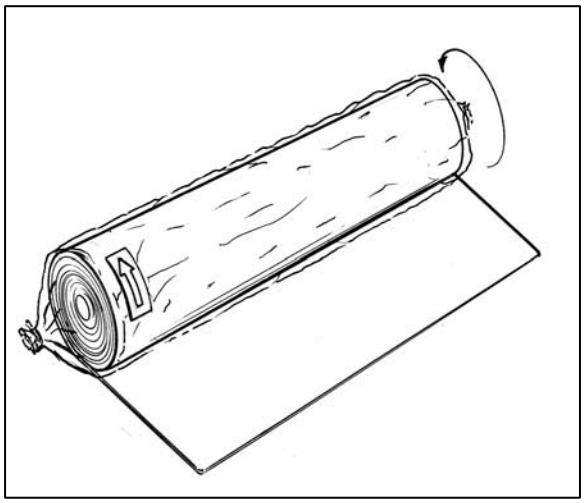


Figure 5. The direction of unrolling is shown by the arrow on the plastic sleeve.

Equipment which could damage the liner should not be allowed to travel directly on it. Acceptable installation, therefore, may be accomplished such that the liner is unrolled in front of

backwards-moving equipment (Figure 6). If the installation equipment causes rutting of the subgrade, the subgrade must be restored to its originally accepted condition before placement continues.

Figure 6. Typical means of liner deployment, using a backwards-moving front-end loader.

If sufficient access is available, the liner may be deployed by suspending the roll at the top of the slope and by pulling the material off the roll and down the slope (Figure 7). Rolls should never be released on the slope and allowed to unroll freely by gravity.

Figure 7. Manual deployment down a slope. It is generally not possible to pull the liner upslope.

Care must be taken to minimize the extent to which the liner is dragged across the subgrade in order to avoid damage to its membrane surface. In cases where there is no other choice except to drag the liner, a thin (20 mil or 0.5 mm) plastic membrane or "slip sheet" should be used as a

temporary subgrade covering to reduce friction damage during placement. The slip sheet should be removed after the liner is deployed.

The liner should be placed so that seams are parallel to the direction of the slope. End-of-roll seams should be located at least 3 ft (1m) from the toe and/or crest of all slopes steeper than 4H: 1V. End-of-roll overlapped seams on slopes should be used only if the liner is not expected to be in tension. All panels should lie flat on the underlying surface, with no wrinkles or folds, especially at the exposed edges of the panels.

The liner should not be installed in standing water or during rainy weather. Only as much material should be deployed as can be covered by the end of the working day with soil or a temporary waterproof tarpaulin. The liner should not be left uncovered overnight. If it is hydrated before cover is applied, the liner may become damaged.

4.2 Placement Strategies

Placement of the liner for most ponds should begin on the side slopes. The main reason for this recommendation is to prevent rainfall from eroding and scouring the prepared subgrade. Another benefit is that the unlined bottom area can be used to stockpile and push cover soil onto the lined slopes. A roadway or ramp area should be left unlined to allow ongoing vehicle access into and out of the pond. Depending on the size of the pond, separate inbound and outbound access ramps may be used. The liner should be deployed on the entire slope extending into the bottom area by approximately 6 feet (2 m).

For corners, the liner should be placed in a "herringbone" pattern as shown in Figure 8. It important for the liner to remain perpendicular to the slope. Panels from both sides of the corner will converge at the corner line. The triangular end of the overlapping panel should be cut along the corner line, while the end of the underlying panel extends beyond the corner line as shown in Figure 8.

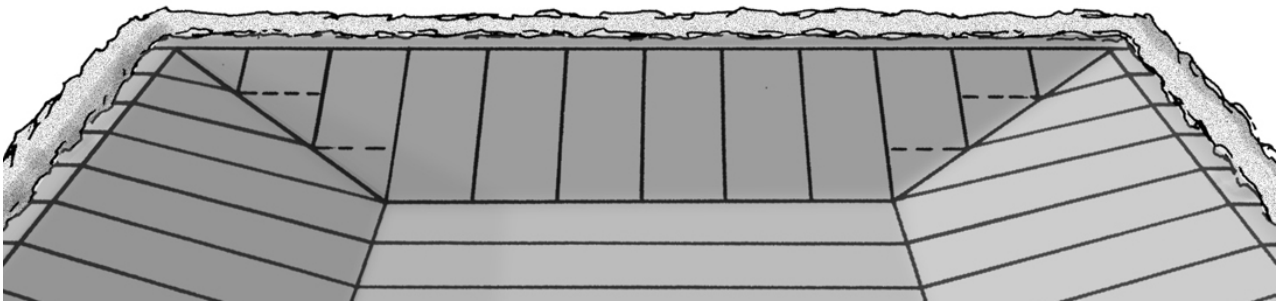


Figure 8. In corners, the liner should be maintained perpendicular to the slope and trimmed into a herringbone pattern.

