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GRI White Paper #43

GMA's Techline and Its 7th Set of Five-Hundred Q & A's

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by
Team GSI
Geosynthetic Institute

Introduction

The Geosynthetic Materials Association's (GMA's) Techline was initiated on September 1, 2004 as being a free worldwide computer service to answer questions involving the many aspects of geosynthetic materials. From the outset, there were no constraints placed on the questioner or their questions. GMA contracted with the Geosynthetic Institute (GSI) for answers, and, here again, there were absolutely no constraints placed on the answers that GSI provided. For the past four years there has been no compensation from GMA and this activity is currently provided by GSI for the benefit of the entire industry. The answers have been addressed to the best of our ability and have been provided generally by Bob Koerner with notable assists by George Koerner (usually laboratory or field related) and Grace Hsuan (usually polymer related). Jamie Koerner assembled the data and curves provided in the periodic summary reports, and Marilyn Ashley provided general information and report preparation…hence "Team GSI"!

Other aspects regarding the answers provided are as follows:

- An attempt has been made to provide *generic answers* to the various questions posed.
- When a specific product was mentioned for an opinion, or specific products mentioned for comparison purposes, our answer was often referred back to the specific manufacturer(s).
- The difficulty level of the questions varied considerably. The easiest questions (ranked as a "5"), where a one sentence answer was sufficient or a particular paper requested, were dealt with quickly. The most difficult questions (ranked as "1") required considerable investigation on our part, sometimes even original research. The latter was obviously not provided but some guidance was offered. These eighteen most difficult questions and answers are provided in the Appendix.
- The large majority of questions ranged between the two extremes of easiest and most difficult.
- Questions other than geosynthetic materials, e.g., soils, rock, steel reinforcement, etc., were not considered and although they were sometimes answered, they are not included in the tabulated results.
- Answers to the questions were generally provided within two days, and often on the same day.
- In addition to monitoring the activity level, specific details are provided in this White Paper which compares all seven sets of 500 Q & A's to one another for a total number of 3500 Q & A's addressed over the past 15 years. This averages to 19.5 per month for the entire duration of the program. Specifically, we assessed this latest set of 500 Q & A's exactly as we have done each of the previous six sets, so that the most recent data can be critiqued as well as compared to the entire seven sets of data. In so doing, the following were specific categories:

- Location (by continent) of the questioners
- Occupation of the questioners
- Type of geosynthetic involved in the questions
- Application category of the questions
- Details on the unique question of "lifetime/durability"
- Difficulty level of questions, as mentioned previously

Activity Level

Regarding the activity level, interim reports on a 3 to 5-month basis were provided to GMA with various selected Q & A's, that often appeared in IFAI's Geosynthetics Magazine. Occasionally, we have had a few questions stemming from the answers that were provided in the magazine; in this regard a second generation set of questions. Additionally, final reports for every 500 sets of Q & A's (similar to this White Paper) were provided accordingly.

The trends regarding overall activity are shown in Figure 1. Only the "good questions" are considered hereafter. (The difference between good questions and total questions represents questions that had nothing to do with geosynthetics in any way; incidentally, most of these were soil or geotechnical related questions. While such questions were usually answered, we felt that they were inappropriate to be include herein. As noted, the trend line for the "good" questions over the fifteen-year period of the program is very erratic when viewed on a monthly basis (averaging out to 19.5 questions and answers per month), but the curve smoothens out when plotted on a yearly basis. After a relatively slow start for the first 2.6 years of the program, the pace stabilized for about 9.0 years, until the last 3.4 years where it is seen to be leveling off. For the most recent 0.4 year (5 months), the questions became quite sparse. Examining this trend further and, for each set of 500 Q & A's, the time taken to achieve each set of 500 questions, and the resulting questions per month, was as follows (see the bold arrowed lines on Figure 1):

1st 500 - 33 months or 15.1 questions/mo.
2nd 500 - 24 months or 20.8 questions/mo.
3rd 500 - 18 months or 27.8 questions/mo.
4th 500 - 18 months or 27.8 questions/mo.
5th 500 - 18 months or 27.8 questions/mo.
6th 500 - 31 months or 16.1 questions/mo.
7th 500 - 41 months or 12.2 questions/mo.

Now to an examination of the individual question categories and the accompanying analysis. Other than the actual data's presentation and discussion, some observations will be incorporated where felt to be appropriate.

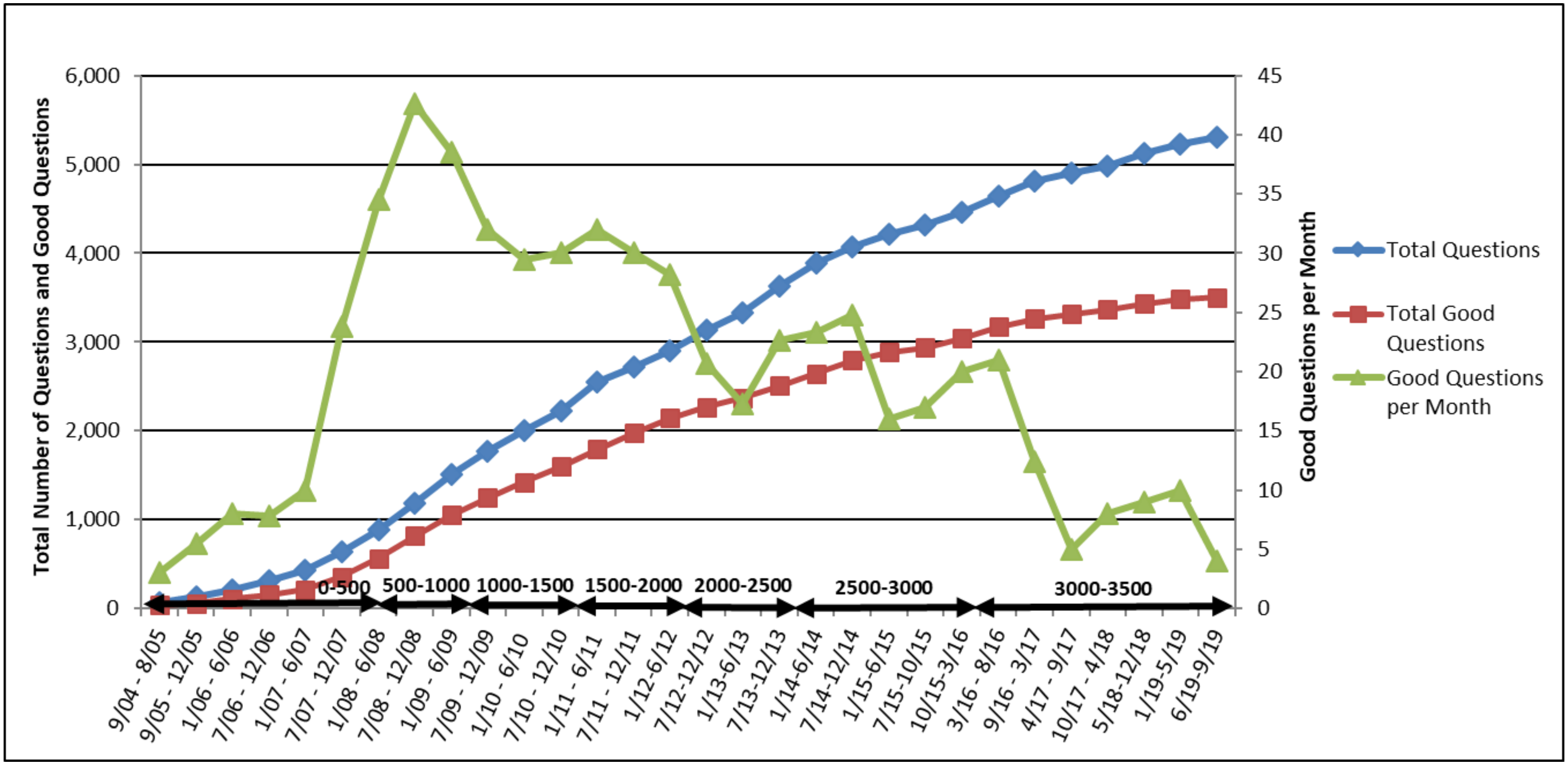


Figure 1. Number of GMA Techline questions and answers in increments of 500.

Information Regarding Location of Questioners

Figure 2 indicates that the vast majority of questioners are from America; (about 54%) which is down 6% from the last set of reporting. Furthermore for the past three sets, the questions from America are about 22% lower than the initial four sets of reporting. Regarding the remaining 46% of the questions beyond the USA, they were ranked accordingly with their respective percentages as follows:

- Canada/Mexico - 8%
- Latin America - 7%
- Europe - 11%
- Near East Asia - 5.5%
- Far East Asia - 2.5%
- Australia/New Zealand - 4%
- Africa - 8%

Latin America showed a 57% increase over the last set and this was mainly from the countries of Columbia, Peru, Brazil and Argentina, in that order. Increases were also seen in Canada/Mexico 19% (with the large majority of them from Mexico), Europe increased 9% over the past set (many countries were involved), Australia/NZ increased 14% (with very few being from New Zealand), and Africa increased 30% (with the very large majority of the questions being from South Africa). Also, to be noted is that Africa has seen a regular increase in questions from the outset of the program in quite an uniform fashion.

