

Statement of Qualifications

*Advanced Deep Well Disposal
Slurry Fracture Injection (SFI) Service*

**Terralog Group of Companies:
Terralog Technologies Inc.
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Submitted by:



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TERRALOG STATEMENT OF QUALIFICATIONS

Since 1996, Terralog Technologies Inc. has been the industry leader in the design, operation and management of deep well disposal-injection of various wastes streams. *Terralog has developed and pioneered the use of the Slurry Fracture Injection (SFI)TM process for the advanced deep well disposal of large volumes of oily viscous and granular waste streams in the petroleum industry.* Terralog is a service company active in Canada, USA, Kuwait, Saudi Arabia, Brunei and Indonesia.

Terralog provides its SFI service in the petroleum industry to dispose of *Exploration & Production wastes* such as produced solids, oily viscous fluids/oily sludge, tank bottoms, contaminated soils, drilling waste (cuttings & fluids), NORM, etc. In doing so, Terralog helps our clients achieve *Zero Discharge Exploration & Production operations*. Terralog also provides its SFI service to municipalities to dispose of waste streams such as waste-water treatment sludge (biosolids), incinerator ash, contaminated soil, and industrial sludge.

There are significant environmental advantages to using the SFI process for management of such waste streams. Terralog provides a complete, integrated SFI service to clients that include: technical feasibility studies, project design, regulatory approval support, project implementation, technical support and complete SFI field operations.

With a strong staff of earth scientists and engineers, Terralog's expertise and focus are on the down-hole mechanics of slurry fracture injection for deep well waste disposal. Special emphasis is placed on design, equipment selection, and operating specifications to maintain waste containment in the target interval, to reduce operating costs, optimize injection operations, and to maximize formation storage capacity and injection well life. With offices in Calgary and Jakarta, Terralog provides clients with a unique combination of geomechanics expertise, regulatory experience, and extensive waste injection design and operations experience.

The Terralog SFI technology is a unique advanced deep well disposal process that incorporates very large volume waste streams, concurrent injection of multiple waste streams, integrated Process Control, high injection rates/pressures, and continuous injection cycles. No other deep well disposal services have these features. Hence Terralog's SFI service provides a Zero Discharge Waste Management Strategy for our clients. Terralog is the industry leader in providing SFI services. Terralog provides a complete project development and SFI service to the global market place.

Technology Summary:

The SFI process is an advanced deep well disposal process used for the continuous (24+days /month) disposal of large volumes (200-500 m³/day) of granular and/or viscous fluid waste streams. Such wastes streams may also be NORM contaminated. These wastes are mixed with water to produce a pumpable slurry; the water is usually produced water from production operations. Deep wells are used to inject the slurry under pressure into a suitable geological formation deep within the earth. During SFI operations, the injection pressures are in excess of the fracture gradient of the disposal formation (i.e. Target Zone). The Target Zone for SFI should be (preferably) poorly

consolidated - high permeability sand, or a high permeability fractured-karstic carbonate (limestone). SFI process incorporates unique operating features that allow for effective 'Process Control' during deep well disposal operations. Process Control systems are an integral part of the deep well disposal SFI operations, and are used to:

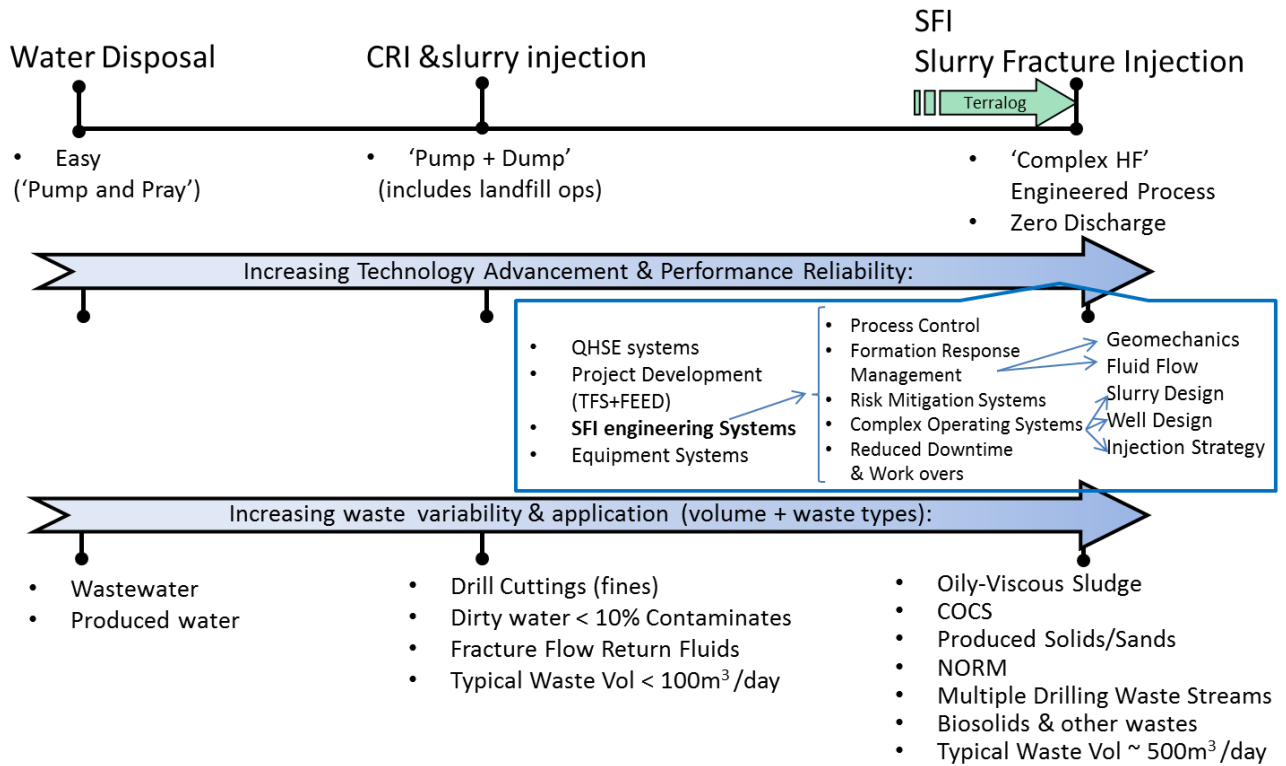
- maintain optimal formation response (fluid flow system response – injectivity and leak-off behaviour; & geomechanics system response – complex fracture development behaviour);
- ensure containment of injected slurry in the disposal zone and permitted interval;
- maintain disposal well integrity (reduce the risk of issues related to wellbore hydraulic and mechanical integrity); and,
- maximize formation storage capacity *insitu*.

With effective Process Control, the SFI process is a cost effective, permanent and environmentally sound deep well disposal technique suitable for disposal of multiple waste streams such as:

- Oily-Viscous Sludge
- Crude Oil Contaminated Solids/Soil
- Produced Solids/Sands
- NORM (Naturally Occurring Radioactive Materials)
- Drilling Wastes, i.e., cuttings and waste muds, fluids, centrifugal mud, etc.
- Fly-ash, and other suitable non-petroleum waste streams

Figure 1 shows a competitive overview of the SFI process with respect to the deep well disposal market place. The service/market space occupied by Terralog is shown in shading. Terralog's innovative SFI Process is an advanced deep well disposal process. Figure 2 shows drilling & production wastes streams that have been successfully disposed using the SFI process, with waste volumes of 200-500 m³/day (1250 – 3150 bbls/day).

Deep Well Disposal Comparison Summary



**Figure 1: Deep Well Disposal Summary
SFI Advanced Deep well Disposal**



Figure 2: Drilling & production waste streams disposal using the SFI process.

SFI Service & Capabilities:

Terralog's unique qualifications for SFI services are as follows:

1. Terralog is a recognized industry leader in providing SFI services in the petroleum industry.
2. Terralog is the only service company worldwide dedicated to providing SFI services. Terralog is involved with SFI/deep well disposal projects in Canada, USA, Kuwait, Saudi Arabia, Brunei and Indonesia.
3. Terralog has successfully designed, operated, and managed advanced deep well disposal facilities and operations worldwide in the petroleum industry:
 - Large-scale projects in U.S., Canada, Norway, Saudi Arabia and Indonesia.
 - *TTI has disposed of over 2.0 million m3 of petroleum waste streams worldwide.* Terralog is the only company that has successfully disposed of this volume of waste using the SFI process.
 - Terralog operates the first SFI deep well disposal project in the GCC; for NORM waste disposal for Saudi Aramco.
4. Terralog is the only company to design and operate specialized SFI facilities.
 - Such SFI facilities dispose up to 15,000 m3/month of waste material
 - Terralog facilities are designed for disposal of multiple waste streams with the SFI process including: oily sludge, tank bottoms, produced solids, drilling wastes, crude oil-contaminated soil, and NORM.
 - Terralog has designed, permitted, and operated SFI projects to dispose of Naturally Occurring Radioactive Material (NORM) waste from upstream petroleum operations.
5. Based on our SFI experience, Terralog has developed 'Best Practices' for deep well disposal operations that have been accepted as standards for deep well waste disposal operations in the petroleum industry. These Best Practices have been 'adopted' and implemented by operators such as Chevron, Statoil and Saudi Aramco.
6. Terralog has developed specialized project management systems, equipment, subsurface engineering, and field-operating systems/procedures based on years of SFI operating experience; that are necessary to maintain efficient, safe and environmentally sound deep well disposal operations.
 - Terralog has specialized deep well disposal management and operational systems, related to: Technical Support, Field operations, Project Management, and HSE controls.
 - *Terralog QMS and EMS for SFI operations are ISO certified (ISO 9001, 14001, OHSAS 18001).*

- Terralog provides experienced personnel for project management, administration and logistics support to ensure the reliable and safe performance of a SFI facility.