After the slopes have been lined, the bottom area should be lined starting with the location farthest from the access ramp(s). Cover soils may be staged at other locations in the bottom area if space is available. The liner materials placed on the floor of the pond should be lapped under the "tails" of the liner previously deployed on the slopes, creating a shingling effect to convey rainfall off the liner system. Liner placement on the bottom areas should continue back toward the access road/ramp system, leaving it to be lined last. Covering of the slope and bottom areas should be completed before the ramp is lined.

5. Anchorage

The liner requires anchorage at the top of the side slopes. Anchorage is most commonly accomplished using an anchor trench. The front edge of the trench should be rounded to eliminate any sharp corners that could cause excessive stress on the liner. Loose soil should be removed or compacted into the floor of the trench.

Soil backfill should be placed in the trench to provide resistance against pullout. The backfill material must be compacted using a hand tamper or a small walk-behind compactor. The size and shape of the trench should be in accordance with Figure 9.

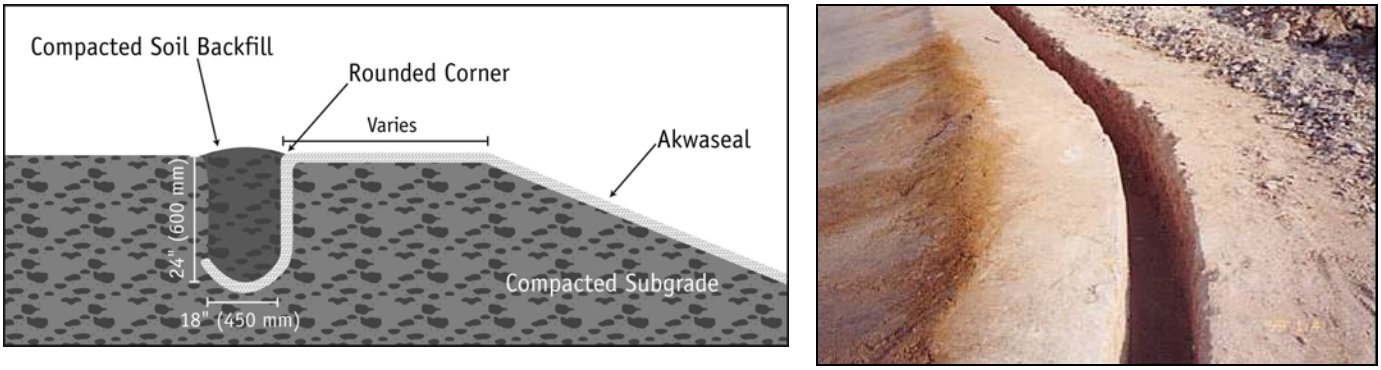


Figure 9. Typical anchor trench at top of slope.

The liner should be placed in the anchor trench such that it covers the entire trench floor but does not extend up the rear trench wall (to prevent water retention in the trench). For gentle slopes of 4H:1V or less, sufficient anchorage may alternately be obtained by extending the end of the liner roll back from the crest of the slope, and placing cover soil. The length of this "runout" anchor is project-specific but is usually sufficient at 5 feet (1.5 m).

6. Seaming

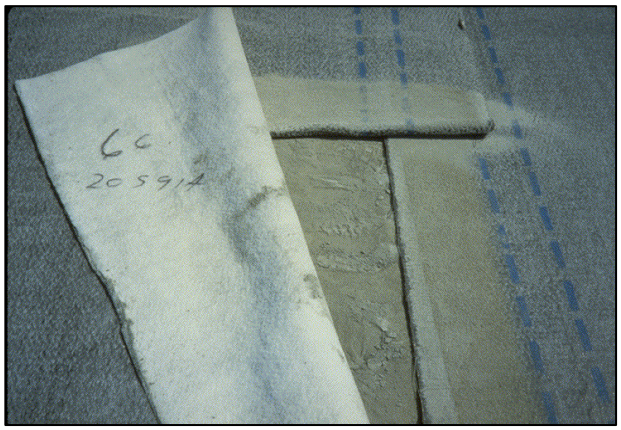


Figure 10. Seaming detail.