Interestingly, for this set of Q & A's, it showed that Near East Asia fell 7% and Far East Asia fell 70% on top of a previous drop of 50%. We have no idea why so few questions were asked by the Asian geosynthetics community. Clearly, their manufacturing sector along with the associated design, testing and installation, appears to be robust; although not without its share of issues as with MSE walls and slopes using geosynthetic reinforcement. There were rarely any questions asked about landfill liners and covers from Asia, not only for this 7^{th} set of questions but for any other set of Q & A's in the past… in fact, we cannot think of any at all!

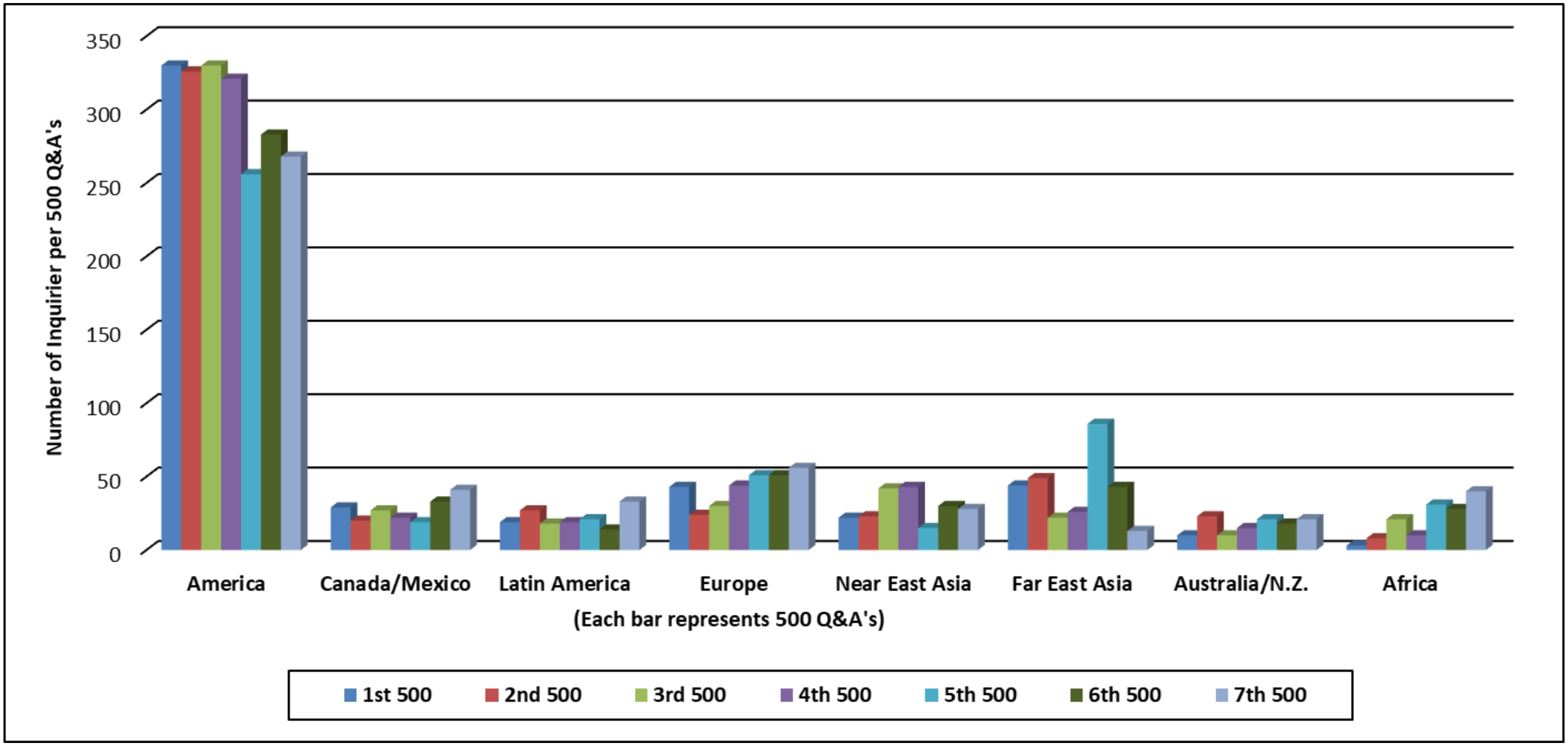


Figure 2. Worldwide locations of questions.
(each bar represents 500 questions)

Occupation of Questioners

Figure 3 represents the occupation of the questioner where, as in the past, the design/consultant group (38%) continues to ask the most questions. Recognize that in America alone there are about 70,000 professional engineering companies (having three or four persons per company) and only a miniscule number of their staff has had any formal training in geosynthetics. Whatever this very small number is, it is felt to be likely even more of an issue in other worldwide countries. In viewing the data, it should be noted that all questions about material standards were placed within this category and they were plentiful (≃ 20%). We feel that GSI's free website listing of 21 specifications, 11 guides, 8 practices and 25 test methods stimulated many of these questions… see www.geosynthetic-institute.org/specs.htm in this regard.

The overall ordering within the group was as follows:

- designer/consultant (38%)
- manufacturer/representative (19%)
- regulator/government agency (17%)
- owners/operators (9%)
- academic (9%)
- installer/contractor (8%)

The second largest group was, and continues to be, the manufacturers and their representative marketing groups (19%). Included in this manufacturing sector were resin and additive producers. It should be noted that this group also asked questions about GRI standards and were often extremely opinionated (often negative) in so doing. This is likely because the standards are developed within the GSI membership completely and, when promulgated, appear as finished documents.

The increase in the questions by regulators and associated government agencies is seen to be rising over the last three intervals and is now at its peak. The main applications have to do with landfill liners and covers as well as surface impoundment liners (80%). Most of the remaining questions were regarding use as berms in separating discrete cells within a landfill and around its boundary with reinforced MSE walls and slopes for increased volume (20%). Several questions had to do with surface impoundment liners in aquaculture (fish farming) applications.

Owners, and by association operators (9%), were mainly involved in landfill operations, including coal combustion residuals, although some were associated with heap leach mining as well as mine tailing's operations. The major single question they asked was associated with long-term/lifetime durability of geosynthetics. There were a few questions on long-term care after the waste mass has been placed for the 30-year post-closure care period. Questions were usually among private landfill owners, but a few of these questions were also posed by public agencies.

Academia, (9%) both faculty and students, might be underrepresented by the data since many questions bypass the Techline and came directly to us via our university email or directly by phone. That said, external efforts such as "Educate-the-Educator" should help faculty and distance learning via computer-based webinars should help practicing engineers. That said, the core of the