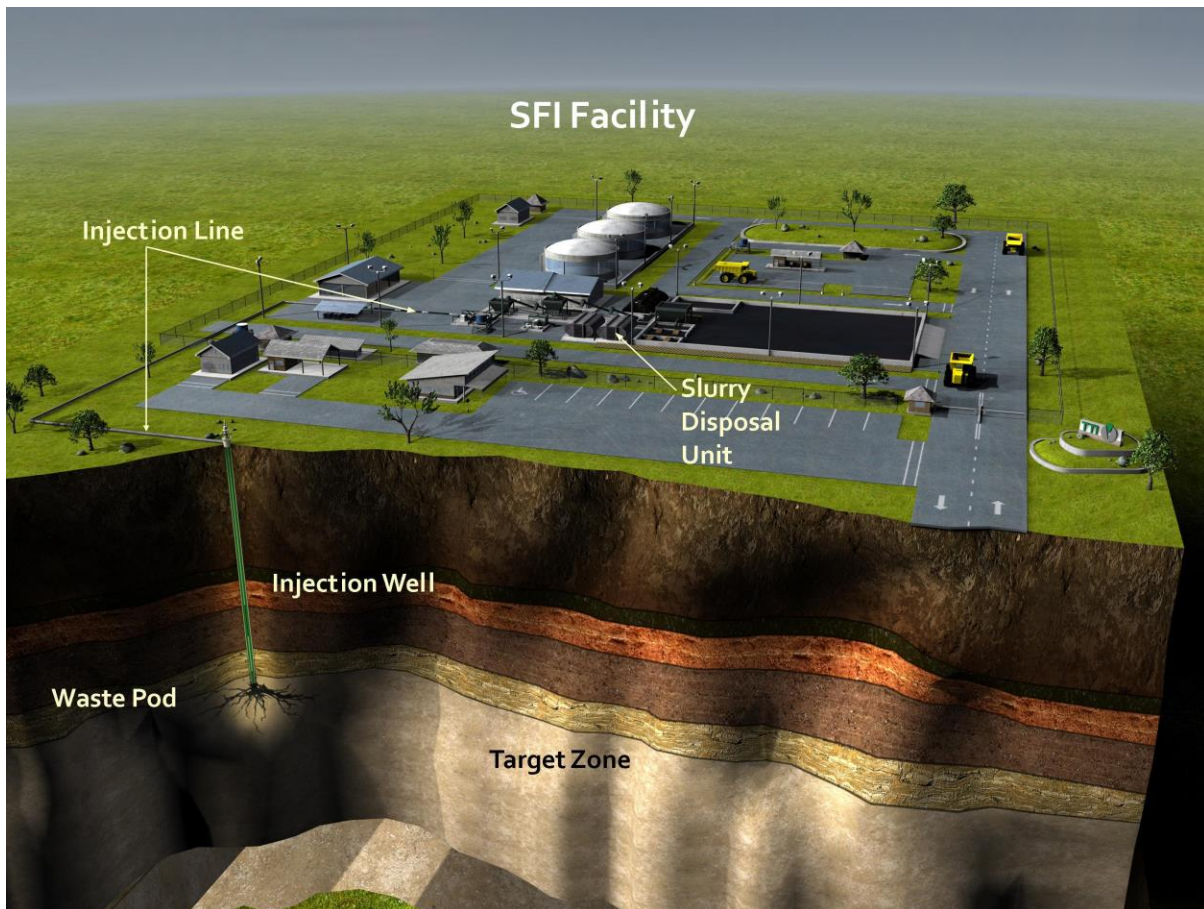


Figure 3: Terralog SFI Facility for Advanced Deep Well Disposal

7. Terralog has specialized technical expertise to monitor and control deep well disposal operations in order to: assure reliable performance of the disposal facility, maintain formation injectivity, reduce downtime due to wellbore plugging and formation damage, and assure containment of the waste material in the target disposal zone.
 - Terralog is the industry leader in deep well disposal technical expertise relating to: geomechanics, rock fracture mechanics, formation management, well-bore design, slurry design optimization, and Process Control.
 - Terralog's technical support provides specialized & proprietary expertise at integrating surface injection operations, slurry design, wellbore design and maintenance, and formation Process Control.
 - Terralog has designed and implemented dedicated process monitoring systems for *insitu* Process Control during SFI deep well disposal operations.