Seams are constructed by overlapping their adjacent edges. Each longitudinal edge of the rolls is marked at the factory with a "lap line" at 12 inches (300 mm) from the edge of the panel and a "match line" at 15 inches (375 mm) from the edge of the panel. The objective in seaming these edges is to place the overlying panel such that the lap line is completely covered (ensuring that a minimum required overlap is achieved) while allowing the match line to remain visible (ensuring that liner material is not wasted).

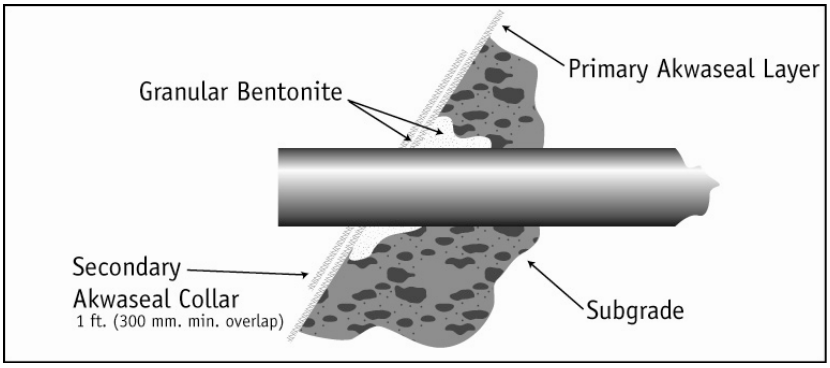
Greater panel overlaps may be required in high-head applications or in yielding subgrade soils.

Before completing the seam, care should be taken to ensure that the overlap is not contaminated with loose soil or other debris. After the panels have been placed, the overlap should then be turned back so that supplemental bentonite (provided by CETCO) can be distributed within the overlap zone at a rate of one quarter pound per linear foot (0.4 kg/m). The location of this "bead" or "fillet" of bentonite should be at 6 inches (150 mm) inward from the edge of the bottom panel (Figure 10).

End-of-panel overlapped seams should be similarly constructed, except the overlap dimension is increased to 24 inches (600 mm). End-of-panel seams on slopes are permissible, but only if the slope steepness is 4H:1V or less. Overlaps should be shingled such that water flows across, and not into, the overlap zone. This is especially important in any application where water will be actively flowing, such as streams and canals.

7. Sealing Around Penetrations and Structures

Cutting the liner should be performed using a sharp utility knife. Frequent blade changes are recommended to avoid irregular tearing of the geotextile components of the liner during the cutting process. The liner should be sealed around penetrations and structures embedded in the subgrade in accordance with Figures 11 and 12. Granular bentonite shall be used liberally (approx. 2 lb/lin ft or 3 kg/m) to seal the liner to these structures.



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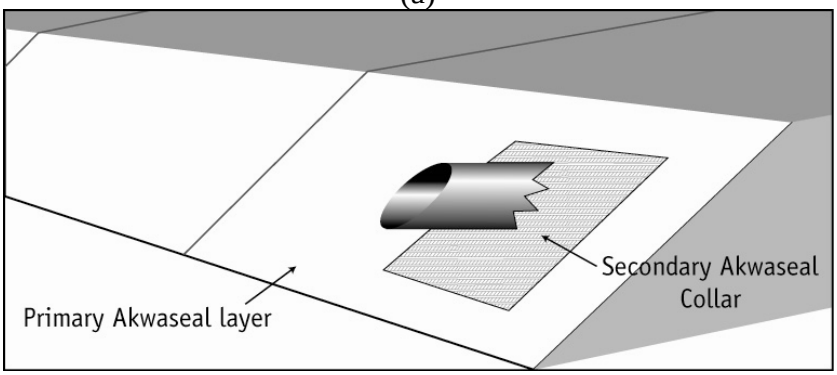