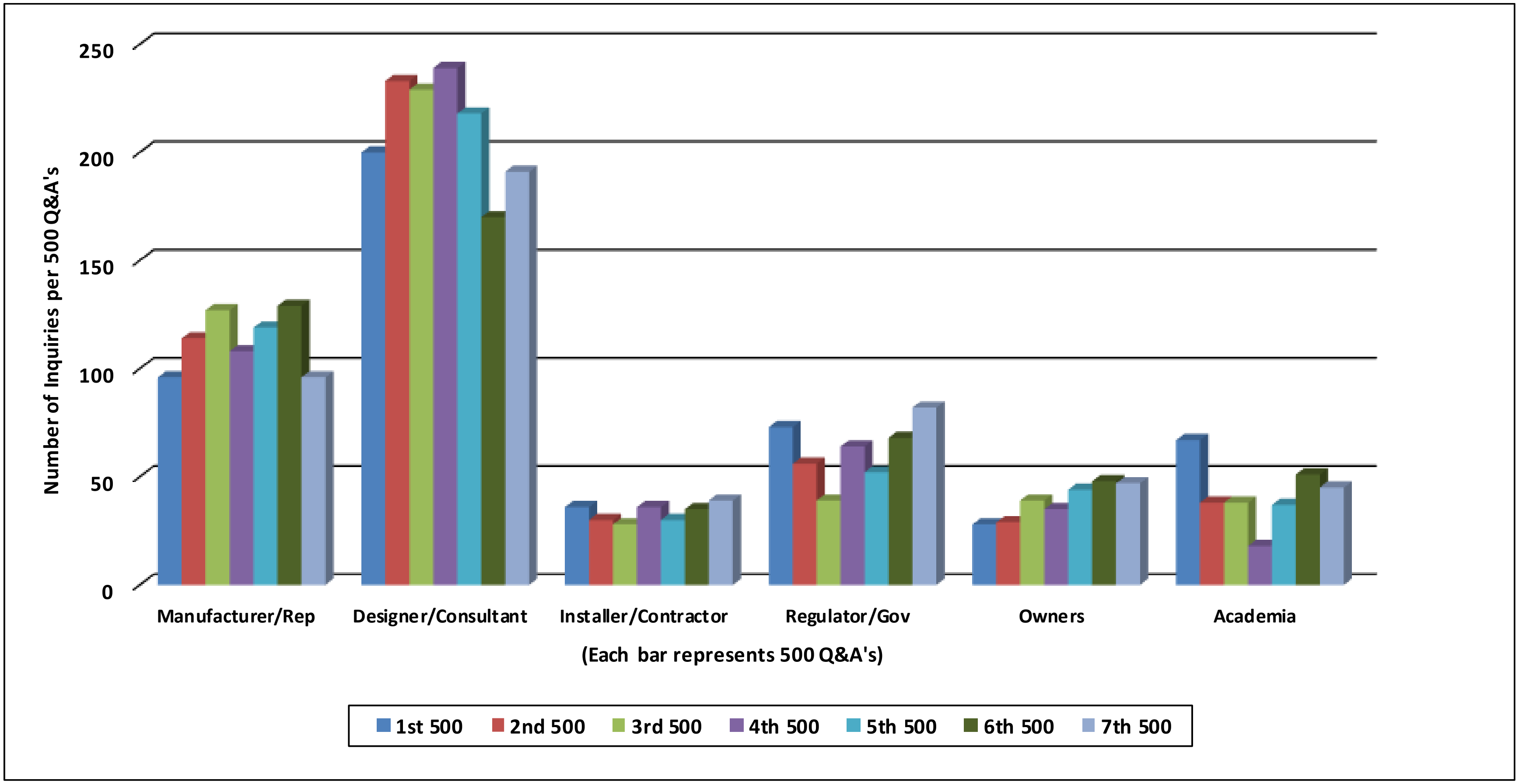


Figure 3. Occupation and questioners.
(each bar represents 500 questions)

problem, i.e., non-geosynthetic trained graduate professional engineers is significant and a severe roadblock with respect to growth within the potential user/designer community. This is felt to be a monumental issue greatly limiting geosynthetic usage and growth. A graduating student or newly employed professional engineer from another industry has little time or incentive to learn about geosynthetics and gain confidence as to proper design and implementation of geosynthetic systems.

Lastly, the installer/contractor group (8%) was, and has been, steady but disappointing over the entire set of data. Installation is so critical to the success of our systems that this last-step in the process must be done with the utmost knowledge, care and concern. We suspect, but do not know with any certainty, that this group is uncomfortable with asking detailed questions to an independent party like GSI. Perhaps linkages with general contractors and geosynthetic installer groups, like the International Association of Geosynthetic Installers, might be helpful going forward. Whatever the way forward, there should certainly be a worldwide effort brought to this very important (make that "critical) segment of the geosynthetics industry. Clearly, quality programs which are required in regulatory technical guidance documents, such as the following[*], are necessary to be taught and understood.

- Manufacturing Quality Control (MQC)
- Manufacturing Quality Assurance (MQA)
- Construction Quality Control (CQC)
- Construction Quality Assurance (CQA)

[*]see "Waste Containment Facilities: Guidance for Construction Quality Assurance and Construction Quality Control of Liner and Cover Systems" by David E. Daniel and Robert M. Koerner, ASCE Press, 2007 ISBN 13:978-0-7844-8859-9, 353 pgs. which is based on the U.S. EPA Technical Guidance Document, EPA/600/R-93/182,September, 1993.

Type of Geosynthetics Involved

Figure 4 presents the specific type of geosynthetic which was involved in each question. In order of frequency, the following percentages were involved:

- geomembranes (GM) - 31%
- geosynthetics (general) - 21%
- geotextiles (GT) - 18%
- geogrids (GG) - 14%
- geonets and drainage geocomposites (GN/GC) - 6%
- geosynthetic clay liners (GCL) - 5%
- geoerosion control materials (GECM) -2%
- geopipe (GP) - 2%
- geocells - 1%

By far, geomembranes are, and have been, the most commonly asked questions of the different geosynthetics. This trend was going down in the three previous increments, but rose substantially in this 7th set of Q & A's. Lifetime/durability, seaming, installation and specifications were the most common, questions however, many questions were asked specifically about scrim reinforced geomembranes. Perhaps this is due to five new GSI specifications promulgated within this time period. The category of geosynthetics in general was difficult for us to classify from the perspective of categorization, e.g., included were the following:

- geocomposites consisting of two, or more, different geosynthetics,
- direct shear testing and analysis involving multiple geosynthetics, and
- a few analytic questions on multi-layered geosynthetics on slopes

Geotextile questions were slightly down from the previous survey but very near to the average of such questions over the entire period of the program since its inception. Geogrid questions show an incremental rise over the last five periods and this can probably be attributed to their popularity of use in reinforced MSE walls and slopes. The questions were mainly strength related, which included both attachments and connections. Surprisingly, there were few questions having to do with comparison of the three different manufacturing methods, i.e., homogeneous, coated yarns or strap types.

Geonet/Geocomposites were down from the last period even though we had multiple questions dealing with Geospacer/Geocomposite materials, e.g., 3-D meshes, protrusions, nubs, cuspations, etc. Geosynthetic clay liner questions dropped significantly and yet the questions we received were different from the mainly midplane shear questions as in the past. The questions in this set presently involved amended clays having increased ion exchange capability. This is currently an active research area among GCL manufacturers. Geoerosion control materials, geopipe and geocells all dropped in comparison to previous sets of data.

