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# Improvements and advances in construction quality assurance for geosynthetics

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**ABSTRACT:** Geosynthetic materials are powerful materials for geotechnical works: projects can be completed with geosynthetics that would be impossible without them. In the applications of barrier materials, drainage, reinforcement, stabilization and erosion protection use of geosynthetics is the current standard of practice. However, as with all materials, geosynthetics must be properly installed to provide the functionality desired. An improperly installed geosynthetic will likely not provide the desired function and lifespan. A broad set of standards and instructions were developed for the construction quality assurance of geosynthetics and these have been historically effective in providing guidance for installation. In the last few years, new tools and techniques have been developed that advance the process and capabilities of construction quality assurance for geosynthetics. This include: The use of digital systems for tracking and testing geosynthetic deployment, welding, installation and performance data and improved and more rapid management and distribution of quality data. The use of global positioning systems, aerial photography and drones to document geosynthetic deployment and installation. The real time digital tracking of installation machinery and variables. The use of these technologies translates into a higher quality installation with lower potential for poor installation quality issues and more rapid review and engineering approval of construction. Examples of these technologies are presented and demonstrated and potential global best-practice technologies are introduced.

## 1 INTRODUCTION

While the focus of this paper is geosynthetic material installation, there are several assumptions made that, while self-evident for the experienced user, should be established here. Most important is that geosynthetic materials need to be properly installed to function. Barriers must be free of holes, reinforcements that are directional must have the proper orientation, drainage must flow in the desired direction without clogs and blockages, etc. Construction Quality Control (CQA) is designed around this precept. Further, an established quality principal can be stated as “everyone does better work when someone is looking over his/her shoulder”. It is a human tendency to perform better when our work output is monitored and evaluated. Also, many of us are usually more capable than one of us – humans’ function more optimally as a group. Thus, Construction Quality Control involves many people in the process and improves overall performance.

As these prior statements are “obvious” also is construction quality control an “obvious” and well-established field. Books, papers, manuscripts and guides have been created on this topic, most geosynthetic material manufacturers publish Installation

Quality Control Manuals that address this topic, there is regulatory and technical guidance available in many countries round the world and every reputable geosynthetic installation company has a CQA program. The purpose of this paper is to address and inform the reader on recent changes to the “CQA-world”. Our societies have advanced in recent years: the vast majority of people on the earth are connected via smartphones and electronic media. Smartphone and computer “Apps” (applications) for communicating, disseminating information and collecting and sharing data including global positioning system (GPS) location on our planet are commonplace. This paper addresses the use of these functions to improve the process of geosynthetic CQA and offers examples and benefits of their use.

These advances are presented in four general categories:

- Improvements in management, control and monitoring of currently commonly existing/CQA data. (Paper and manual data to digital)
- Advances in capture, control and monitoring of new and additional aspects of CQA data. (Digital to digital – i.e. welding conditions from welder to CQA database)

- Advances in capture, control and management of new and additional aspects improving CQA location performance. (Drone mapping to as-builts, i.e.)
- Summary of the benefits these and other new techniques bring to owners, regulators, insurers and the general population.

## 2 MANAGEMENT OF EXISTING DATA

In every CQA program there is a great deal of data: in fact, the CQA program could be considered to be the existence and accumulation of data. This data has many forms and uses, Critical data for CQA of a geosynthetics installation includes the following at a minimum: qualification and acceptance of the soils the materials are placed on/within, location and identification of materials deployed, records and testing evaluations of the welding and joining of materials (this includes test welds, continuous testing such as ASTM 5820 Air Channel testing for example and destructive testing), locations and welding records for penetrations and other irregular features of the installation, construction of a diagram/map illustrating the installation (commonly called an “as-built”), weather and meteorological data and other pertinent information. The volume of information for a site run with good quality CQA is significant; a final CQA report can run several hundred pages with scores of charts, maps and tables. Moreover, this data is commonly reviewed on a daily basis. In some instances, approvals are required before advancing to the next step(s) and locations. Further, the geosynthetic installation must be integrated into the overall project progress, meshing with normal site activity, soil installations and movements, traffic restrictions and other important non-geosynthetic related activities.

Management control and daily inspections of this information and the results of quality testing are much more easily, rapidly and efficiently accomplished with digital tracking of the data. The installation operators and CQA inspection staff is equipped with smartphones or tablets and the data is generated, input, recorded, sorted and examined digitally.