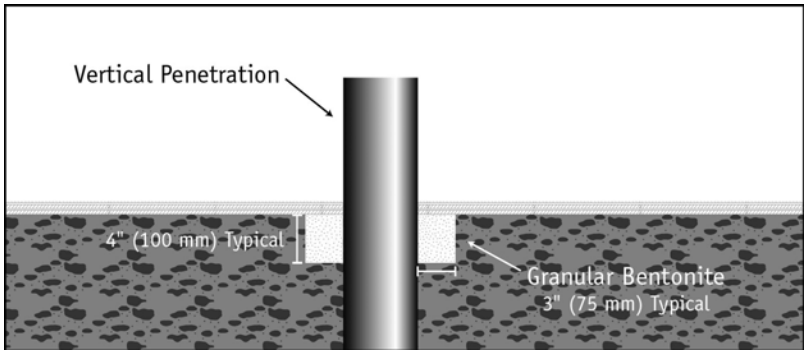
(b)

Figure 11. Horizontal pipe penetrations are potential leakage zones and must be detailed properly. These diagrams show the proper installation procedures.

When the liner is placed over a horizontal pipe penetration, a notch should be excavated into the subgrade around the penetration (Figure 11a). The notch should then be backfilled with granular bentonite. A secondary liner collar should be placed around the penetration as shown in Figure 11b. It is helpful to first trace an outline of the penetration on the liner and then cut a starburst

pattern in the collar to improve its fit around the penetration. Granular bentonite should be applied between the primary Akwaseal layer and the secondary liner collar.

As discussed previously, vertical penetrations are not generally recommended because of their tendency to induce leak problems. However, if a vertical penetration is needed, it should be prepared by notching into the subgrade as shown in Figure 12a. The penetration can be completed with two separate pieces of liner as shown in Figure 12b. Alternatively, a secondary collar can be placed as shown in Figure 11.



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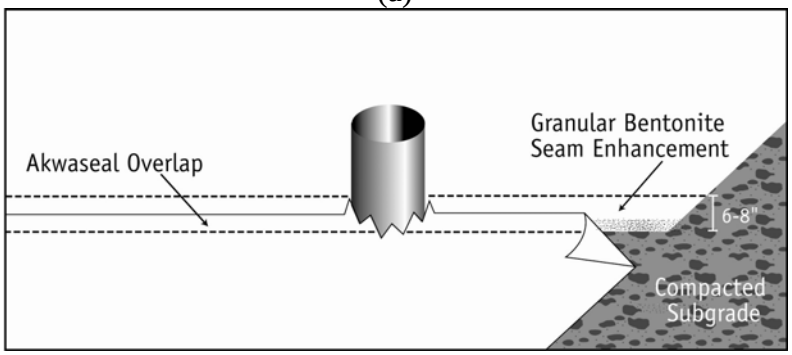

(b)

Figure 12. Detailing around a vertical penetration.

When the liner is terminated at a structure or wall that is embedded into the subgrade on the floor of the containment area, the subgrade should be notched. The notch is filled with granular bentonite, and the liner should be placed over the notch and up against the structure (Figure 13). The connection to the structure can be the accomplished by placement of soil or stone backfill in this area. When structures or walls are on or at the top of a slope, additional detailing may be required as shown in Figure 13.

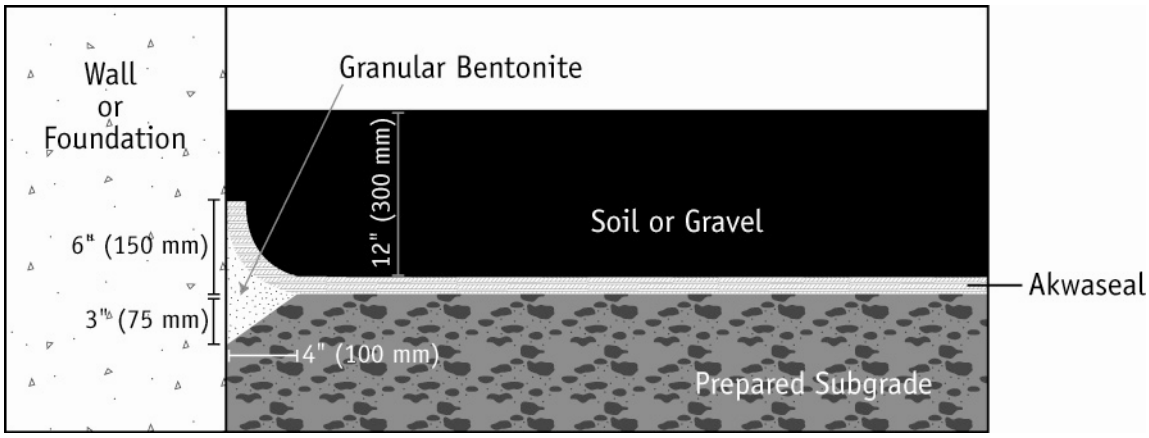

Figure 13. Termination of the liner at a structure embedded in the subgrade.