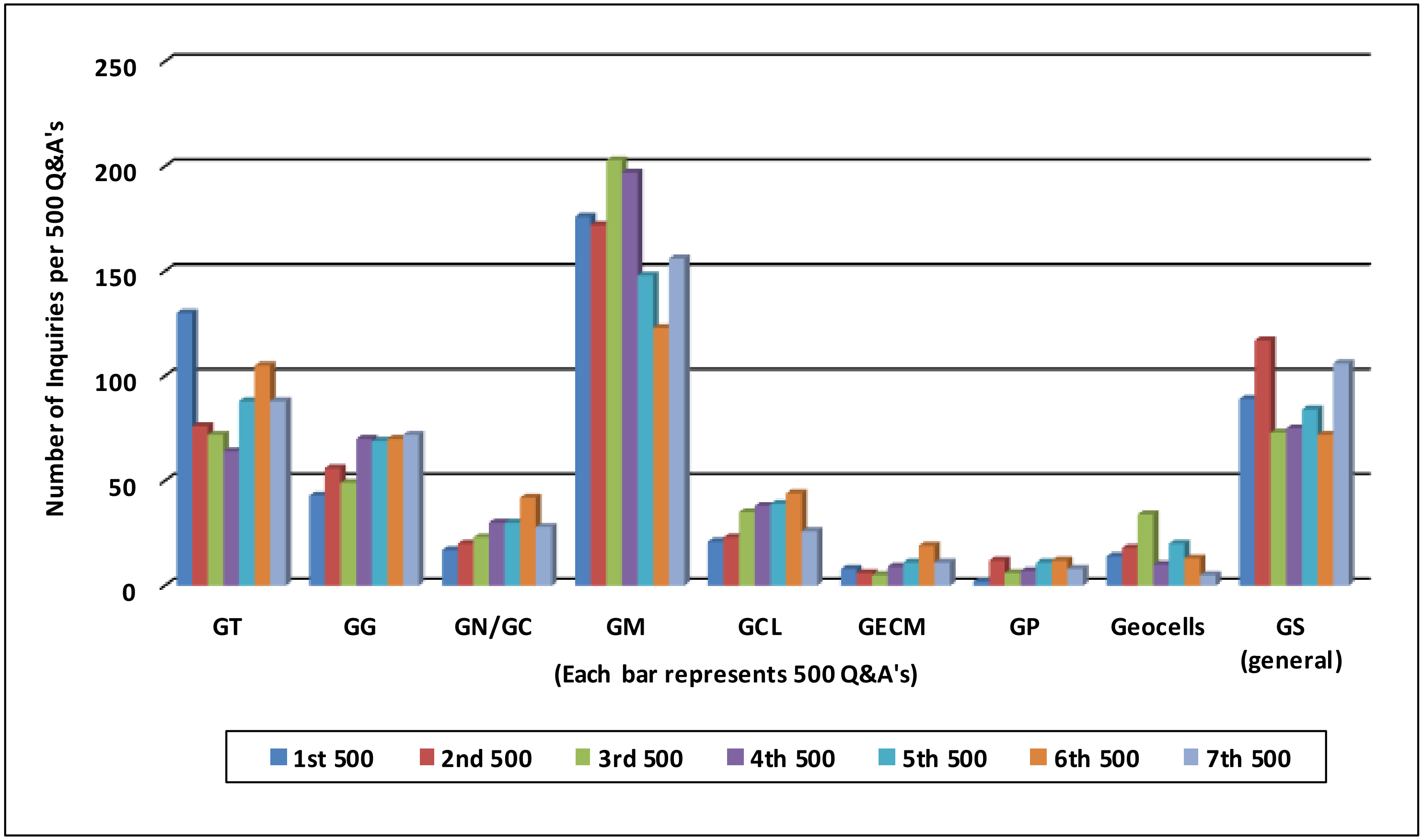


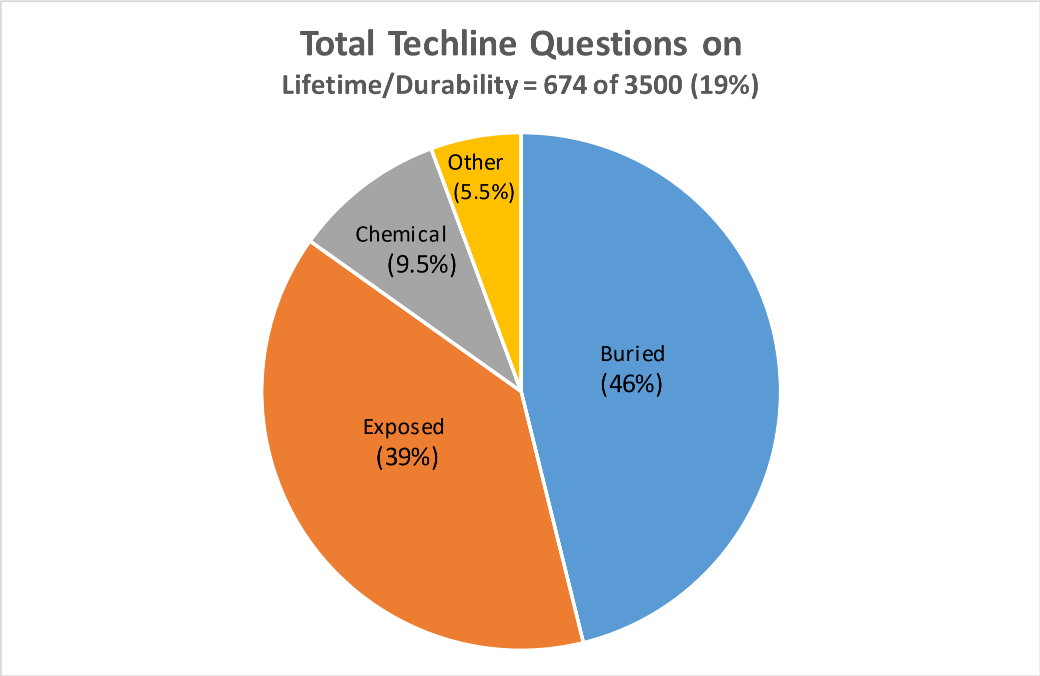
Figure 4. Type of geosynthetics involved.
(each bar represents 500 questions)

Application Category of Questions

The important category of identifying a focused topic area is presented in Figure 5. With the exception of lifetime/durability questions (which has remained incredibly steady for the entire time frame), the other categories have major variations. For the most recent 500 questions reported here, the results of the number of questions per applications topic were as follows:

- design/specifications - 32%
- lifetime/durability - 17%
- installation - 16%
- strength - 11%
- general information - 10%
- seaming - 9%
- clogging - 5%

Design and Specifications are most frequently asked and have risen markedly since the beginning of the program. The design questions are extremely broad insofar as questions and our answers are concerned. This often results in us sending design procedures from GSI publications or written papers by others. The specification questions are much more focused. One item, however, is GSI's lack of a geogrid specification. There is a recent AASHTO M288-17 specification, however, its property specificity is felt to be rather weak. Lifetime and durability continues to be regularly asked. In this regard, we have reviewed the 81 questions in this current set and find it closely follows the previous six sets of Q & A's as the following pie chart indicates. This represents 19% of all questions asked since the program began. Each set is extremely constant. Hopefully, in this regard, different people are asking the questions.



Further analysis of lifetime/durability questions in Figure 5 since program inception.

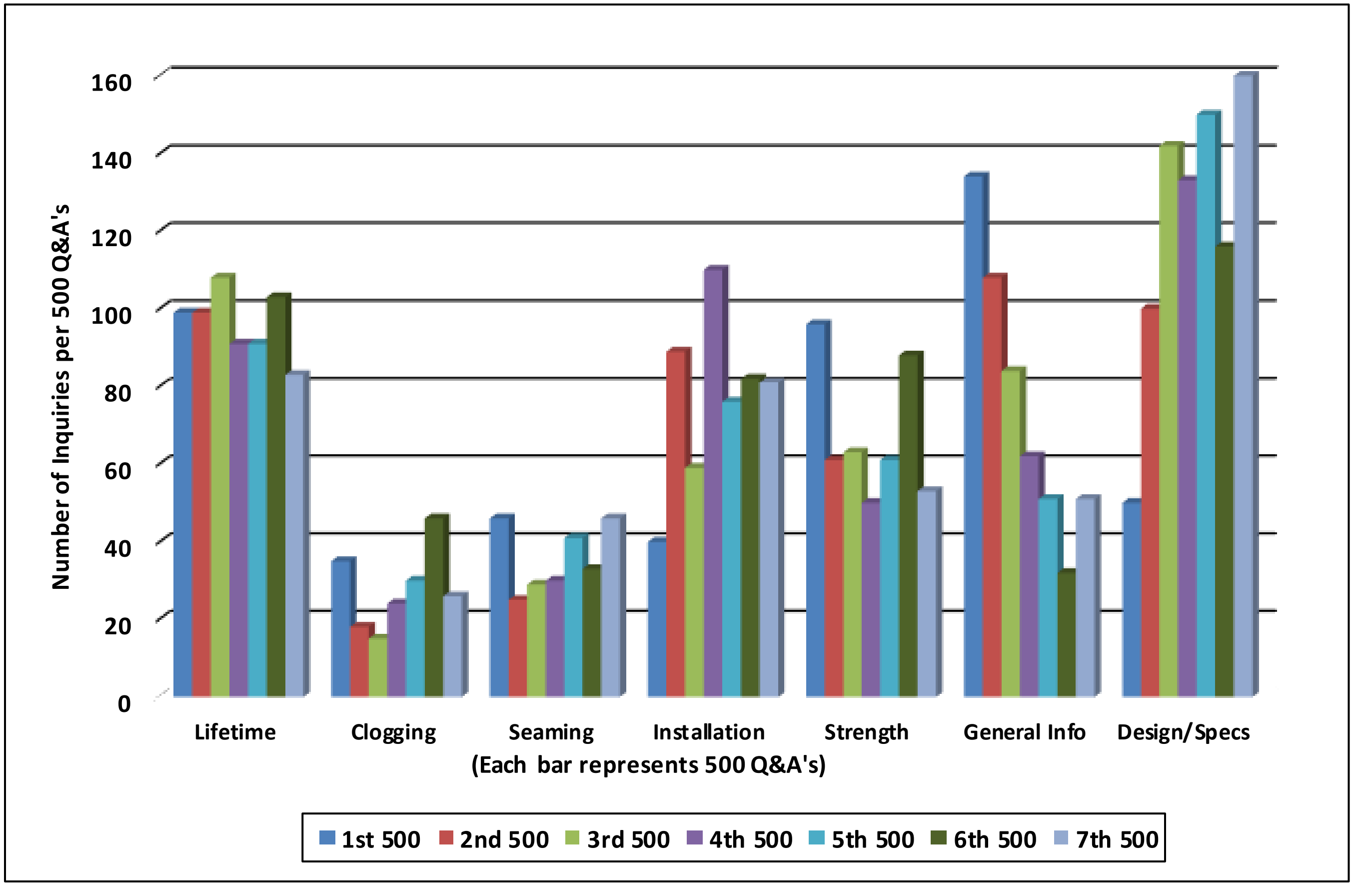


Figure 5. Application category of questions.
(each bar represents 500 questions)

Strength questions generally refer to tensile strength of geogrids, geotextiles and geostrips, conversely, compressive strength questions often referred to geospacers and drainage geocomposites. Also, peel strength of geotextiles to geocomposite cores was asked several times as was exit connections of the core itself.

While installation questions have remained steady after a slow beginning, there are several questions that are regularly asked. For example, elimination of geomembrane waves when backfilling, friction connection of geogrids to masonry block walls, destructive sampling practices, exit scenarios for geonet and geospacer composites at walls, slopes and landfills and permanence of polymer-modified GCL bentonite. Some almost humorous questions dealt with the proper placement direction of geogrids which have different strength properties in their machine and cross-machine directions. Seaming is obviously an installation issue, but singled out specifically due to its importance. Questions had to do with horizontal seams on slopes, smart hot wedge welders, details regarding electric leak location techniques, seaming new to old geomembranes, destructive sampling statistical methods so as to avoid the one destructive test per 500 ft. of seaming paradigm, indentation of geomembranes during hot wedge welding, and permeance of tapes used to seam thermoset geomembranes. Clogging questions of geotextiles and drainage composites decreased greatly since the last reporting period. There were a few questions dealing with vegetative growth and ochre clogging. Lastly, general information was higher than the last set, but now near the overall average. Questions included market size, field panel layouts, extreme hot and cold placement of geomembranes, handling regulatory agency "notice of deficiency" comments, and where to find specific installation information were in this category.