A system developed by C3T (Construct 3 Technologies) and utilized by Gen-X of Johannesburg, South Africa which is called Geo-Q is an early leader in the field.

The following screenshot indicates the various tabs used for recording data in a typical installation. The materials are received and exist by roll number in the Material Stock Delivery Section. As material is deployed and panels placed it is recorded in the Materials Cutting List and Panel Placement sections. Damaged product is logged. Seaming details are recorded and the results of destructive and non-destructive testing is recorded. Repairs, Patching and Joints (penetrations) also are tracked digitally.

Material Stock Delivery (MSD) 7350.00 m <sup>3</sup> Last updated: 2019/02/27 12:18:12	Damage Log (DL) 7.00 m <sup>2</sup> Last updated: 2019/02/27 12:18:12	Material Cutting List (MCL) 3515.00 m <sup>2</sup> Last updated: 2019/02/27 12:18:12
Panel Placement (PP) 3448.25 m <sup>2</sup> Last updated: 2019/02/27 12:18:12	Trial Weld (TW) 10 (4.50 m) Last updated: 2019/02/27 12:18:12	Seam Log (SL) 4 (145.00 m) Last updated: 2019/02/27 12:18:12
Joint Log (J) 1 (1.00 m) Last updated: 2019/02/27 12:18:12	Destructive Test (DT) 1 Last updated: 2019/02/27 12:18:12	Non Destructive (ND) 5 Last updated: 2019/02/27 12:18:12
Patch Log (PL) 2 (1.50 m) Last updated: 2019/02/27 12:18:12	Repair Log (RL) 1 Last updated: 2019/02/27 12:18:12	Waste Factor (WF) 71.25 m <sup>2</sup> (2.02 %) Last updated: 2019/02/27 12:18:12

Figure 1. Screenshot of Geo-Q quality tracking contents page

Various levels of oversight can be implemented. The following screenshot illustrates an example of recording of damage to a roll of geosynthetic material. The damaged material is noted and if necessary multiple management approvals/acknowledgements can be initiated. These can be transmitted digitally, within the system, dramatically improving response time and documentation accuracy.

Seq	Check	Foreman	Comments	Engineer	Comments	Contractor	Comments	Check	Comments
1	Material damage on incident recorded (subgrade formed and repaired). Damaged material marked (SAND 10482025) 8.2 x 4.			APPROVED by Ryan Muller on 2019/02/27 12:18:12		APPROVED by Sean Carrigan on 2019/02/27 12:18:12		APPROVED by Marko Noman on 2019/02/27 12:18:12	

Figure 2: Screenshot of Geo-Q damage log example

The Aquatan AQ-Cloud™ system, Johannesburg, South Africa, is another early leader in this field. A screenshot of that content design is shown below.

Receipt Inspection	Non-Destructive Test
Surface Acceptance	Destructive Test
Panel Placement	Repair Report
Trial Seam	Certificate of acceptance of completed work
Panel Seaming	Delay Form
Punch list	
Delays	

Figure 3. Screenshot of AQ-Cloud quality tracking contents page

Prior to the deployment of materials, the surface needs to be inspected and accepted by the Lining Contractor, the Civil/Earthworks Contractor and Engineer. A picture is taken of the surface area and each party physically signs digitally on the tablet.

As material is deployed, the panel placement form is completed. The operator will select the type of material and the associated roll number from the database. This prevents human errors from slipping in and accidentally recording the wrong roll number. The operator will at this point assign a layer number to enable identification of the panels on a multi-liner installation project. The system also automatically keeps track of how much material is used of each roll.

The trial seam needs to be completed and data recorded before the seaming of the deployed panels can commence. The system has built in hold points such as these to prevent the procedures being bypassed which could be detrimental to the quality of the project. The details relating to each and every seam is recorded under the panel seaming records.

A principal benefit that results from the digitization of records is the ability to track the performance of staff and operators over multiple projects and installations. An example from the Q-Cloud system is illustrated in figures 4 and 5.