8. Damage Repair

If the liner is damaged (torn, punctured, etc.) during installation, it may be possible to repair it by placing a patch to fit over the damaged area (Figure 14). The patch should be cut to size such that a minimum overlap of 12 inches (300 mm) is achieved around all parts of the damaged area. Granular bentonite should be applied around the damaged area prior to placement of the patch. It may be necessary to use an adhesive such as wood glue to affix the patch in place so that it is not displaced during cover placement. Smaller patches also may be tucked under the damaged area to prevent patch movement.

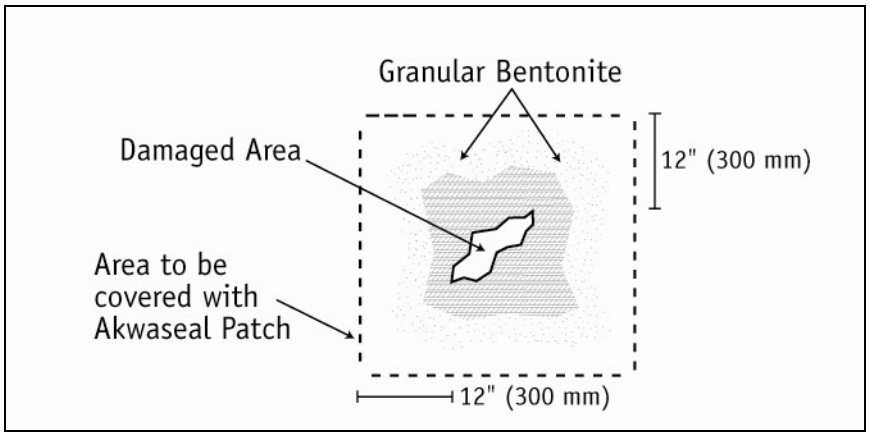

Figure 14. Damage repair through patching.

9. Covering The Liner

All pond projects require that the liner be covered with a layer of soil and/or stone. The cover serves several vital functions in the pond system. Specifically, it:

- *Confines* the liner and prevents free swell of the bentonite, allowing the bentonite layer to function effectively as a water barrier and to prevent flow within the overlapped seams.

- *Protects* the liner from damage by humans, animals, plants. Also protects against damage by ultraviolet light, erosional forces, and extreme weather conditions.

- *Beautifies* the pond by giving the liner system a natural appearance.

In general, the deeper or thicker the cover layer, the better the long-term hydraulic performance of the liner system. But it is seldom cost-effective or practical to install thick cover soil layers. A more practical question is, how much cover is necessary to provide adequate containment?

9.1 Cover Thickness

The minimum recommended thickness of cover soil on the liner is 12 inches or 300 mm. This recommendation is based on the following:

1. The confining stress provided by 300 mm of soil is adequate to keep the overlaps closed and to prevent lateral seam leakage.

2. A soil layer of 300 mm is sufficient to distribute loads from typical earthmoving equipment which would otherwise damage the liner.

3. It is very difficult to install thinner layers of soil on a liner without damaging it.

Some projects may require more cover material when disruptive forces such as scouring or wave action are considered. In these projects, up to 2 feet (600 mm) of cover may be necessary. Fine-grained soil would be placed directly on Akwaseal, followed by a cushioning geotextile and a layer of angular stone.

9.2 Cover Placement

Equipment operators should understand that the liner must be protected. They must not allow soil or stone to fall a long distance when a loader bucket is emptied. They must not drive directly on the liner unless it is proven that the vehicle in question can do so without damaging the liner. As a general rule, tracked equipment should not be permitted to come in direct contact with the liner. Rubber-tired equipment is usually acceptable, assuming a firm foundation has been established.

Figure 15. Cover soils should be pushed from the bottom of the slope up, not from the top down.