Difficulty Level of Questions

The issue of question difficulty is, of course, extremely subjective. A question on antioxidant chemistry is difficult for a geotechnical engineer, while the idiosyncrasies of using peak or residual shear strength on a steep slope might be difficult for a chemist, and vice versa for many other questioners! Between the GSI team, we hope we got the answers right; or at least, close to being right.

Nevertheless, a grouping was made on a sliding scale of 1 (hardest)-to-5-(easiest). As seen on Figure 6, the easiest (at 7%) were mainly requests for papers and directions of where to retrieve information. The medium Category 3 (at 54%) were considered to be reasonable *state-of-the-practice* questions, with Category 4 (19%) being somewhat easier and Category 2 (16.5%) requiring some *digging* on our part. Lastly, Category 1 questions (3.5%) were really difficult for us and we did our best. Several required us to consult others in the industry for which we are thankful. To give insight into these most difficult questions, see the Appendix which gives the questions and our answers to the 18 (3.6%) Category 1 questions.

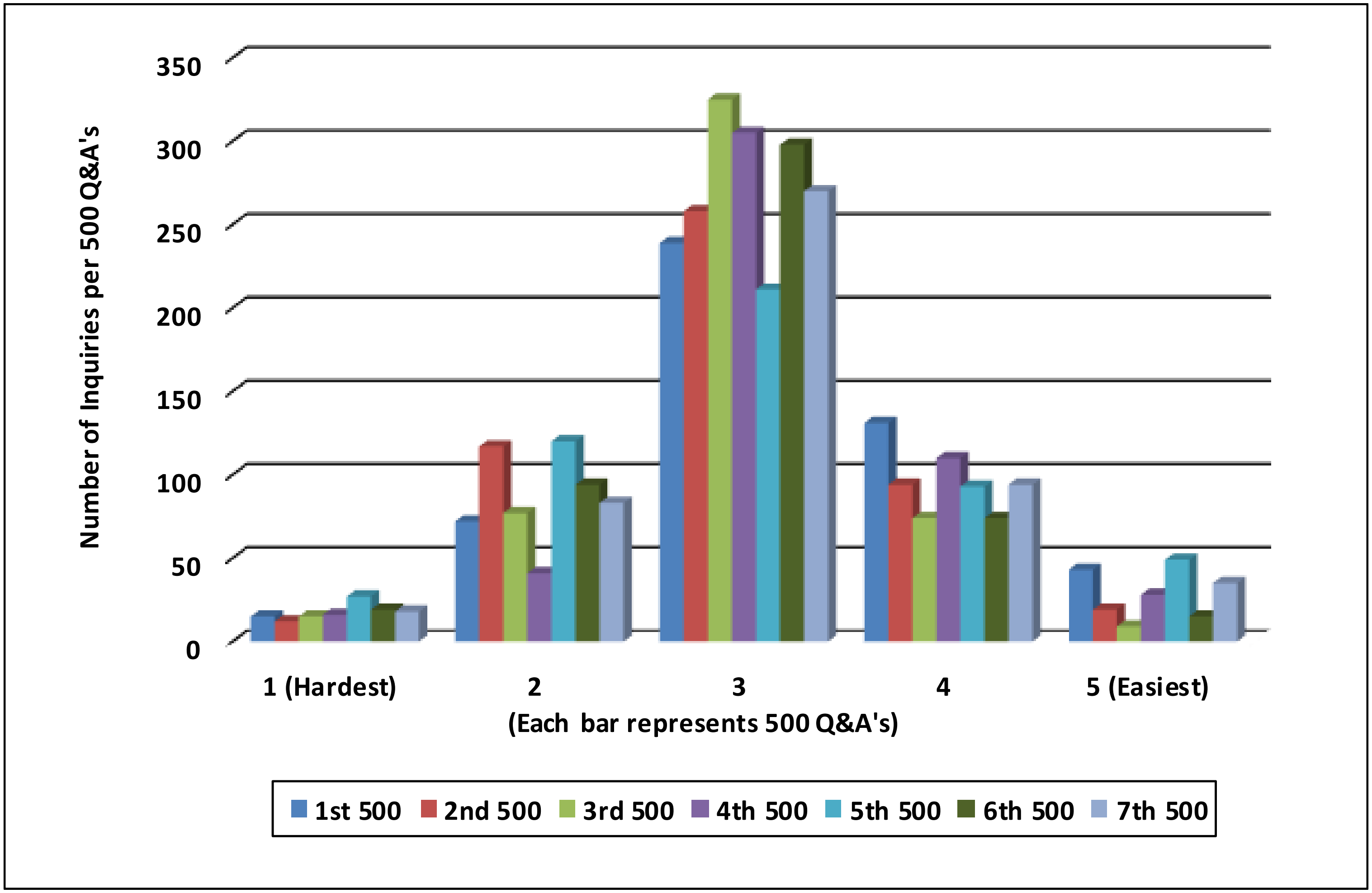


Figure 6. Difficulty level of questions.
(each bar represents 500 questions)

Concluding Remarks

We usually respond to the Techline questions (gmatechline@ifai.com) within one or two days and sometimes within hours. This rapid turn-around time often engenders the questioner to come back against our answer with another related question. It sometimes goes back-and-forth for several iterations but this is the nature of such electronic dialogue. In this regard, the Techline is analogous to questions asked during Webinars, which we offer on behalf of both the Geosynthetic Institute (GSI) and the American Society of Civil Engineers (ASCE). At the close of each of these Webinars we are now suggesting that participants go to the GMA Techline for further interaction. The two efforts (Techline and the Webinars) appear to be very complimentary and we enjoy doing both.

Let us close this 7th set of Q & A's via the Techline by saying that this entire 15-year process of responding and answering 3,500 questions was very insightful to us and interesting as well. It was a pleasure in so doing. Perhaps the most disconcerting aspect is that there has been too little movement between the seven discrete sets of 500 questions over time. Perhaps this is due to new people entering the geosynthetic industry asking familiar questions about our evolving technology but this is not known to be fact. Regarding the questions in this most recent set, the categories we selected are completely repetitive from past sets of 500 Q & A's. As you will note there are patterns which have been set over time. Note Figure 4 and particularly Figure 5. In turn this observation suggests that the "educational" status of geosynthetics has not advanced significantly nor have large numbers of new professionals been exposed to geosynthetics. Clearly, education is at the heart of growth and robustness of any technology; geosynthetics included. Much greater advancements in this regard to both faculty and professionals seems to be warranted and is hereby encouraged.

Appendix

Most difficult questions and our answers in this most recent 7th set of 500 Techline Q & A's

Q1: I am a Ph.D. student and I am sending this email to you since I have a couple of questions regarding Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method (ASTM D4595) and I would be grateful if you let me know your idea on them. I know that GSI has its own apparatus for this test so I thought you are the best people who I can ask my question form.

1. We did some tests at a lab using nine samples and we came up with a wide range for the tested geotextile. The average failure load for 60 kN/m and the average strain at the failure was 6.1% when based on the material specification, these values are supposed to be 70 kN/m and 10%. We also saw the variability in stiffness.

   I want to know if you have seen this kind of inconsistency in the tests you have done so far or not. Also, what is the source of this inconsistency? The geotextile, the test device and procedure, or something else.

2. Are you using hydraulic jaws or roller grips? or both? and what is the effect of either of them on the results?
3. Have you seen slippage so far? How do you prevent slippage?
4. If we want to do some tests at your lab how much should we pay for each test? and what should be the size of original samples to fit your apparatus?

Thanks a lot again for your response in advance.

A1: Wide width testing is one of several poorly controlled geosynthetic tests. From our statistical data base the coefficient of variation within a specific lab is 11%. For your strength fabric you can use clamp-type grips. To test for slippage scribe a line on the fabric at the edge of the grips and observe if slippage occurs. Although looking at your data you might be gripping too hard. This would decrease both strength and elongation at failure… Bob Koerner

Q2: I had submitted a question to the GMA Techline that George Koerner had answered for me initially regarding repairing cut geogrids in September 2015.

We now understand that the material we will need to repair is actually a geotextile. George had indicated that for PET coated you should tie with knots plus a cap strip overlay to repair the seams.

I wanted to drill down a little more with the answer he provided now that we understand what geosynthetic material we are expecting to encounter in our test pit excavation that would like to repair. We will be performing the repair work in a test pit excavation and will be near the water table. Based on George's answer above, is there any literature/document procedures detailing the repair of a geotextile and, perhaps, uncoated woven polyester geotextiles in general?