Date	Seam no.	Layers	Material	Seam length	Seamer	Ambient temp	Machine no	Machine temp	Machine speed	Weather	Location
November 21 2018 4:15 PM	1/219	2/2	HDPE smooth(1.5mm)/HDPE smooth(1.5mm)	2.0	Richard Nigma	28	367	390	2.0	Hot	Southern wall (division west)
November 21 2018 4:48 PM	2/19	2/2	HDPE smooth(1.5mm)/HDPE smooth(1.5mm)	24.5	Richard Nigma	28	367	390		Hot	Southern wall
December 4 2018 4:31 PM	20/21	2/2	HDPE double textured(1.5mm)/HDPE double textured(1.5mm)	9.0	Tonic Mathabatha	34	378	390	2.0	Hot	Floor
December 4 2018 5:01 PM	20/22	2/2	HDPE double textured(1.5mm)/HDPE double textured(1.5mm)	6.0	Tonic Mathabatha	34	378	390	2.0	Hot	Floor
December 4 2018 9:17 AM	25/31	2/2	HDPE smooth(1.5mm)/HDPE smooth(1.5mm)	5.0	Tonic Mathabatha	34	378	390	2.0	Hot	Northern wall
December 6 2018 9:32 AM	31/255	2/2	HDPE smooth(1.5mm)/HDPE smooth(1.5mm)	5.0	Tonic Mathabatha	34	378	390	2.0	Hot	North west corner (division wall)
December 7 2018 5:50 AM	15/23	2/2	HDPE smooth(1.5mm)/HDPE double textured(1.5mm)	4.5	Tonic Mathabatha	26	378	390	2.0	Hot	Eastern wall to floor
December 7 2018 5:52 AM	20/23	2/2	HDPE smooth(1.5mm)/HDPE double textured(1.5mm)	2.0	Tonic Mathabatha	26	378	390	2.0	Hot	Eastern wall to floor
January 10 2019 11:36 AM	20/21/22	4/4/4	HDPE double textured(1.5mm)/HDPE double textured(1.5mm)/HDPE double textured(1.5mm)/HDPE double textured(1.5mm)	0.5	Thulane Manti	32	31	260		Hot	Floor
January 10 2019 11:49 AM	21/20/19	4/4/4	HDPE double textured(1.5mm)/HDPE double textured(1.5mm)/HDPE double textured(1.5mm)/HDPE double textured(1.5mm)	0.5	Thulane Manti	32	31	260		Hot	Eastern wall to floor
January 29 2019 3:48 PM	7/8	6/6	HDPE smooth(2.0mm)/HDPE smooth(2.0mm)	16.5	Richard Nigma	34	342	390	2.0	Hot	Eastern wall
January 29 2019 5:58 PM	8/10	6/6	HDPE smooth(2.0mm)/HDPE smooth(2.0mm)	28.5	Richard Nigma	34	342	390	2.0	Hot	Southern wall