Cover placement activities typically involve one piece of equipment dumping the cover in a pile near the site, and one piece of equipment spreading the cover. These activities should be coordinated such that the placement effort does not outpace the covering effort. At the end of the

working day, the exposed liner should be completely covered with the exception of a leading edge where the next day's liner installation will overlap. This will ensure that the liner will not be accidentally damaged and displaced by equipment or other forces. The leading edge of the liner should be protected from damage by rolling it under itself. If the leading edge is at the base of a slope to be covered, plywood sheets will afford protection while allowing access by cover placement equipment.

Cover for the liner should be placed at the bottom of the excavation so that it can be pushed upslope (Figure 15). Although it may be more convenient to dump cover soil at the top of the pond and push it downslope, enormous tensile stresses can occur on the liner from the thick cover layer resting (without a toe buttress) on the slope and from the weight of the equipment pushing on it. By staging liner deployment such that one or more access ramps are left unlined until the end of the project (Figure 16), the cover soil can be efficiently delivered to the bottom of the pond without damaging the liner system or causing undue expense. It is important to include this provision in the project specifications so that contractors can plan for this covering methodology.

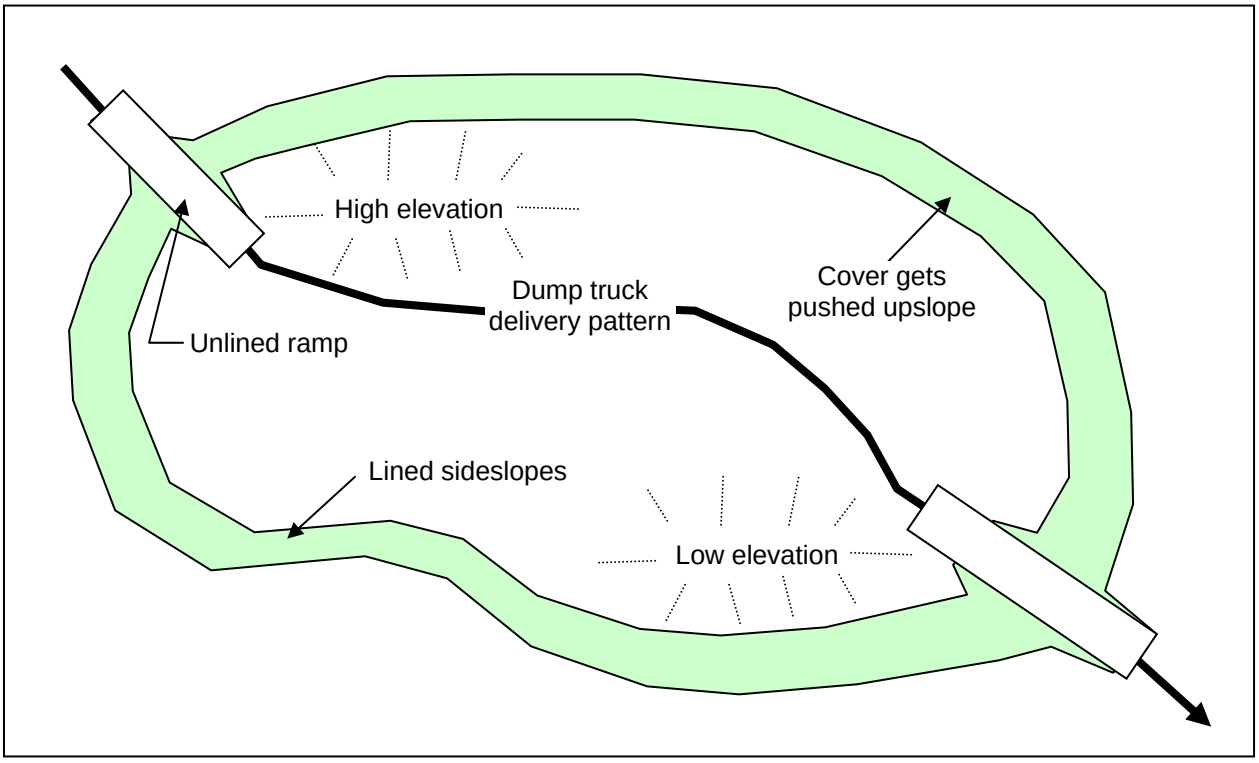

Figure 16. Suggested operations flow for movement of cover materials.