A2: Joining/seaming of a geotextile is much more "doable" than with a geogrid. Instead of tying the individual ribs together you now should consider sewing. Even in tight spaces a hand-held sewing machine can maneuver albeit with some difficulty. For your situation, it is important to use a sewing thread of different color than the fabric itself (for inspection purposes) and it should be PET thread (to match the strength of the fabric). You might also want to use back-to-back stitches since you will likely not have a selvage to work against. You will not get the full strength of the unseamed fabric and, depending on its strength, get from 50 to 80% of it… We have data in this regard if you want to look at it… Bob Koerner

Q3: I am a geotechnical engineer and my colleague forwarded me your e-mail contact information. We are looking at building a soil embankment to remediate a deteriorated bulkhead wall along a tidal river. To minimize the impacts of dredging and construction, we are investigating the possibility of using geogrid reinforcement to allow steepening of the slope face from a 2H:1V to a 1.5H:1V, as well as potentially using basal reinforcement over organics and river sediments to improve the global stability. I have looked into the use and installation of geogrid-reinforced embankments underwater but, other than some scant marketing material which appears to indicate it is feasible, I have not been able to find much comprehensive information relative to considerations for reduction in the geogrid strength/performance to account for the underwater placement (stone is dumped - not compacted and the geogrid likely needs to be ballasted so it does not float, placement of geogrid is in the blind and is likely to have more slack and therefore require deformation of the embankment before being engaged, how can the basal reinforcement geogrid be anchored to tension the grid adequately, etc.).

Given your knowledge and experience with geosynthetics, we think you are the right group to reach out and if possible, have a brief discussion with to get your thoughts on this use of geogrids, especially if you have had experience with other projects that have similar applications. Or if not, point us in the direction of someone other than yourself that could potentially be of help.

Appreciate your time, and thanks in advance for any help you can give us.

A3: There seems to be two separate issues, as you state the situation. First of all, we don't really know how to build a reinforced embankment under water with the same care and considerations as building on soil in air! In your case, the grids you are considering will float and the soil cannot be uniformly placed or compacted. Second, using geogrids for basal reinforcement over deep foundations under water is possible but again with great difficulty. There are systems using grid encased stone mattresses and they should work in this regard. Do contact the geogrid manufacturers in this regard.

Q4: We have encountered a matter that we have not experienced before and we are not sure how to proceed.

We are currently building an industrial waste facility designed with a double composite barrier system. The barrier consists of a 1.5 mm secondary double textured HDPE geomembrane and a 2.0 mm primary double textured HDPE geomembrane.

During the installation of the primary geomembrane we noted a groove being created during the seaming process by the wedge welder. The installer stated that the groove is created by the "drag bar" of the wedge welding machine. Upon cutting open one of the seams (see attached photos) we see the groove is created in both the bottom geomembrane, which forms the base of the air channel that is later pressure treated, and the top geomembrane, which forms the air channel's cover. The groove created is approximately 0.3 to 0.5 mm deep.

The installer states that the seams pass according to our specification because they pass the shear and peel tests.

We are concerned because we have specified a GRI-GM13 specification geomembrane that calls for 2.0 mm thick geomembrane. The effect of this groove, although located within the air channel of the seam, reduced the thickness locally to 1.5 mm.

Unfortunately, we have picked up that this is occurring after several panels have been installed and we have to make a call on whether those seams should be cut out and repaired or not. We have instructed the installer to stop installation until other wedge welding devices are brought to site that won't cause the groove.

Have you encountered this before?

A4: Most dual track wedge welders have a follower (sometimes called drag-bar or toggle) within the recessed central portion of the wedge. This is to be sure that the air channel is kept open for the subsequent air pressure test.

In your case, we agree with your installer and feel that the follower is rubbing against the upper or lower sheet thereby abrading the inside air channel. Since the sheets are hot it doesn't take much friction to do so and we feel that you are seeing the resulting outcome. It is not acceptable as you state the situation and certainly must be remedied accordingly… Bob & George Koerner

Q5: We have been building large panels of various nonwoven geotextile weights in our factory for the last 15 years and have had great success with wedge welded seams.

When installing such a cushion layer under lining systems and over laying geotextile layers it works really well installing large panels already built to 20,000 sq. ft. which saves time when battling wind and weather in the field.

The typical weld values are very similar to sewn seams without the damage you can have trying to get the hand-held sewing machines to cooperate, especially in the dirt, dust, rain and wind found in the field. We can dig up some weld strength data for your review if that would be helpful in answering the questions posed. It is our opinion that wedge welding cushion geotextiles is a better and more repeatable process than sewn seams.

I have attached a couple of aerial shots from our drone showing the fabricated geomembrane products and fabricated geotextile (8 oz/yd^2 nonwoven) in a pond for oil and gas water installed during cold weather. The fabricated products made it a quick and efficient installation without the extra time welding every 15 ft. on textile and 22.5 ft. on the liner sections. We used a reinforced LLDPE fabricated to 20,000 sq./ft. in each panel.

A5: For many years I have been under the impression that geotextiles for reinforcement applications should be sewn while geotextiles for separation or cushioning could be thermally joined. The transfer of stresses across the seams being the major difference, i.e., one relies on tensile stress transfer for reinforcement, cushioning much less so. The data that George Koerner has developed shows that different joining methods give rise to very different stress transfer across the seam. Included in his study are four thermal methods (manual hot air, automatic hot air, manual not wedge, propane torch) as well as adhesive, double-sided tape and sewn. For joining GCLs, the percentages of strength mobilized with respect to the unseamed material is as follows: 52, 64, 36, 31, 128, 65 and 87%. Marilyn Ashley will send you the paper. For your application of a cushioning geotextile, hot wedge seaming (particularly automatic hot wedge which we did not try) might indeed be very acceptable. From your experience it appears to be very practical. However, the required percentage of strength capable of being transferred is, I believe, a designers decision. In this same regard George has also developed a very easy-to-use nondestructive testing method for field use.

Lastly, for thick nonwovens, the fact that the two jointed ends tend to lay flat using a non-sewing method might actually be better for the overlying geomembrane's more uniform support behavior. This is not nearly the case with prayer, J-type or butterfly sewn seams…
Bob Koerner

Q6: We are in the process of updating our geomembrane standard, and we have a couple of questions we would like to get your opinion on.

1. Of the materials listed in the table below, which are suitable (or not) for use with live fish (aquaculture)? I've heard that PVC may produce toxic gasses (chlorine).
2. Our current minimum thickness requirements are shown in the table below. Some people would like us to increase the minimum thickness for HDPE (and perhaps others) from 40 mil to 60 mil because they say 40 mil HDPE is hard to wedge weld. What is your opinion on this? What are the minimum thicknesses for the various materials based on seaming considerations? Aren't the more flexible materials easier to seam than HDPE?

Minimum Geomembrane Thickness Criteria		
Type	Minimum Thickness	
	Wastewater	Clear Water
HDPE	40 mil	30 mil
LLDPE	40 mil	30 mil
LLDPE-R	36 mil	24 mil
PVC	40 mil	30 mil
EPDM	45 mil	
fPP	40 mil	30 ml
fPP-R	30 mil	24 mil
PE-R	NR	24 mil

A6: You ask questions which are very controversial so my answers are more opinion added to others but without any commercial bias which others may have…

1. The polyolefins (HDPE, LLDPE and fPP) have all been used in fish farming. Where added tensile strength is necessary the reinforced variety has been used as well. EPDM has also been used successfully. PVC is a concern insofar as plasticizer extraction is concerned and, as such, the type and amount of plasticizer(s) might also be important. Do contact several PVC manufacturers since I suspect such questions have been asked previously.
2. Regarding thickness, I feel that 40 mil should be the minimum for nonreinforced GMs and 36 mil for reinforced GMs. This is based on installation survivability which is often unknown and/or unobserved.
3. All polyolefin GMs generally require some amount of extrusion fillet welding even if only in patching and repair. It takes a lot of careful detail.
4. Regarding ease of seaming, the dual track hot wedge is the premier method and the device itself does the work… the operator merely guides its pathway.

Hope this helps and best regards.

Q7: It was suggested by some co-workers that I contact you about some questions we have on a current project. We are working on a highway project where we will be widening a highway by placing up to about 35 ft of fill adjacent to the existing retaining wall and constructing a new retaining wall. The project specifications required that little to no load be placed on the existing retaining wall and existing sheet pile wall (see attached sketch). We were thinking about providing two layers of geosynthetics, one layer attached to the existing MSE wall and one layer draped over the existing retaining wall, to minimize friction due to settlement and downdrag from placement of the new fill. Do you have typical values for geosynthetic friction angles? We were thinking an HDPE geomembrane and a nonwoven geotextile. From what I can find, it seems that we'd be in the 9 to 11 deg. range.