Figure 4. Screenshot of AQ-Cloud panel seaming records page

Date	Sample ID	Des. No.	Seamer	Seam num	Layers	Machine num	Pre 1	Pre 2	Pre 3	Pre 4	Pre 5	Pre 6	Pre 7	Pre 8	Pre 9	Pre 10	Pre 11	Pre 12	Pre 13	Pre 14	Pre 15	Pre 16	Pre 17	Pre 18	Pre 19	Pre 20	Pre 21	Pre 22	Pre 23	Pre 24	Pre 25	Pre 26	Pre 27	Pre 28	Pre 29	Pre 30	Pre 31	Pre 32	Pre 33	Pre 34	Pre 35	Pre 36	Pre 37	Pre 38	Pre 39	Pre 40	Pre 41	Pre 42	Pre 43	Pre 44	Pre 45	Pre 46	Pre 47	Pre 48	Pre 49	Pre 50	Pre 51	Pre 52	Pre 53	Pre 54	Pre 55	Pre 56	Pre 57	Pre 58	Pre 59	Pre 60	Pre 61	Pre 62	Pre 63	Pre 64	Pre 65	Pre 66	Pre 67	Pre 68	Pre 69	Pre 70	Pre 71	Pre 72	Pre 73	Pre 74	Pre 75	Pre 76	Pre 77	Pre 78	Pre 79	Pre 80	Pre 81	Pre 82	Pre 83	Pre 84	Pre 85	Pre 86	Pre 87	Pre 88	Pre 89	Pre 90	Pre 91	Pre 92	Pre 93	Pre 94	Pre 95	Pre 96	Pre 97	Pre 98	Pre 99	Pre 100	Pre 101	Pre 102	Pre 103	Pre 104	Pre 105	Pre 106	Pre 107	Pre 108	Pre 109	Pre 110	Pre 111	Pre 112	Pre 113	Pre 114	Pre 115	Pre 116	Pre 117	Pre 118	Pre 119	Pre 120	Pre 121	Pre 122	Pre 123	Pre 124	Pre 125	Pre 126	Pre 127	Pre 128	Pre 129	Pre 130	Pre 131	Pre 132	Pre 133	Pre 134	Pre 135	Pre 136	Pre 137	Pre 138	Pre 139	Pre 140	Pre 141	Pre 142	Pre 143	Pre 144	Pre 145	Pre 146	Pre 147	Pre 148	Pre 149	Pre 150	Pre 151	Pre 152	Pre 153	Pre 154	Pre 155	Pre 156	Pre 157	Pre 158	Pre 159	Pre 160	Pre 161	Pre 162	Pre 163	Pre 164	Pre 165	Pre 166	Pre 167	Pre 168	Pre 169	Pre 170	Pre 171	Pre 172	Pre 173	Pre 174	Pre 175	Pre 176	Pre 177	Pre 178	Pre 179	Pre 180	Pre 181	Pre 182	Pre 183	Pre 184	Pre 185	Pre 186	Pre 187	Pre 188	Pre 189	Pre 190	Pre 191	Pre 192	Pre 193	Pre 194	Pre 195	Pre 196	Pre 197	Pre 198	Pre 199	Pre 200	Pre 201	Pre 202	Pre 203	Pre 204	Pre 205	Pre 206	Pre 207	Pre 208	Pre 209	Pre 210	Pre 211	Pre 212	Pre 213	Pre 214	Pre 215	Pre 216	Pre 217	Pre 218	Pre 219	Pre 220	Pre 221	Pre 222	Pre 223	Pre 224	Pre 225	Pre 226	Pre 227	Pre 228	Pre 229	Pre 230	Pre 231	Pre 232	Pre 233	Pre 234	Pre 235	Pre 236	Pre 237	Pre 238	Pre 239	Pre 240	Pre 241	Pre 242	Pre 243	Pre 244	Pre 245	Pre 246	Pre 247	Pre 248	Pre 249	Pre 250	Pre 251	Pre 252	Pre 253	Pre 254	Pre 255	Pre 256	Pre 257	Pre 258	Pre 259	Pre 260	Pre 261	Pre 262	Pre 263	Pre 264	Pre 265	Pre 266	Pre 267	Pre 268	Pre 269	Pre 270	Pre 271	Pre 272	Pre 273	Pre 274	Pre 275	Pre 276	Pre 277	Pre 278	Pre 279	Pre 280	Pre 281	Pre 282	Pre 283	Pre 284	Pre 285	Pre 286	Pre 287	Pre 288	Pre 289	Pre 290	Pre 291	Pre 292	Pre 293	Pre 294	Pre 295	Pre 296	Pre 297	Pre 298	Pre 299	Pre 300	Pre 301	Pre 302	Pre 303	Pre 304	Pre 305	Pre 306	Pre 307	Pre 308	Pre 309	Pre 310	Pre 311	Pre 312	Pre 313	Pre 314	Pre 315	Pre 316	Pre 317	Pre 318	Pre 319	Pre 320	Pre 321	Pre 322	Pre 323	Pre 324	Pre 325	Pre 326	Pre 327	Pre 328	Pre 329	Pre 330	Pre 331	Pre 332	Pre 333	Pre 334	Pre 335	Pre 336	Pre 337	Pre 338	Pre 339	Pre 340	Pre 341	Pre 342	Pre 