9.3 Cover Type

The cover on the liner must not contain large and/or angular stones capable of damaging the liner. Cover soils should have a particle size ranging from fine to < 1 inch (25 mm) in diameter, unless a cushioning geotextile is placed on the liner. Common sense should play a primary role in assessing the suitability of the cover. If there are many sharp stones visible in the proposed cover soil, then it probably is not an appropriate material. Stone may be used as cover only if it is a washed gravel or similarly graded materials that does not possess sharp edges.

The cover should also be compactable. Non-cohesive soil (pure sand) and fat clay may not be suitable if the soil cannot be placed and trafficked by equipment without rutting. Therefore, dry soils should be wetted to improve workability and compaction, and especially wet soils may require additional time to dry out before being placed over the GCL.

10. Cover Soil/Stone Stability

The liquid containment system must be designed to provide long-term performance under all expected operating conditions. Fundamental to this objective is the integrity and stability of the cover soil. Akwaseal needs the confinement provided by cover soil so that the overlaps will self-seal and the bentonite is not permitted to reach free-swell conditions. Failure to provide and maintain these conditions could result in failure of the liner system. In other words, when confinement is provided through an initial application of cover, that cover must not be compromised.

10.1 Erosion Prevention

Erosion occurs as a result of a driving force of rapidly moving water which overcomes the gravitational and cohesive resisting forces of a cover soil. In pond applications, rapidly moving water can be caused by drainage of a sloped area or by shoreline wave impact. Erosion can be prevented in two ways. The first and most cost-effective preventative strategy is to utilize sensible design practices:

- *Use moderate slopes.* Water velocity can be reduced if grades are as gentle as possible.
- *Use erosion-control materials.* Mulch and hay bales represent the crudest form of erosion control products, but there are a variety of cost-effective natural fiber and synthetic products that offer superior performance over a longer term.
- *Limit slope lengths.* A long slope will allow water velocity to reach critical levels. Shorter slopes and mid-slope diversion swales will alleviate this problem.
- *Use energy diffusion devices.* Inflow and outflow areas within a pond may be subjected to scouring by rapidly moving water. Water velocities can be reduced in these areas by erecting baffles, deploying large stones, or installing other energy-diffusion structures.

10.2 Alternative Cover Materials

Interior sideslopes of ponds may be exposed to wave action, animal contact, fluctuating water levels, and equipment loadings such as mowers or other vehicles. All of these elements can contribute to erosion, and for this reason, alternative cover materials may be required. The use of concrete, rip rap, or protective geotextiles are all valid means by which slopes may be preserved.

11. Weather

Akwaseal is rugged and durable product than can withstand wet conditions during installation. Provided that the subgrade still meets the properties described in Section 3, the liner may be installed in wet and rainy (or snowy) weather.

The bentonite component of Akwaseal will absorb water in wet conditions. As a result, the liner becomes heavier and more difficult to move. It also becomes softer and more susceptible to damage by installation equipment or by stones in the cover soil. For these reasons, extra care should be taken when the product is installed in wet weather.

Akwaseal is not affected by warm or cold temperatures and there are no restrictions or limitations relating to ambient temperatures, again provided that the subgrade can be properly prepared.

Wind uplift during installation is possible, although rare, with Akwaseal. Very high winds may be able to displace the liner, and so some form of ballast should be used if these conditions are present. Sandbags are commonly used for this purpose. Due to the self-weight of Akwaseal, wind uplift is not encountered frequently.

12. Construction Quality Assurance (CQA)

Construction Quality Assurance refers to a set of procedures performed during the project to ensure that the liner is placed and covered in accordance with the instructions provided herein. In most pond projects, this added level of oversight may not be necessary or desirable. However, some CQA concepts are useful to employ even in the absence of a dedicated CQA plan.

The most important CQA procedures are those which can prevent damage to the liner. Prior to installation, an the subgrade should be inspected for soft spots, protrusions, and uneven surfaces (such as ruts). These areas should be repaired before the liner is deployed. Prior to covering, the liner itself should also be inspected to ensure that it has not been damaged; the overlaps are adequate, and that the details and penetrations have been properly constructed. Finally, the covering process should be monitored to ensure that the liner is not damaged by equipment or rocks in the cover soil. Periodic thickness measurements should also be taken. If CQA oversight functions are performed as described above, there is a far greater chance that problems will be prevented. The owner of the pond should make sure that a record of CQA activities and inspections is created as part of the contract documents.