A7: Your proposed project has all of the "tricks-of-the-trade" in it and it even sounds doable! Some miscellaneous items follow.

1. Downdrag (negative skin friction) is certainly a concern. Smooth LLDPE should be considered since its friction angle is low and its flexibility high in comparison to HDPE.
2. The amount of downdrag depends on the soil backfill. Do consider a well compacted graded gravel soil or lightweight fill materials some of which are as low as 5% unit weight that of gravel in this regard.
3. The wrap-around layers will help reduce lateral pressure but do use "stiff" geogrids which take up load instantly. (I have always thought about pre-stressing GTs and GGs but haven't figured out how to do it!)
4. Geofoam over the existing pipe is swell and it can probably be formed to fit into your space. However, do consider lightweight aggregate materials of which there are several.
5. The load transfer platform/deep foundations should be placed to minimize vibrations of the existing wall.

Hope these comments are appropriate and best wishes in your project.

Q8: We mentioned, related to the thermal expansion and contraction of geomembranes, in our mail via IAGI the matter of migration of an exposed (no capping) HDPE liner down slope (1% slope) as a result of thermal expansion and contraction. The result in a very short period of time was the accumulation of a huge wave/wrinkle at the deep end wall-to-floor intersection, resulting in significant trampoline forming at the shallow end of the wall-to-floor intersection. In one of the cases the tension became so significant that it pulled the membrane out of the anchor trench.

The remedy we proposed is to either:

1. empty the dam, remove the fold at the deep end, extend the liner at the shallow end back into the anchor trench and have a grid of durable soilcrete filled bags (5m cc) filled with stabilized soil across the entire floor…
   or…
2. If the client is unable to empty the dam (which may be the case, but have the disadvantage of the large wrinkle at the deep end remaining in place) to introduce a new suitable anchor trench at the toe of the shallow side wall for anchoring the existing floor liner, reinstall the liner on the shallow wall into the original top of wall anchor trench then extrusion weld the two liners on the down slope side of the new anchor trench at the toe of the shallow side wall. The exposed floor liner will still be supported appropriately with a durable soilcrete filled bag.

We also had the challenge of a penetrating concrete structure in the centre of the sloping floor to which the liner was to be mechanically fixed. The tension pulled the liner out and tore it in places from under the compression fixing. We introduced an engineered anchor trench around the structure and reconnected to a new liner mechanically to the concrete which was then welded to the floor liner beyond the trench. The purpose of which was to remove the tension from the mechanical fixing allowing he anchor trench to do the job. Here we did not support the liner with bags as the tailings were deposited immediately on completion of the liner works.

We would appreciate your view on the above and possible improvements or alternative ways of dealing with such a situation. We are having a meeting with the client next week. If you can provide us with some input by then we will very much appreciate it.

A8: Thanks for being in on the webinar yesterday and for asking bout your sliding pond liner. Speaking with George we recommend a combination of your two alternates.

1. Keep the pond full and leave the wave at the low end and forget about it… It will eventually fail at the crease but that may take many, many years. We are working on lifetime of creased geomembranes presently.
2. Drop many sandbags through the water so as to give ballast to the GM. How many sandbags is the issue but you can monitor slippage at the anchor trench at the shallow end and if movement is detected drop more sandbags… and so on.
3. Weld a parallel GM strip to the end of the liner and tuck it into the anchor trench.

Regarding concrete anchorages for mechanical devices in a pond with moving GMs… Yuck!! Its been a problem of maintenance for many geomembrane lined impoundment projects… cut and patch, etc., etc. As with many exposed geomembrane industrial sites, ongoing observation and maintenance is necessary.

Q9: I am aware of the section in your book regarding geomembrane "permeability" and get from it that it aims to calculate an equivalent Darcian permeability using vapor diffusion via Fick's law. Can one use the derived permeability then when calculating flow using Darcy's Law? A 60m head gives a hydraulic gradient equal to 60/0.0015 = 40000! Using this gradient the resulting leakage is still small but by no means negligible. Maybe I am overanalyzing the matter or fail to appreciate that it is inferred that the derived Darcian permeability applies to Darcian flow.

Further to the above, can one argue that it is then clean water only, and that the majority or perhaps all dissolved metal salts such as Ca, Na stay behind?

A9: Yes, the Darcian permeability goes right into Darcy's formula for the resulting flow values. The high gradient (for your case) coupled with the low diffusion value works out reasonably well… Incidentally, any liquid diffusing through a geomembrane as a vapor only to recondense on the other side as a liquid is the cleanest liquid ever produced!!! The contaminants simply don't travel along with the vapor.

Q10: I am involved in a lively discussion regarding appropriate temporary protection for a large earthmoving project.

Original specs called for jute with a longevity of 1-2 years. The contractor says his jute lasts only 6-9 months and he wants to substitute coir that has a vendor claimed longevity of 4-6 years. The difference for this project is about $160,000.

The site is in temperature climate. Can we expect jute (under seeded with grass) to be a viable source of protection for 1-2 years, or is that a worthless claim by a vendor?

A10: At GSI we have a pretty good handle on all types of geosynthetics insofar as exposed lifetime are concerned. That said, we have nothing on natural materials like jute or coir fibers made into erosion control products. Most categorizations call them "temporary erosion control materials", but rarely (if ever) define temporary as to the number of months or years of durability.

In thinking how one might approach a simulated incubation setup it promises to be much more than simply using an accelerated weathering device like we do with plastics. The fibers or yarns would have to be a biological environment simulating site specific conditions…I suspect it would be very difficult.

That said, lifetimes based on past practice with specific materials in like environments seems possible to give a ballpark value but we have nothing to offer it this regard, however, manufacturers are likely to have such lifetime data for their specific products.

Q11: The final version of the ICOLD Bulletin 55 on Geotextiles as Filters in Dams is receiving one last check for editing before being sent for translation and publication. In that document your GRI Report has been referenced as a design method for estimating geotextile service life in particular. (Thousands of people owe you thanks.)

Two comments from the Technical Committee on Embankment Dams were about nomenclature and recycled materials. The first comment on nomenclature questioned the use of "geotextile filters" verses "geofilters" and it is resolved to use the former to align with IGS considerations (but your opinion is also welcome). The 2nd issue is on durability and questions to what extent does the use of post-consumer recycled polymer (PP or PPT) influence the durability estimate compared to virgin material used in manufacture? Your guidance on any quantitative response would be highly appreciated. I have been unable to find an appropriate reference in the member section, and apologize if I am overlooking the obvious. Any comments or guidance from you would be highly appreciated.

A11: Regarding your questions…

1. "Geofilters" is a trademark of a commercial manufacturer, so do use "geotextile filters" which is completely generic.
2. This question is more difficult to answer and I take our past geomembrane discussions to give insight. We feel that a certain percentage of "rework" is okay in a formulation providing it is of the same formulation and is "clean". We ended up specifying a maximum of 10% although even 50% did not significantly affect properties. Regarding "post consumer plastics" the variability is so great that we decided to eliminate even a very small percentage of this very variable material.

Hope this helps but do ask if anything is needed at any time.

Q12: Although we have numerous geomembrane lined lagoons containing polluted water in the mining industry, there are a few which contain acidic water of pH at 3.5 to as flow as 2.0 In a couple of these facilities there is a drainage pipe penetration through the liner system which has a make-off between liner and pipe. Two systems of make-off are used - either a bolted stainless steel baton holding down the HDPE geomembrane to a concrete make-off with a neoprene gasket on either side of the geomembrane, or the geomembrane is welded to a factory formed boot that is clamped to the pipe with a stainless steel circular clamp. The first option if preferred especially for large facilities.

Are you aware of any research results which define the durability of neoprene rubber when exposed to low pH acidic water (varying from arsenic acid to sulphuric acid and occasionally hydrochloric acid)?

The follow up question is whether it is appropriate to provide buffer protection by covering the exposed gasket with a bitumastic material?

I hope to hear from you at your earliest convenience but hope even more that we will meet again in the not too distant future.

A12: Very sorry not responding sooner but my computer has been very sporadic for quite some time. Regarding your question on acid reaction of neoprene to very low pH liquids the closest we have to neoprene insofar as actual data is EPDM to both organic and inorganic acids in temperatures of 38 and 70°C. Both are thermoset plastics and the EPDM has excellent resistance in all cases. As a result, I think you are clear but it is a slightly different material.

Lastly, covering with a bituminous might look comforting but I don't think it's very permanent…Otherwise, very best regards and I'll be much quicker next time...Bob Koerner

Q13: Are there any comprehensive tests (or a general synopsis) of the environmental toxicity of leachate from nonwoven polypropylene fabrics when aged in fresh water or salt water solution? Regulatory and municipal bodies in Europe and New Zealand are requesting more info about products that are used in riparian and coastal environments.

Thank you for your time.