343	Pre 344	Pre 345	Pre 346	Pre 347	Pre 348	Pre 349	Pre 350	Pre 351	Pre 352	Pre 353	Pre 354	Pre 355	Pre 356	Pre 357	Pre 358	Pre 359	Pre 360	Pre 361	Pre 362	Pre 363	Pre 364	Pre 365	Pre 366	Pre 367	Pre 368	Pre 369	Pre 370	Pre 371	Pre 372	Pre 373	Pre 374	Pre 375	Pre 376	Pre 377	Pre 378	Pre 379	Pre 380	Pre 381	Pre 382	Pre 383	Pre 384	Pre 385	Pre 386	Pre 387	Pre 388	Pre 389	Pre 390	Pre 391	Pre 392	Pre 393	Pre 394	Pre 395	Pre 396	Pre 397	Pre 398	Pre 399	Pre 400	Pre 401	Pre 402	Pre 403	Pre 404	Pre 405	Pre 406	Pre 407	Pre 408	Pre 409	Pre 410	Pre 411	Pre 412	Pre 413	Pre 414	Pre 415	Pre 416	Pre 417	Pre 418	Pre 419	Pre 420	Pre 421	Pre 422	Pre 423	Pre 424	Pre 425	Pre 426	Pre 427	Pre 428	Pre 429	Pre 430	Pre 431	Pre 432	Pre 433	Pre 434	Pre 435	Pre 436	Pre 437	Pre 438	Pre 439	Pre 440	Pre 441	Pre 442	Pre 443	Pre 444	Pre 445	Pre 446	Pre 447	Pre 448	Pre 449	Pre 450	Pre 451	Pre 452	Pre 453	Pre 454	Pre 455	Pre 456	Pre 457	Pre 458	Pre 459	Pre 460	Pre 461	Pre 462	Pre 463	Pre 464	Pre 465	Pre 466	Pre 467	Pre 468	Pre 469	Pre 470	Pre 471	Pre 472	Pre 473	Pre 474	Pre 475	Pre 476	Pre 477	Pre 478	Pre 479	Pre 480	Pre 481	Pre 482	Pre 483	Pre 484	Pre 485	Pre 486	Pre 487	Pre 488	Pre 489	Pre 490	Pre 491	Pre 492	Pre 493	Pre 494	Pre 495	Pre 496	Pre 497	Pre 498	Pre 499	Pre 500	Pre 501	Pre 502	Pre 503	Pre 504	Pre 505	Pre 506	Pre 507	Pre 508	Pre 509	Pre 510	Pre 511	Pre 512	Pre 513	Pre 514	Pre 515	Pre 516	Pre 517	Pre 518	Pre 519	Pre 520	Pre 521	Pre 522	Pre 523	Pre 524	Pre 525	Pre 526	Pre 527	Pre 528	Pre 529	Pre 530	Pre 531	Pre 532	Pre 533	Pre 534	Pre 535	Pre 536	Pre 537	Pre 538	Pre 539	Pre 540	Pre 541	Pre 542	Pre 543	Pre 544	Pre 545	Pre 546	Pre 547	Pre 548	Pre 549	Pre 550	Pre 551	Pre 552	Pre 553	Pre 554	Pre 555	Pre 556	Pre 557	Pre 558	Pre 559	Pre 560	Pre 561	Pre 562	Pre 563	Pre 564	Pre 565	Pre 566	Pre 567	Pre 568	Pre 569	Pre 570	Pre 571	Pre 572	Pre 573	Pre 574	Pre 575	Pre 576	Pre 577	Pre 578	Pre 579	Pre 580	Pre 581	Pre 582	Pre 583	Pre 584	Pre 585	Pre 586	Pre 587	Pre 588	Pre 589	Pre 590	Pre 591	Pre 592	Pre 593	Pre 594	Pre 595	Pre 596	Pre 597	Pre 598	Pre 599	Pre 600	Pre 601	Pre 602	Pre 603	Pre 604	Pre 605	Pre 606	Pre 607	Pre 608	Pre 609	Pre 610	Pre 611	Pre 612	Pre 613	Pre 614	Pre 615	Pre 616	Pre 617	Pre 618	Pre 619	Pre 620	Pre 621	Pre 622	Pre 623	Pre 624	Pre 625	Pre 626	Pre 627	Pre 628	Pre 629	Pre 630	Pre 631	Pre 632	Pre 633	Pre 634	Pre 635	Pre 636	Pre 637	Pre 638	Pre 639	Pre 640	Pre 641	Pre 642	Pre 643	Pre 644	Pre 645	Pre 646	Pre 647	Pre 648	Pre 649	Pre 650	Pre 651	Pre 652	Pre 653	Pre 654	Pre 655	Pre 656	Pre 657	Pre 658	Pre 659	Pre 660	Pre 661	Pre 662	Pre 663	Pre 664	Pre 665	Pre 666	Pre 667	Pre 668	Pre 669	Pre 670	Pre 671	Pre 672	Pre 673	Pre 674	Pre 675	Pre 676	Pre 677	Pre 678	Pre 679	Pre 680	Pre 681	Pre 682	Pre 683	Pre 684	Pre 685	Pre 686	