- ‘Process Control’ during SFI operations refers to:
 - Ensuring formation containment of injected slurry.
 - Ensuring optimal formation injectivity and geomechanics response to injected slurry.
 - Assessing and ensuring hydraulic integrity of the disposal well.
 - Maximizing formation storage capacity.
 - Terralog provides data management systems for deep well disposal operations, using specialized database applications and data management processes.
 - Terralog provides experienced personnel for SFI field operations (HSE, field supervisors, field crews) and Technical Support (SFI Engineers).
8. Terralog personnel are experienced with regulatory issues related to deep well disposal-injection processes, providing clients with support necessary for obtaining consent and approval from in-country regulatory agencies; including:
- Liaison with regulatory agencies for project permitting
 - Preparation of applications for regulatory approvals
9. Terralog has demonstrated project delivery capability.
- Terralog has experience operating and maintaining SFI facilities in remote oilfield locations, worldwide.

Terralog principals have authored many technical papers on deep well disposal, slurry injection mechanics and field operations, and have been active researchers in this topic for more than ten years (see attached references). In recognition of this expertise, Terralog was awarded a research contract by The US Department of Energy (DE-AC26-99BC15222) for the project “Development of Improved Oilfield Waste Injection Disposal Techniques: Database Assembly, Model Development, and Field Verification”. In this project Terralog compiled and analyzed detailed formation response data from more than 800 slurry waste injection episodes in the US and Canada (Bruno et al, 2001), and developed optimum design and operating guidelines. Dr. Maurice Dusseault (Terralog Senior Technical Advisor) and Mr. Roman Bilak (President Terralog Technologies Inc; President Director of PT Terralog) have consulted to industry operators and regulatory agencies for various international deep well waste disposal/injection operations. Mr. Bilak participated on a panel of industry and regulatory personnel that drafted new regulations for dedicated waste injection operations in Indonesia. Dr. Dusseault and Mr Bilak have participated on various industry panels and in conferences related to deep well waste disposal.

Terralog operational *SFI milestones* can be summarized as follows:

- Terralog has a primary role in the design and operation of the first dedicated slurry fracture injection (SFI) project for NORM waste in the GCC region (Aramco in Saudi Arabia).

- Terralog has a primary role with the design, permitting, and project management of the first dedicated SFI projects for drilling & oil production waste streams in SE Asia and the GCC region (Middle East).
- Terralog operated the world's largest SFI project, the Duri SFI project in Sumatra, Indonesia; to dispose of upstream drilling & oil production related waste streams. Terralog developed, obtained regulatory approval, and currently operates (for Chevron Pacific Indonesia) a multi-well dedicated SFI facility to handle oil production wastes at the Duri oilfield.
- Terralog has designed, permitted and operated more than half a dozen large volume SFI projects for various clients in Western Canada (Srinivasan et al, 1997).
- Terralog designed, permitted and operated the first crude-oil contaminated soil disposal SFI project in California (Srinivasan et al, 1998).
- Terralog designed and permitted the first offshore cuttings injection project in California.
- Terralog also assisted with the design and permitting the largest slurry injection project in Gulf of Mexico on behalf of Chevron, in which approximately 2 million barrels of oilfield waste (NORM and NOW) was injected into a single well from 1998 to 2000 (Reed et al, 2002).
- Terralog provided technical support and project management of deep well disposal projects for drilling & oil production waste streams on offshore platforms in the North Sea (Equinor in Norway) (Marika et al. 2009).
- Terralog has developed 'Best Practice' procedures for deep well disposal operations. These Best Practices have been adopted (through contracts with Terralog) by major energy companies and service companies in the petroleum industry.
- Terralog is considered a vendor of choice by regulatory agencies around the world for deep well waste disposal projects (e.g. US-Environmental Protection Agency, California Division of Oil & Gas, the Alberta Energy Regulator, and Indonesia State Ministry of Environment).

Finally, Terralog has completed technical feasibility and FEED studies for large volume SFI/deep well disposal projects for clients around the world, including:

- Eastern Province, KSA (Saudi Aramco)
- The North Sea (Equinor and BP Norge)
- Abu Dhabi (ZADCO, ADOC)
- MacKenzie Delta, Canada (ExxonMobil, ConocoPhillips)
- Indonesia (Chevron, BP Indonesia)
- Kuwait (Joint Operations: Kuwait Gulf Oil Co & Saudi Arabian Chevron)
- West Africa (Chevron Nigeria, Chevron Angola)
- Kazakhstan (Tengizchevroil)
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