A13: As you might be aware there is nothing in polyethylene resin to cause toxicity… It is simply carbon and hydrogen in a repeating structure. Aged in fresh or salt water makes no difference. However, fabrics when manufactured consist of an additive package containing some carbon black (no problem) and antioxidants. The latter are very complex structures but only present in trace amounts, e.g., less than 1%. I have no idea if they can leach out of the structure and, if so, what concern they may be.

The above said, they can be evaluated by elevated temperature incubation in deionized, fresh or salt water baths and subsequent testing of the incubating liquid but it will take years for results and at an enormous cost.

Hope this helps.

Q14: I was discussing with my boss on the viability of reconstructing a fusion seam that failed destructive testing by cutting off the overlap and extrusion welding over the edge of existing weld. My boss said the second heating of the material will ultimately cause a weakening of the bond between the 2 panels, but if I could find anything to the contrary he would take it into account. Are they any recent studies that show it is acceptable to extrude over a fusion weld and does this vary between 40/60 mil thicknesses or HDPE/LLDPE?

A14: The concern over the occasionally used technique of extrusion welding over a fusion seam previously made of a wedge welder has been discussed often in light of weakening of the original seam, its geomembrane on either side of the fusion weld, or the geomembrane on either side the proposed extrusion weld has been raised. However, not from the concern over weakening the bond, but instead over crystallizing the welded area possibly leading to stress crackling sensitivity.

We did some testing after several melt cycles and found no degradation of the HDPE in the area of the seams. Since LLDPE is less crystalline than HDPE, I would think it is not sensitive either. While not common, and if okay by the CQA inspector, I would say okay. Regarding the testing of the new seam the vacuum box method could be upgraded to using a cooper wire in the weld area and passing a electric wand over it which might be more comforting to all involved.

Q15: Thank you for your previous reply. I am actually a CQA field inspector for geosynthetics installation. I had asked because I was trying to reduce the amount of extrusion seaming we had to do by reconstructing failed seams via grind and weld instead of placing caps. My boss did mention the crystallization which, I suppose, I should have phrased differently. He also said the only way he could change the capping policy was if I could find something that said it was fine. I'll let him know that capping is still best practice.

A15: Thanks for the clarification of your request. Let me explain further. For us to give general advise on geosynthetic matters is quite doable and we do it regularly. However, to make a definitive recommendation for a specific project opens us up to providing consulting services which carries with it insurance and possible litigation implications. This goes well beyond our non-contractual status with you or any other firm and, as such, we cannot make anything specific in the manner you suggest.

Q16: I'm pretty sure I have seen papers which talk about virtual elimination of manufacturing defects in modern HPDE sheet plant - are you aware of any paper around this?

A16: Thank you for your question which has been asked several times. More specifically, we have been asked to publish something (even anything) on blemishes or anomalies on manufactured geomembranes of all types insofar as CQA inspectors guidance and/or remedies. Quite frankly, we have been "chicken" to do so in a formal setting. What we have, and might be of help to you, is to include two ppt slides given in our QA/QC webinars and courses. They are attached and speak for themselves.

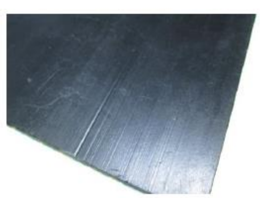
Slide 1 - Various Blemishes/Anomalies in Different Manufactured Geomembranes

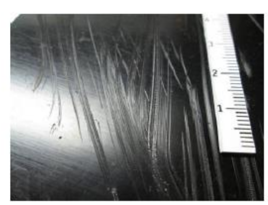

Gels (or Fisheyes)


Blisters


Inclusions


Melt Fracture


Die Lines


Scratches (or Abrasions)

Slide 2 - Commentary on Blemishes/Anomalies

- they usually occur during manufacturing
- they should be handled in the factory but are often only discovered when unrolled in the field
- corrective actions are…
  - overlay a "bead" of extrudate
  - cover with a round patch
  - use sheet in noncritical area
  - reject sheet entirely
- ultimate decision is by MQA or CQA per commentary in the QA plan or document

Q17: I have an interesting soil-structure problem for your consideration. At 5% and 10% strains the geosynthetic could correspond to stretching of say 1 or 2 ft for the broad width failure zones being considered before engaging those strengths. The slope may be lost by then or the soil strength reduced from re-molding more than the reinforcing compensates.

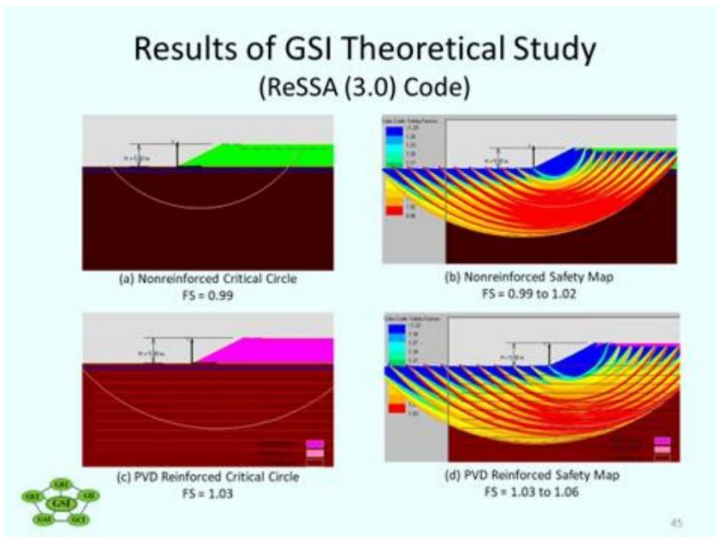
We have designed several soil nail walls and have never relied on the shear resistance of the bars because the soil is often weak or soft enough to flow around the nails and the failure zone is wide enough that steel bars will just flex too much before any shear is engaged. But we find that the more horizontal the bars are, the better the stability. And that vertical bars are no help, but that conclusion could be an artifact of our assumptions. So it was just my intuition based on that experience and soil nail paradigm that the vertical reinforcing would be questionable. It just seems that the PVDs in your example could deform a very large amount before they could engage any meaningful tension strength and then the soft soil may have sheared enough to have lost strength from re-molding.

It also seemed to me that the vector of the soil movement under the embankment was mostly going to put compression in the PVDs under the pad. I believe that the vertical PVDs were not extended out past the bottom of the slip circle for the molasses tanks, but it seems if they were, the soil movement vector would have an upward component and could create tension on the PVDs and resistance to the rotation of the soil mass.

I'll think some more and get back to you. Thank you for bringing up this interesting aspect and for the thoughtful reply. Can you get the ReSSA guys to recode for vertical reinforcing? I'll bet they can do that pretty quick.

A17: Thanks for taking the webinar with your colleagues and for the question that you gave as I signed-off at the allocated time by ASCE. In regard to your email, let me say that I deliberated upon my answer until now and think that there is an alternative way to what you suggest in which the PVDs are acting. Yesterday during the webinar I only showed the critical failure surfaces for the nonreinforced and PVD reinforced cross sections. Below I have added the safety maps which the ReSSA computer code also calculates as shown below on the right sides of those given yesterday. Please note that a massive zone of the foundation soil is at incipient failure. In particular, these red zones are all between 0.99/1.02 and 1.03/1.06, factors-of-safety respectively. What this says to me is that a massive zone of soil is moving in a semicircular orientation from right-to-left. This being the possible case, the PVDs are deforming in a gigantic bulge which would very possibly deform them such that any specific localized kinking is removed leaving the now gradually stretching PVDs in a straightened, although greatly bowed orientation. Therefore, my conclusion is that the PVDs are indeed being stressed in tension and as the bowing continues their deformation increases. Fortunately, in the PVD specification we have required tensile strengths at 5%, 10% and break deformations. By the way, I will add these two safety maps to the webinar for the next time it is presented.

Don't hesitate to come back to me in this regard since we both realize this entire discussion is largely hypothetical. Nevertheless, I think the discussion is personally very interesting and relevant… Bob Koerner



Q18: Could you please assist with a question that has come up? Is there any international literature that sets a maximum permeability for the soil layer below a composite HDPE/GCL in a landfill barrier? There seems to be a rule of thumb that it should not be more permeable than 1×10^{-5} cm/sec, to prevent possible bentonite erosion issues and to generally facilitate some form of attenuation below the barrier?

A18: At the root of the issue is that most (if not all) regulations call for a CCL beneath a GM (as in a composite GM/CCL liner) to have a maximum permeability of 10^{-7} cm/s. If a GCL is used its permeability is from 1 to 5×10^{-9} cm/s. It (the GCL) being thin, however, if often backed up by a low permeability soil layer but of what permeability??? I believe that your question is how much higher than 1×10^{-7} can it be? Indeed designers do use 1×10^{-5} cm/s and using Terzaghi & Peck's multilayer soil approach the net of the GCL and lower soil layer permeabilities comes out to be about 1×10^{-7} cm/s which is what is called for with a CCL beneath the GM by itself… all of that said, the regulator has to buy it… hope this helps… Bob Koerner