Pre 687	Pre 688	Pre 689	Pre 690	Pre 691	Pre 692	Pre 693	Pre 694	Pre 695	Pre 696	Pre 697	Pre 698	Pre 699	Pre 700	Pre 701	Pre 702	Pre 703	Pre 704	Pre 705	Pre 706	Pre 707	Pre 708	Pre 709	Pre 710	Pre 711	Pre 712	Pre 713	Pre 714	Pre 715	Pre 716	Pre 717	Pre 718	Pre 719	Pre 720	Pre 721	Pre 722	Pre 723	Pre 724	Pre 725	Pre 726	Pre 727	Pre 728	Pre 729	Pre 730	Pre 731	Pre 732	Pre 733	Pre 734	Pre 735	Pre 736	Pre 737	Pre 738	Pre 739	Pre 740	Pre 741	Pre 742	Pre 743	Pre 744	Pre 745	Pre 746	Pre 747	Pre 748	Pre 749	Pre 750	Pre 751	Pre 752	Pre 753	Pre 754	Pre 755	Pre 756	Pre 757	Pre 758	Pre 759	Pre 760	Pre 761	Pre 762	Pre 763	Pre 764	Pre 765	Pre 766	Pre 767	Pre 768	Pre 769	Pre 770	Pre 771	Pre 772	Pre 773	Pre 774	Pre 775	Pre 776	Pre 777	Pre 778	Pre 779	Pre 780	Pre 781	Pre 782	Pre 783	Pre 784	Pre 785	Pre 786	Pre 787	Pre 788	Pre 789	Pre 790	Pre 791	Pre 792	Pre 793	Pre 794	Pre 795	Pre 796	Pre 797	Pre 798	Pre 799	Pre 800	Pre 801	Pre 802	Pre 803	Pre 804	Pre 805	Pre 806	Pre 807	Pre 808	Pre 809	Pre 810	Pre 811	Pre 812	Pre 813	Pre 814	Pre 815	Pre 816	Pre 817	Pre 818	Pre 819	Pre 820	Pre 821	Pre 822	Pre 823	Pre 824	Pre 825	Pre 826	Pre 827	Pre 828	Pre 829	Pre 830	Pre 831	Pre 832	Pre 833	Pre 834	Pre 835	Pre 836	Pre 837	Pre 838	Pre 839	Pre 840	Pre 841	Pre 842	Pre 843	Pre 844	Pre 845	Pre 846	Pre 847	Pre 848	Pre 849	Pre 850	Pre 851	Pre 852	Pre 853	Pre 854	Pre 855	Pre 856	Pre 857	Pre 858	Pre 859	Pre 860	Pre 861	Pre 862	Pre 863	Pre 864	Pre 865	Pre 866	Pre 867	Pre 868	Pre 869	Pre 870	Pre 871	Pre 872	Pre 873	Pre 874	Pre 875	Pre 876	Pre 877	Pre 878	Pre 879	Pre 880	Pre 881	Pre 882	Pre 883	Pre 884	Pre 885	Pre 886	Pre 887	Pre 888	Pre 889	Pre 890	Pre 891	Pre 892	Pre 893	Pre 894	Pre 895	Pre 896	Pre 897	Pre 898	Pre 899	Pre 900	Pre 901	Pre 902	Pre 903	Pre 904	Pre 905	Pre 906	Pre 907	Pre 908	Pre 909	Pre 910	Pre 911	Pre 912	Pre 913	Pre 914	Pre 915	Pre 916	Pre 917	Pre 918	Pre 919	Pre 920
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Figure 7 illustrates the output of this type of measurement. In the illustration, taken from the Bullock paper, welding machine setpoint data can be tracked and upsets are readily visible. The “X” axis on the graphs represents location: distance from the beginning of that particular weld. This data is uploaded digitally and also can be monitored by the welding operator using a digital interface. This feature can be additionally developed to include GPS location and recording to allow for the exact placement of the welding machine upset and the area of concern for weld integrity. Several benefits include the ability of management to review and identify these areas of concern, CQA staff to use this data to improve the effectiveness of destructive sample testing and early identification of operator or machine errors.

#### 4 ADVANCES IN LOCATION AND IDENTIFICATION (GPS AND “AS-BUILTS”)

The data capture and operations described above are significant improvements to CQA operations. A further advancement is linking this data to verifiable, easily relocated locations: this is being done with GPS (Global Positioning Systems): the digital capture of data at specific GPS locations is a powerful tool.

GPS is familiar to most people as the systems that power directional guidance in automobiles. While powerful, those systems of single point GPS positioning lack sufficient accuracy for critical CQA operations. An automobile is commonly positioned with an accuracy of approximately 10 meters. This is wider than the width of most geosynthetic products and thus improvements are necessary to improve the accuracy to pinpoint where specific rolls/panels and welds can be confidently located. This is best done using a GPS base unit that is installed on or immediately adjacent to the project site and can produce GPS accuracy to approximately one meter.

The photos below illustrate a process used by COMANCO of Plant City, FL to prepare visual inspection of sites and create a real-time as-built record that accurately identifies all pertinent locations within the installation for CQA activity and future location/inspection.



Figure 8. Photos (3) of drone overflight preparation courtesy of COMANCO

In the example illustrated in this section, a camera equipped drone is used for daily overflights of the project installation. Large (1 meter by 1 meter) location markings, as indicated in Figure 7, are created and identified by GPS location. The drone overflight records the status of the installation at that point and reconciles the visual markings with GPS positioning.

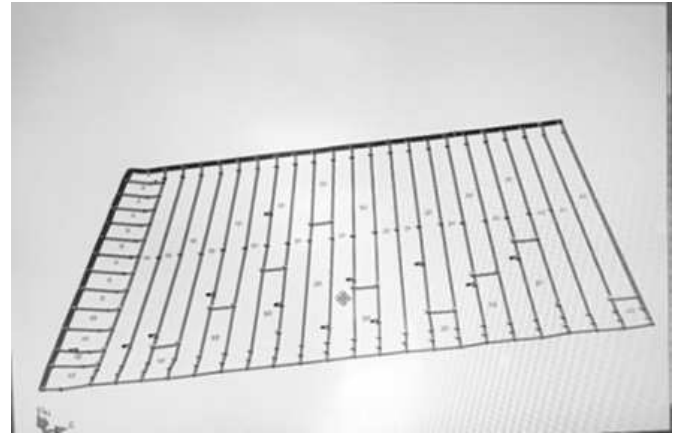


Figure 9. Screenshot of as-built preparation courtesy of COMANCO

The results of the overflights are used to generate the as-built drawing as illustrated in figure 9. Roll numbers and panel deployments are integrated into the document. Further, during construction, any upsets or particular circumstances are labeled with a GPS location.



Figure 10. Photo of GPS location of a “T” joint, courtesy of COMANCO

In the photo above, Figure 10, a material roll end/beginning and the resulting “T” joint is marked with a GPS location. This protocol can also be used for the locations of destructive samples, repairs, penetrations and any other special circumstances. By using this methodology, the digital as-built (constructed for each layer of geosynthetic) becomes a very powerful document for both CQA and

potentially for identification and correction of future issues. Current best practice for leak-free barrier sites, for example, uses a electronic leak location survey which is also coordinated through GPS location. Overlay of a leak location survey result with a digital as-built, both accurate to a meter or less, would be a very powerful tool for performance evaluation and leak location identification and repair.

## 5 BENEFITS TO OWNERS AND THE GENERAL PUBLIC

The advances above offer multiple benefits to owners, project participants and the general public. The broadest of these is the improved assurance that the installation and performance of the site and construction will be as designed and intended. Reliability, organization, record-keeping and inspection are clearly facilitated by these methods and protocols. Clearly, use of these techniques and equipment is an indicator of geosynthetic installation professionals, who are expert in their fields. A requirement for the use of some or all of these techniques is a simple way to improve the quality of the installation.

Longer term, there is also great benefit for the users of these systems. The ability to access performance across multiple projects easily will allow evaluation of materials, staff performance and equipment over a statistically more significant period. This can be used to optimize training content and frequency, identify and optimize machine performance and maintenance schedules and provide a multitude of other benefits.

Overall, the use of these techniques in CQA will produce faster, more durable, more reliable and efficient installations that allow the benefits supplied by geosynthetic materials to be fully realized.

## 6 CONCLUSIONS

The author has presented new and powerful techniques for construction quality control that are currently being utilized by progressive and capable installation companies. Clearly, these systems and protocols will continue to improve and evolve. It is not the authors intention to single out a “best-practice” as this point, however the use of digital CQA is clearly beneficial and the addition of this requirement into engineers designs and installation requirements is appropriate and beneficial to the engineers, site owner and all people involved and effected by a project.

## 7 ACKNOWLEDGMENTS

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